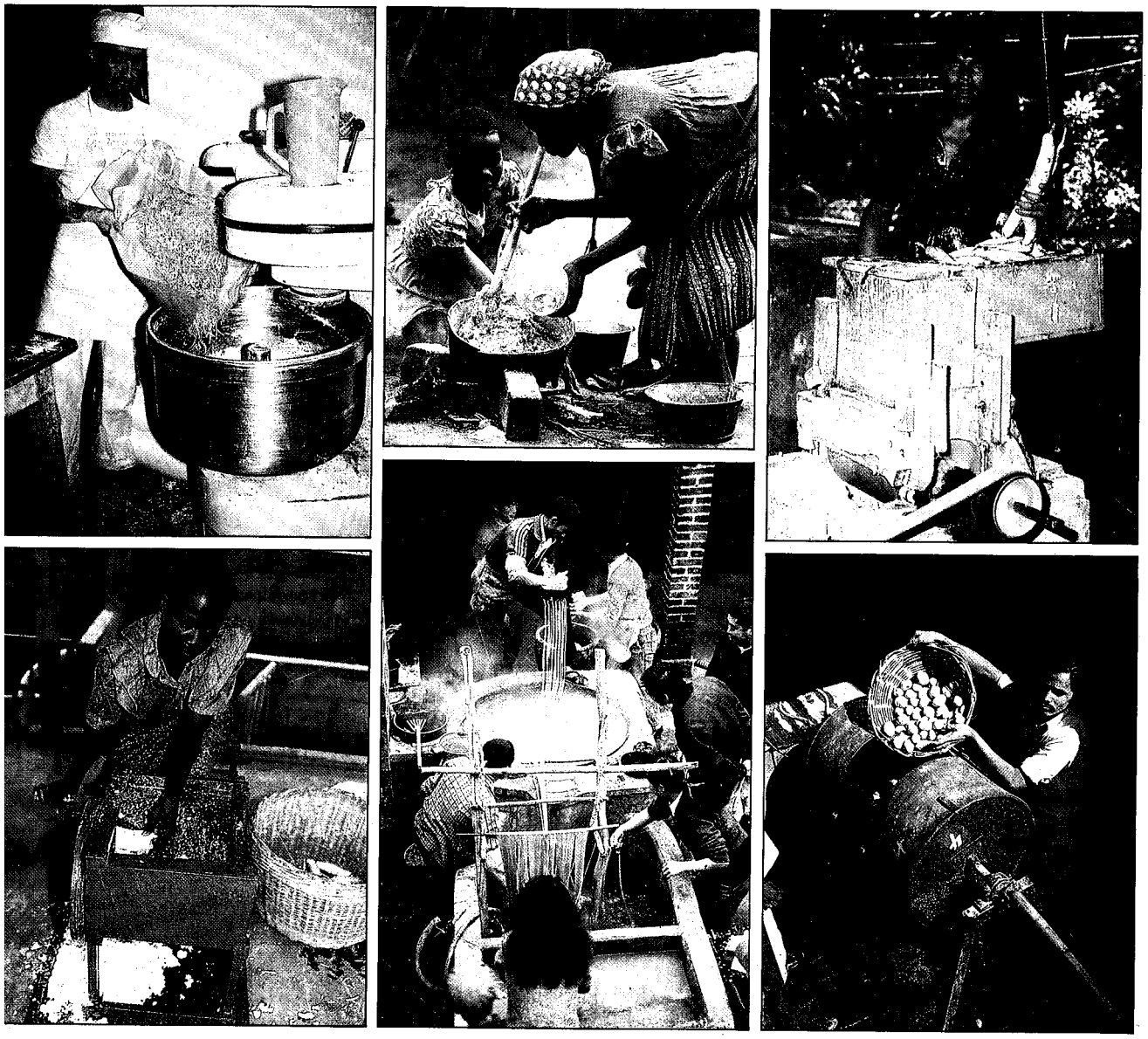


Product Development for Root and Tuber Crops

Volume III - Africa

INTERNATIONAL POTATO CENTER (CIP)

International Institute of Tropical Agriculture

THE INTERNATIONAL POTATO CENTER (CIP) is a scientific, autonomous, and non-profit institution dedicated to developing and disseminating knowledge for greater use of the potato, sweetpotato, and other tuber crops as basic foods in the developing world. CIP was established by agreement with the Government of Peru and is supported by the Consultative Group on International Agricultural Research (CGIAR) whose members provide funding for international agricultural development.

THE INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE (IITA) is a non-profit, international agricultural research and training institute supported primarily by the CGIAR. IITA employs about 180 scientists and professional staff members from over 40 countries and about 1,400 support staff, mostly from Nigeria. IITA's four objectives are: (1) to improve agricultural production systems for the African humid and subhumid tropics which can be sustained without degradation of the environment; (2) to improve the performance of selected food crops which can be integrated into improved and sustainable production systems; (3) to develop national agricultural research capabilities including human resources on a basis of shared responsibility with IITA, by means of training, information, and other outreach activities; and (4) to improve food quality and availability, including food storage, processing, and marketing.

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Product Development

for

Root and Tuber Crops

Volume III—Africa

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The purpose of this publication is to encourage debate and advancement of knowledge about production, processing, marketing, and utilization of root and tuber crops in developing countries. The views expressed are those of the author(s) and do not necessarily reflect the official position of the institutions to which they are affiliated.

Abstract

Processing of root and tuber crops is the focus of increasing interest by farmers, traders, researchers, and policymakers in many parts of Africa. This publication includes a wealth of information on the progress made to date with new or improved products and processes that utilize cassava, sweetpotato, or potato. Individual papers discuss work underway in Burundi, Cameroon, the Congo, Côte d'Ivoire, Ghana, Kenya, Nigeria, Rwanda, Tanzania, Uganda and Zaïre. The document also contains selected reports on processing activities in Colombia, Peru, Vietnam, and the Philippines. Particular attention is given to production, marketing, and consumption trends that either have facilitated or resulted from the growth in processing. In addition, an overall approach to product development is outlined followed by specific papers on each of the components including: assessing processing potential; research in support of product and process development; pilot plants; and expansion to commercial operation. Examples are provided for each of these components based on experiences in the countries represented. Case studies outlining the knowledge acquired and lessons learned include cassava processing for animal feed, new snack foods from sweetpotatoes, and village-level potato processing for flours and mixes. The document also presents recommendations for future activities in priority areas of endeavor and suggested areas for collaboration with the International Potato Center (CIP) and the International Institute of Tropical Agriculture (IITA) for work on product development for roots and tubers in Africa.

Compendio

El procesamiento de raíces y tubérculos es de creciente interés para los agricultores, comerciantes, investigadores y políticos en muchos países de Africa. Esta publicación incluye una amplia compilación de información sobre el progreso observado hasta la fecha con productos y procesos (sean nuevos o mejorados) de yuca, batata (camote) y papa. Las presentaciones discuten trabajos que ya están en marcha en Burundi, Cameroon, el Congo, Côte d'Ivoire, Ghana, Kenya, Nigeria, Rwanda, Tanzania, Uganda y Zaïre. El documento contiene también informes seleccionados sobre actividades de procesamiento en Colombia, Perú, Vietnam y las Filipinas. Se presta especial atención a las tendencias de producción, comercialización y consumo de estos cultivos, en la medida que han facilitado o alternativamente han sido resultado del crecimiento de la actividad de procesamiento. Además, se presenta un enfoque global seguido por ponencias específicas sobre cada uno de los componentes incluyendo: la evaluación del potencial del procesamiento; investigación sobre productos y procesos; establecimiento de las operaciones a nivel piloto; y la expansión hacia la operación comercial. Se presentan diversos ejemplos de cada componente para los países mencionados. Entre los estudios de caso que sintetizan la experiencia adquirida y las lecciones aprendidas para un producto o proceso específico, están el procesamiento de yuca para la alimentación animal, bocaditos y dulces de camote, y procesamiento de papa a nivel rústico para hacer harinas y mezclas. El documento presenta también recomendaciones para iniciativas futuras en temas de alta prioridad, en lo que se refiere al desarrollo de nuevos productos y procesos de raíces y tubérculos; recomendaciones para la colaboración entre países de la región; y propuestas para el apoyo del Centro Internacional de la Papa (CIP) y el International Institute of Tropical Agriculture (IITA) en el desarrollo de productos de raíces y tubérculos en Africa.

Résumé

La transformation des racines et des tubercules ne cesse de recueillir l'attention soutenue des fermiers, des commerçants, des chercheurs et des politiciens dans de nombreux pays de l'Afrique. Cette publication comprends un bon nombre d'informations sur les progrès réalisés jusqu'ici quant aux produits et procédés nouveaux ou améliorés ayant trait au manioc, la patate douce ou à la pomme de terre. Ce document discute également des travaux en cours au Burundi, Cameroon, Congo, Côte d'Ivoire, Ghana Kenya, Nigeria, Rwanda, Tanzanie, Uganda et Zaïre. Ce document présente aussi les resultats des activitiés dans le domaine de la transformation en Colombie, Peru, Vietnam, et aux Philipines. Une attention particulière est portée aux diverses tendances de production, de commercialisation et de consommation de ces produits dans la mesure où elles ont rendu plus faciles ou ont contribué aux augmentations observées. D'autre part, une vue globale est présenté quant au développement des produits en question, suivie de documents spécifiques à chacun de ses composants, y compris: l'évaluation du potentiel de transformation, la recherche sur le développement des produits et procédés, les projets pilotes et le déroulement des opérations jusqu'à la commercialisation. Des examples basés sur les expériences des pays représentés sont fournis pour chacun des composants. Des études de cas spécifiques exposent les connaissances acquises et les leçons apprises sur la transformation du manioc pour l'alimentation des animaux, celles de la patate douce dans l'élaboration de nouveaux types d'aliments pour snack bar et celles de la pomme de terre pour préparer de la farine et des mélanges directement dans les villages. Les rapports des différents pays ont permis d'identifier les facteurs limitants et des créneaux de recherche pour l'avenir. Le document contient aussi un résumé des nécéssités par pays, des recommandations pour une collaboration entre pays voisins quant au travail sur le développement de produits à partir de racines et de tubercules en Afrique, ainsi que des propositions de coopération avec le Centre International de la Pomme de Terre (CIP) et l'Institut International d'Agriculture Tropicale (IITA).

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Foreword

Over the last two decades, many African countries have become increasing concerned about how to reduce postharvest losses and increase value added for root and tuber crops through improving traditional technologies and adopting new ones to better suit their needs. In the years ahead, accelerating urbanization, the need for greater rural employment, and aspirations for higher incomes and more diversified, easier to prepare diets will push postharvest issues even higher on the agenda of most national agricultural research institutes. Postharvest research, training, and information have long been an integral part of the International Potato Center's (CIP) work. Processing, storage, marketing, and breeding for processing, consumption and nutrition continue to be key components of CIP's work in Asia, Africa, and Latin America. With the addition of sweetpotatoes and six, lesser known Andean roots and tubers to CIP's portfolio of activities, postharvest activities will take on even greater importance.

Exciting developments—such as the explosive growth in the transformation of sweetpotatoes for animal feed in China—have convinced us that there are tremendous opportunities to expand postharvest activities for roots and tubers to other parts of the developing world, as well as to provide access to the technical and socioeconomic information about these achievements to interested individuals working in this field. We are grateful to the International Institute of Tropical Agriculture (IITA) for hosting the workshop on which this proceedings is based. For these reasons, then, CIP is proud to join with the Centro Internacional de Agricultura Tropical (CIAT) and the International Institute of Tropical Agriculture (IITA) to help diffuse knowledge gained through the years of accumulated experience documented in this publication. We look forward to helping bring about similar successes in the years ahead.



Hubert Zandstra
Director General
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Lima, Peru

Objectives of the Workshop

The objectives of the workshop on processing, marketing, and utilization of root and tuber crops in Africa included to:

- Document recent trends in production, marketing, processing, and utilization of roots and tubers for African countries and for the region as a whole;
- Discuss results, problems, and opportunities in the field of product development for roots and tubers in Africa as well as other parts of the developing world among national researchers, development workers, and specialists from international organizations;
- Present and analyze procedures—including specific research methods, development approaches, and strategies—to integrate the work of different disciplines, institutions, and interest groups involved in the development of products and processes for roots and tubers;
- Analyze mechanisms to address the priority needs of national programs in the area of product and process development for roots and tubers to encourage greater public and private support for product development efforts for these crops, including adoption of appropriate government policies and involvement of commercial enterprises in research and development initiatives; and
- Review proposals to promote greater horizontal cooperation between national institutions in the field of postharvest research generally and new product development specifically, and to broaden the scope for interaction between the International Potato Center (CIP) and the International Institute of Tropical Agriculture (IITA) in response to the common needs of the region.

Recommendations

On the basis of the oral presentations and discussions that took place during the course of the workshop, the participants provided numerous suggestions for improving the proposed manual on root and tuber processing, marketing, and utilization in developing countries. These covered style (include more diagrams and flow charts, standardize terminology), content (include information on anti-nutrition factors) and organization (make reference to case studies). They also formulated a series of recommendations regarding:

- country-level priority needs to facilitate product development for roots and tubers;
- proposed areas of collaboration between national researchers and the international centers at the country-level;
- suggested contributions by local institutions to regional efforts in product development; and
- areas for possible collaboration among the international centers at the national or regional level.

I. Country Needs

National requirements to further advance work on product development for roots and tubers at the local level include the following:

Market Assessments/Utilization/Promotion

- Analyze demand for (price, income elasticities), consumption, and supply of cassava products (Congo).
- Assess potential uses of processed cassava (Tanzania).
- Conduct market study/cost analysis of cassava flour (Kenya).
- Undertake acceptability, nutritional studies of processed cassava products (Congo).
- Promote newly introduced processed products such as *gari* (Burundi), cassava bread (Nigeria), and sweetpotato bread (Burundi, Cameroon).
- Conduct baseline market assessments for sweetpotatoes in processed form (Uganda, Kenya, Tanzania).

- Procure better information on the level and determinants of sweetpotato consumption (Tanzania).
- Quantify and communicate to decision makers how specific government policies may hinder (e.g., import subsidies) or help (small enterprise credit) product development for cassava (Nigeria), potato (Kenya), and sweetpotato (Cameroon, Kenya, Nigeria, Uganda).

Varieties/Clones/Germplasm

- Evaluate sweetpotato varieties for their nutritional characteristics on a systematic and continuous basis (Kenya, Tanzania).
- Select sweetpotato varieties for protein levels for animal feed (Nigeria).

Products and Processes Research

- Ensure that certain attributes of traditional cassava processing (e.g., removal of HCN) are not lost with the introduction of technical improvements (General).
- Need to improve the quality of traditional processed cassava products (General).
- Conduct an inventory of traditional cassava processing (Congo).
- Characterize cassava-based weaning foods from organoleptic, biochemical, nutritional, and rheological parameters (Nigeria).
- Evaluate storage stability of composite flour made from cassava (Kenya).
- Conduct drying and ensilage trials on sweetpotato for animal feed (Nigeria).
- Regularly assess culinary characteristics of sweetpotato products (Tanzania).

Equipment/Machinery

- Develop low-cost equipment for sweetpotato processing that facilitates ease of entry and seasonal processing (Cameroon, Kenya).
- Create revolving fund to provide small-scale bakers with graters (Cameroon).
- Develop intermediate scale machinery for cassava processing (Nigeria).

Pilot Plants

- Conduct on-farm drying trials for cassava flour (Kenya).
- Develop simple, low-cost methods of sweetpotato storage (Rwanda, Tanzania).

Training

- Need to train local personnel in research on product development for sweetpotato so as to exploit potential for technology transfer from abroad (Uganda).
- Conduct training of trainers for gari production (Burundi).
- Need to train extension staff on preparation and use of composite flour (Kenya).

II. Collaboration at the Country level

National representatives also expressed their interest in collaborating with the International Potato Center (CIP) and the International Institute for Tropical Agriculture (IITA) in specific research and development initiatives in the field of product development for root and tuber crops as follows:

General

- Greater CIP presence in the region for product development research.
- Greater integration of cassava and sweetpotato initiatives in the field of product development.
- Collaboration to bring the importance of and potential for processed roots and tubers to the attention of policymakers.

Research

- Participation with CIP and IITA in initiatives to strengthen linkages between public research institutions and the private sector in the area of product development (General).
- Joint project with CIP on product development for sweetpotatoes (Uganda).
- Joint project with CIP on sweetpotato for animal feed (Nigeria).

Training

- Scholarships for processing/utilization research at/by the international centers (General).

Information

- Dissemination of information on sweetpotato products and processes from other developing country regions (General).

- Continued exchange of experiences and information through workshops and symposia (General).

III. Country Contributions to Product Development

Specific areas where participating country representatives felt their national institutions might contribute to product development for roots and tubers in the region include the following:

Research/Technical Assistance

- Technical assistance in cassava processing research (Nigeria).

Training

- Degree training in the postharvest field focusing on roots and tubers (Kenya, Nigeria)
- Short courses on root crop processing for processors and technicians (Ghana).
- Short-term training in the area of rustic potato processing (Kenya).

IV. Support from CIP and IITA

The workshop generated both suggestions from the country participants and proposals from the Center representatives for support from CIP and IITA for research and training in the area of product development for root and tuber crops in Africa.

Suggestions to CIP and IITA

In addition to the collaborative initiatives and country needs previously alluded to, the following specific suggestions for CIP and/or IITA support were made by country representatives present.

- Facilitate the supply of sweetpotato varieties from various sources, particularly Asia, to countries of the region.
- Help national institutions secure financial support for product development initiatives.
- Document existing processing practices for root crops.
- Assist in the exchange of information between researchers in the region working on product development for roots and tubers and professional counterparts in developed countries.

- Facilitate access to Center databases on roots and tubers in developing countries.

Proposals from CIP and IITA

Both Centers are eager to help identify priority projects in the area of product development for roots and tubers. In the past, such projects typically have been evaluated on a case by case, country by country basis. However, both Centers are increasingly aware of the need for and advantages of closer integration of their work with national and network counterparts in this field. As specific circumstances may require, both Centers are willing to join with local counterparts in the search for special project funding.

- CIP places high priority for the immediate future on market/technology/policy assessments as a first step toward broader interaction with national institutions in the area of product development for sweetpotatoes. These assessments will analyze not only the economic potential for processed sweetpotato products but also the technical capabilities and government policies that may influence such activities for the purpose of prioritizing across a wide array of possible alternatives.
- IITA places similar emphasis on processing research from a holistic or systems' perspective;
- IITA has expertise in the following fields: small-scale cassava processing (e.g., *gari*); analysis of cassava characteristics such as eating quality, starch, and cyanide content; and, design of project proposals for research and pilot testing. Short-term individual or group training in these fields can be undertaken subject to prior consultation.
- Both CIP and IITA have considerable information on product development for roots and tubers that can be accessed through contacting their respective information units, or local representatives in the region.

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Production of this document would not have been possible without the active collaboration of a number of institutions and individuals. In Nigeria, sincere thanks are due to the hosts of the workshop, the International Institute of Tropical Agriculture (IITA) and in particular to Hans Gasser, director of the Training Program, for his willingness to hold the event there; to Mpoko Bokanga, Jim Gulley, Rainer Zachman, and Michael Ayaji for their help in planning and organizing the workshop. In the Cameroon and Kenya, a word of thanks to Carlos Martin, Sylvester Nganga, Peter Ewell, and the International Potato Center's (CIP) regional staff for their help with invitations and logistics. In Colombia, a note of gratitude goes to Christopher Wheatley, formerly of the Centro Internacional de Agricultura Tropical (CIAT), for his contribution to organizing and conducting the workshop. At CIP headquarters in Lima, Peru, particular appreciation is due Gisela Castro, Patricia Chiroque, Margarita Zevallos, and Mónica Aliaga for word processing and page layout, and to Yolanda Rivas for proofreading, page layout, and cover design. Thanks go as well to María Lozano and Víctor Madrid for drawing the figures and maps, to Anselmo Morales and Cecilia Lafosse for preparation of the cover, and to Víctor Suárez for assistance with computer programming.

A very special thanks to Felix Nweke, John Lynam, and Coffi Prudencio for their gracious permission to reprint the various Collaborative Study of Cassava in Africa (COSCA) working papers included on this volume. COSCA is an inter-institutional effort. The aim is to provide baseline information on cassava over a wide area. Such information is needed to improve the relevance and impact of agricultural research on the crop in Africa in order to realize the potential of cassava in increasing food production and incomes of the people of Africa. The COSCA working paper series includes preliminary results of the various components and phases of the COSCA surveys. The series is aimed at scientists and researchers working with national agricultural research systems in Africa (NARS), the international research community, policy markers, donors, and members of international development agencies that are interested in cassava. We are pleased to include material from the series in this volume.

Abbreviations and Acronyms

AACC	American Association of Cereal Chemists
ACIAR	Australian Center for International Agricultural Research
ADAB	Australian Development Assistance Bureau
AE	adult equivalent
AGDP	Agricultural Gross Domestic Product
AGRICONGO	Institut de Recherche pour l'Appui and Développment Agricole en Zones Tropicales
ANOVA	analysis of variance
APA	African Potato Association
ARCT	African Regional Center for Technology
AVRDC	Asian Vegetable Research and Development Center
Cal	calorie
CBB	Cassava bacterial blight
CGPRT	Coarse Grains, Pulses, Roots and Crops Center
CIAT	Centro Internacional de Agricultura Tropical
CIP	International Potato Center
CMB	cassava mealybug
CMD	cassava mosaic virus disease
CNRCIP	Cameroon National Root Crop Improvement Program
CNRS	Centre National de la Recherche Scientifique
COSCA	Collaborative Study of Cassava in Africa
CPI	consumer price index
CTI	Compatible Technology Inc.
DAI	Development Alternatives Inc.
DDF	District Development Fund
DFTN	Department of Food Technology and Nutrition
DRC	domestic resource cost
DRI	Integrated Rural Development Program
DRS	Dryland Research Station
DSE	German Foundation for International Development
EC	European Community
ECA	Economic Commission for Africa
EIU	Economist Intelligence Unit
ELF	European Landworkers Federation
ENA	Enquête Nationale Agricole (National Agriculture Survey)
ENBC	Enquête Nationale sur le Budget et la Consommation des Ménages (National Budget and Consumption)
ENSET	Ecole National Superieure D'-Ensigmente Technique
EPADU	Export Policy Analysis and Development Unit
FAO	Food and Agricultural Organization of the United Nations
FBU	Burundese francs
FDTA	Fond de Développment des Technologies Alimentaires
FIIRO	Federal Institute of Industrial Research
g	grams
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
GMS	glycerol monostearate

GSM	green spider mite
GTZ	Deutsche Gesellschaff für Technische Zusammenarbeit
ha	hectare
HBS	household bridget survey
IAR	Institute of Agricultural Research
IAR&T	Institute of Agricultural Research and Training
ICA	Colombian National Program
ICH	International Child Health Unit
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICTA	Instituto de Ciencia y Tecnología Agrícola
IDESSA	Institut des Savanes de Bouake
IDRC	International Development Research Center
IFPRI	International Food Policy Research Institute
IFS	International Foundation for Science
IIBC	International Institute of Biological Control
IICA	Instituto Interamericano de Cooperación para la Agricultura
IITA	International Institute of Tropical Agriculture
ILO	International Labour Organization
ILRAD	International Laboratory for Research on Animal Diseases
INIAA	Instituto Nacional de Investigación Agrícola y Agroindustrial
INSA	National Institute for Agronomic Sciences
INTA	Instituto Nacional de Tecnología Agropecuaria
IPM	Integrated Pest Management
IRA	Institute of Agronomic Research
ISABU	Institut des Sciences Agronomiques du Burundi
ISAR	Institut des Sciences Agronomiques du Rwanda
ISER	Instituto de Economía y Sociología Rural
ISNAR	International Services for National Agricultural Research
ISTRC-AB	International Society for Tropical Root Crops - Africa Branch
KARI	Kenya Agricultural Research Institute
KCC	Kampala City Council
kg	kilogramo
km	kilometer
KSP20	Katumani sweetpotato 20
LBT	laboratorire de biotechnologie
LENA	Laboratoire d'Etudes Sur la Nutrition et l'Alimentation
LERPAN	Laboratoire des Etudes et des Recherches Sur a Physiologie, l'Alimentaiton et la Nutrition
LM	Laboratoire de Microbiologie
LMPC	Laboratoire de Physiologie el Métabolisme Cellulaire
LNT	Laboratoire de Nutrition Tropicale
m	meter
MAAIF	Ministry of Agriculture, Animal Industries and Fisheries
MALD	Ministry of Agriculture and Livestock Development
MDB	Marketing Development Bureau
mg	miligramos
MGP	mono-glycerol palmitate
MINAGRI	Ministry of Agriculture
mm	milimeter

MOA	Ministry of Agriculture
n.a.	not available
NAS	National Academy of Sciences
NCPB	National Cereals and Produce Board
n.d.	not determined
NGO	non-governmental organization
NRCRI	National Root Crops Research Institute
NRI	Natural Resources Institute
NFS	new farming system
ORSTOM	Institut Francais de Recherche Scientifique pour le Développement en Cooperation
PNE	Programme National Engrains
PRACIPA	Programa Andino Cooperativo de Investigación en Papa
PRODA	Project Development Agency
R&D	Research and Development
RCMP	Resource and Crop Management Program
RH	relative humidity
SDC	Swiss Development Cooperation
SEAMEO	Southeast Asian Ministers of Education Organization
SEARCA	Southeast Asia Regional Center for Graduate Studies and Research in Agriculture
SEP	Service des Etudes et Planification
SOTEC	Society for Development of Appropriate Technology
SRE	short run price elasticity
t/ha	tons per hectare
t	tons
TBS	Tanzania Bureau of Standards
TFNC	Tanzania Food and Nutrition Center
UNDP	United Nations Development Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations International Children's Emergency Fund
UON	University of Nairobi
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
V	volts
ViSCA	Visayas State College of Agriculture
vs	versus
w.b.	wet basis
WAI	water absorption index
WHO	World Health Organization
yr	year

I. Overview

This publication has three basic objectives. The first is to report on global, regional, and national trends in production, marketing, processing, and utilization of roots and tubers with particular emphasis on Africa. The second is to present an overall strategy for the successful development of new products and processes made from roots and tubers. The third is to document the progress made in processing, market assessments, or pilot plant operations in the case of particular commodities in specific African countries with some additional examples from Asia and Latin America.

The document contains six sections. The first paper in Section I (Overview) and the eleven papers in Section II (Commodity and Country Reports) provide a descriptive analysis of trends in production, commercialization, transformation, and utilization for roots and tubers first at the global and regional level; then, in the case of cassava and sweetpotato, at the country level. The second paper in Section I presents a strategy for new product and process development. Key components of this strategy are subsequently elaborated on in the initial papers of Section III (Assessment of Processing Potential), Section IV (Products and Processing Research), Section V (Setting Up Pilot Plants), and Section VI (Expansion into Commercial Production). The remaining papers in these sections document experiences with each of these components in Africa and in a few instances, Asia and Latin America.

Much of this publication is dedicated to documenting location-, time-, and commodity-specific experiences with developing new or improved products or processes for cassava and sweetpotato in Africa. Section I aims to provide a broader context for this material. It begins with an overview of recent trends for roots and tubers in developing countries. This is followed by the presentation of an overall strategy for processing and utilization initiatives.

The last three decades have witnessed a remarkable expansion of processing and new product development for root and tuber crops in developing countries generally and in Africa in particular. In **Transforming Traditional Food Crops: Product Development for Roots and Tubers,** Gregory J. Scott and Víctor Suárez first quantify these overall trends, perhaps less apparent at the project or even country level. They then examine the factors that have contributed to them. These include the agronomic and biochemical characteristics of root and tuber crops themselves and the evolution of production, consumption, and utilization for cassava, potato, and sweetpotato in Africa in comparison to Asia and Latin America. Special attention is given to the growth in utilization of cassava and sweetpotato for processed products for human

consumption and the prospects for continued expansion in the years ahead. Scott and Suárez go on to note that future processing developments will be influenced by demographic changes, income growth, government policies, and new technologies for roots and tubers. The paper includes a bibliography of recent publications on root and tuber processing in developing countries.

In the paper **Integrated Root and Tuber Crop Projects: A Strategy for Product Development**, Christopher Wheatley and Trudy Brekelbaum briefly review essential strategic elements of an integrated project including a systems orientation, inter-institutional collaboration, multi-disciplinary focus, active participation by final users, and an emphasis on demand-driven technological research. Such elements are necessary, they argue, if improvements of the post-harvest system are to benefit small farmers. They then go on to describe the stages of an integrated project beginning with problem and opportunity identification; applied research on products, processes and equipment; a pilot project phase; and expansion to commercial-scale operation. Wheatley and Brekelbaum conclude by pointing out the benefits of such an approach and its relation to other rural development efforts.

Transforming Traditional Food Crops: Product Development for Roots and Tubers

Gregory J. Scott and Víctor Suárez[1]

Abstract

Recent trends in production and utilization of roots and tubers point to a growing interest in new product development. This paper outlines the factors that have influenced the growing importance of product transformation of roots and tubers in developing countries over the last three decades. After a review of the agronomic and bio-chemical characteristics for cassava, potato, and sweetpotato, the paper analyzes global and regional patterns for production and use of these commodities. Sharp increases in potato production for fresh consumption; explosive growth in cassava processing in particular countries; and the use of sweetpotato for animal feed in China and Brazil are highlighted. Development trends including demography, income growth, and government policies are noted as key factors influencing future prospects for expanded processing.

Key words: cassava, potato, sweetpotato, production, utilization, new products, developing countries.

Introduction

The last three decades have witnessed remarkable increases in food production in many developing countries. Nevertheless, decision makers as well as members of the scientific community feel that further increases in productivity, farm incomes, and food consumption could well be realized. An emerging consensus among specialists in different disciplines suggests that this goal can best be achieved by an approach that emphasizes expanded utilization of agricultural commodities. The steps involved in this process are referred to in this publication as product development.

Product development is not a novel concept; but, on the eve of the 21st century, it has taken on new meaning in the agricultural sector of developing countries. There are many reasons for this. Perhaps, the most basic is that product development—albeit a general concept—is often associated with manufactured goods, the use of high technology, and developed countries (see e.g., Kotler 1986). The treatment here applies to food crops, both labor and capital-intensive techniques, and markets in developing countries (see also Austin 1992). In addition, the focus is on cassava, potatoes, and sweetpotatoes. These crops are frequently characterized as "traditional" or "subsistence" and not generally thought of as transformable for sale in a modern, commercial environment.

While certain modifications to the concept of product development might facilitate its application to roots and tubers, is there a justification for investing resources in this activity? The remainder of this paper addresses this issue by reviewing the different factors that contribute to the need for and advantages of this procedure for these commodities in developing countries today. It initially describes the agronomic and bio-chemical characteristics of their parent plants. This highlights the peculiar features of roots and tubers that lend themselves to—if not require, transformation to facilitate greater utilization. An analysis of production trends pinpoints those tendencies in output, area planted, and yield that suggest both the opportunity (growing supplies) and the need (declining area planted) for alternative uses for these crops. Subsequent discussion of recent changes in prevailing utilization patterns emphasizes the extent to which location specific experiences might well be put to wider use. A brief mention is made of market developments—beyond those for root and tuber crops themselves—that influence these trends before concluding with

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a short statement about future potential and some unanswered questions.

The Crops and Their Characteristics

This publication focuses largely on the three major root and tuber crops: potatoes (*Solanum tuberosum*), sweetpotatoes (*Ipomoea batatas*), and cassava (*Manihot esculenta*). Other roots and tubers that are given some, albeit minor, mention include: yams (*Dioscorea* spp.), cocoyam (*taro, yautia* = *Colocasia esculenta*) and tannia (*Xanthosoma* spp.).

Collectively, these crops occupy about 50 million ha worldwide (Horton et al. 1984), producing over 550 million t annually, about two-thirds of which is harvested in developing countries. Cassava alone is an important food crop for some 500 million people in the Third World (De Bruijn and Fresco 1989). Cassava, potatoes, and sweetpotatoes are now grown in roughly 100 developing countries in all parts of the world. Their wide adaptability to diverse growing conditions reflects, in part, their agronomic characteristics.

Both potatoes and sweetpotatoes have a considerably shorter vegetative cycle than other root crops (Table 1). Hence they fit better into tight cropping systems than, for example, cassava which has a growing period from 9 to 24 months, depending on soil fertility and ambient temperature. Although potato yields are highest under cool conditions, the crop is grown extensively in areas with high daytime temperatures; e.g., Tunisia and Bangladesh (see Horton and Monares 1984; Scott 1988). However, potatoes do not tuberize well at night time temperatures that exceed 20°C (Midmore and Rhoades 1987). Partly for that reason, prime planting and harvesting dates for potatoes in most developing countries coincide with particular seasons during the calendar year. In contrast, sweetpotatoes, cassava, and other roots are best cultivated under higher temperatures. Potatoes require less total rainfall than cassava; but rain must be fairly continuous, particularly at the beginning and during the tuberization phase of the vegetative cycle. Drought can be devastating for a potato crop, much less so in the case of cassava and sweetpotato. For commercial yields, potatoes need much higher inputs of fertilizer and organic matter, whereas cassava and sweetpotatoes are known as crops that will produce good returns even in poor soils and without chemical fertilizers or heavy doses of locally available organic matter. Cultural practices (e.g., handling of seed, weeding, pest control) all tend to be more demanding for potatoes than for cassava or sweetpotatoes. Furthermore, potatoes can normally be left in the ground for only short periods after their prime harvesting date. Cassava is "stored in the ground," unharvested for many months by farmers in developing countries. The seasonal nature of root and tuber production is one major reason why transformation of some sort is required to enable their continuous use throughout the year. The bio-chemical characteristics of these crops constitute another.

Biochemical Traits

Perishability and bulkiness are two singular traits of roots and tubers. Fresh cassava has a dry matter content of about 40%; sweetpotatoes, 30%; and potatoes, 20%. Physiological deterioration of fresh cassava roots begins 1-3 days after harvest (Ospina and Wheatley 1992). Although potatoes and sweetpotatoes have a much longer shelf life, their harvested roots and tubers are also living organisms that require adequate respiration and proper handling to prevent sprouting, spoilage, or pest damage. While these particular bio-chemical traits present serious problems for expanded utilization of these crops, others attributes—much less frequently mentioned—offer distinct opportunities.

As Horton (1988) points out, "Root crops are often thought of as 'starchy staples' that provide low-cost energy but little else to the human diet;" and he goes on to note, this generalization is misleading. Quantities of protein, essential vitamins, and minerals vary considerably across roots and tubers. On average, cooked potatoes and yams have about 2% protein, or twice that found in cassava (Table 2). Cassava, potatoes, and sweetpotatoes all provide ascorbic acid, whereas cereal-based foods have none. Potatoes and sweetpotatoes also contain the important amino acid lysine which commodities such as rice are deficient in (Woolfe 1987, 1992). Furthermore, cassava, potatoes, and sweetpotatoes significantly outyield the cereals in dry matter (i.e., calorie production) per unit area. Potatoes are particularly productive on a carbohydrate per hectare per day basis (Table 3). These various considerations have strongly influenced production trends for roots and tubers over the last three decades.

Production Trends

Developing countries produced 149 million t of cassava, 122 million t of sweetpotatoes, and 79 million t of potatoes in 1988-90 (Table 4). Production increases for the period 1961-90 were 100%, 31%, and 173% for the three crops, although output of sweetpotatoes actually

Table 1. Characteristics of root and tuber crops.

Characteristics	Cassava	Potatoes	Sweet-potatoes	Tannia	Taro	Yam
Growth period (mo)	9-24	3-7	3-8	9-12	6-18	8-11
Annual or perennial plant	per.	ann.	per.	per.	per.	ann.
Optimal rainfall (cm)	100-150	50-75	75-100	140-200	250	115
Optimal temperature (°C)	25-29	15-18	>24	13-29	21-27	30
Drought resistance	yes	no	yes	no	no	yes
Optimal pH	5-6	5.5-6.0	5.6-6.6	5.5-6.5	5.5-6.5	n.a.
Fertility requirement	low	high	low	high	high	high
Organic matter requirement	low	high	low	high	high	high
Growable on swampy, water-logged soil	no	no	no	no	yes	no
Planting material	stem cutting	tubers	vine cutting	corms/ cormels	corms/ cormels	tubers
Storage time in ground	long	short	long	long	moderate	long
Postharvest storage life	short	long	short	long	variable	long

Source: Derived from Kay, D.E. 1973. Tropical Products Institute. London, as presented in Horton 1988.
n.a. = Data not available.

Table 2. Nutritional composition of a 100 g edible portion of various foods.

Food[a]	Water (%)	Protein (g)	Food Energy (kcal)	Protein/ Caloric Ratio (g/000 g)	Fats (mg)	Ash (mg)	CA (mg)	P (mg)	Fe (mg)	Na (mg)	K (mg)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Ascorbic Acid (mg)
Maize (grits)	87	1.2	51	24	0.1	0.6	1	10	0.1	205	11	0.02	0.01	0.2	0
Potatoes	80	2.1	76	27	0.1	0.9	7	53	0.6	3	407	0.09	0.04	1.5	16
Plantains	80	1.3	77	17	0.1	0.7	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]
Taro (raw)	73	1.9	98	19	0.2	1.2	28	61	1.0	7	514	0.13	0.04	1.1	4
Yams (raw)	74	2.1	101	21	0.2	1.0	20	69	0.6	--	600	0.10	0.04	0.5	9
Rice	73	2.0	109	18	0.1	1.1	10	28	0.2	374	28	0.02	0.01	0.4	0
Spaghetti	72	3.4	111	31	0.4	1.2	8	50	0.4	1	61	0.01	0.01	0.3	0
Sweetpotatoes	71	1.7	114	15	0.4	1.0	32	47	0.7	10	243	0.09	0.06	0.6	17
Common beans	69	7.8	118	66	0.6	1.4	50	148	2.7	7	416	0.14	0.07	0.7	0
Cassava	68	0.9	124	7	0.1	0.6	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	26
Fresh white bread	*36*	*8.7*	*269*	*32*	*3.2*	*1.9*	*70*	*87*	*0.7*	*507*	*85*	*0.09*	*0.08*	*1.2*	*trace*

Source: US Dept. of Agriculture (USDA). 1975. Composition of foods. US Dept. of Agriculture, Washington, D.C., USA; W-T. Wu-Leung, F. Busson, and C. Jardin. 1968. Food composition table for use in Africa. US Dept. of Health, Education and Welfare, Public Health Service, Bethesda, MD, USA as presented in Horton 1988.
[a]Boiled unless otherwise indicated. Edible portions of potatoes and other root crops and plantains do not include peels.
[b]Dashes denote lack of reliable data.

Table 3. Top ranking food crops in developing market economies in terms of dry matter production/ha and edible energy and protein production/ha/day.

Dry matter prod/ha		Energy prod/ha/day		Protein prod/ha/day	
Crop	t	Crop	mj	Crop	kg
Cassava	3.0	Potatoes	216	Cabbages	2.0
Yams	2.4	Yams	182	Dry broad beans	1.6
Potatoes	2.2	Carrots	162	Potatoes	1.4
Sweetpotatoes	2.1	Maize	159	Dry peas	1.4
Rice	1.9	Cabbages	156	Eggplants	1.4
Carrots	1.7	Sweetpotatoes	152	Wheat	1.3
Cabbages	1.6	Rice	151	Lentils	1.3
Bananas	1.5	Wheat	135	Tomatoes	1.2
Wheat	1.3	Cassava	121	Chickpeas	1.1
Maize	1.3	Eggplants	120	Carrots	1.0

Source: Horton and Fano 1985.

Table 4. Food crop production in developing countries, 1961-90.

	1988-90			Change (%)[a]								
	Production	Area	Yield	Production			Area			Yield		
	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
Rice, paddy	484,379	143,000	3.4	52.3	52.6	132.4	17.7	6.6	25.5	29.5	43.1	85.2
Wheat	224,612	100,450	2.2	79.5	94.0	248.3	19.8	12.9	35.3	49.8	71.8	157.4
Maize	196,916	83,213	2.4	73.1	65.1	185.9	22.0	14.7	40.0	41.9	43.9	104.3
Cassava	149,193	15,074	9.9	41.2	41.3	99.5	28.4	17.8	51.3	9.9	19.9	31.8
Sweetpotatoes	122,057	9,063	13.5	52.2	-14.1	30.6	-4.1	-24.9	-28.0	58.7	14.3	81.4
Potatoes	79,066	6,363	12.4	73.8	56.8	172.5	31.9	35.7	79.0	31.7	15.6	52.3
Soybeans	48,857	30,255	1.6	130.7	169.2	521.0	27.6	104.7	161.3	80.8	31.5	137.7
Bananas	44,766	4,004	11.2	43.7	45.4	108.9	41.0	25.7	77.2	1.9	15.6	17.9
Sorghum	42,288	38,600	1.1	38.7	3.4	43.4	-0.8	-5.7	-6.5	39.9	9.7	53.4
Tomatoes	33,881	1,848	18.3	78.0	118.8	289.4	48.0	59.0	135.3	20.3	37.6	65.5
Millets	26,894	34,994	0.8	17.9	2.0	20.3	2.3	-12.5	-10.5	15.3	16.6	34.4
Barley	25,156	18,401	1.4	-7.0	35.3	25.9	-15.6	6.8	-9.9	10.2	26.8	39.7
Groundnuts in shell	21,907	19,687	1.1	19.0	34.5	60.0	14.8	4.5	19.9	3.6	28.7	33.4
Yams	18,083	2,087	8.7	53.6	36.2	109.2	34.3	31.0	76.0	14.4	3.9	18.9
Cabbages	15,774	816	19.3	65.9	71.4	184.3	27.8	18.7	51.8	29.8	44.3	87.3
Beans, dry	13,324	23,889	0.6	17.9	24.4	46.7	15.4	15.1	32.9	2.1	8.1	10.4
Chickpeas	6,294	9,204	0.7	-18.3	9.4	-10.6	-16.3	-4.2	-19.8	-2.4	14.2	11.5
Broad beans, dry	3,657	2,822	1.3	-22.4	2.6	-20.4	-23.7	-19.9	-38.9	1.6	28.1	30.2
Lentils	2,093	2,900	0.7	24.5	108.9	160.0	22.2	61.1	96.8	1.9	29.7	32.1

Source: FAO Basic Data Unit, unpublished statistics.

[a] 1 = (1973-75 vs 1961-63); 2 = (1988-90 vs 1973-75); 3 = (1988-90 vs 1961-63).

declined by 14% in the latter half of the period. Area planted to sweetpotatoes also fell sharply in recent years. However, this was more than offset by a near doubling of yields. Area planted in potatoes grew steadily over the last three decades—up 79% since 1961; more, in fact, than any other of the major food crops except soybeans and tomatoes (albeit that it started from a much smaller base than the coarse grains or beans). Area in cassava production grew by about 50%. Yields improved 32%. Prospects for product development for roots and tubers reflect, broadly speaking, all these tendencies; however, production trends have been highly varied, not only across commodities but also for the same commodity across (and even within) regions. Statistics on the evolution of output, area planted, and yield, therefore merit closer scrutiny.

Regional Distribution

Although cassava, potatoes, and sweetpotatoes all originated in Latin America, the principal locus of their production has gravitated away from this region. Two-thirds of current developing country output of these crops is in Asia, and this distribution has tended to become more concentrated over time. This pattern largely reflects the high concentration of potato (76%) and sweetpotato (93%) production in the region. China alone produces nearly 40% of the developing world's potatoes and over 85% of its sweetpotatoes (Tables 5 and 6). Africa still produces nearly half (44%) the developing world's cassava (Table 7). Output of potatoes and cassava grew much faster in Africa and Asia whereas production of sweetpotatoes in Latin America actually declined by 22% since 1961.

Asia has the largest number (n=33) of potato-producing countries and the heaviest concentration of big producers (Table 8). Africa has more cassava-(n=38), and sweetpotato-(n=36) producing countries. In contrast, Latin America has numerous countries that produce minor quantities (<10,000 t/yr) of cassava (n=12) and sweetpotatoes (n=12).

Sweetpotato

Although cassava, potatoes, and sweetpotatoes are grown in many more countries than perhaps is commonly realized, production is concentrated in relatively few locations. For example, 16 countries with the largest sweetpotato production account for nearly 97% of this total (Table 9) and also for 98% of the change in output since 1961.

Recent trends in sweetpotato area planted and production have been highly uneven. In a number of countries, output and area have fallen (e.g., China, Indonesia, Philippines, Brazil) since the mid-1970s. Reasons cited

Table 5. Potato production, area, and yield in developing countries by regions, 1961-90.

	1988-90			Change (%)[a]								
	Production	Area	Yield	Production			Area			Yield		
	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
Africa[b]	6,116	650	9.4	75.0	91.1	234.3	86.7	48.0	176.4	-6.3	29.1	21.0
(Sub-Saharan)[c]	2,282	381	6.0	70.3	40.8	139.9	83.3	31.4	140.9	-7.1	7.2	-0.4
Asia[d]	60,073	4,695	12.8	89.7	58.3	200.4	39.9	46.0	104.3	35.6	8.4	47.0
(China)	31,597	2,801	11.3	99.9	22.5	144.8	41.9	37.6	95.3	40.8	-11.0	25.4
Latin America[e]	12,877	1,018	12.7	29.2	38.8	79.3	1.4	-1.7	-0.3	27.4	41.2	79.9
Total	79,066	6,363	12.4	73.8	56.8	172.5	31.9	35.7	79.0	31.7	15.6	52.3

Source: FAO Basic Data Unit, unpublished statistics.

[a] 1 = (1973-75 vs 1961-63); 2 = (1988-90 vs 1973-75); 3 = (1988-90 vs 1961-63).

[b] Africa not including South Africa.

[c] Africa - (Morocco, Algeria, Tunisia, Egypt, Libya) - (South Africa).

[d] Asia - (Israel, Japan) + Oceania - (Australia, New Zeland).

[e] North and Central America + South America - (Canada, USA).

Table 6. Sweetpotato production, area, and yield in developing countries by regions, 1961-90.

	1988-90			Change (%)[a]								
	Production	Area	Yield	Production			Area			Yield		
	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
Africa[b]	6,492	1,315	4.9	44.5	29.7	87.4	73.0	18.3	104.6	-16.4	9.6	-8.4
(Sub-Saharan)[c]	6,401	1,311	4.9	46.1	29.5	89.3	73.6	18.3	105.4	-15.8	9.5	-7.9
Asia[d]	113,380	7,453	15.2	53.7	-15.4	30.1	-8.9	-29.5	-35.7	68.6	20.0	102.4
(China)	104,824	6,304	16.6	58.0	-15.7	33.2	-10.5	-31.8	-39.0	76.5	23.7	118.3
Latin America[e]	2,185	295	7.4	14.5	-31.6	-21.6	12.5	-23.2	-13.6	1.8	-11.0	-9.3
Total	122,057	9,063	13.5	52.2	-14.1	30.6	-4.1	-24.9	-28.0	58.7	14.3	81.4

Source: FAO Basic Data Unit, unpublished statistics.

[a] 1 = (1973-75 vs 1961-63); 2 = (1988-90 vs 1973-75); 3 = (1988-90 vs 1961-63).

[b] Africa not including South Africa.

[c] Africa - (Morocco, Algeria, Tunisia, Egypt, Libya) - (South Africa).

[d] Asia - (Israel, Japan) + Oceania - (Australia, New Zeland).

[e] North and Central America + South America - (Canada, USA).

Table 7. Cassava production, area, and yield in developing countries by regions, 1961-90.

	1988-90			Change (%)[a]								
	Production	Area	Yield	Production			Area			Yield		
	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
Africa[b]	65,344	8,440	7.7	35.2	49.6	102.3	25.3	18.4	48.3	7.9	26.4	36.4
(Sub-Saharan)[c]	65,344	8,440	7.7	35.2	49.6	102.3	25.3	18.4	48.3	7.9	26.4	36.4
Asia[d]	52,836	4,013	13.2	61.4	74.7	181.8	27.0	36.5	73.4	27.1	27.9	62.6
(China)	3,271	230	14.2	99.1	38.5	175.9	93.4	18.2	128.5	3.0	17.3	20.7
Latin America[e]	31,013	2,621	11.8	33.4	-2.1	30.6	39.1	-3.7	33.9	-4.1	1.7	-2.5
Total	149,193	15,074	9.9	41.2	41.3	99.5	28.4	17.8	51.3	9.9	19.9	31.8

Source: FAO Basic Data Unit, unpublished statistics.

[a] 1 = (1973-75 vs 1961-63); 2 = (1988-90 vs 1973-75); 3 = (1988-90 vs 1961-63).

[b] Africa not including South Africa.

[c] Africa - (Morocco, Algeria, Tunisia, Egypt, Libya) - (South Africa).

[d] Asia - (Israel, Japan) + Oceania - (Australia, New Zeland).

[e] North and Central America + South America - (Canada, USA).

Table 8. Distribution of developing countries by volume of cassava (C), potato (P), and sweetpotato (SP) production, 1988-90.

	Number of countries											
	Africa			Latin America			Asia			Total		
Production	C	P	SP	C	P	SP	C	P	SP	C	P	SP
0/no information	16	24	18	18	25	25	44	32	40	78	81	83
<10,000 t	4	6	10	12	4	12	6	6	8	22	16	30
<50,000 t	6	11	11	5	6	1	3	6	4	14	23	16
<250,000 t	8	7	7	4	4	5	4	9	4	16	20	16
>250,000 t	20	6	8	8	8	4	8	12	9	36	26	21
Total	54	54	54	47	47	47	65	65	65	166	166	166

Source: FAO Basic Data Unit, unpublished statistics.

Table 9. Sweetpotato production, area, and yield in selected developing countries, 1961-90.

	1988-90			Change (%)[a]								
	Production	Area	Yield	Production			Area			Yield		
Country[b]	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
China[c]	104,824	6,304	16.6	58.0	-15.7	33.2	-10.5	-31.8	-39.0	76.5	23.7	118.3
Indonesia	2,118	232	9.1	-20.9	-12.8	-31.0	-26.6	-31.9	-50.0	7.8	27.9	37.9
Vietnam	1,920	328	5.9	-4.6	74.6	66.6	-5.1	50.1	42.5	0.5	16.4	16.9
Uganda	1,718	412	4.2	201.2	3.7	212.4	209.1	-15.1	162.4	-2.6	22.2	19.0
India	1,262	159	8.0	56.2	-18.4	27.6	49.5	-26.7	9.7	4.5	11.3	16.3
Rwanda	817	147	5.5	12.0	43.1	60.2	9.0	81.9	98.2	2.7	-21.3	-19.2
Brazil	683	68	10.1	15.5	-59.2	-52.9	6.0	-55.9	-53.2	8.9	-7.6	0.7
Philippines	675	140	4.8	11.8	-17.1	-7.3	17.6	-19.6	-5.4	-4.9	3.1	-2.0
Burundi	655	91	7.2	-11.3	57.3	39.4	-0.5	36.5	35.8	-10.9	15.2	2.7
Kenya	561	57	9.8	80.0	107.7	273.8	23.4	81.1	123.4	45.9	14.7	67.3
Bangladesh	538	52	10.4	95.0	-21.2	53.7	64.1	-19.3	32.5	18.8	-2.3	16.0
Korea Rep.	528	23	22.6	45.2	-68.8	-54.7	18.8	-74.3	-69.4	22.2	21.4	48.4
Tanzania	526	245	2.1	92.3	29.1	148.3	367.4	70.9	698.9	-58.9	-24.5	-68.9
Korea DP	501	35	14.4	38.4	57.8	118.3	42.9	48.6	112.2	-3.1	6.2	2.9
Madagascar	479	91	5.3	-14.2	81.3	55.6	0.0	57.8	57.8	-14.2	14.9	-1.4
Papua New Guinea	460	101	4.6	37.9	12.8	55.6	21.6	12.2	36.5	13.4	0.5	14.0
All developing countries	122,057	9,063	13.5	52.2	-14.1	30.6	-4.1	-24.9	-28.0	58.7	14.3	81.4

Source: FAO Basic Data Unit, unpublished statistics.

[a] 1 = (1973-75 vs 1961-63); 2 = (1988-90 vs 1973-75); 3 = (1988-90 vs 1961-63).

[b] Data are for the 16 countries with the largest production.

[c] Includes Taiwan.

for this include: (1) expansion of production infrastructure (i.e., irrigation) for other crops, and (2) switching to higher value vegetable crops in response to growth in urbanization, income, and the associated demand for a more diversified diet (see e.g., Calkins 1979; Chin 1989).[2] Trends in sweetpotato production have been just the opposite in several other countries. Sweetpotato output expanded rapidly during the last decade in various locations including Kenya, Rwanda, Burundi, the Democratic Republic of Korea, and Madagascar. Rapid population growth resulting in increased pressure on farmland was a prime factor explaining this trend in many of these countries; e.g., Rwanda (see Von Braun et al. 1991). Minimal prodution costs and the crop's ability to do well on even marginal soils also contributed to this trend (Ewell and Kirkby 1991).

More broadly speaking, 7 of the 16 countries producing the largest amounts of sweetpotato have experienced a drop in production since 1973-75. In the absence of detailed information, most observers attribute this to weak demand or the lack of alternative markets (see CIP 1988, 1988a, 1989). A recent survey of national program scientists found that, in their opinion, these two factors were by far the most important constraints to increased production (CIP 1989a).

Potato

Eighteen of the largest potato-growing countries produce nearly 90% of the developing world's potatoes (Table 10) and account for almost 90% of the increase in production since 1961. In addition to China, the biggest growth in output has taken place in South Asia (Bangladesh, India and Pakistan), North Africa (Algeria, Egypt and Morocco) and the Middle East (Iran and Turkey). The potato fits extremely well into the cereal-based cropping systems found in these countries. The introduction of improved, short-duration varieties of wheat and rice into these systems has opened up a niche in the agricultural calendar. The availability of irrigation, abundant supplies of cheap labor—particularly in South Asia—and the introduction of improved varieties and chemical fertilizers, have facilitated a rapid rise in yields and an expansion in area planted (see e.g., Chowdhury and Sen 1981; Scott 1988; Kokab and Smith 1989). The huge increase in output in Colombia is also noteworthy. Growth there seems partly attributable to the rapid expansion in the processing sub-sector (Rodriguez and Rodriguez 1992).

The strong internal demand for food; the desire by the vast majority of low-income consumers to diversify their diets; modest per capita consumption of potatoes; in the case of the North African countries, the highly lucrative, European export market; and, in South Asia the expansion in postharvest infrastructure (i.e., cold storage facilities) have also contributed strongly to these trends. In several Latin American countries, on the other hand, potato production has been adversely affected by drought, cheap imports of cereals, and, in the case of Chile, a shift in area planted to higher value, fruit and vegetable crops for export (see Fu 1979; Scott 1985).

Several other, less important producers have witnessed substantial increases in potato output over the last three decades (e.g., Syria). In these countries, as well as the aforementioned cases, policy makers and potato scientists are increasingly interested in developing alternative uses for this commodity to avoid a possible collapse in prices resulting from an abrupt saturation of the domestic market. In a recent survey, unstable prices and supplies were cited by national program scientists as the most important constraints to increased potato production (see Scott 1991).

Cassava

Five countries produce 64% of the developing world's cassava: Brazil, Thailand, Zaïre, Nigeria, and Indonesia (Table 11). Thus, although cassava ranks second in Latin America in annual production (fresh weight basis) among the 19 major food crops, Brazil harvests 74% of the regional total. Zaïre and Nigeria account for about 50% of Africa's cassava; Thailand and Indonesia for over 70% of all the cassava grown in Asia. As with potatoes and sweetpotatoes, however, trends in cassava production across countries have been highly uneven.

Among the eight largest producers in Sub-Saharan Africa, increases in cassava output for the period 1961-90 were 90% or more in six cases (Table 11). Dorosh (1989) argues that the major factors that have contributed to the growth of cassava production in these countries include "the low labor input requirements, ability to produce a crop on degraded soils, and drought tolerance." Unlike the labor-abundant economies of

[2] Little quantitative research has been done on the relationship between changes in income and the consumption of fresh sweetpotato roots in developing countries. Studies carried out in the Philippines (Alkuino 1983; Bouis 1991) and Peru (Collins 1989) show this relation to be much more complex than previously believed with consumers' response depending on income levels, sweetpotato varieties, place of residence and so on (see also Watson 1989).

Table 10. Potato production, area, and yield in selected developing countries, 1961-90.

	1988-90			Change (%)[a]								
	Production	Area	Yield	Production			Area			Yield		
Country[b]	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
China	31,597	2,801	11.3	99.9	22.5	144.8	41.9	37.6	95.3	40.8	-11.0	25.4
India	14,558	925	15.7	82.1	181.1	411.9	41.8	69.7	140.7	28.4	65.6	112.7
Turkey	4,237	191	22.2	55.0	82.5	182.8	28.1	5.5	35.1	21.0	72.9	109.3
Argentina	2,656	112	23.6	7.4	57.5	69.2	-30.7	-5.1	-34.2	54.9	66.0	157.0
Colombia	2,560	168	15.2	68.5	128.4	284.8	56.0	67.4	161.1	8.0	36.4	47.4
Brazil	2,222	163	13.6	37.9	42.9	97.1	-2.6	-14.5	-16.7	41.5	67.2	136.6
Korea DP	2,042	155	13.2	55.2	82.7	183.6	36.4	54.7	110.9	13.8	18.1	34.4
Iran	1,984	124	16.0	64.6	280.5	526.4	63.9	271.0	508.2	0.4	2.6	3.0
Egypt	1,719	80	21.4	90.7	131.7	341.9	75.0	91.3	234.7	9.0	21.1	32.0
Peru	1,651	192	8.6	17.1	-2.4	14.2	2.9	-26.9	-24.8	13.8	33.6	52.0
Bangladesh	1,144	117	9.8	127.4	44.8	229.3	49.4	38.2	106.5	52.2	4.8	59.5
Mexico	1,044	72	14.4	76.5	61.8	185.6	16.9	30.7	52.8	51.0	23.8	86.9
Algeria	903	106	8.5	81.3	113.5	287.0	161.4	73.8	354.3	-30.7	22.8	-14.8
Morocco	885	50	17.8	26.9	254.1	349.4	-6.3	152.5	136.5	35.5	40.2	90.0
Chile	880	60	14.7	-3.3	11.2	7.5	-15.9	-22.4	-34.8	15.0	43.3	64.8
Bolivia	695	131	5.3	45.2	-9.9	30.9	10.0	8.3	19.1	32.0	-16.8	9.9
Pakistan	680	67	10.1	114.8	165.1	469.6	76.2	173.0	381.0	21.9	-2.9	18.4
Nepal	627	82	7.7	29.3	107.7	168.6	27.4	55.1	97.6	1.5	34.0	35.9
All developing countries	79,066	6,363	12.4	73.8	56.8	172.5	31.9	35.7	79.0	31.7	15.6	52.3

Source: FAO Basic Data Unit, unpublished statistics.

[a] *1 = (1973-75 vs 1961-63); 2 = (1988-90 vs 1973-75); 3 = (1988-90 vs 1961-63).*

[b] *Data are for the 18 countries with the largest production.*

Asia, most African agriculture has a much lower man/land ratio. The relatively meagre manpower needed for cassava cultivation as well as the fairly flexible cultural practices make the crop attractive to farmers with a diverse set of farm and non-farm occupations. Population pressure, shorter fallows, and the shortage of fertilizers and organic matter are added reasons growers in Africa are attracted to cassava (ibid.).

Cassava has proven to be popular in Thailand because of its high drought tolerance, stable yields, and flexible planting and harvesting dates (Konjing 1989). With the growth in exports of dried cassava to the European Community (EC), strong market demand has also been a major contributing force to the growth in production (see Phillips 1979; Sarma and Kunchai 1989). Similar agronomic factors have been responsible for the growth in cassava output in the Philippines (Cabanilla 1989). Strong rural demand for food as well as the use of cassava for animal feed and manufacturing in the domestic market—the Philippines exports only negligible quantities—have been other important reasons behind the growth in production. The Indonesian case

Table 11. Cassava production, area, and yield in selected developing countries, 1961-90.

	1988-90			Change (%)[a]								
	Production	Area	Yield	Production			Area			Yield		
Country[b]	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
Brazil	23,209	1,856	12.5	28.7	-10.1	15.8	37.5	-9.5	24.4	-6.3	-0.7	-7.0
Thailand	22,424	1,543	14.5	221.3	254.0	1,037.5	283.3	235.4	1,185.6	-16.2	5.6	-11.5
Zaire	17,333	2,256	7.7	29.1	51.6	95.6	22.4	36.9	67.5	5.5	10.7	16.8
Nigeria	16,636	1,504	11.1	30.1	68.6	119.4	23.5	49.4	84.5	5.4	12.9	18.9
Indonesia	16,139	1,341	12.0	6.0	33.3	41.3	-3.9	-7.5	-11.1	10.3	44.1	59.0
Tanzania	7,230	671	10.8	54.4	61.5	149.3	35.1	-14.3	15.7	14.3	88.5	115.4
India	5,308	269	19.8	240.3	-16.7	183.4	42.4	-28.0	2.5	139.0	15.6	176.4
Mozambique	4,019	941	4.3	23.1	25.6	54.6	6.7	17.7	25.5	15.4	6.7	23.1
Paraguay	3,806	235	16.2	31.4	190.5	281.8	25.9	164.0	232.5	4.4	10.0	14.8
Uganda	3,393	375	9.1	125.5	36.2	207.0	82.9	-29.1	29.6	23.2	92.2	136.8
China	3,271	230	14.2	99.1	38.5	175.9	93.4	18.2	128.5	3.0	17.3	20.7
Ghana	3,115	364	8.6	50.3	83.2	175.3	67.2	48.8	148.7	-10.1	23.2	10.7
Vietnam	2,650	293	9.1	-0.7	134.4	132.8	0.4	90.9	91.7	-1.1	22.8	21.5
Madagascar	2,252	339	6.6	30.5	80.2	135.3	19.5	74.6	108.6	9.3	3.2	12.8
Philippines	1,856	215	8.6	35.2	169.8	264.8	11.0	112.5	135.9	21.8	27.0	54.6
Angola	1,817	500	3.6	28.6	10.8	42.5	25.2	4.2	30.4	2.7	6.3	9.2
All developing countries	149,193	15,074	9.9	41.2	41.3	99.5	28.4	17.8	51.3	9.9	19.9	31.8

Source: FAO Basic Data Unit, unpublished statistics.

[a] 1 = (1973-75 vs 1961-63); 2 = (1988-90 vs 1973-75); 3 = (1988-90 vs 1961-63).

[b] Data are for the 16 countries with the largest production.

presents both elements. Cassava exports are considerable in volume and value terms.[3] Roughly 35% of domestic output goes to the local starch industry for human consumption (see Kasryno 1989).

In Latin America, growers in Brazil have switched to other more profitable crops which, in turn, reflects weak demand; hence the decline in production (10%) and area planted (10%) between 1973 and 1990. Prospects for expanded utilization of cassava in northeast Brazil appear to have slowed, if not reversed, this trend in recent years (see Ospina and Wheatley 1992). The Brazilian experience with cassava—combined with similar developments in Colombia and Ecuador in Latin America (see Best and Wheatley 1990), as well as in Thailand and Indonesia in Asia—has contributed to renewed interest in the evolution of utilization patterns for roots and tubers generally.

[3] Exports of gaplek (i.e., dried cassava chips base) have fluctuated between 149,000 and 710,000 t since 1970. In 1986, 97% of these exports were to Germany (see Kasryno 1989).

Consumption and Utilization

Roots and tubers are often thought of as food crops first and last. While more than half of production goes for human consumption in fresh form, the share of output devoted to different uses varies considerably across crops, regions, and countries. Furthermore, utilization patterns for sweetpotatoes and, to a lesser extent, cassava have experienced noteworthy changes over the last 30 years. For example, processing for animal feed has assumed major importance in a number of countries. These trends, and prospects for similar developments in the future, mean consumption and utilization patterns for roots and tubers are the focus of increasing scrutiny. It also should be noted, however, that estimates of "processing" or "waste" as a percentage of root and tuber production are difficult to interpret. In many countries, waste in the form of damaged roots and vines is processed or fed to livestock. On the other hand, some production is lost due to physical or autolytic processes, microbiological attack, and pest damage (see NAS 1978). Furthermore, given the higher water content and bulkiness of roots and tubers, postharvest losses would appear to be higher than for the cereal crops (see Coursey 1982). But little quantitative information is available other than that based on inferences of an a priori type (e.g., sweetpotatoes are perishable; therefore, a certain percentage of the harvest is lost) or desktop "guesstimates." Consequently, available statistics must be interpreted with caution.

An estimated 60% of potato production in developing countries is for human consumption, 15% for feed, 10% for seed, 5% for processing, and about 10% is lost to waste (Table 12). FAO Food Balance Sheets statistics indicate these percentages have remained constant over time. Potatoes are eaten in one of four different ways in the tropics: as a basic staple, a complementary vegetable, a seasonal vegetable, or a delicacy to be consumed on special occasions (Poats 1983).

In most countries, potatoes are a seasonal vegetable or a delicacy. They are the centerpiece of the diet only in the highlands of South America and parts of Central Africa. What is noteworthy, however, is their rapidly expanding role as a complementary vegetable in South Asia (e.g., Pakistan, India, and Bangladesh), in North Africa (e.g., Egypt, Tunisia) and in eastern and southern Africa (e.g., Kenya, Rwanda, and Madagascar). Most consumers like the taste of potatoes, but find them too expensive to eat on a daily basis.

Traditional or simple rustic processing of potatoes for human consumption is a common practice in Peru, Bolivia, and, to a lesser extent, Ecuador. Typically potatoes are solar dried (see Yamamoto 1987). A modernized version of such practices has also been tried in Colombia (Mantilla 1988) and Guatemala (Esquite and Perez 1990). Simple processing of potatoes is also practiced in Madagascar on a limited basis (Rasolo et al. 1987) and is being tested experimentally in Cameroon (Nave 1989) and Zaïre (Ravuna 1990). Potatoes are processed at the village-level in Bangladesh, India, and Pakistan (see e.g., CTI n.d.; Sikka 1988).

The potato tends to be a relatively costly commodity in most developing countries. Hence the value added involved in transformation makes them prohibitively expensive as processed food products for all but the highest income households, or simply non-competitive vis-à-vis cheap substitutes for industrial use (as

Table 12. Changes in utilization (%) of cassava (C), potatoes (P), and sweetpotatoes (SP) in developing countries, 1961-90.[a]

	1961-63			1973-75			1988-90		
Utilization	C	P	SP	C	P	SP	C	P	SP
Food	69.6	62.7	76.6	68.5	59.8	69.8	70.1	61.7	52.0
Feed	12.9	13.5	12.4	14.0	17.9	19.1	12.0	15.1	37.0
Processing[b]	3.5	2.4	4.8	3.7	4.1	5.0	4.3	5.5	5.3
Seed	0.0	13.1	0.3	0.0	10.1	0.1	0.0	8.5	0.1
Waste	14.0	8.3	5.9	13.9	8.1	6.0	13.6	9.2	5.7

Source: FAO Food Balance Sheets, unpublished statistics.

[a]Totals may not add up to 100 due to rounding.

[b]Includes other uses.

starch) or livestock feed (see e.g., Gomez and Wong 1989). China is an exceptional case where a growing share of potato production goes to noodle-making, flour, and snack foods (Gitomer 1987).

Producer prices for potatoes in relation to unit production costs have generally been quite favorable as witnessed by the sharp increase in area planted in Asia, Sub-Saharan Africa, and parts of Latin America. As a result, only in the last decade or so have bumper crops for potatoes in a number of countries stirred an interest in serious attempts to develop alternative market outlets.

Growth of the fast food industry in Southeast Asia, Central America, Mexico, and parts of South America (Colombia and Brazil) represent an exception to this scenario. Strong demand for potatoes in this particular market niche in these locations appears to override cost considerations in the short-run and serves as an attractive financial incentive to expand local supply to cater to industry needs in the medium term (Scott et al. 1992).

Feed statistics in great measure reflect the substantial use of potatoes in China for pig feed. Most of this involves the use of small, decayed tubers and vines (see Gitomer 1987). Feed use of potatoes in Africa and Latin America is negligible and largely confined to on-farm utilization of non-marketable tubers.

Sweetpotato Utilization

Utilization patterns for sweetpotatoes have undergone some major changes in the last three decades, particularly in Asia (see Scott et al. 1992a). While over 50% of the output still goes for human consumption in fresh form in all three regions, nearly 40% of the production now serves as animal feed (Table 12). Processing of sweetpotatoes for human and industrial use has also attracted growing interest.

Much less is known about consumption patterns for sweetpotatoes than cassava or potatoes (Horton et al. 1984). It is considered a "poor man's food" or a survival crop in many parts of Latin America, Africa, and Asia (see e.g., Collins 1989; Watson 1989). However, it is also eaten as a seasonal vegetable and, under certain market conditions, actually can be sold at a higher price than potatoes (see e.g., Maggi 1990).

Sweetpotatoes are most commonly boiled in developing countries. In China, for example, they are peeled and cooked with rice in a breakfast porridge. They are also served fried, roasted, or mashed (Fig. 1). Sweetpotato leaves or "tips" are a delicacy in the Philippines, as well as an important supplementary source of essential vitamins and minerals at certain times of the year.[4]

Sweetpotato processing for human consumption is also remarkably diverse and widespread (Woolfe 1992). Some 5-10% of annual production in China is processed into noodles, starch, chips, and candy (see Tang et al. 1990). Ketchup, a soft drink, cakes, and candies are all made from sweetpotatoes in the Philippines (see Truong 1989). *Dulce de batata*, a cheese-like sweet, is among the most popular dessert dishes in Argentina (Boy et al. 1989). A recipe substituting grated, fresh sweetpotatoes for imported wheat flour has gained a foothold in the Peruvian bread market (Cavero et al. 1991). These are but a few of the most noteworthy examples.

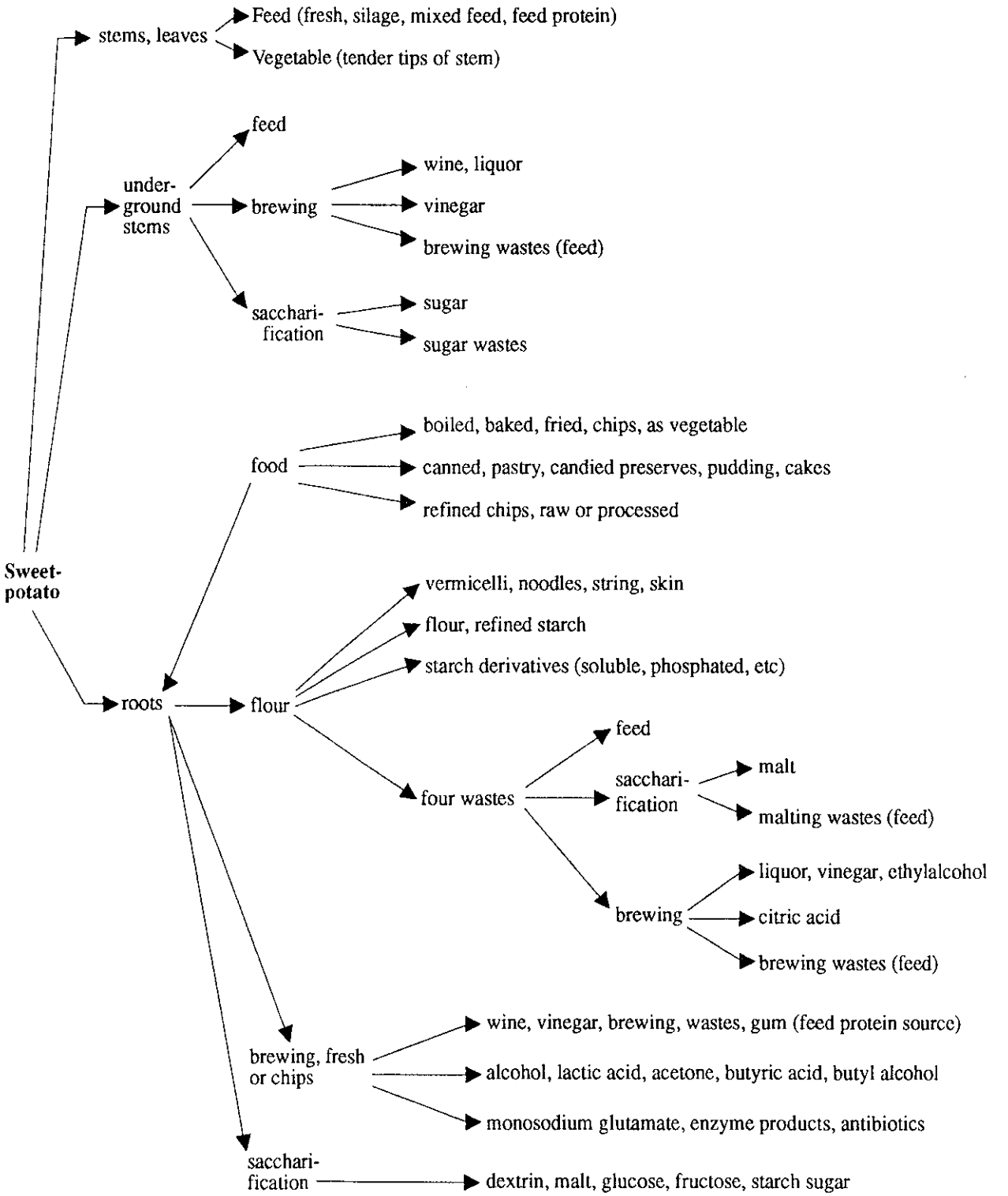
Sweetpotato is almost always used—in some form, in some amount—as an animal feed wherever it is produced in developing countries. FAO statistics indicate sweetpotato use for animal feed is 40% of total output in China, 35% in Brazil, 30% in Madagascar, 17% in the Republic of Korea, and 5% or less in the remaining 11 of the 15 largest sweetpotato producers. The estimated percentages have remained stable during the last three decades in all the countries except China (12% in 1961-63) and Korea (2% in 1961-63). However, recent Chinese estimates indicate as much as 35% of sweetpotato output now goes to animal feed.[5] Explanations for this sharp increase include growth in cereal production—meaning fewer sweetpotatoes are needed to supplement cereal consumption; rising demand for meat products (principally pork) for which sweetpotatoes serve as a feed component (Ge 1992); and changes in government policy; e.g., the introduction of the "responsibility system," which permits the sale of agricultural surpluses for profit. Furthermore, an EC bilateral agreement allowed China to export up to 600,000 t of dried sweetpotato chips to member countries duty free during the 1980s (see Calpe 1992).

Roots for pigs and vines for cattle are the most commonly cited forms of sweetpotato utilization as animal feed in Asia as well as in Africa and Latin America (Scott 1992; Woolfe 1992). Both are employed in a variety of ways. Many sweetpotato farmers in

[4] Personal communication, Dr. Howarth Bouis, International Food Policy Research Institute (IFPRI), Washington, D.C..

[5] Personal communication, Prof. Z. Tang, Crop Research Institute, Sichuan Academy of Agricultural Sciences (see also Tang et al. 1990).

Figure 1. Comprehensive utilization of sweetpotato.



Source: Ge et al. 1992.

northern China slice and then dry the roots before using them as pig feed (Lu et al. 1989). This type of simple processing often takes place in the field itself. Slicing, then sun-drying the roots, is a well-known procedure for production of pig feed from sweetpotatoes in Taiwan (Calkins 1979; Tsou et al. 1989). It has also been done—although on a more limited basis—in the Philippines (Palomar et al. 1989) and Vietnam (Hoang et al. 1989).[6] Virtually all feed production from sweetpotatoes takes place at the farmer or village-level. Only limited quantities of composite feeds are produced industrially.

Cassava Utilization

About 70% of cassava production goes to human consumption in Africa and Asia. Less than half of cassava output is eaten fresh in Latin America. According to FAO estimates, these percentages have remained stable over the last three decades (Table 12).

Although processing of cassava into dried chips for animal feed in Asia has attracted great attention (see Phillips 1979; Calpe 1992), on a fresh weight basis, Latin America uses six and a half times the volume of cassava for feed purposes (1.7 vs 11.2 million t). The attention-getting in Asia has materialized because a hefty share of fresh cassava has been dried into chips for export to the EC. This highly lucrative market has spawned huge increases in production in selected countries, most notably Thailand, and has infused a profit-seeking dynamism into the processing sub-sectors for this commodity in several Asian economies. Price supports and subsidies to locally produced feed inputs as well as cheap imports—both largely the result of government policy—have dampened the stimulative effects of a mushrooming demand for meat products on cassava production and processing in Latin America (see Lynam 1989).

The role of fresh cassava in the diet varies from that of a basic foodstuff among rural households in Central and West Africa, parts of South Asia, Latin America, and the Far East to a high-priced vegetable in urban markets in many of these same locations (Horton et al. 1984). The form in which cassava is consumed varies considerably.

In Latin America, Lynam (1989a) observes that the roots are traditionally eaten in one of three principal ways: fresh (boiled or fried); as a roasted flour called *farinha de mandioca* particularly in North and Northeast Brazil and neighboring territories; and, as a type of unleavened bread called *casabe* in the Caribbean basin (see also Lancaster et al. 1982). In Sub-Saharan Africa, cassava roots are consumed fresh as a major staple in many areas or eaten as a vegetable in others (Dorosh 1989). Cassava leaves are also eaten as a vegetable particularly in Central Africa. *Gari*, a dry granular meal made from fermented cassava, is the most common form of cassava consumption in West Africa. Dorosh (1989) estimates that "...*gari* may account for more than 70% of cassava consumption in Nigeria, 40-50% in Cameroon, 40% of consumption in Ghana, 30% in Côte d'Ivoire." Other common forms of cassava consumption include a sun-dried cassava flour (called *lafun* in southwest Nigeria) and a sticky *purée* or heavy soup made from fermented cassava (Nigerian *foufou*). In East Africa, cassava is commonly made into a flour from dried roots or chunks of roots.

According to George (1989), baked roots are the principal form of cassava consumption in India. He also observes that cassava is used in small amounts "...to make chips, flour, and *sago*, a type of wet starch that is roasted, dried, and finished." In Indonesia, cassava roots are eaten boiled, fried, or steamed (Kasryno 1989). They also are processed into *gaplek* (dried cassava chips) and starch.

Cassava has three other important uses in developing countries: animal feed for the domestic market; industrial purposes such as in starch and glue; and dried cassava for export. In Sub-Saharan Africa, only negligibly recorded quantities of cassava go to these uses. [7]Feed (37%) and other non-food uses (7.6%) account for almost half of cassava output in Latin America. About 10% of cassava availability in Asia is for feed and processing. Asia annually exports another 20 million t fresh weight in the form of dried cassava—nearly the equivalent of regional production—primarily to Europe. This latter type of use has been the most dynamic, increasing from an average of 1.7 million t (in fresh roots) annually in 1961-63 to 20.3 million t in 1981-83 (Sarma and Kunchai 1989).[8] Unfortunately prospects for increased, if not at least continued, cassava exports to Europe and possibly other developed countries are overshadowed by impending changes in trade agreements; i.e., the Uruguay Round of the General Agreement on Tariffs and Trade (GATT). These developments suggest this type of cassava utiliza-

[6] In the Philippines, drying and slicing the roots has apparently not been profitable (see Palomar et al. 1989).

[7] FAO Food Balance Sheet statistics indicate less than 2% of cassava production goes to feed use or processing.

[8] Thailand alone accounted for 17.6 million t, China 1.5 million t, and Indonesia 1.1 million t in 1981-83 (Sarma and Kunchai 1989).

tion has limited potential for expansion because of the possible abolishment of special trade arrangements that facilitated its emergence and growth. Partly for that reason, attention has increasingly focused on the internal market for cassava-based products in many developing countries.

Dry cassava for inclusion in concentrated feed rations has established itself as a growth node for rural development projects in parts of Colombia, Ecuador, and Northeast Brazil over the last ten years (see Best and Wheatley 1990; Ospina and Wheatley 1992). The success of these efforts has generated questions about the feasibility of replication in other parts of the developing world. This will depend on future developments in a number of key areas.

Future Developments

In addition to changes within the cassava, potato, and sweetpotato economies of developing countries, prospects for product development for roots and tubers will be greatly influenced by a series of other factors. These include demographic changes; growth in incomes; availability of substitute food and feed sources; the evolution of the market for derivative products (e.g., meat, processed foods); government agricultural and trade policies; and, improved production and processing technology.

Demographic Changes

With the notable exceptions of China (1.3%), Brazil (1.8%), India (1.8%), Indonesia (1.7%), and the Philippines (1.9%), most developing countries have projected population growth rates of well over 2.0% for the period 1989-2000 (World Bank 1990). Since the vast majority of these households are located in rural areas, the resulting pressure on land has important implications for both production and utilization of food crops. Growers will be compelled to modify their cropping patterns to give greater importance to higher yielding commodities, to bring more marginal land into regular cultivation, and to seek out ways for converting raw materials into higher valued products.

The demand for food, both on and off the farm, as well as the aspirations for the fullest possible exploitation of available production will stimulate farm families to reduce postharvest losses due to dehydration, spoilage, or pest damage. The incentives to convert what cannot be readily sold or consumed at harvest into marketable products should be formidable. In this regard, Coursey (1982) notes that there is great potential to combine the acquired ingenuity of traditional practices with the formal knowledge derived from modern science.

Urbanization will also have a strong influence on product development. Nearly one in three consumers in developing countries now resides in urban areas. Furthermore, rates of urbanization are two to three times the rates of population growth. For roots and tubers to compete more effectively with alternative commodities, e.g., to reduce transport costs, they will have to be processed in more significant quantities. Alternatively, urban consumers will increasingly demand food items that are easier to prepare and preserve. Changes in eating habits will also manifest themselves in greater demand for more diversified diets, i.e., less plant food and more livestock products, particularly meat. As a result, the established market niche for roots and tubers as animal feed could convert itself into a substantial share in the form of ingredients for feed concentrates.

Income Changes

Income changes have a somewhat more paradoxical effect on the outlook for product development. For example, rapid income growth may make the consumption of fresh roots and tubers less attractive to certain types of consumers; but then processed products such as french fries could become more affordable. Moreover, rising incomes typically increase the demand for meat products. Processed roots and tubers already serve as an important component in animal feed in many developing counties. Furthermore, this use has expanded as countries have been unable to expand feed production from cereal crops to satisfy mushrooming demand. China is a prime example (see Gitomer 1987).

Government Policies

Many countries have experienced dramatic reversals of government policy with regard to food and feed imports over the last few years, partly as a result of changes in world markets, the burden of accumulated debt, or in an effort to create more opportunities for domestic agricultural production. Similar changes in the years ahead will strongly influence the potential for root and tuber crops as processed products.

Several of the agro-biological and socio-economic factors outlined above will take time for their full impact to be felt. In the meantime, the prospects for the expanded use of roots and tubers as processed products would appear to be greatest in those regions and countries where a substantial supply of the commodity already exists, where food and/or feed shortages have

already materialized, and where continued or expanded imports of food or feed do not appear to be sustainable for economic or political reasons. In the case of roots and tubers for animal feed, a number of countries in Asia (e.g., sweetpotatoes in China, see Gitomer 1987) and to a lesser extent in Latin America (e.g., cassava in Brazil, see Ospina and Wheatley 1992) would appear to meet these criteria. Preliminary indications also suggest an emerging market for processed potatoes in Central America and Southeast Asia. The prospect of accelerated changes in government policies—with the attendant impact on production and utilization patterns for roots and tubers—raise further questions about the potential for future technological improvements for these commodities.

Technical Change for Roots and Tubers

Improvements in yield, dry matter content, and digestibility of cassava, potatoes, and sweetpotatoes should make them increasingly more attractive as a primary material for processed products for human food and animal feed. For example, average yields for sweetpotatoes in developing countries doubled over the last 25 years, primarily because of developments in China (Table 1). Yet, the yield increases in the People's Republic appear to have been largely the result of changes in cultural practices, i.e., increased plant density, rather than the utilization of improved varieties or chemical fertilizers and pesticides (Mackay 1989). This is partly explained by the fact that up until recently sweetpotatoes have received relatively few resources for research and development (R&D). Relative to the value of production, funding for sweetpotato research worldwide has been lower than that for any other major food commodity (see Gregory et al. 1989). Average potato and cassava yields in developing countries are also well below what is technically possible. Potato productivity is about half that found in most developed countries. Cassava yields in Sub-Saharan Africa are 50% less than those in Asia (Table 7).

Most sweetpotatoes currently cultivated in developing countries have a dry matter content of around 30%. Results of research at the Asian Vegetable Research and Development Center show that "...the mean dry matter content of breeding lines improved from 25.9% to 35.1% in five years. Theoretically this program increased chip yield for animal feed by 40%..." (Tsou et al. 1989). Moreover, the international germplasm collection for this crop includes varieties whose dry-matter content is as high as 45%.[9] Similar observations apply to cassava and potatoes. Consequently, the potential is there to raise the processing utility of these crops by incorporating varieties with higher dry matter content into the material available to growers.

Conclusion

Root and tuber crops have considerable unrealized potential as new products for human, animal, and industrial use as manifest the remarkable increases in their utilization in processed form in a number of developing countries over the last three decades. Several indicators point to an accelerated trend in this direction for these commodities. Among the factors contributing to this emerging pattern are the agronomic and biological characteristics of the crops, recent trends in production, and developments beyond the food systems for these particular commodities. Because these factors encompass a diverse set of considerations (e.g., agronomy, demography, livestock production), the potential for developing new products from roots and tubers in any particular situation will depend on a knowledge of elements from different disciplines as applied to local circumstances. The remainder of this volume is dedicated to the presentation of this approach referred to as product development. It also includes country reports on the recent experience with particular commodities in this regard as well as papers that examine the results of specific attempts to transform roots and tubers into more readily marketable products.

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Integrated Root and Tuber Crop Projects: A Strategy for Product Development

Christopher Wheatley and Trudy Brekelbaum[1]

Abstract

Integrated projects have often proven to be a successful strategy for developing new products for roots and tubers in developing countries. This paper briefly reviews the essential elements of an integrated project including a systems orientation, inter-institutional collaboration, multi-disciplinary focus, active participation by final users, and an emphasis on demand-driven technological research. The paper goes on to describe the stages of an integrated project beginning with problem and opportunity identification, applied technical research, a pilot project phase, and then commercial-scale expansion. The paper concludes by noting the benefits of the integrated project approach as well as its relationship to broader, integrated rural development efforts.

Key words: postharvest technology, research, roots and tubers, developing countries, new products and processes.

Introduction

As can be seen from the previous paper, root and tuber crops have a tremendous potential for contributing to socio-economic development of rural areas. To realize this potential, an efficient combination of new products, prices, distribution systems, and promotion foci needs to be designed. When doing this, it is essential to bear in mind that the scale of these elements must be appropriate for root and tuber crop farmers who have mostly small or some medium-sized operations, and who generally have weak links to processing technology and non-traditional markets.

One strategy that has proven highly successful is that of integrated projects. These permit the agro-industrial transformation of the crop by linking improved production and processing technology, marketing techniques, and institutional innovations in processes requiring technical and socio-economic integration. In short, improvement in postharvest systems will not be achieved solely through the generation of technological innovations. Other components such as farmer organization and training, provision of credit, establishment of efficient distribution channels, and inter-institutional coordination and cooperation are all important aspects to be considered.

Essential Strategic Elements

Based on experiences in developing postharvest handling, storage, and processing technologies for root and tuber crops, the following elements are considered essential for integrated development projects.

Multi-sectorial Integration

Simultaneous treatment of production, processing, and commercialization processes is key to the integration of a project. Although the manner of articulation will vary chronologically, what is important is that they are all part of a single process. This "systems orientation" for technology development should extend from produc-

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tion to include storage, processing, and utilization of the crop. The production and postharvest systems should not be divorced and developed separately since they can serve as a means of relating the producer to the final consumer for their mutual benefit. An optimum path to accelerate agro-industrial diversification of root and tuber crops, while activating producers' groups, is around integrated projects.

Inter-institutional Integration

Successful adoption of postharvest technology requires the close interaction of research and development (R&D) institutions in both the public and private sector throughout the process of technology generation and transfer. The most important interaction comes at the pilot project stage when researchers may test and adapt the technology; subsequently, extension workers can modify institutional and organizational schemes to facilitate technology transfer in close collaboration with farmer associations or co-ops. Private sector input can be particularly important in adapting technology generated by research institutions for commercial-scale production.

Functional integration also includes the articulation of technical, financial, and entrepreneurial assistance. The quality of assistance depends on the existence of a good general strategy and clear guidelines for managing the program, particularly where there are multiple organizations with different resources, loyalties, objectives, and strategies. Integration is coordinated around common objectives and activity plans. The more institutional participation there is in planning the program, the better will be the chance for success.

Multi-disciplinary Focus

Analyses of the potential role of root and tuber crops require a multi-disciplinary focus in order to conduct R&D research, determine the production potential, cost structures, competitive prices, and the potential demand for the crop and products based on the analyses, existence of local farmers' groups, institutional presence, and other important factors.

Individual R&D institutions rarely have sufficient resources to have a full-fledged staff with expertise in a wide range of disciplines. This is where creative arrangements can be made by setting up public and private sector inter-institutional working groups around specific tasks, benefitting from the disciplines available. When the Visayas State College of Agriculture (ViSCA) in the Philippines developed a sweetpotato beverage, for example, they entered into an arrangement with a large food and beverage company whereby a multi-disciplinary team was created between the two institutions. Thus, it was possible to bring together the expertise of a food product development specialist, a process development engineer, a marketing specialist, a fruit processing plant manager, an agricultural extension specialist, and the ViSCA researcher/ inventor for the scaling-up process.

Participation

When selecting a project site, a key criterion is the existence of producer groups that are interested in the program and that have the capacity to work with it. Project administrators need to analyze what incentives will stimulate farmers' participation and how much they are willing to sacrifice to work toward the objectives.

Active participation of root and tuber crop producers and processors in the planning and execution of activities increases the technical and economic efficiency of the programs. Participation is basically an apprenticeship process. Producers, administrators, and technicians need to interact in order to learn each other's perspectives, farmers' felt needs, and organizational capacities.

The long-term impact of the program depends on the producers'/processors' capacity to assume full responsibility for the operation and maintenance of processing activities implemented by the program. They need to know how to discuss constructively; speak in public, negotiate, identify and solve problems; be familiar with technology and the market; know how to administer resources and keep accounts, make efficient investments, and plan future activities. This capacity is created gradually through their daily involvement in solving problems, working in groups, and training new members.

Demand-driven Technology

Postharvest technology development should be based on the existing or potential demand for a product. The demand for a product implies the existence of a consumer who should be the starting point for the development of new or improved processes or products. The socio-economic status, habits, and preferences of the consumer are guides for the type of R&D work that will be carried out. This information will not only influence process and product design, but eventually crop production technology as well.

Objectives of an Integrated Project

- Catalyze a series of inter-institutional interventions to generate socio-economic development of a region and improve the incomes and well-being of root and tuber crop farmers.
- Provide technical assistance services and training related to root and tuber crop production, processing, and commercialization.
- Promote the formation and strengthening of farmer associations involved in root and tuber crop production and processing.

A Model for Postharvest R&D

Successful technology generation and transfer has required disciplinary, institutional, and sectorial integration in all phases of the process from opportunity identification, through product and process research, testing and adaptation, and ending in the final commercial introduction or adoption of the technology. This integration, which does not normally occur spontaneously, is best achieved within a project framework, with clearly defined objectives, activities, and responsibilities for each participating institution. There are four distinct phases, which are briefly dealt with here.

Problem and Opportunity Identification

The approach to postharvest R&D for roots and tubers undertaken by the International Agricultural Research Centers (IARCs) and their national counterparts is market orientated. It is based on identifying unsatisfied consumer needs; that is, problems and opportunities. At the same time, it is meant to solve the production and postharvest problems of root and tuber crop farmers who have mostly small or some medium-sized operations.

Research on Products and Processes

This is the stage in which market studies and consumer research are carried out in order to identify the demand and required characteristics of the selected product. Technical research is undertaken on the product itself and on the development of the process for its production.

Root and tuber crop producers cannot assume the costs of R&D; therefore, inter-institutional linkages become important in order to take advantage of technological developments in production and processing as well as advances in commercialization and promotion systems, within an atmosphere of minimizing risks for small farmers. In the Latin American situation, market and consumer studies have been carried out by local institutions with support from IARC social scientists. The technical research that is undertaken may be both basic and applied in nature. Since the IARCs and National Agricultural Research and Development Systems (NARDS) have limited resources to undertake research, they seek to enter into collaborative projects with food science and technology institutions that can provide specialized capital and human resources. Links have been formed with institutes and universities in both developed and developing countries.

Pilot Project

Once a processing or conservation technology has been thoroughly tested at the experimental level and the market and consumer studies indicate that a demand for the product exists, a pilot project is initiated. The objective of a pilot project is to introduce, into a specific growing region and on a reduced scale, both the postharvest technology that has been developed and the associated production technology that will enable farmers to increase crop productivity and reduce costs. This is achieved by adopting an approach in which production, processing, and marketing activities are linked within the same project framework.

The pilot stage is used to evaluate the technical, economic, and operational feasibility of the postharvest technology under real conditions. At the same time, suitable market channels for the product are identified and preliminary promotional activities are undertaken. It is important to ensure that the product can meet the quality specifications as required by the potential clients. Experience is also gained in aspects of farmer organization and training which may be employed in the expansion stage to follow. Concurrently with the activities in the area of processing and marketing, production research is carried out both on-farm and at local experiment stations. At the end of the pilot project stage, sufficient firsthand data are available to formulate a proposal for a full-scale root/tuber-based development project.

Pilot projects can also provide a framework within which the IARCs can interact with NARDS. This interaction permits the validation and adaptation of existing production and postharvest technology, together with the techniques that have been developed for market analysis. Especially useful is the possibility of feedback,

so that the research carried out by the IARCs and NARDS may be constantly adjusted or reoriented according to the requirements of the differing ecological or socio-economic conditions in each country. This mechanism is invaluable for improving the relevance of research.

Donor agencies have recognized the importance of pilot project testing and adaptation of production and postharvest technologies, therefore, funds can now be readily obtained for carrying out these activities. The IARCs also provide training to NARDS staff in formulating proposals to be presented to these agencies.

Commercial-scale Expansion

The experience of the pilot project stage provides the foundations from which to replicate or expand the use of the technology. Given the real cost of the technology is now known, the resources required to obtain its adoption on a wider scale may be calculated. This includes provision of credit for root/tuber production and the establishment of a processing capacity, the institutional requirements necessary to provide training and technical assistance to farmers and those involved in processing, and a plan for the efficient distribution and promotion of the product. The formation of second-order farmer/processor organizations to coordinate such activities as marketing, farmer training, and credit provision is often essential.

An important activity at this stage is to establish a monitoring system to determine exactly how the benefits of the introduced production and postharvest technology are being distributed. Such a system should be incorporated into the pilot projects so that the national executing agencies may assess the advance of the project and introduce any modifications in its orientation that may be necessary.

During this phase, administration of the project passes into the hands of the beneficiaries themselves. Throughout this process, crop producers and processors increasingly take over responsibility, until their association assumes complete control over the project. The project may be used as a model for the training of project personnel and participating farmers.

Benefits of an Integrated Approach

An integrated root and tuber crops project is valuable for improving the crop production system. It is also useful for mobilizing people around community development problems. The project creates enthusiasm and confidence in the participants' capabilities. This increases enormously the power of all parties involved, including small farmers, researchers, development agents, and public administrators. The integrated project is an important vehicle for reinforcing, stabilizing, and expanding local-level capacity to solve problems that previously inhibited social development. It is a way to generate conditions for economic and social development that will respond primarily to local needs and opportunities, after which it adopts regional and national projections.

Conclusion

The integrated project simultaneously addresses aspects related to production, postharvest treatment, and marketing of the crop. Nevertheless, none of these aspects is an end in itself; they are essential components that must be systematically articulated to develop a commercial product and make it accessible to the consumer. The integrated project defines the tasks of production and processing in such a manner that they are conceived and implemented as a part of the product development task. Product development is oriented in accordance with the specific characteristics of a final market and interprets the effectiveness of its actions from the standpoint of objectives that go beyond what is strictly agricultural.

Commercial acceptance of the final product is the element in which the activities of crop production, processing, and commercialization are integrated, and to which they are oriented. Therefore, the methodological starting point of the integrated project is the interface between the final product and the consumer; a contact that is established after commercialization and is essential for effective marketing. Hence the characteristics that consumers attribute to a product that they wish to acquire mark the critical starting point.

This methodological organization does not contradict the existence of an internal process in which the production, utilization and commercialization components each have a temporary preeminence in the process of final product development. On the one hand, it is possible to consider these functions as "episodes" (even parallel ones) at the rate in which they are integral—albeit distinct—parts of the whole. On the other hand, the functions of production, processing, and commercialization take turns in assuming the role of "leader" during the process of creating the final product. In all cases, the individual efficiency of each component strongly affects the results of the entire integrated project.

Integrated root and tuber crop projects require high levels of commitment, social participation, and administrative performance. In an integrated project, the design

of effective organizational strategies for implementation is emphasized. This assumes an evaluation and refinement of systems that will gradually transfer power to farmers so they can autonomously administer root/tuber crop-based agro-industrial enterprises and also provide the general direction of the regional development that these enterprises will generate. The project also requires accentuating technical, administrative, and organizational training for farmers. Finally, it identifies channels and models for establishing cooperation between the various public and private institutions that offer support services in technology generation, product design, technical extension, credit, and marketing and promoting products.

An integrated root and tuber crops project has elements in common with integrated rural development (IRD) programs. Both emphasize the relationship and mutual support of economic and social development and the importance of active beneficiary participation. For both, decision making is a multi-faceted process because they seek multiple objectives at different levels. Hence the programs need to use multi-disciplinary teams. Both programs explicitly identify the rural poor as their principal clients. As a result, they seek to raise employment and income levels, to promote more equitable distribution of income, and to increase access to services for the less privileged sectors.

Nonetheless, an integrated root and tuber crops project differs from an IRD program. First, an integrated root and tuber crop project concentrates its activities in a reduced geographic area and seeks narrower objectives than those of an IRD program. A root and tuber crop project can therefore be incorporated with IRD. Second, an integrated root and tuber crop project requires public and private investment, but, above all, it is a technology-induced development program. The element that releases development is not so much the infusion of capital for infrastructure or operations but the adoption of technology. Technological innovations permit the exploitation of a series of national resources, especially local ones, that previously were underused.

II. Commodity and Country Reports

Trends in production, marketing, processing, and utilization of cassava and sweetpotato in African countries are the subject matter of this section. Similar patterns are also discussed for potatoes for the region as a whole. Such information complements the descriptive analysis of the aggregate data in the previous section by providing more detail about these commodities in particular countries. The country reports also identify contributing factors or limiting constraints to growth in output, use and income from cassava and sweetpotato in specific locations.

Cassava is the major source of food in the rural areas of Cameroon's forest zone, where it provides 30% of the total calorie intake. In **Cassava in the Cameroon**, J.T. Ambe and A. Foaguegue first identify the country's five main agro-ecological zones. They then go on to enumerate the principal cassava producing areas. Cassava is processed into a number of products for human consumption including *gari*, chips, and doughnuts, as well as a number of local foods. These products, particularly *gari*, have a ready market in urban areas although poor transportation and market information prevent them from realizing their full commercial potential. Research on cassava by the National Root Crop Improvement Program has focused on varietal improvement and development of cultural practices, as well as the introduction and promotion of improved processing and preservation techniques.

Cassava is the third most important food crop in Côte d'Ivoire, after yams and plantains. In **Le Manioc en Côte d'Ivoire**, Kouadio Tano and N'dri Coulibaly indicate that current per capita consumption is roughly 30 kg/yr. Cassava is eaten in a wide variety of forms both fresh and processed. Marketing tends to be highly local with each town or city supplied by surrounding growing areas. The authors draw attention to the limited amount of socio-economic research on prevailing production systems as well as the efficiency of traditional processing techniques. Future research aims to rank the most important varieties according to consumer preferences; to determine the technological characteristics of these varieties; and to identify principal constraints to production, processing, and marketing.

Production of cassava in Ghana far exceeds that of all the other major crops combined. As Ramatu M. Al-Hassan indicates, the importance of **Cassava in the Economy of Ghana** is perhaps most evident when one goes beyond production itself to consider processing, utilization, and marketing activities. Cassava processing is done mainly by small-scale, traditional processors, most of whom are women. The crop is transformed into a variety of products principally for human consumption. New product development has focused on substitutes for traditional foods,

but includes efforts to make an instant breakfast food and composite flours. Among the topics for future research, estimates of the cost of production for traditional as well as new processed products merit high priority.

Cassava is a major staple food in Nigeria supplying about 70% of the daily calorie intake of over 50 million people. In **Cassava Research, Production and Utilization in Nigeria**, B.O. Ugwu, O. Ajobo, and G. Orkwor provide a brief overview of recent trends in output, consumption, and trade. For example, although cassava is grown all over the country, production is highly concentrated in three states. The authors go on to document some of the institutions involved in research on cassava as well as the work on varietal improvement, agronomy, and utilization of the crop.

Cassava is among the major food crops in Tanzania with an annual output of over 1.5 million tons. In **Cassava Production, Consumption and Research in the United Republic of Tanzania**, M. A. M. Msabaha and B.W. Rwenyagira provide a brief synthesis of recent developments for this commodity. Cassava has a long history of providing food security in the country. Perhaps, for that reason, it is widely grown all over Tanzania. Current production constraints include diseases such as cassava mosaic virus disease; pests like termites; and poor marketing infrastructure. Cassava processing (roots and leaves) is done largely by women and principally for human consumption. Subsidized prices for preferred cereals and the lack of variety in cassava products discourage greater consumption. Research has focused on varietal improvement for pest and disease resistance as well as assessing the efficiency of traditional and new (e.g., livestock feed) types of cassava processing.

Cassava in Uganda is the focus of the paper by G.W. Otim-Nape and J.U.A. Opio-Odongo. As the authors note, cassava ranks second among major food crops in terms of total production (fresh weight) and is the most important root crop. Cassava constitutes a main component of the local diet and is consumed throughout the year — in boiled, roasted, and processed form (as flour or alcohol). Major production constraints include diseases such as cassava bacterial blight, pests, and poor agronomic practices, e.g., timely planting, optimum spacing. Cassava researchers are working to overcome these limiting factors through research and extension.

Zaïre is the largest producer of cassava in Africa and the third largest in the world. In **Cassava in Zaïre**, Brooke A. Greene analyzes the latest production trends before briefly summarizing the results of recent fertilizer trials and efforts at varietal improvement. Declining soil fertility, the limited availability of chemical fertilizers, insecticides, and small tools are at the top of a long list of serious problems affecting agricultural production generally and cassava production specifically in Zaïre. Cassava is estimated to provide 71% of the theoretical requirements of calories and 18% of the proteins. Roots are consumed in both fresh and processed form. Households use the sale of cassava, primarily as *cossettes*, to stabilize their incomes over the year. Most storage is done by leaving the crop in the ground. Marketing problems (e.g., transport) constitute a major constraint to expanded production of cassava in Zaïre.

Sweetpotato is grown in every country South of the Sahara. Yet, relatively little has been written about the prospects for the crop in this region. In **Sweetpotato in African Food Systems**, Gregory J. Scott and Peter Ewell provide an overview of patterns and trends in production, marketing, and consumption before presenting an assessment of the crop's future prospects. Scott and Ewell note, for example, that output doubled during the last 30 years but that these figures are the composite of widely divergent tendencies both among countries and over time. The authors draw particular attention to the need to overcome the twin constraints of bulkiness and

perishability through initiatives to introduce appropriate processing technologies and products. These efforts will need to be accompanied by the introduction of improved germplasm both to raise yields and to increase dry matter content beyond the levels found in local varieties.

Sweetpotato is a major staple food in Uganda. In **Sweetpotato: A Source of Incomes for Low-income Rural Families in Uganda**, B. Bashaasha and R.O.M. Mwanga review recent production trends as well as describe current marketing patterns for the crop. Among their principal findings are the positive growth for sweetpotato production 1985-90 of 4.5% per year with national output reaching two million tons by the end of this period. Sweetpotato is widely grown by small farmers in Uganda primarily for home consumption. Nevertheless, the crop constitutes a valuable source of income for poor families. As transport costs are high, postharvest losses extensive, storage inadequate and processing inefficient, ample room exists for improvements in prevailing postharvest practices.

Sweetpotato production has grown faster in Rwanda than output for other important crops and as fast as potato. Partly for that reason, the crop has attracted increasing interest by scientists, policymakers, and farmers as a way to keep per capita availability of calories steady despite the demands placed on the local food system by a rapidly growing population. David G. Tardif-Douglin's paper on **Sweetpotato in Rwanda** provides an overview of the crop's importance and role in production systems, how it is marketed, the nature and extent of demand for the roots, and what are the necessary and sufficient conditions to expand sweetpotato consumption among the growing numbers of urban poor. Major emphasis is given to improvements in handling, processing and transportation both in themselves and as a way to reduce the retail price.

Potato is a food crop often not readily associated with African food systems. However, as Gregory J. Scott points out in **Trends and Prospects for the Potato South of the Sahara**, potato production (2.2 million t in 1991) has increased faster than any other food crop except sugar cane and rice over the last three decades. Nearly 90% of regional output, however, is concentrated in eight countries. Principal production constraints include the shortage, cost, and timely availability of good quality seed; diseases such as late blight; declining soil fertility; and the limited resources of national potato programs. Potato sales are an important source of cash income. But, on average, potato consumption ranges from 2 kg in Burundi to nearly 50 kg in Rwanda. Renewed efforts for technological improvements in the more favored areas will be required if increases in production are to keep pace with growing food requirements. More support for postharvest initiatives (e.g., storage, marketing) by the private sector deserves particular attention by policymakers and development specialists.

Cassava in the Cameroon[1]

J. T. Ambe and A. Foaguegue[2]

Abstract

Cassava is a major source of food in the rural areas of the forest zone in Cameroon. Amongst the households located there, it provides 30% of the total calorie intake. Approximately 115,000 ha are cultived in cassava nationwide, an area equivalent to 6% of the total area cropped. Of the normal production of 1.4 million tons, approximately 30% is sold. Cassava is processed into a variety of food products both traditional and modern. These products have a ready market in urban markets.

Key words: production, area, processing, marketing, research.

Introduction

The Republic of Cameroon is divided into ten provinces and has a population of about 10 million people. It has a broad variation in ecology, from evergreen forest to steppe. The altitude range is 0-4,000 m and rainfall 900-3,000 mm/yr. Soils vary from very poor, sandy, sedimentary to very rich volcanic soils. About 58% of the Cameroon is in the tropical forest zone.

There are five major agro-ecological zones in the Cameroon: (a) the western highland, covering the West and North West provinces, (b) the coastal lowland, covering the Littoral and South West provinces, (c) the southern plateau, covering the Center, South and East Provinces, (d) the Adamaoua Plateau, in Adamaoua Province, and (e) the Guinea-Sudan and Sudano-Sahelian zones, covering the North and Far North Provinces (Map 1 and Table 1).

Producing Areas

Apart from the North and Far North provinces, cassava is grown throughout Cameroon. The main producing areas are the Central, South West, East, Adamaoua, and South provinces (Tables 2 and 3; Map 2).

Utilization

Cassava is the major source of food in the rural areas of the forest zone, where it provides 30% of the total calorie intake. Cassava is also used as a food security crop where cereals are the major source of food. Among the tropical root and tuber crops grown in Cameroon, cassava ranks first in per capita consumption (Table 4).

Cassava is processed into many different food products (Fig. 1). Sweet (low cyanide) varieties are eaten roasted or boiled. Bitter (high cyanide) varieties are processed for 3 to 5 days before consumption to reduce the cyanide content. Processing involves fermentation, sundrying, grinding, grating, milling, smoking, and boiling.

There are many food products made from cassava:

- *gari:* a granular flour obtained by grating, fermenting, and frying the grated pulp with or without palm oil

[1] This paper is taken from Status of Data on Cassava in Major Producing Countries in Africa: Cameroon, Côte d'Ivoire, Ghana, Nigeria, Tanzania, Uganda and Zaïre. Collaborative Study of Cassava in Africa (COSCA) Working paper No. 3, Edited by Felix Nweke, John Lynam, and Coffi Prudencio. It is reprinted here with permission of the editors.

[2] Institut de la Recherche Agronomique, B.P. 537, Ngaoundere, Cameroon; and Institut de la Recherche Agronomique, Djombe Station, Cameroon, respectively.

Table 1. Characteristics of the agro-ecological zones in Cameroon.

Zone	Area (000 ha)	Altitude (m)	Annual rainfall (mm)	Area cropped (000 ha)
Sudano-sahelian	3,426	Mainly low	<900	412
Guinea sudanian	6,780	low	900 to 1,500	150
Adamaoua plateau	6,199	±1,000	1,000 to 1,500	83
Southern plateau	22,503	500 to 850	1,500 to 2,500	518
Coastal lowland	4,513	0 to 500	±2,500	282
Western highlands	3,119	1,200 to 1,800	1,500 to 2,500	522
TOTAL	46,540			1,967

Source: Based on 1984 agricultural census data.

Table 2. Area under cassava production compared to total area cropped in the Cameroon.

Province	Total area cropped (000 ha)	Total area planted with cassava (000 ha)	Area cropped with cassava %
Central	262	18	7
South West	201	16	8
East	142	29	20
South	115	9	8
North West	229	6	3
Littoral	82	5	6
West	293	3	1
Adamaoua	83	29	35
North	150	0	0
Far North	412	0	0
Cameroon	1,969	115	6

Source: Based on 1984 agricultural census data.

Table 3. Annual cassava production and sales in the Cameroon.

Province	Annual production (000 t)	Quantity sold (000 t)	% Sold
Central	374	82	22
South West	304	146	48
East	197	36	18
South	129	15	12
North West	110	61	55
Littoral	98	27	28
West	88	24	27
Adamaoua	80	26	33
North	-	-	-
Far North	-	-	-
Cameroon	1,380	417	30

Source: Based on 1984 agricultural census data.

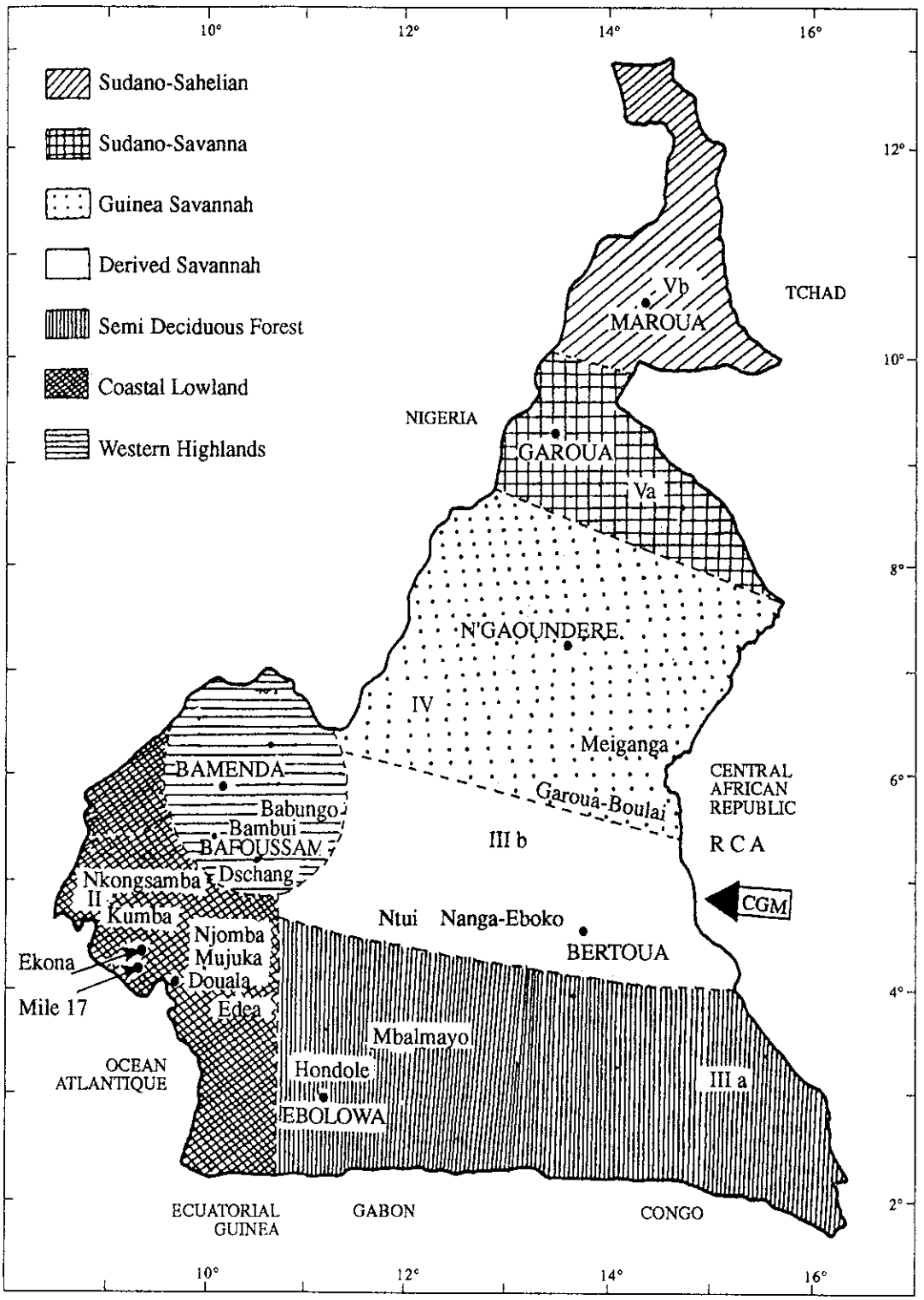
- porridge: cassava flour cooked in water
- *myondo or bobolo:* cylindrically shaped wraps of fermented cassava paste which are steamed for about one hour and eaten with soup
- *mentoumba* (cake): cassava paste mixed with palm oil, salt, crayfish, and pepper, wrapped in leaves and steamed for about one hour
- chips: chipped fresh cassava, boiled in water and then soaked for three days (water is changed daily) and then eaten directly
- doughnuts: deep-fried cassava paste mixed with banana purée and other seasonings
- *foufou:* a flour obtained after fermenting, drying, and milling cassava into powder, mixed with boiling water and eaten with soup.

Cassava is also used in soap making, starch, and *arki* (an alcoholic beverage).

Marketing

Wholesalers collect the various cassava products from the local markets/producers and take them to the cities where they are resold either wholesale or retail. Processed cassava products especially those that are easily prepared into meals, e.g. *gari*, have a ready market in the urban centers. Poor transportation and

Map 1. Agro-ecological zones of Cameroon.



Map 2. Distribution of crop production in Cameroon.

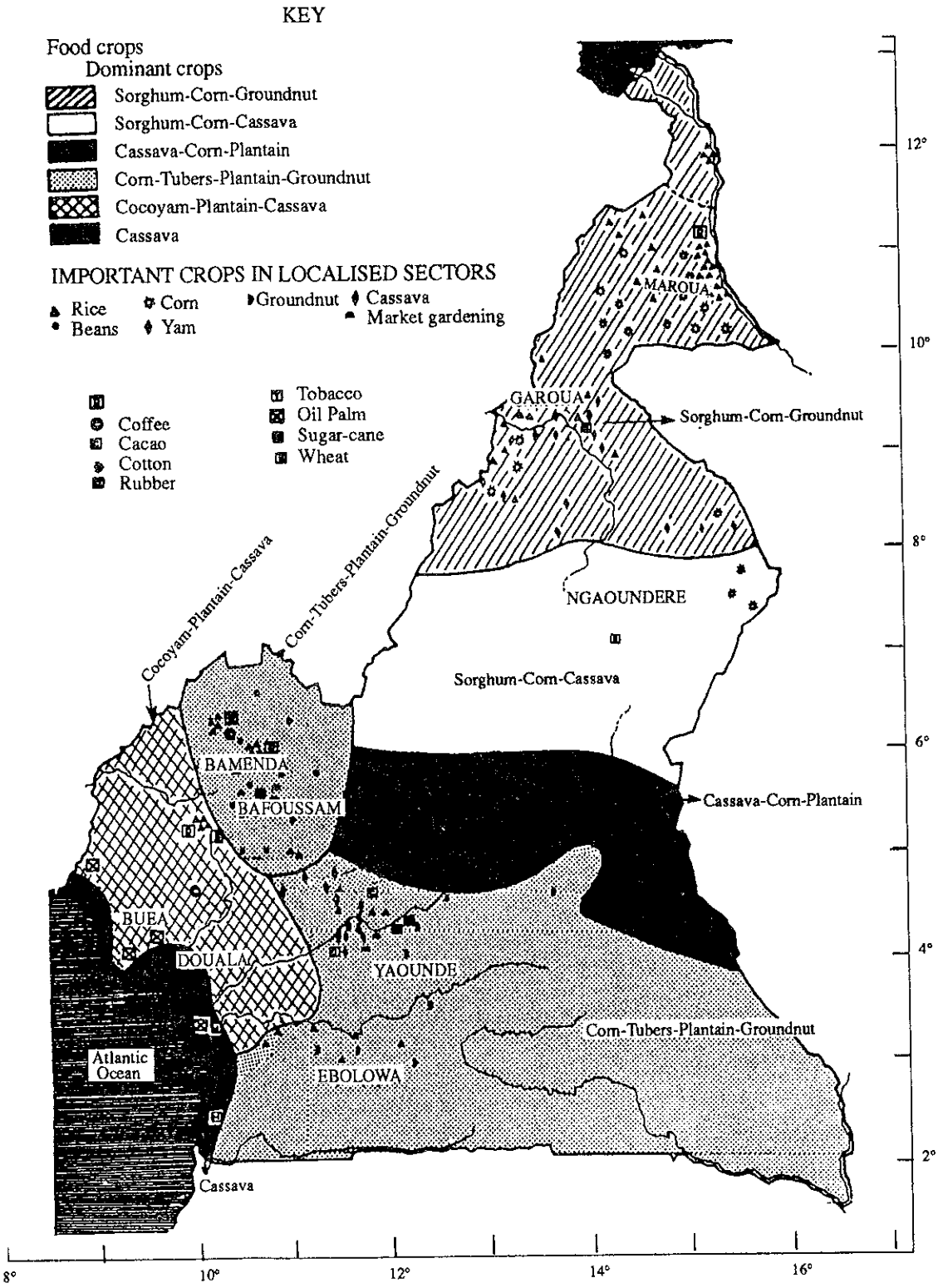


Figure 1. Some traditional food products made from cassava in Cameroon.

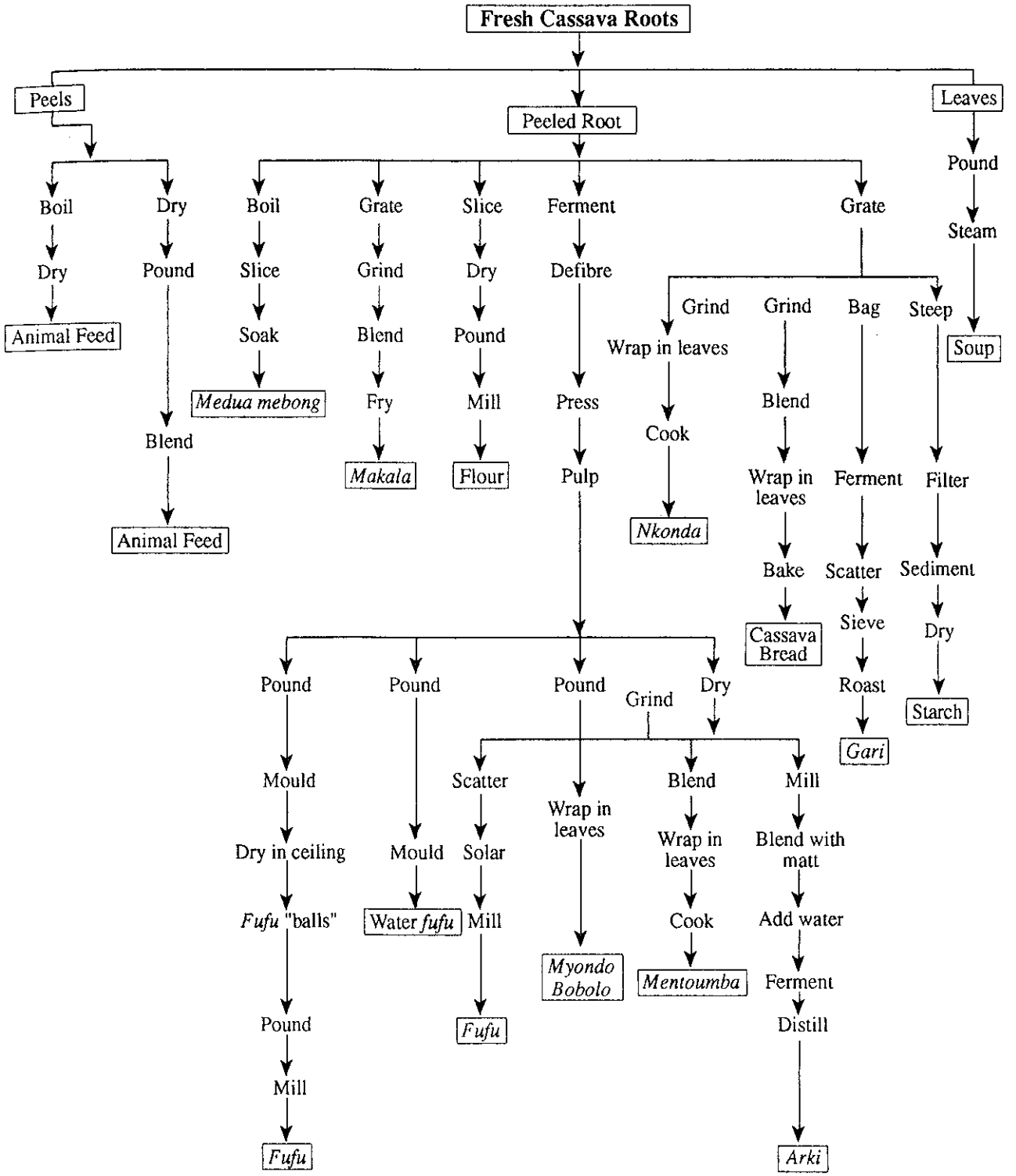


Table 4. Cameroon: Daily calorie intake from root, tuber and plantain crops, 1979-1981.

Source	Calorie/capita/day
Cassava	235
Yam	83
Cocoyam	128
Sweetpotatoes	34
Plantain	193
Sub-total roots, tubers and plantains	673
Overall calorie consumption from all sources	2,410

Source: FAO, Food Balance Sheets 1979-81.

market information systems hinder the movement of these products to larger markets. Farm to market roads are not well-developed and transportation costs are high. In most cases, the farmer sells his fresh produce at a give-away price. In many villages located along major roads, processed cassava products are sold in front of the processor's house. Informal trade in cassava products exists between Cameroon and neighbouring countries, especially Gabon.

Research

Research on cassava is carried out in Cameroon by the Cameroon National Root Crop Improvement Program (CNRCIP), which was started in 1973. One major objective of CNRCIP is to develop production systems acceptable to smallholder, low resource farmers. CNRCIP promotes and distributes high-yielding cassava cuttings; identifies and breeds disease and insect resistance into cassava varieties; promotes the development of cultural practices which maximize returns from improved or local cassava varieties with minimum input; introduces and promotes improved processing and preservation techniques to reduce postharvest losses; and, advises consumers and processors on how to improve the nutritive quality of cassava products.

Some high-yielding varieties have been developed and released by the program. A method for the incorporation of soybean into cassava flour to improve its nutritive quality has been developed. A description of the farming system is available for the Central, East, and North West Provinces. Data on production are available from the cassava and cassava products. There are no time series data available on the production and consumption levels of cassava products, nor on the source and quantities of cassava glues and starches used in local crafts and industrial establishments.

Le Manioc en Côte d'Ivoire[1]

Kouadio Tano et N'dri Coulibaly[2]

Résumé

Le manioc est la troisième produit vivriére de la Côte d'Ivoire après l'igname et le bannier plantain. Avec une consommation par habitant de 30 kg par an, le manioc est l'un des aliments de base en Côte d'Ivoire. Le manioc ne fait que l'objet d'un commerce interne. D'une façon générale, on peut dire que la recherche sur de manioc a été limitée par le manque de moyens. La recherche envisagée pourrait s'orienter vers l'identification des principales variétés et leur caractéristiques technologiques en plus que la mise en évidence des contraintes au niveau de la production, de la transformation, et de la distribution.

Mots clés: production, utilisation, commercialisation, recherche.

Production

Selon les statistiques officielles de la production agricole, le manioc est le troisième produit vivrier de la Côte d'Ivoire après l'igname et la banane plantain. Il représente en moyenne 20% de la production totale des racines-tubercules et du plantain. En raison de sa grande plasticité aux plans pédologique et climatique, sa culture est largement répandue dans tout le pays avec, toutefois, une certaine prédominance pour la région Sud qui a fourni, en moyenne, 40% de la production nationale de 1960 à 1984. Les autres zones importantes sont le Centre et l'Ouest (Tableau 1, Cartes 1 et 2).

Consommation

Avec une consommation par habitant 30 kg par an, le manioc est l'un des aliments de base en Côte d'Ivoire auquel les ménages affectent environ 15% du budget consacré aux produits vivriers. Les formes de consommation sont nombreuses et varient selon les ethnies et les régions. Les principales formes sont par ordre croissant de complexité:

- le manioc bouilli à l'eau;
- le manioc frais, cuit à la braise;
- le manioc frais bouilli et pilé seul ou avec du plantain ou de l'igname (*foufou*);
- le pâte de manioc (*tôh*) obtenue à partir de la farine de manioc;
- le "*placali*" qui est la pâte obtenue avec du manioc broyé et fermenté;
- le *gari*; et
- l'"*attiéké*" qui est une sorte de semoule de manioc.

Commercialisation

Le manioc ne fait que l' objet d'un commerce interne. En raison de la grande répartition de sa production dans le pays, les échanges sont surtout de courte distance. On n'a pas de circuits longs comme dans le cas du plantain et de l'igname. Chaque ville, dans une région donnée, est approvisionnée à partir de son arrière-pays immédiat.

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[1] Ce papier est tiré du "Status des Données sur Les Tres Grands Pays Producteurs du Manioc en Afrique: Cameroun, Côte d'Ivoire, Ghana, Nigéria, Tanzanie, Uganda and Zaïre, Etude Collaborative du Manioc en Afrique (COSCA), Document de Travail N° 3, édité par Felix Nweke, John Lynam et Coffi Prudencio. Réimprimé ici avec permission des editeurs.

[2] Université d'Abidjan, Côte d'Ivoire; et IDESSA, B.P. 635, Bouaké, Côte d'Ivoire.

Tableau 1. Côte d'Ivoire: Evolution de la production de manioc (000t) par régions, 1960 à 1984.

Régions	1960	1965	1970	1975	1980	1984
Sud	209	237	272	366	401	510
Est	23	25	33	59	45	54
Centre Ouest	19	22	22	58	138	162
Ouest	83	85	82	156	156	189
Centre	78	86	102	268	205	250
Nord	38	45	30	31	71	85
Ensemble manioc	450	500	540	939	1,010	1,250
Ensemble racines tubercules plantain	2,243	2,580	2,928	4,546	4,190	4,980
Pourcentage manioc	45	47	50	39	39	40

Source: Ministère de l' Agriculture, République du Côte d' Ivoire 1984.

Disponibilité de données sur le manioc

Des séries chronologiques sur une longue période existent pour la plupart des variables qui nous intéressent dans les domaines suivants:

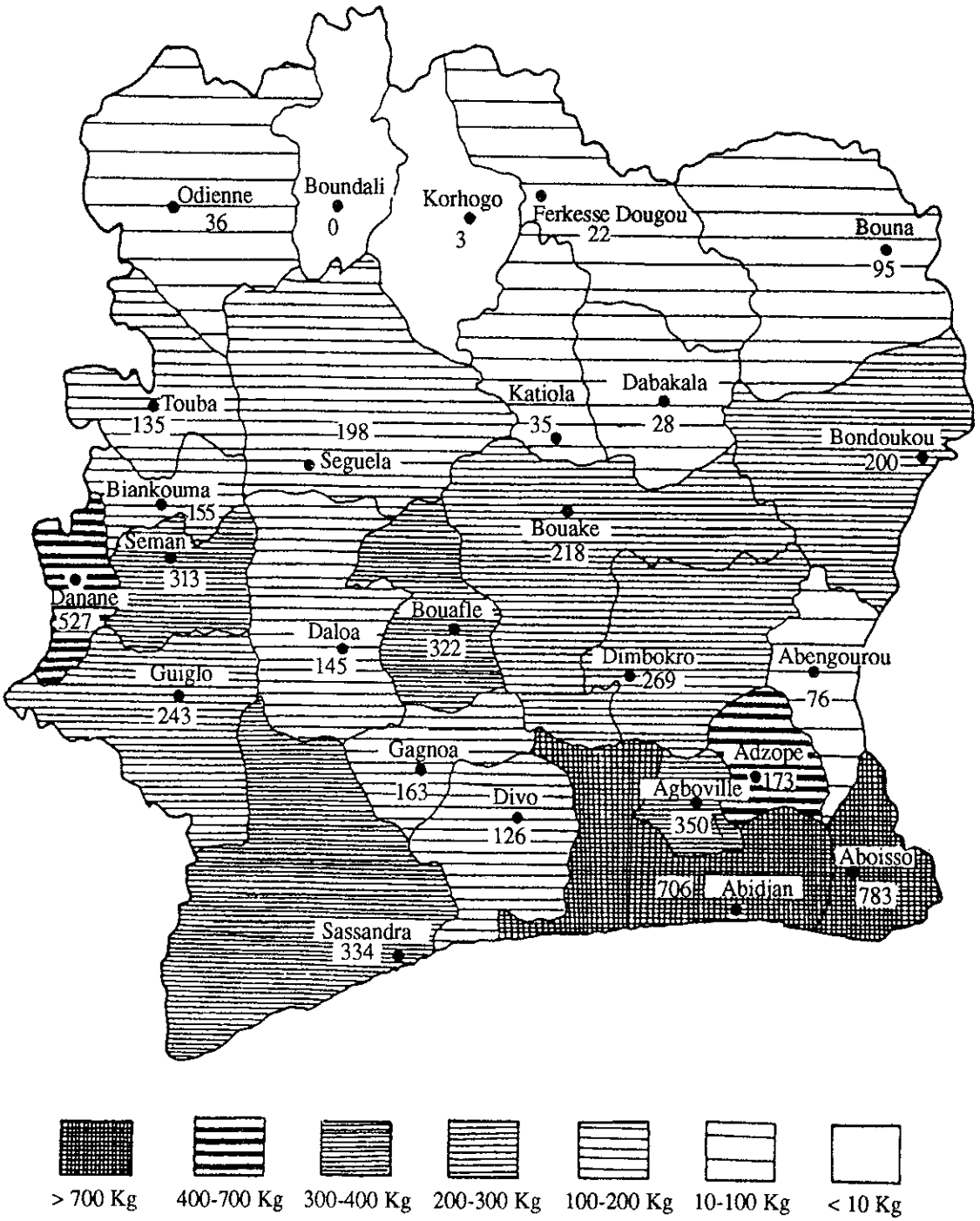
- Production: statistiques de productions et superficies pour l'ensemble des vivriers de 1947 à 1985.
- Pluviométrie: données pour les principales villes de 1951 à 1987.
- Population: recensement général de la population en 1975 et 1987 et après 1987.
- Consommation: enquête budget consommation auprès des ménages en 1979, et depuis, enquête permanente auprès d' un échantillon plus réduit de ménages. Les quantités de produits ainsi que les dépenses de consommation sont suivies.
- Prix: suivi permanent des prix au consommateur des principaux vivriers depuis 1960, à Abidjan et dans quelques autres villes. Certaines données de prix au producteur existent également; depuis 2 ans on a des données régulières sur les prix de gros des produits vivriers.

Etat de la recherche sur le manioc

De façon générale, on peut dire que la recherche sur le manioc a été très timide et les résultats relativement moyens. Ainsi au niveau agroéconomique, l'essentiel des travaux réalisés ont été concentrés sur la description des systèmes de production, de transformation artisanale et de distribution dans les centres urbains. Seuls quelques travaux récents abordent l'analyse économique des systèmes de production ainsi que l'efficacité des procédés de transformation artisanale.

La recherche agronomique a, de son côté, conduit un programme plus structuré sur l'amélioration et le développement de la culture. Confié à l' Institut des Savanes de Bouaké (IDESSA), ce programme est exécuté dans le cadre d'un réseau multilocal. Il porte à la fois sur les techniques culturales et l'amélioration variétale. Les recherches réalisées de 1977 à 1984, ont permis de disposer de recommandations pratiques sur la culture du manioc en Côte d'Ivoire. Ces recommandations concernent le choix et la préparation du sol et du matériel végétal, la plantation (dates, modalités et densités), la fertilisation, l'entretien et la lutte contre les maladies et les parasites. Deux groupes de variétés etaient conseillées aux paysans. Il y a d' une part les variétés à potentiel de production moyen (15 à 25 t/ha); elles sont tardives (18 mois), et à utilisation polyvalente (consommation en frais et transformation). Ce sont BONOUA, H3 et KATAOLI. D'autre part, il y a des variétés à haut potentiel de production (30 à 37 t/ha), récoltables à partir de 14 mois et qui nécessitent une transformation avant consommation—CB, TA49, TA2A, B33 et B6.

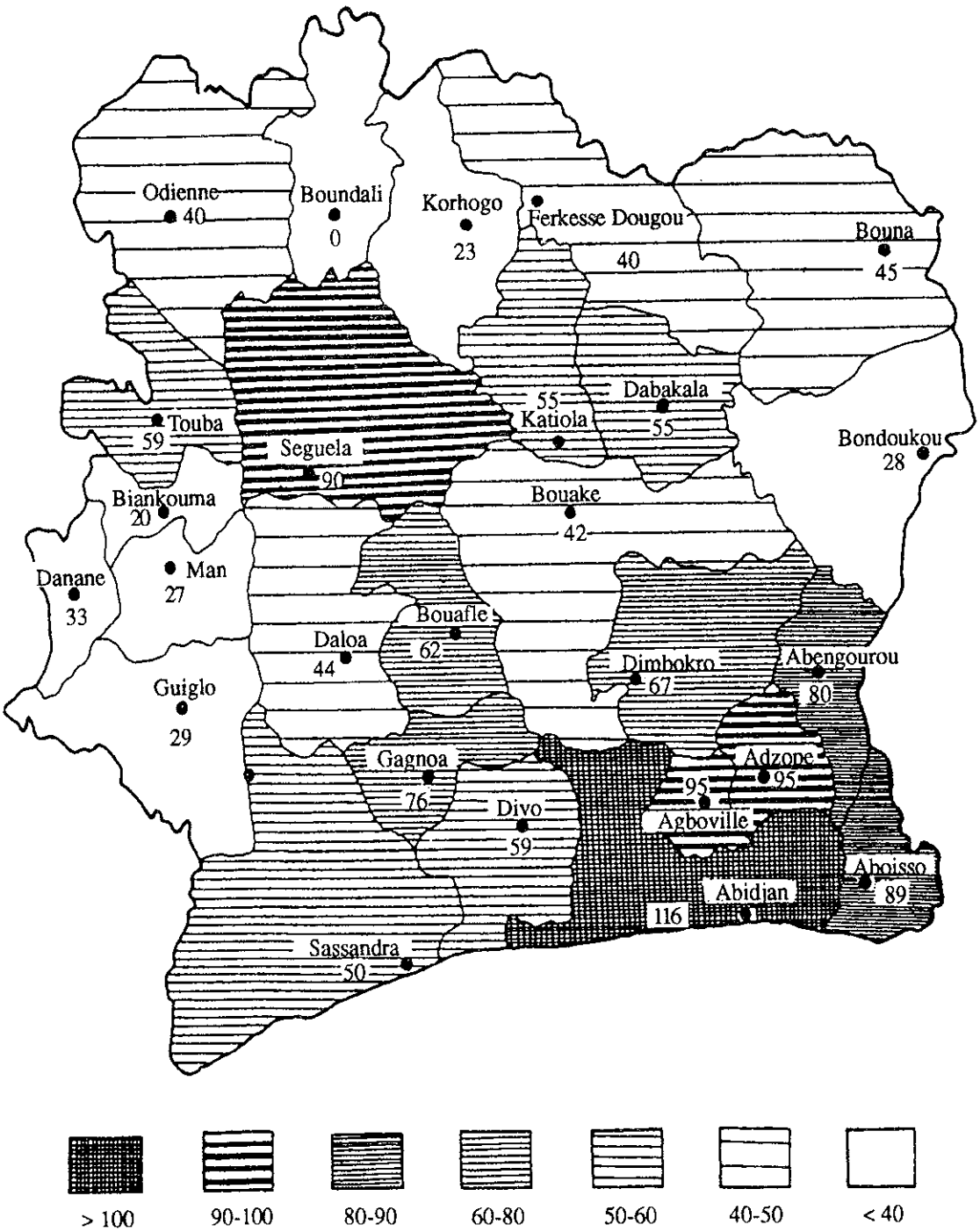
Carte 1. Production de manioc en kg/ha/an en Côte d'Ivoire.[a]



Source: IDESSA/IDC, *Section Manioc.*

[a] D'après recensement et statistiques agricoles, 1979.

Carte 2. Rendement moyen en manioc en quintaux/ha en Côte d'Ivoire.[a]



Source: IDESSA/IDC, Section Manioc.

[a] D'après statistiques agricoles, 1979.

Parallèlement à ces recherches agronomiques, une expérimentation industrielle destinée à mettre au point une filière de traitement de la racine fraiche pour obtenir de l' *attiéké* déshydraté et de la farine panifiable a été initiée par le Ministère de l' Agriculture. Réalisée par la société Ivoirienne de Technologie Tropicale (I2T), cette action a abouti à une maîtrise du processus industriel pour la fabrication de l'*attiéké* et de la farine panifiable. Mais le prix de revient quelque peu élevé de ces produits limite la demande au niveau national.

Les attentes

Il faut reconnaître que le faible niveau de la recherche actuelle sur le manioc est dû au manque de moyens. Le projet d' Etude Collaborative du Manioc en Afrique (COSCA) est une occasion d' aider à déterminer, au niveau global, les axes prioritaires de la recherche sur le manioc en Côte d' Ivoire et aussi de faire des recherches spécifiques sur des sujets importants et déjà identifiés. La recherche ainsi envisagée pourrait, par exemple, s' orienter vers:

a) L'identification et la'hiérarchisation des principales variétés cultivées qui sont appréciées par les consommateurs;

b) La détermination des caractéristiques technologiques de ces variétés; et

c) la mise en évidence des contraintes majeures au niveau de la production, de la transformation et de la distribution.

Cassava in the Economy of Ghana[1]

Ramatu M. Al-Hassan[2]

Abstract

Cassava is a major food crop in Ghana. It is grown throughout the country either in pure stands or intercropped. Cassava is eaten both in fresh and processed form. Cassava processing in done by small-scale processors, most of whom are women. *Gari* is the most important processed product and is eaten in a variety of ways. Postharvest research on cassava has concentrated on development of cassava products to replace fresh roots in the preparation of *foufou* and *akple*. The shortage of economic studies both on cassava cultivation and utilization is noteworthy.

Key words: production, utilization, processing, marketing, research.

Production

Cassava is a major staple food crop in Ghana and in terms of area planted and output, ranks next to maize (Tables 1 and 2). The value of the gross output of fresh cassava roots ranged from 2.6 million cedis in 1985 to 117 million cedis in 1987 (cedi 1.00 = US$0.0025). The 1987 figure represents a 22% share in the agricultural gross domestic product (AEDP), the highest among all agricultural products (Table 3).

Table 1. Area planted (000 ha) in major crops in Ghana.

Crop	1984	1985	1986
Maize	724	405	450
Cassava	813	356	375
Sorghum	251	250	240
Millet	231	222	240
Yam	223	111	120
Rice	69	87	90

Source: Ministry of Agriculture.

Table 2. Output (000 t) of major food crops in Ghana.

Crop	1984	1985	1986
Cassava	4,065	3,075	3,040
Maize	574	395	495
Sorghum	176	185	190
Millet	139	120	140
Yam	725	560	660
Rice	76	80	80

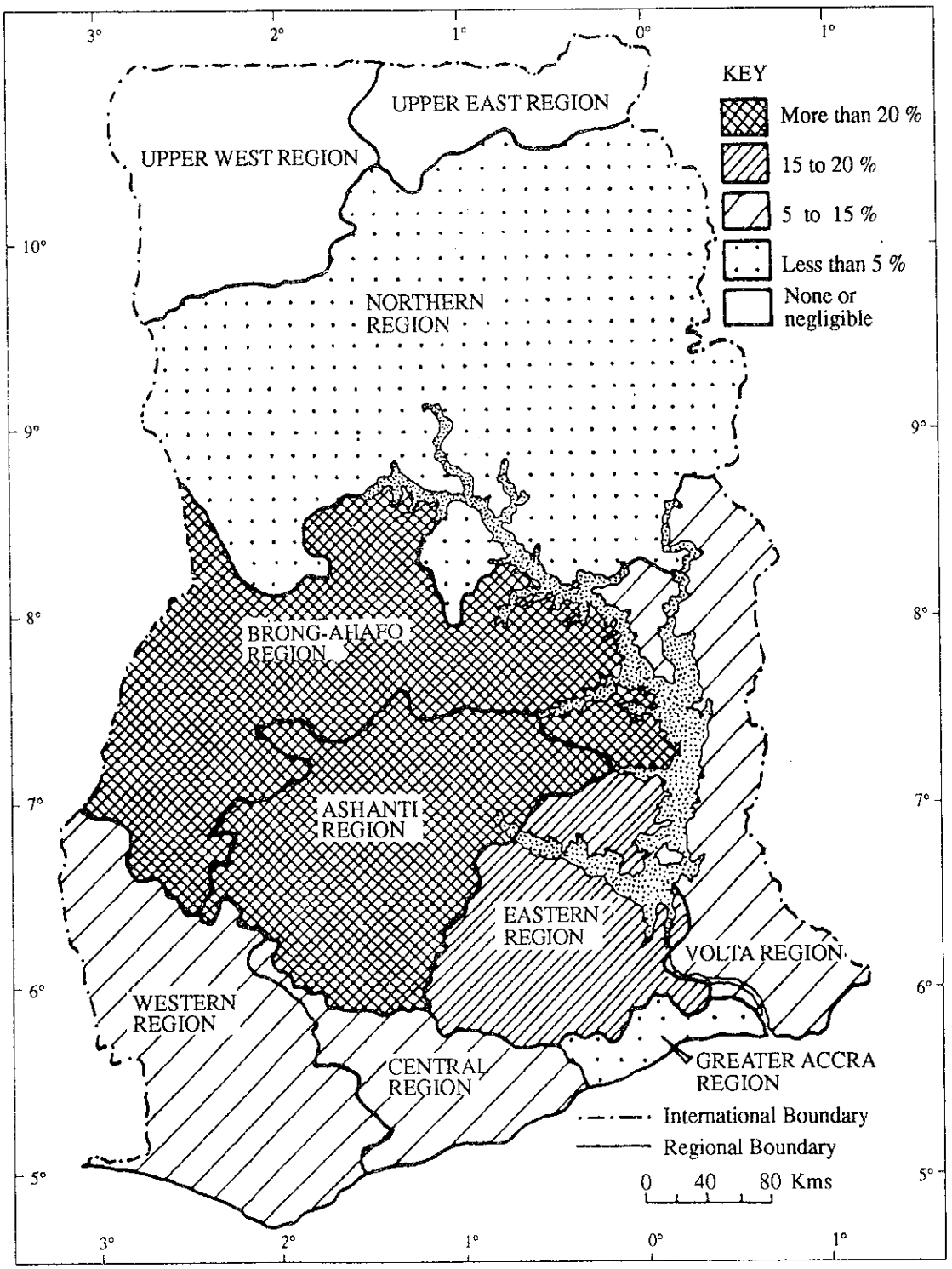
Source: Ministry of Agriculture.

Cassava is grown throughout Ghana, although production is concentrated in the south (Map 1 and Table 4). Brong-Ahafo, Ashanti, and the Eastern Region produce about 65% of the total output, while the Central, Western, and Volta Regions produce 29%. In the southern parts of Ashanti, Volta, Greater Accra, Central, Western, and Eastern Regions the area planted with cassava exceeds 40% of all area under cultivation (Table 5). The Volta Region has the highest number of farmers growing cassava (45,417) as the predominant crop (Fig.

[1] This paper is taken from Status of Data on Cassava in Major Producing Countries of Africa: Cameroon, Côte d'Ivoire, Ghana, Nigeria, Tanzania, Uganda and Zaïre., Collaborative Study of Cassava in Africa (COSCA) Working Paper No. 3, edited by Felix I. Nweke, John Lynam, and Coffi Prudencio. It is reprinted here with permission of the editors.

[2] Department of Agricultural Economics, Faculty of Agriculture, University of Ghana. Legon, Ghana.

Map 1. Intensity of cassava production by regions in Ghana.



1). Ashanti Region follows with 43,533 farmers growing cassava as the predominant crop.

Table 3. Contribution of various components to Agricultural Gross Domestic Product (AGDP) in Ghana, 1987.

Product	Production (000 t)[a]	Revenue (C Million)[b]	%
Cassava	2,943	117,720	22
Maize	553	21,120	4
Fish	350	28,000	5
Cocoa	210	74,000	14
Cotton	2	450	-
Tobacco	2	272	-
Sorghum/Millet	300	9,000	2
Rice	81	5,670	1
Oil palm	51	4,590	1
Yam	1,001	70,070	13
Plantain	1,005	60,300	11
Cocoyam	1,000	50,000	9
Vegetables	125	12,500	2
Poultry (birds)	6,000	3,600	1
Sheep (head)	500	4,000	1
Goats	500	3,000	1
Cattle	200	10,000	2
Forestry, Others[3]	-	60,000	11
Total	-	544,292[c]	100

Source: Ministry of Agriculture 1987.
[a]Unless otherwise stated.
[b]C 1.00 = US $0.0025.
[3]Estimate.

Cassava is grown in pure stands or intercropped—either as the dominant or subsidiary crop. Data from 1986 crop surveys indicate that cassava is mainly interplanted as a subsidiary crop (Table 6). Where cassava is planted in rotation, it is usually the last crop before fallow. This is probably because cassava is a hardy plant that tends to do well even under poor soil conditions.

Table 4. Area planted and production of cassava by region in Ghana (1986 and 1987 annual average).

Region	Area (000 ha)	Production (000)	% of total production
Western	52	338	10.8
Central	45	335	10.0
Eastern	82	489	18.3
Greater Accra	6	32	1.1
Volta	40	255	8.8
Ashanti	75	600	21.7
Brong-Ahafo	85	722	24.5
Northern	22	139	4.7
Upper East	0	0	0.0
Upper West	0	0	0.0
Total	407	2,910	100.0

Source: Ministry of Agriculture 1987.

A national average field size of 2.4 hectares of cassava per farmer was reported in 1986. In 1987, fresh root yields ranged from a low of 5.5 t/ha in Greater Accra to 8.5 t/ha in Brong-Ahafo (Table 7).

Processing

Cassava processing is done mainly by small-scale traditional processors, most of whom are women. The Volta Region, where cassava is widely consumed, also produces most of the processed cassava products. Areas around Pokuasi in the Eastern Region are also known for *gari* processing. All over Ghana, however, wherever cassava is grown, pockets of processors, particularly *gari* processors, meet local consumer needs.

Attempts to establish large-scale *gari* processing factories have largely failed for various reasons. The principal one being an inadequate supply of cassava roots. Transporting the fresh roots to processing sites also poses a problem, as feeder roads are lacking in most areas. Bediako (1978) highlighted the drudgery involved in *gari* processing and the desire expressed by traditional processors to own grating machines.

Table 5. Area (000 ha) planted to five major crops by region, 1987.

Region	Maize	Rice	Sorghum/ Millet	Cassava	Yam	Total	Cassava as % of total
Western	42	7	0	53	7	109	48.8
Central	42	2	0	42	2	88	47.6
Eastern	75	5	0	90	20	190	47.0
Greater Accra	6	1	0	6	0	13	46.9
Volta	38	2	10	43	8	101	42.6
Ashanti	72	3	0	80	20	175	45.8
Brong-Ahafo	88	13	20	85	48	254	33.5
Northern	100	35	130	23	60	348	6.6
Upper East	4	8	125	0	0	137	0.0
Upper West	21	7	61	0	6	95	0.0
Total	489	82	346	422	171	1,510	28.0

Source: Ministry of Agriculture 1987.

Table 6. Cassava production systems by region, 1986.

	Pure stands		As dominant crop		As subsidiary crop in mixture	
Region	Area (ha)	%	Area (ha)	%	Area (ha)	%
Western	3,400	7	19,200	37	28,400	56
Central	21,000	45	4,000	8	22,000	47
Eastern	26,000	35	10,000	14	37,000	51
Greater Accra	2,000	39	900	17	2,300	44
Volta	16,000	45	8,000	22	12,000	33
Ashanti	4,500	6	19,400	28	46,100	66
Brong-Ahafo	0	0	7,500	9	77,500	91
Northern	0	0	1,000	5	19,000	95
Upper West	0	0	0	0	0	0
Upper East	0	0	0	0	0	0
Total	72,900	18	70,000	18	244,300	63

Source: Ministry of Agriculture 1987.

Figure 1. Ghana: Number of cassava farmers by region, 1987.

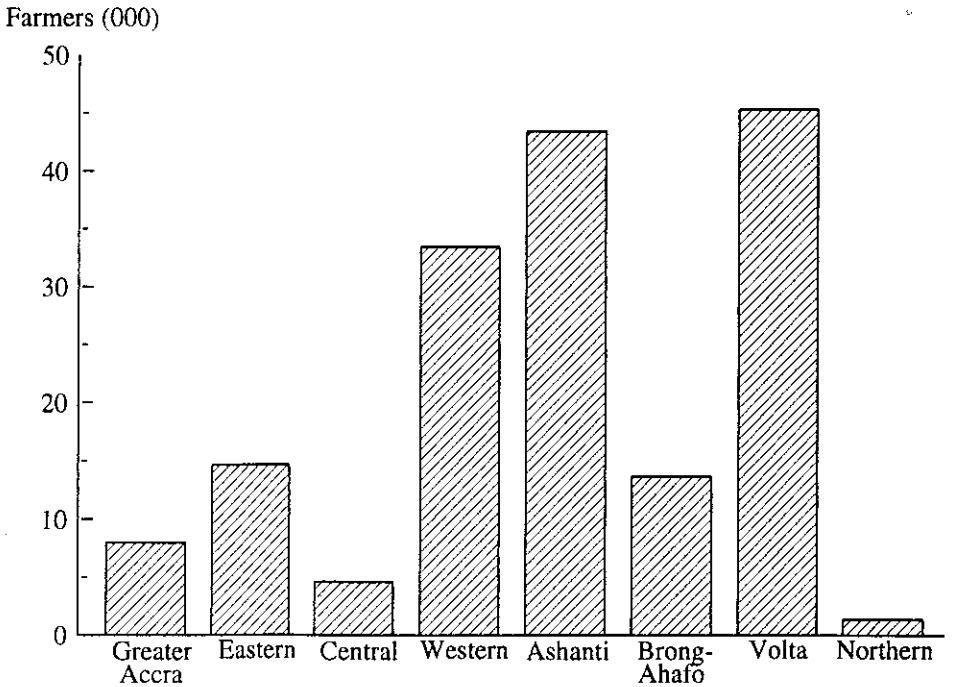


Table 7. Estimated yields of fresh cassava roots by region in Ghana (1986 and 1987 annual average).

Region	t/ha
Western	6.5
Central	7.5
Eastern	6.0
Greater Accra	5.5
Volta	6.5
Ashanti	8.0
Brong-Ahafo	8.5
Northern	6.5
Upper East	-
Upper West	-

Source: Ministry of Agriculture 1987.

In collaboration with the African Regional Center for Technology (ARCT), the Ghana Food Research Institute is establishing a pilot demonstration project for *gari* production. An objective of the project is to set up a small- to medium -scale unit for the production of *gari* and other cassava products consistent with the current and planned pattern for cassava production in the rural areas of Africa. A second objective is to use the Unit as a training center for processors and technicians with a view to accelerating the dissemination of information about the improved technology.

Utilization

Traditionally, cassava is used in the form of fresh roots, peeled and boiled (*ampesi*); fresh roots, roasted and peeled and eaten; fresh roots, boiled and pounded into *foufou*; peeled tubers cut into pieces and sun-dried; and dried chips milled into flour, used to prepare *kokonte*, a food similar to *foufou*.

Gari is, however, the most popular processed cassava product in Ghana. It normally takes 4 to 5 days to process. The cassava roots are washed, peeled, and grated and the grated meal is then put into muslin, jute, or grey baft bags. Liquid starch is then pressed out of the grated mash by placing heavy objects on the bags. The wet meal is sieved to remove the larger pieces. The fine grain is spread out to dry and later fried into *gari*. The end product is a gelatinized grainy flour which has a distinct sour taste. *Gari* is eaten in a number of ways. It can be mixed with cold water and sugar and taken as a meal. It can also be mixed with hot water to form a sticky mass (*eba*) which is eaten with soups or stews. It can be moistened and mixed with an oily stew contain-

ing tomatoes, onions, and spices. This mixture is lightly fried and is known as *gari-fortor*. *Gari* is also mixed with milk and sugar and eaten like porridge, hot or cold. *Agbelima* (cassava dough) is another food product made from cassava by washing, peeling, grating, and soaking, however, the starchy liquid is not removed, but the entire grated mass is allowed to ferment lightly. It is either used alone to prepare *akple* or mixed with maize dough.

An unfermented cassava flour is made by grating, drying, and sieving the cassava roots to produce a fine meal. A little water and salt are added and the mixture is moulded into flat cakes and steamed. This food is called *yakayake* and is eaten with soup or stew. As an alternative to steaming, the salted mixture can be moulded into balls and deep-fried in palm kernel or coconut oil to make *agbole kaklo*.

The Ghana Food Research Institute has developed flours from cassava that can be used in the preparation of *foufou* and *akple*. The processed flours are easier to transport and store longer than fresh roots or dough. One of these flours, instant *foufou* flour, is now being marketed under the trade name of "Lukapap". The acceptability to the public of this product is yet to be evaluated.

Cassava leaves and roots are also used in livestock feed. The leaves and tender stems are fed to sheep, goats, and rabbits. Dried cassava chips are also used as a carbohydrate component in compounding livestock rations.

A principal by-product of gari processing is liquid starch from which two other products, tapioca and laundry starch are produced. The liquid starch extracted during *gari* preparation is allowed to sediment and the supernatent liquid is decanted. The liquid starch is then dried and fried over a low fire to form tapioca granules. Instead of frying, the starch may also be dried and used as laundry starch. The extent of production of industrial starch and glue in Ghana is not known. Preliminary enquiries indicate that the starch used in the textile factories is probably all imported.

There is no up-to-date data on the actual domestic consumption of cassava products. This is because no household consumption surveys have been carried out in recent years. In 1962, a household expenditure survey showed that cassava together with its products accounted for another 12% of expenditure on local food, while all the cereals with their products taken together accounted for 12%. The survey showed that of the food crops, expenditure on cassava was only second to *kenkey*, a popular staple food prepared from maize (Ghana 1962). Although these findings may well be out of date, they can still serve as an indication of the importance of cassava in the diet of the ordinary Ghanaian. More current household consumption surveys are needed.

Table 8 presents demand projections for fresh cassava roots. The surplus indicated should be viewed with caution, for it is not clear whether the projection of demand is for fresh cassava for use as *foufou* or *ampesi* alone, or includes fresh cassava used in the processing of other products, such as *gari, agbelima*, or *kokonte*.

Table 8. Projections of demand and production (000 t) of cassava in Ghana, 1984-89.

Year	Demand	Production	Surplus
1984	1,875	4,065	2.19
1985	1,932	3,075	1.14
1986	1,993	3,040	1.05
1987	2,007	2,943[a]	0.94
1988	1,870	2,170[a]	0.20
1989	2,020	2,310[a]	0.20[a]

Source: Ministry of Agriculture 1987.
[a]Net production allowing for postharvest losses.

Marketing

Owing to its bulky and highly perishable nature, the transportation of fresh cassava roots is usually restricted to the urban centers located near production areas. Fresh roots from farms and villages are evacuated to roads by headload.

In the case of Accra, fresh roots may be transported for distances of up to 40 km by truck or rail. The major source of fresh cassava roots for Accra is the Eastern Region, as far as Koforidua. The bulk of *agbelima* and *gari* supplied to Accra is from the southeast, mainly from the Volta Region.

While the exact flow of processed cassava products is not known, their distribution is probably wider than that of fresh roots. There is a brisk but informal trade in *gari* and *agbelima* along the Ghana-Togo border, mainly by means of headload.

The Ghana Export Promotion Council believes that an export market for *gari* in the Western countries could be developed. Other cassava products which have export potential, but are not produced in commercial

quantities for export are cassava starch, cassava chips, and cassava pellets. Ghana exported 55 t and 53 t of cassava to European countries in 1986 and 1987, respectively (see Table 9).

Table 9. Export of *gari*, from Ghana (1985 to 1st quarter of 1988).

Year	Quantity (t)	US$	Destination
1985	n. a.	122.00	Togo
1986	55	10,155.80	UK, West Germany
1987	53	8,642.85	UK, USA
1988	52	12,073.55	UK, USA, Canada

Source: Ghana Export Promotion Council.
n.a.: Not available.

Status of cassava research

The major thrust of research on cassava by the Ghana Food Research Institute, Accra, has been in the area of postharvest management including storage, processing, and utilization. Studies conducted on storage of fresh cassava roots at the institute aim at improving the traditional methods of storage (Ankrah et al. 1980; Ankrah 1980; Ankrah and Osei-Yaw 1981; Ankrah 1984). In a study on the storage of cassava roots by Amewushika and Osei-Opare (1987), basket and wood shavings were used as a medium for storing fresh cassava roots. This resulted in a longer storage period of up to 6 months, which maintained a high quality tuber suitable for making *foufou* and *ampesi*.

Most of the postharvest research efforts in cassava processing have concentrated on the development of dry cassava products to replace fresh roots in the preparation of *foufou* and *akple*. The now commercialized instant *foufou* powder, "Lukapap", mentioned earlier, is the result of such research. Another flour, dehydrated fermented cassava dough has been developed. This product was found to be acceptable for the preparation of *akple* in terms of texture and nutrients. It is not being produced commercially at present.

Lartey (1969) also made an attempt at developing an instant breakfast food from *gari*. He milled gari into fine flour and blended it with sugar, powdered milk, and salt. The product can be used in baking or as an instant breakfast food or as a thickening agent in soup. Results of this study have not been commercialized.

Experiments on the use of cassava starch to fortify locally milled wheat flour for biscuits and cakes have also been successful (Andah 1975). Flour with 10% starch provided superior baking qualities than wheat flour alone.

Student studies (Amaning-Kwarteng 1974, Essien 1974, Obuobi 1974, Dadzie 1975, Fleishcher 1975, Odoi 1976, Dodoo 1981, Yinka 1982, and Adarkwa-Ntiamaoh 1985) on the use of cassava in livestock feeding were carried out in the Department of Animal Science, University of Ghana. Finally, Blay and Budu (1987) have recently conducted a study on drying methods for the production of more wholesome *kokonte*.

Agronomic research on cassava includes studies on fertilizer requirements, plant density, planting methods, and cassava-based intercropping. The absence of economic studies on cassava in Ghana is rather striking. The economic implications of all the agronomic studies will have to be evaluated if more meaningful and acceptable recommendations are to be made to farmers. Current use and availability of vital inputs including land, labor, fertilizer, and credit need to be examined to explain the rather small size of holdings and apparently low yields.

Evaluation of the cost of production of traditional products such as *gari, agbelima,* and *kokonte* will help determine possible areas for cost reduction. Similar evaluations should also be conducted on new products being developed to determine their economic feasibility. Studies on demand and supply for cassava products should be initiated. Price and income elasticities of demand are required for the evaluation of the impact of price and income policies. For the same reasons, supply response parameters need to be estimated. Inter-regional flows and consumption rates of cassava and its products have to be established to determine deficit/surplus regions and implications for policy. The profitability of using cassava in feed rations needs to be evaluated. Substitution of maize for cassava in feeds must be based on relative returns from the final product and not on cost reduction.

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Cassava Research, Production and Utilization in Nigeria[1]

B. O. Ugwu, O. Ajobo and G. Orkwor[2]

Abstract

Cassava is a major staple food crop in Nigeria supplying about 70% of the daily calorie intake of over 50 million Nigerians. Although cassava is cultivated in 19 states of Nigeria, the bulk of production is grown in only three. Cassava is mainly used for human consumption. About 70% of all cassava harvested is processed into *gari*. There is great potential for processed cassava products, including starch and as a carbohydrate base in poultry feed. Several research institutes in Nigeria do work on cassava. This includes development of new varieties, integrated pest management, agronomy, and processing.

Key Words: processing, processed products, varieties, technologies.

Introduction

Cassava (*Manihot esculenta* Crantz) was introduced into the coastal areas of Nigeria in the last half of the 16th century by the early Portuguese explorers. Since then cassava has become a major staple food crop. It supplies about 70% of the daily calorie intake of over 50 million Nigerians.

Production

In Nigeria, cassava can grow as far as latitude 13 north of the equator and as high up as 2,000 m. However, soil and climatic factors, such as rainfall, restrict its production mainly to areas lying between the guinea savanna and the rain forest vegetation zones.

Cassava growing areas in Nigeria can be grouped into three: major, medium, and marginal, based on production levels and percentage of households cultivating cassava. The major cassava producing states are, in order of importance—Bendel, Imo, Oyo, Anambra, Benue, Rivers, and Cross River. In these states, the estimated annual production ranges from 100,000 t in Cross River to 463,000 t in Bendel. In all these states, with the exception of Cross River, more than 50% of the households are reported to cultivate cassava (Table 1). Medium cassava producing states are Kwara and Ondo where the annual production figures lie between 50,000 t and 100,000 t. Over 50% of the households in these two states are estimated to cultivate cassava. The remaining states are classified as marginal cassava producers as the annual production is estimated at less than 50,000 t. Apart from Lagos and Ogun states, less than 50% of the households are estimated to cultivate cassava (Table 1).

Utilization

Cassava is used mainly for human consumption, although small proportions of total production are used in livestock feed and as industrial raw material. Cassava

[1] This paper is taken from Status of Data on Cassava in Major Producing Countries in Africa:Cameroon, Côte d'Ivoire, Ghana, Nigeria, Tanzania, Uganda and Zaïre. Collaborative Study of Cassava in Africa (COSCA) Working Paper No. 3, edited by Felix I. Nweke, John Lynam, and Coffi Prudencio. It is reprinted here with permission of the editors.

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Table 1. Cassava production (annual averages for 1982/83 and 1983/84 cropping seasons) by state in Nigeria.

State	Production (000 t)	Households cultivating cassava (%)
Anambra	213	76
Bauchi	0	0
Bendel	463	92
Benue	173	78
Borno	0	0
Cross River	101	15
Gongola	22	17
Imo	395	96
Kaduna	11	13
Kano	6	15
Kwara	73	70
Lagos	7	77
Niger	6	42
Ogun	11	88
Ondo	67	77
Oyo	300	89
Plateau	7	25
Rivers	127	95
Sokoto	0	0

Source: Federal Office of Statistics, Lagos 1985.

in its various processed forms is used to prepare a wide range of meals in Nigeria, *eba*, prepared from *gari*, is the most popular cassava meal in all of Nigeria. It is estimated that about 70% of the total cassava harvest is processed into *gari* (Ngoddy 1977). *Lafun*, prepared from flour, is very popular especially in the western states of Nigeria. *Foufou* prepared from cassava fermented in water, is very popular in the eastern states and Bendel, especially in the rural areas. *Tapioca*, cassava roots parboiled, sliced, fermented overnight in water, washed, and dried is also popular in the eastern states and Bendel. Pure cassava starch is cooked and eaten with *banga* soup, mainly in Bendel State.

The processing of each of the products from which these meals are prepared involves some fermentation. In addition to processed cassava products, fresh roots of low cyanide varieties are eaten raw, boiled, or roasted in some parts of Nigeria.

Cassava is now used as a carbohydrate base in compounding livestock feed, as a partial substitute for maize. By-products from cassava processing are widely used to feed chicken and goats in the traditional sector. In the industrial sector, there are at least five large-scale cassava starch mills. There is great potential for cassava starch utilization in Nigeria's wood, paper, textile, sweetener, and alcoholic beverages industries, to name a few. These industries largely depend presently on imported starch. The current erratic supply from domestic sources is due to the large demand for cassava for human consumption. Unless supplies increase the potential for the use of cassava in industry will not be realized.

Trade

Although there are speculations about the informal trade in *gari* across the borders of Nigeria to other West African countries there is no record of such trade. There is extensive internal trade in cassava mainly for human consumption. This trade is largely in processed products and generally between rural and urban areas. Even in the extreme north of Nigeria where production is limited, processed cassava products are sold in urban centers.

Research on cassava

The National Root Crops Research Institute (NRCRI) in Umudike in eastern Nigeria is mandated by the federal government to carry out research on cassava. However, there are a number of other research institutes in Nigeria which are also involved in cassava research. They include the International Institute of Tropical Agriculture (IITA), Ibadan; the Federal Institute of Industrial Research (FIIRO), Oshidi; the Project Development Agency (PRODA), Enugu; the Institute of Agricultural Research (IAR), Samaru; and the Institute of Agricultural Research and Training (IAR&T), Ibadan. Cassava research is also being carried out in some universities. Such research covers almost all aspects of cassava production, processing, distribution, and consumption.

Several high-yielding, disease and pest tolerant varieties of cassava, for example, U/41044 and U/7706 developed at NRCRI, and TMS 30555, TMS 30572, and TMS 30211, developed at IITA, have been released to Nigerian farmers. In addition, based on the results of uniform yield trials, NRCRI has also released as planting material four top selections labeled 82/2, 8210, 8220, and 8208. These varieties are resistant to major cassava pests and diseases such as cassava mealybug (CMB), cassava green spider mite (GSM), cassava bacterial blight (CBB), and cassava mosaic virus disease (CMD).

An integrated approach involving chemical and cultural control measures (early planting and planting depth) has proved effective in combating the CMB and GSM. Bioagents, such as *Epidinocarsis lopezi* (the natural enemy of mealybugs) have been bred and released in some locations by IITA in collaboration with NRCRI. This, in addition to the other technologies, has led to a drastic reduction in the population of CMB.

Studies have resulted in the development of technologies for row planting, regular spacing, fertilizer practices for the major soil types, beneficial intercropping systems, and optimum time of planting for the various ecological zones. Weed control studies at NRCRI and IITA have shown that weeds can be controlled where cassava is grown as a sole crop or an intercrop by the use of herbicides and live cover crops such as *egusi* melon (*Colocrithyis citrulus*). In collaboration with the FAO, the NRCRI has developed a multi-furrow planter and harvester which has proven efficient, although some modifications may be necessary for manufacturing it locally.

Whole cassava meal and cassava peel meal have been developed as a carbohydrate base for poultry feed. These can substituted up to 75% for maize depending on the class of poultry and the method of production. Techniques have also been developed for processing cassava into powdered starch and for further processing the powder into cold water starch for textile finishing, home laundry purposes, and adhesives.

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Cassava Production, Consumption and Research in the United Republic of Tanzania[1]

M. A. M. Msabaha and B. W. Rwenyagira[2]

Abstract

Cassava is an important food crop in Tanzania. The crop is grown all over the country. Most of the recent growth in production has come from increased area planted as average yields remain low due to a variety of constraints. Cassava processing is done mostly by women and is for human consumption. A small percentage of processed cassava goes to animal feed and starch. Research has focused on disease resistant varieties, integrated pest management, and postharvest technologies.

Key words: yields, production constraints, processing, improved varieties.

Introduction

The United Republic of Tanzania has a population of about 22 million people and an agrarian economy. Agriculture contributes 50% of Gross Domestic Product, generates 75% of the foreign exchange earnings, and employs about 90% of the labor force (MALD 1983). The dominant mode of agricultural production is smallholder farming. Maize is the major food staple followed by rice, sorghum/millet, and cassava (MALD 1987).

In 1984, the government launched a national food program for the period 1985 to 2000, and one of the strategies adopted was to emphasize the production and consumption of cassava. The crop has a long history of providing food security in the country particularly during famine. It is compatible with local feeding systems; is a source of cash income; and is used as a raw material for some industries. In 1986, the UNICEF office in Dar es Salaam sponsored a case study for reviewing the production, consumption and uses of cassava in the country.

Production

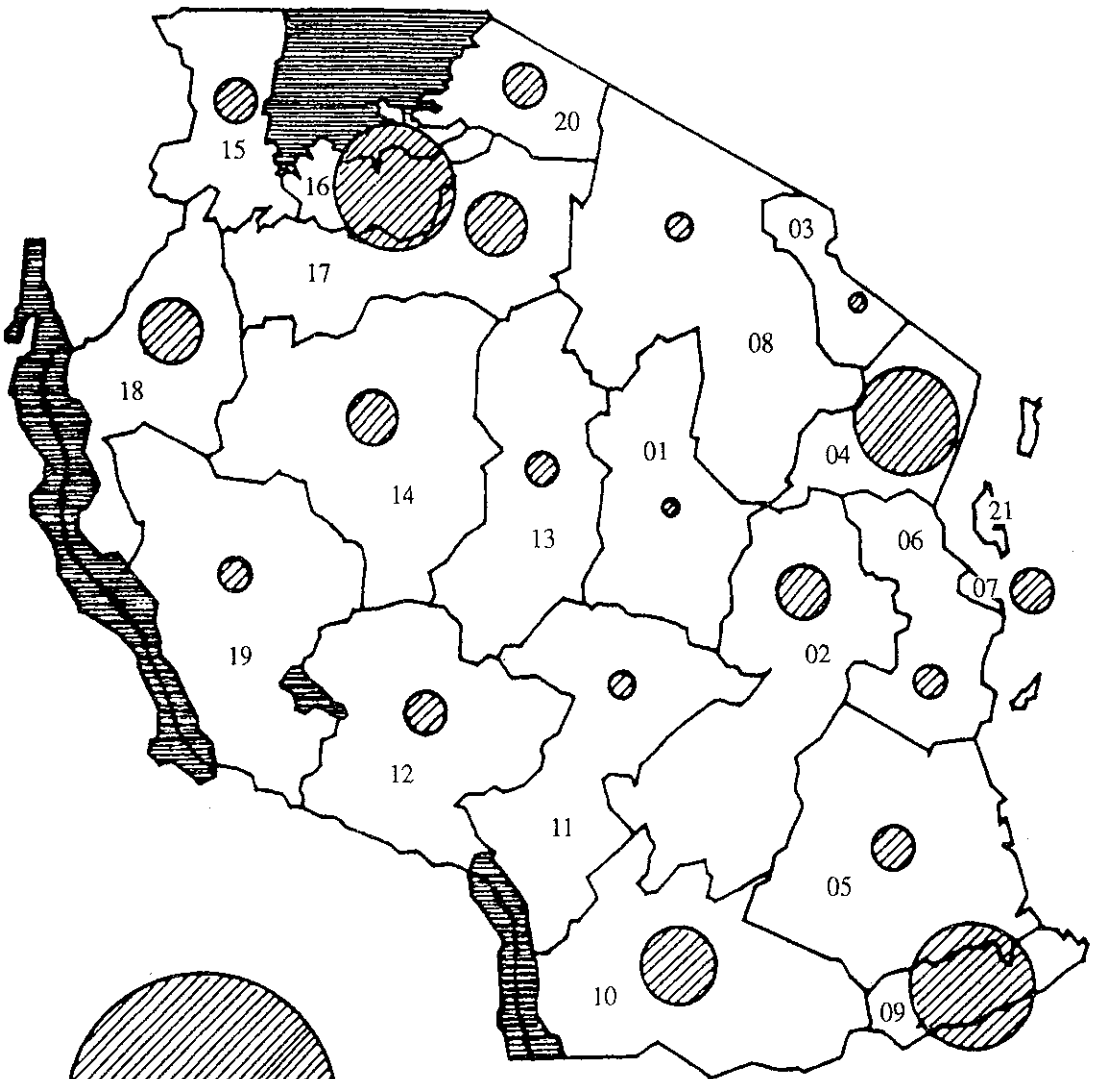
Estimates of production of the major food crops in Tanzania, namely, maize, rice (paddy), wheat, cassava and millet/sorghum are summarized in Table 1. Up to 1987, there was an increase in production of all food crops except cassava which showed a decline from 2.03 million t in 1986 to 1.71 million t in 1987 (Table 1). Annual production figures for the period 1975 to 1987 show that the highest annual mean production of 1.77 million t per year was recorded for maize. The annual growth in the production of food crops was greatly influenced by the expansion in area planted (MALD 1982).

Limited farming system surveys carried out in the country indicate that farmers practiced more intercropping than monoculture. Most cassava varieties grown are local in origin. Estimated average yields of dry roots for local and improved varieties under farmers' conditions are 1.4 and 5.0 t/ha, respectively (MDB 1985). However, at research stations, yields of local and improved varieties are around 2 t and 10 t of dry roots per

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[2] Mwanza Research Station, and Ministry of Agriculture, Tanzania, respectively.

Map 1. Cassava production in Tanzania.[a]



One sq cm = 100,000 t of dried cassava.

Regions:

01 Dodoma	08 Arusha	15 Kagera
02 Morogoro	09 Lindi	16 Mwanza
03 Kilimanjaro	10 Ruvuma	17 Shinyanga
04 Tanga	11 Iringa	18 Kigoma
05 Mtwara	12 Mbeya	19 Rukwa
06 Pwani	13 Singida	20 Mara
07 Dar-es-Salaam	14 Tabora	21 Zanzibar

Source: Tanzania Food and Nutrition Centre (TFNC) Data Report 1982.

[a]The map shows cassava production by region for 1979/80.

Table 1. Tanzania: Production (000 t) of main food crops, 1975-87.

Year	Maize	Paddy	Wheat	Cassava	Millet/Sorghum
1975	1,367	265	82	986	435
1976	1,499	346	69	1,182	525
1977	1,664	314	64	1,348	604
1978	1,465	387	55	1,252	826
1979	1,720	262	70	1,411	1,157
1980	1,726	291	87	1,207	849
1981	1,839	200	90	1,456	705
1982	1,654	320	95	1,658	970
1983	1,651	350	58	1,967	793
1984	1,939	356	74	1,894	1,157
1985	2,067	425	83	1,923	850
1986	2,127	496	71	2,032	922
1987	2,359	644	72	1,709	954
Mean	1,771.3	358.1	74.6	1,541.9	826.7

Source: Marketing Development Bureau 1987.

hectare, respectively (Msabaha et al. 1985). Production of dry roots from the regions between 1975 and 1987 is summarized in Map 1.

Cassava is widely grown all over the country. The most important cassava growing areas are around Lake Victoria (Nwanza, Shinyanga, and Mara regions); Lake Tanganyika (Tabora and Kigoma regions); Lake Nyasa (Ruvuma region); along the coastal strip of the Indian Ocean (Tanga and all Zanzibar Regions); and along the Ruvuma Valley (Mtwara Region). The altitude of these areas is between sea-level and 1,500 m, and rainfall is between 800 mm and 1,200 mm per annum. There is not much cassava grown in the higher altitude areas of Mbeya and Iringa regions.

Important production constraints for cassava in Tanzania are:

i. Disease: The most important cassava diseases are cassava mosaic virus disease (CMD) which causes yield losses of up to 90% in susceptible varieties (Jennings 1970) and cassava bacterial blight (*Xanthomonas campestris* pv *manihotis*) which is equally devastating. CMD is widely distributed in the country, whereas CBB is restricted to areas around Lake Victoria and Lake Nyasa.

ii. Pests: Termites, cassava green mite (*Mononychellus* spp), and cassava mealybug (*Phenacoccus manihoti*) are the most serious cassava pests in the country. The corresponding estimates of yield losses in susceptible varieties caused by these pests are 39% to 49% (AIR 1984), 50% to 80% (Shukla 1986), and 52% to 100% (Msabaha 1987). All the pests are widespread except cassava mealybug.

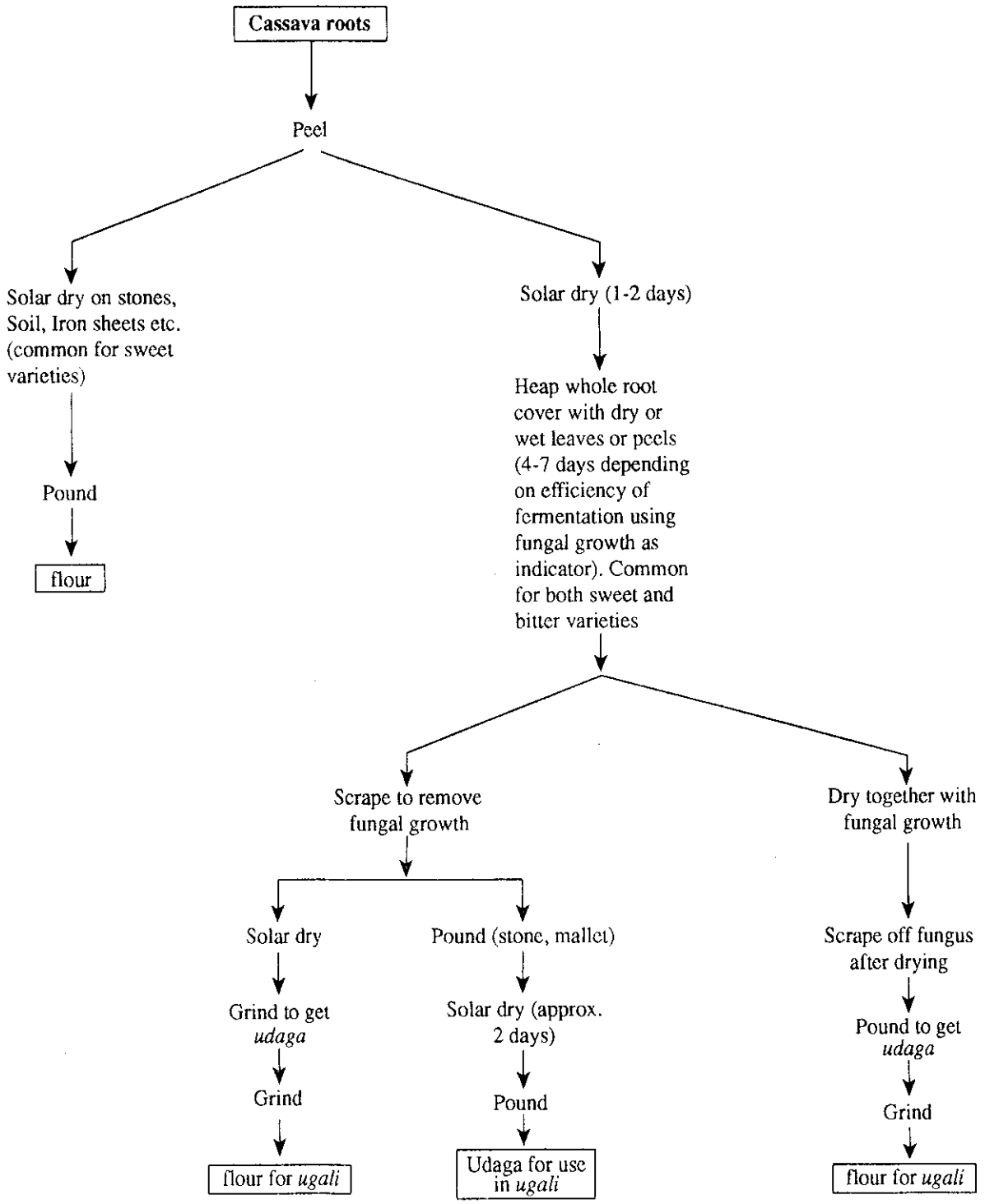
iii. Agronomy: Most farmers do not follow recommended agronomic practices. Frequently, cassava is planted late and left to grow with weeds particularly in monoculture.

iv. Lack of improved planting materials: There is no institution responsible for the multiplication and distribution of the improved materials to farmers. Consequently, farmers plant any variety available. In most cases, such varieties have low genetic potential in yield or poor resistance to major pests and diseases.

v. Poor marketing infrastructure: Most cassava producing centers are in the rural areas. Transport from the production centers to marketing places in urban centers is very costly.

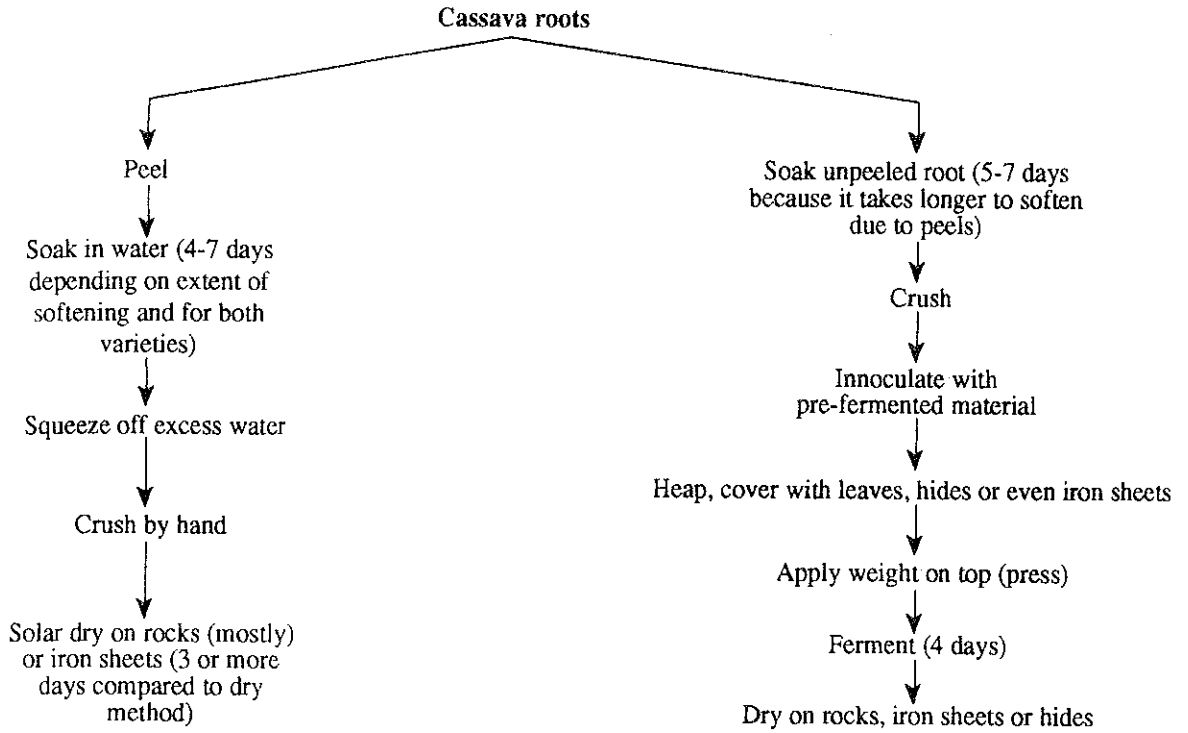
vi. Cultural: Some tribes have customs which prohibit consumption of cassava-based products.

Figure 1. Dry methods of processing cassava in the lake zone area of Tanzania.



Source: Msabaha, Kepakepa and Laawal 1986.

Figure 2. Wet method of processing cassava roots in Tanzania.



Source: Msabaha, Kepakepa and Laawal 1986.

Utilization

Cassava processing is mostly done by women. Processing methods differ depending on the end product. The most common methods for processing cassava into dry chips and flour are summarized in Figures 1 and 2. Processing for immediate use involves peeling and roasting on charcoal or frying in oil to provide a quick meal. Processing of cassava leaves involves pounding or crushing the leaves before cooking. Sometimes the leaves are soaked in water before cooking to reduce the hydrocyanic acid (HCN) level.

A small percentage of the processed cassava is utilized in domestic animal feed. In 1985, the Tanzania Animal Feeds Company used dry cassava in manufacturing animal feed for poultry and pigs (MALD 1987).The poultry feeds contained 5% to 10% cassava flour and the feeds for pigs contained 20% cassava flour (Msabaha et al. 1986). The manufacturing of such cassava-based feeds was, however, stopped because it was expensive. Cassava is processed into starch at the Tanzania Starch Manufacturing Company located in Mwanza. The factory has a capacity to process 40 t of wet cassava or 15 t of dry cassava per day (MALD 1987). The starch is used by some textile, paper, and confectionery industries in the country.

Factors which limit the consumption of cassava have not been thoroughly assessed. However, consumer prices of preferred cereals are relatively more subsidized than the consumer price of cassava. There is lack of variety in the cassava-based products in the local markets and cassava-based dishes in restaurants and hotels. At present, common cassava-based products in the markets are limited to fresh cassava roots and leaves and dry cassava chips and flour. Most of the cassava products in the market are low in quality, have short shelf-lives, and relatively high HCN residues. The Tanzania Bureau of Standards (TBS) is working on standards for dry chips and flour. The Tanzania Food and Nutrition Centre (TFNC) and Sokoine University of Agriculture are working on improving the efficiency of methods for reducing HCN during processing.

Research and Training

The National Root and Tuber Crops Improvement Program in the mainland is financed by government, while the component program in Zanzibar is financed by both the government and the International Development Research Centre (IDRC). In general, the resources for research have been very limited; however, the program has been able to train staff to build up in-program capability. Scholarships received from the International Institute of Tropical Agriculture (IITA), Ibadan, helped to train a good number of the staff.

Improved varieties which are high yielding and moderately resistant to cassava mosaic virus disease (CMD) and green spider mite have been developed. Multiplication of improved materials on station and distribution to nearby farmers is carried out on a limited scale. A germplasm collection consisting of local and exotic (improved IITA planting material) varieties has been established. There are about 370 varieties in the collection which have been classified as "bitter", "intermediate", or "sweet". Preliminary work has been done to assess the efficiency of traditional processing methods of cassava, and on the utilization of cassava-based products in formulating livestock feed. The work was carried out at Sokoine University of Agriculture and the results are promising.

Although the resources to carry out research continue to be restrictive, work continues. The breeding program aims at developing low HCN varieties which are high-yielding and resistant to major pests and diseases. Agronomy activities will focus on the improvement of cassava-based farming systems, collecting baseline data, and developing systems for the use of inorganic and organic fertilizers. Surveys to establish the distribution of major pests and diseases will be carried out along with the development of Integrated Pest Management (IPM). Biological control, host plant resistance and cultural control will be the main components of IPM. Methods to improve traditional processing and better postharvest storage technologies will be tested. Potential uses of cassava will be studied. The multiplication of planting materials will be carried out along with on-farm evaluation of promising clones. The training of staff to carry out the research activities, however, will depend on the availability of scholarships/fellowships from donor agencies.

Table 2. Tanzania: Cost of energy from major staples.

Staple	Kcal/100g	Shs/1000Kcal[a]
Maize	362	4.70
Rice	354	9.89
Wheat flour	350	9.89
Sorghum	353	5.10
Millet	365	6.30
Cassava (dry)	342	3.51

Source: Jonsson 1986.
[a]TShs/1.0 = US$0.005.

Table 3. Tanzania: Percentage of total energy intake from the consumption of cassava by regions.

Region	% of energy intake from cassava
Mtwara	59.5
Kigoma	59.0
Mwanza	55.3
Lindi	40.9
Mara	35.7
Ruvuma	29.5
Morogoro	22.4
Shinyanga	19.4
Coast	16.0
Kagera	10.0
Tanga	9.3
Tabora	7.5
Rukwa	6.7
Mbeya	5.1
Arusha	4.1
Iringa	4.0
Singida	1.9
Kilimanjaro	1.8
Dodoma	1.4
Dar-es-Salaam	n.a.
Zanzibar (all regions)	n.a.

Source: Jonsson 1986.
n. a. = not available

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Cassava in Uganda[1]

G. W. Otim-Nape and J. U. A. Opio-Odongo[2]

Abstract

Cassava is the most important root crop in Uganda. It is grown in all districts but particularly in the Eastern and Northern Regions. Cassava processing and consumption vary across regions depending on the varieties grown, local customs, and tastes. Cassava roots are eaten raw or roasted. Boiled and mashed cassava are also popular. Cassava is also used to make flour, local alcohol, and industrial starch. Major production constraints include diseases such as cassava bacterial blight, pests, and poor agronomic practices.

Key words: production, consumption, processing, production constraints.

Production

Cassava is the most important root crop in Uganda. Among African countries, Uganda ranks fifth in both the quantity produced and the area of land under cassava. In 1983, over 3.2 million t of fresh cassava roots were produced (Fig. 1). Total production in 1986 was estimated to increase by 30%. There was a general increase both in area planted and quantity produced throughout the period 1971-83. There was a sharp decline between 1976 and 1978 which can be attributed to the acute shortage of agricultural inputs in the country, particularly hoes and animal-drawn implements. The problem was further worsened by the ill effects of war in 1979, which severely reduced productivity in the entire agricultural sector.

After the war, production of cassava dramatically increased from 848,000 t in 1979 to 3.2 million t by 1983, a four-fold increase; and from a yield of 3.8 t /ha in 1978 to 9.7 t in 1981. These improvements are the result of the government's present policy of reviving the entire agricultural sector through the provision of agricultural inputs and incentives. During the same period, Ugandan farmers shifted away from growing cash crops, such as cotton, which demand high labor input and yield low financial returns,when compared to food crops, such as cassava and maize.

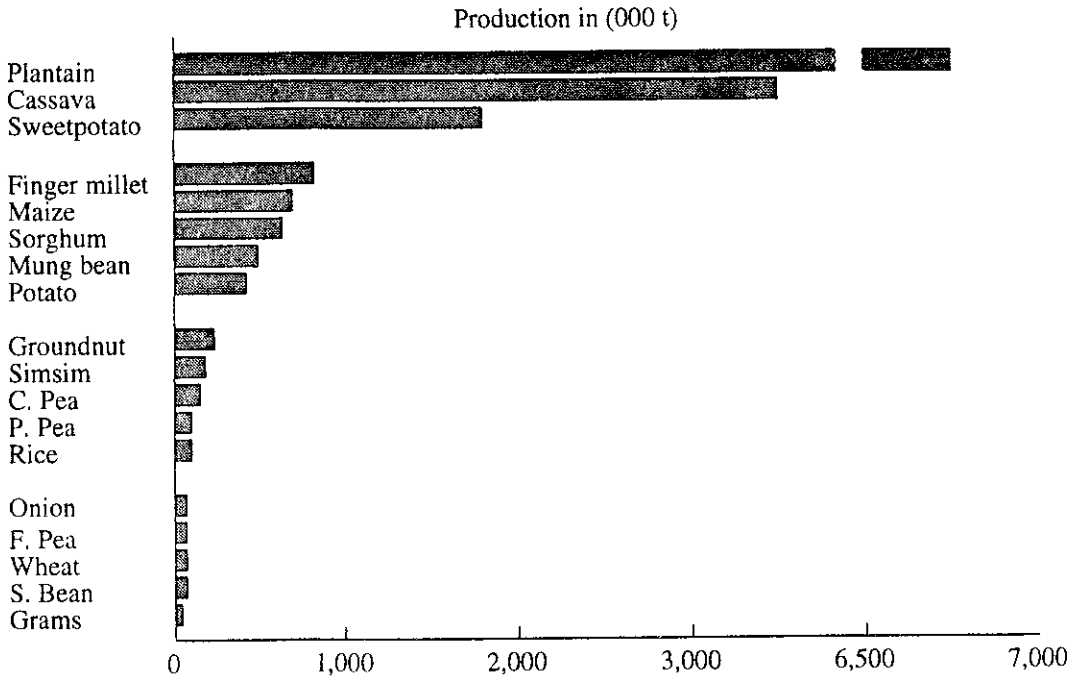
Cassava ranks second among major food crops in Uganda (Table 1). It is preceded only by bananas and closely followed by sweetpotato and finger millet. With its relatively low labor demand and high-yielding ability, cassava has more advantages than most other crops. At present it is grown in all the districts of Uganda particularly in the relatively drier Eastern and Northern Regions where it commands a major role as a staple food (Table 2). In the Central Region and some colder areas of the Western Region, cassava has been largely replaced by plantains, sweetpotatoes, or potatoes.

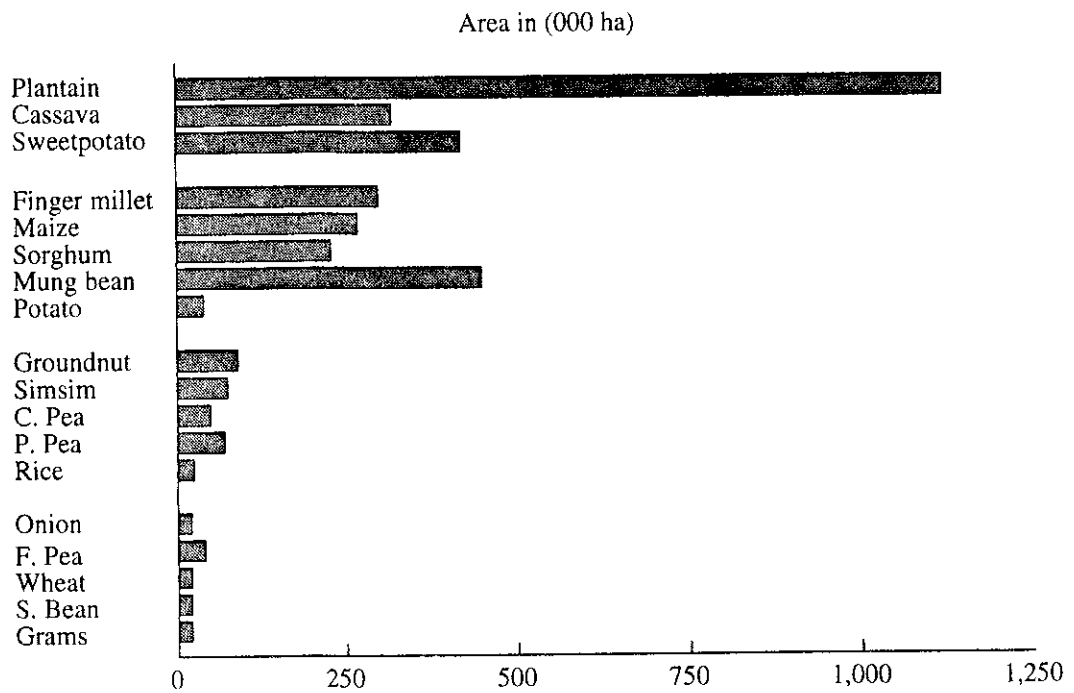
Cassava is mainly grown by smallholder farmers on plots varying from 0.1 ha in the Lake Victoria region to 0.9 ha in the Eastern, Northern, and Northwestern Regions. Stem cuttings, about 30 cm long, are planted horizontally in the ground at spacings of about 1 m x 1 m. About 30% of the total cassava is planted with the first rains, 50% of it is intercropped with various annual crops, such as groundnuts, beans, or maize, which are harvested after three to four months to leave pure stands of cassava. Commercial planting of cassava is rare,

[1] This paper is taken from Status of Data on Cassava in Major Producing Countries in Africa: Cameroon, Côte d'Ivoire, Ghana, Nigeria, Tanzania, Uganda and Zaire, Collaborative Study of Cassava in Africa (COSCA) Working Paper No. 3, edited by Felix I. Nweke, John Lynam, and Coffi Prudencio. It is reprinted here with permission of the editors.

[2] Namulonge Research Station, P.O. Box 7084, Kampala, and Professor, Makerere University, Uganda, respectively.

Figure 1. Uganda: Relative importance of cassava with respect to production and area cultivated of other crops, 1980-83.





Source: Otim-Nape 1987.

Table 1. Uganda: Relative importance (%) of major staple foods, 1965-66, and 1970-86.

Year	Cereals	Plantain	Cassava	Potato
1965-66	44	30	18	8
1970-71	31	37	22	10
1975-80	30	55	33	12
1980-81	28	32	30	10
1981-82	28	32	29	11
1982-83	28	31	28	13
1983-84	19	41	23	17
1984-85	27	35	26	12
1985-86	27	35	26	12

although the Lira Starch Factory has a large estate of cassava in the Northern Region. Because of the subsistence nature of cassava cultivation in Uganda, the use of fertilizers and herbicides are rare.

Cassava is generally ready for harvesting twelve months after planting. Where cassava is intended for sale, the whole field may be harvested at once; however, when intended for family use, it is harvested as needed.

Table 2. Uganda: Areas under cassava by region, 1981-83 average.

Region	Area (000 ha)	%
Northern	128.28	37.8
Eastern	89.79	26.5
Western	77.07	22.7
Southern (Central)	44.01	13.0

Utilization

In general, cassava is a main component of the food system and is eaten throughout the year (Table 3). Sweet (low cyanide) varieties are consumed raw, roasted, boiled, or dried and milled into flour. Food preferences among the people of Tororo and Soroti/Kumi districts of Uganda indicate that cassava is eaten in combination with other starches (Table 4).

Traditional processing methods were found to vary among regions, depending on the varieties grown, local customs, and tastes. Raw sweet cassava is eaten in Lira, Apach, and Iganga districts. In Iganga, raw cassava is only eaten during the harvest of other crops like groundnuts, millet, cotton, and sorghum, when farmers spend the whole day in the fields harvesting and no cooking is done. In Apach and Lira, raw cassava is eaten as a snack and thirst quencher.

Table 3. Uganda: Relative importance (%) of major staple foods by area, 1987.

Area	Grains	Plantain/Banana	Cassava	Potato
Lake Victoria crescent	30	60	5	5
Northern Bugania	20	60	15	5
Busoga/Bukedi	50	25	10	15
Bugisu/Sebei	40	40	5	15
Teso	70	-	25	5
Karamoja	45	-	55	-
Lango/Achol	50	-	45	5
W. Nile/Madi	45	-	50	5
Bunyoro/Toro	30	15	45	10
Ankole	40	50	5	5
Kigezi	60	15	5	20
National	39	33	20	8

Table 4. Uganda: Food preferences among farmers in the Eastern and Northern regions.

Food mixtures	Farmers sampled in districts %	
	Tororo	Soroti/Kumi
cassava + millet	50.0	32.5
cassava + sorghum	44.0	47.5
cassava + sweetpotato	0.0	20.0
cassava alone	6.0	0.0
Total	100.0	100.0

Source: Uganda National Root Crop Improvement Programme.

Sweet cassava roots are also roasted with or without the peel. Although some cyanide is present in unscraped roots, this is destroyed by heat. The moist soil on the surface of the root dries and falls away when it is exposed to the sun or fire for some time. The roots are then buried in hot ashes at temperatures of 100-150°C or are placed in hot cinders and turned continuously for 20 to 30 minutes. Roasted cassava is common among school children as a snack, especially among children in boarding schools.

Boiled and mashed cassava is a popular food in Uganda. The roots are peeled, scraped, and then washed in water. The peeled roots are cut up and split to remove the fibrous core. The roots are then put in cold water and boiled. When the roots are soft they may be mashed, or pounded and eaten with a sauce. In Iganga, the roots are boiled with spices and with other foods like groundnuts, *simsim*, and mutton. Cassava roots are also steamed between banana stalks and leaves, which impart a certain flavor to the roots which is popular in Iganga and Kampala.

Traditionally, the problem of storage has usually been overcome by leaving the roots in the ground until needed. If more cassava is harvested than needed, however, the excess is peeled and sliced into chips and allowed to dry for three or four days in the sun. The dried slices or chips are then stored in a cool dry place, usually in tins and granaries. When the chips are to be eaten, they are ground into flour called *moko mogo orunga*, which is used in preparing *kwon* or *ugali*. *Kwon* is prepared by adding cassava flour to boiling water until a thick firm paste is formed.

Cassava flour may also be mixed with millet or sorghum in a ratio of two parts cassava to one part millet, or three parts cassava to one part sorghum. The proportions tend to vary depending on the availability of either cereals or cassava, or on how soft the bread should be. When the cereals have been exhausted, the pure cassava flour is eaten. In Lira and Apach, mixtures of cassava and millet or cassava and sorghum are ground and the flour is used to make porridge. In Apach, the chips are allowed to ferment for three to four days until they get mouldy. The mould is scraped off and the chips are further dried in the sun. The fermentation imparts a flavor to the flour which the consumers find desirable. The cassava and grain flour mixtures are also processed into other edible products like bread, *chapatis*, and pancakes. The proportions are indeterminate and depend on the availability of the grain flour; sometimes pure cassava flour is used.

Local alcohol, *enguli*, *waragi*, or *kwete*, is distilled from dry cassava roots for drinking. Industrial starch is manufactured at the Lira Starch Factory, about 200 miles north of Kampala.

Cassava as a source of cash income for the farmer

According to a recent on-farm survey by the Uganda Root Crops Improvement Programme, out of the total cash earnings from farm produce, 80% and 60% are earned by farmers from the sale of cassava in Soroti/Kumi and Tororo districts respectively. Cassava is sold as fresh roots, dry chips, flour, or *waragi*.

Production constraints

Diseases. Bacterial diseases reported in Uganda include cassava bacterial blight (CBB), bacterial leaf spots and stem gall, possibly due to *Agrobacterium tumefaciens*. Among viral infections, only cassava mosaic virus disease (CMD) occurs in the country. Fungal diseases recorded are brown leaf spot, concentric ring leaf spot, anthracnose, vascular wilt, root rot, and white root rot. Cassava bacterial blight and cassava mosaic virus disease are the most serious diseases of cassava in the country. Cassava bacterial blight exhibits wide pathogenic variability in Uganda and detailed studies on the distribution, symptoms, methods of innoculation, epidemiology, and control of CBB in Uganda have been made. The planting of CBB-resistant varieties in experimental plots has demonstrated the most effective form of control.

Cassava mosaic virus disease belongs to the gemini virus group and occurs throughout the country where it causes serious economic loss. The disease is transmitted

by the white fly vector, *Bemisia tabaci*, generally under natural field conditions through infected planting material. Past research efforts in East Africa concentrated on developing CMD-resistant cassava varieties and releasing them to farmers. In the early 1950s, two CMD-resistant varieties known as *bukolasa* 8 and 11 were released to farmers to replace the common susceptible local varieties. This program proved very successful, but with the general breakdown of agricultural services in the 1970s as a result of political instability, farmers relaxed the mosaic control regulations. The result is that cassava mosaic virus has become the most serious cassava disease causing the greatest economy loss of cassava in the country today. Recent research at Mugaga, Kenya, and at Serere, Uganda, has indicated that CMD can be effectively controlled by the use of mosaic free planting material and roguing. When this practice is combined with the planting of resistant to moderately resistant varieties, the control can be most effective.

Pests. In Uganda, the cassava (green) mite comprises four tetranychid mites, *Mononychellus tanajoa* (Bondar), *Tetranychus telarius* L. (= *T. urticae Koch*), *T. cinnabarinus* (Boaisd), and *Oligonychus gossypii* (Zacher). Of these, only *M. tanajoa*, the green mite, is of economic significance in cassava. *M. tanajoa* is widespread and is considered to be the most destructive pest of cassava in Africa. It is most destructive during the dry season, when severe infestations cause heavy defoliation of the plants. Control measures currently being tested include releasing phytosid mites (natural enemy of the green mites) in infested areas, and by distributing the newly developed resistant variety, *Ebwanateraka.*

Poor agronomic practices. A recent on-farm survey carried out by the Uganda Root Crop Improvement Programme indicated that farmers' agronomic practices in the production of cassava are poor. Even simple measures such as timely planting and optimum spacing of cassava are lacking. The recent survey also showed that labor costs appear higher than the cost of using herbicides. A reduction in the number of hand weedings through timely use of herbicides could reduce weeding costs. There is a need to introduce herbicides, to advise farmers on optimal spacing, and to recommend better intercropping systems.

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Cassava in Zaïre

Brook A. Greene[1]

Abstract

Zaïre is the third largest producer of cassava in the world. Cassava is the most important source of food energy for a majority of the population and a major source of rural income. Declining soil fertility and demographic changes will encourage more intensive production methods. Government price and marketing liberalization policies are directed towards encouraging continued excess production of cassava in order to stabilize urban prices and encourage utilization in agro-industrial development.

Key words: rural income, food energy, excess supply, consumer prices, agro-industries.

Introduction

World production of cassava (or manioc: *Manihot esculenta* Crantz) was about 125 million tons in 1988 and was used in the following manner (figures in brackets refer to Africa):

- 60% (88%) used in human consumption, directly or processed
- 30% (2%) used for animal feeds, unprocessed or processed
- 10% (10%) wasted
- 25% (0.1%) exported
- 24% (0%) imported (Dorosh 1988).

The four largest producers in the world in order of importance are Brazil, Thailand, Zaïre, and Nigeria. Together they produce about 67% of total production (IITA 1988). Africa produces about a third of world production, or 45 million tons with the four largest producers being Zaïre (29%), Nigeria (23%), Tanzania (11%), and Mozambique (6%) (Dorosh 1988).

Average yields varied between 3 to 15 t/ha with a very modest, if any, increase over the period 1970/74 to 1980/84. New varieties released by International Institute for Tropical Agriculture (IITA) were only being used on a limited hectarage and mainly in Nigeria. Over this period, annual rates of growth in production were estimated by Dorosh, who warned that figures were only rough estimates, to have been on the order of 1.2%, 2.9%, and 3.4% for West, Central, and East/Southern Africa, respectively. Most of the increase during this period had taken place due to area expansion rather than increases in average yields. After 1984, IITA, especially its Resource and Crop Management Program, has been encouraging research and development of improved varieties throughout West and Central Africa in particular. One can expect national average yields to improve to some extent with the adoption of new varieties, but more through the adoption of other inputs such as chemical or organic fertilizers and improved cultural methods.

With regard to total available energy, cassava ranks fourth after rice, maize, and sugarcane as a source of energy, providing more energy (joules) per ha and per year than any other crop except sugar cane. In compari-

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son with other root crops, cassava ranked first in the world in 1984 followed by sweetpotatoes. In tropical Africa, cassava also ranked first, providing three times as much total energy as yams (Dorosh 1988). The International Food Policy Research Institute (IFPRI) estimated that one hectare of cassava produced on average 9 times the energy produced by one hectare of maize, 12 times that of rice and 7 times that of plantain. Cassava roots plus leaves provide three times the amount of protein in rice, 2 and 1/2 times that of maize, and 7 times that of plantain. Further, the mineral and vitamin content of cassava is higher than that of maize, rice, or plantain (Tshikala and Lumpungu 1989).

Cassava is the major food crop in Zaïre, where it is known as manioc. Staple foods ("*produits vivriers*") made up 36% of the total value of agricultural produce marketed during 1986 with the other most important agricultural products being coffee(17%), assorted wood products(7%), and oil palm products(5%). The agricultural sector as a whole contributed 11% to the total estimated Gross National Product in this year (*Marchés Tropicaux et Méditerranéens* 1988).

In summary, cassava is an important crop for Zaïre, Africa, and the world. It is particularly suitable for small farmers due to its ability to produce on marginal land, to withstand variable and unfavourable climates as well as resist insects and diseases, it's usefulness in providing food over a long period of time as well as providing a wide range of food by-products with high energy content (IITA 1989).

Production

In 1987, the *Service des Etudes et Planification (SEP)* of the Department of Agriculture interviewed 240 farm households in five out of the nine regions of Zaïre. The survey covered a band of the country from the region of Bas-Zaïre in the West through Bandundu, West and East Kasai, and Shaba in the East, called the "*Bande Sud*", and including some 40% of the total population. Results indicate that 98% of households surveyed produced cassava and 94% maize (*Département de L'-Agriculture* 1987). Cassava is cultivated by the majority of rural households in Zaïre. Marketable surpluses flow into urban centers from surrounding areas that have some form of available transportation, either roads, rail, or rivers. Major surpluses are marketed from Bas Zaïre and Bandundu regions into the largest urban center, the capital Kinshasa (Map 1).

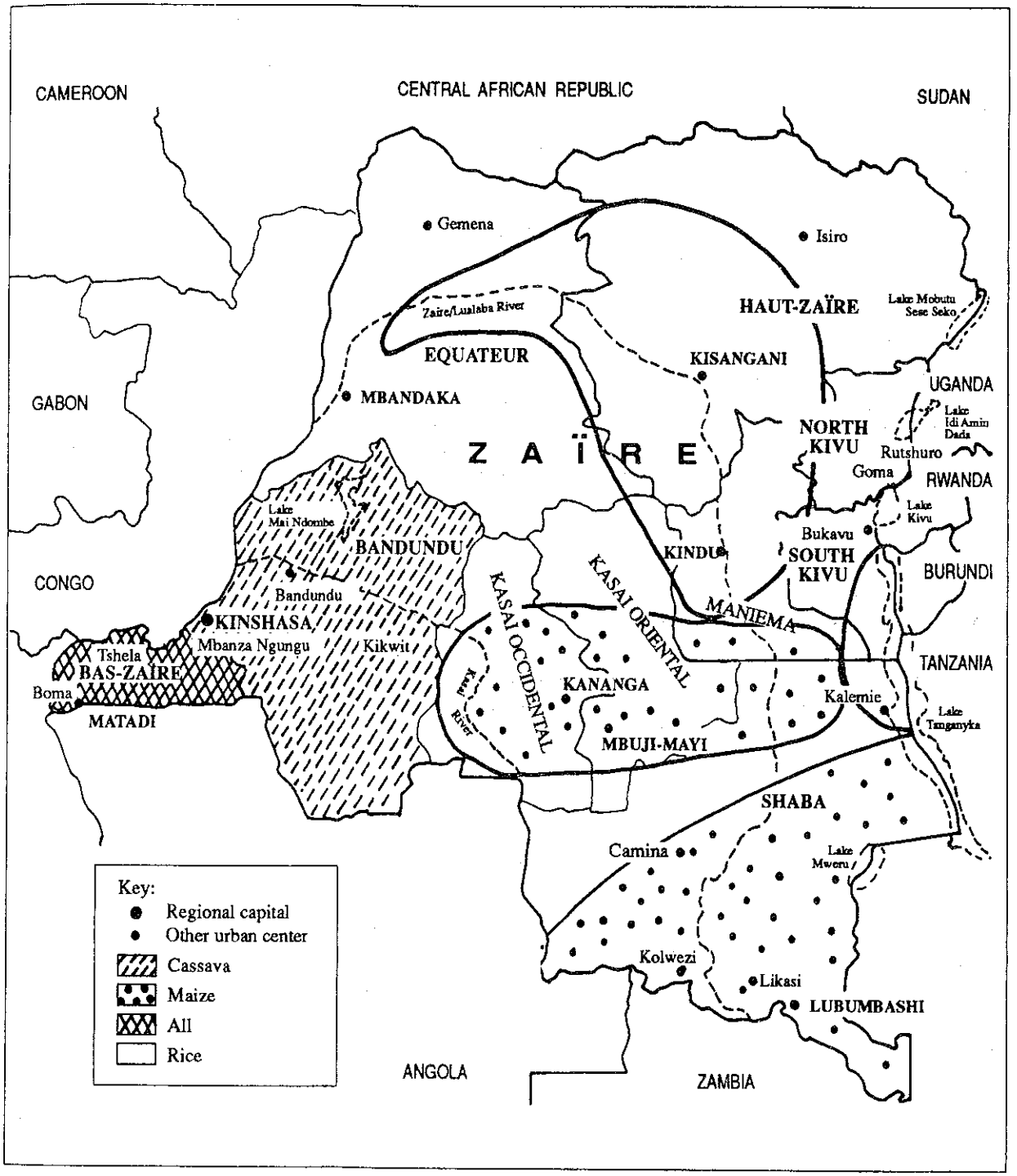
Total national cassava production was 10.3 million tons in 1971 according to data published by the Division of Agricultural Statistics in the Department of Agriculture, although production figures vary with the source and should be used only as rough indicators (*Département de L'Agriculture* 1986). The estimates were 12.6 million tons in 1979 and 17.4 million tons in 1989 (quoted in Shapiro and Tollens 1992). This gives an annual rate of growth in production of 3.2% for the period 1979/89, a figure very close to the estimated rate of annual growth in population (Table 1). Using this, the estimated figure would be roughly 19 million tons in 1992 and 24 million tons in the year 2000. This compares with the estimate by IFPRI of 22.4 million tons (Tshikala and Lumpungu 1989).

Cassava is by far the most important staple food produced in Zaïre. Total production was roughly 17 times that of maize and 35 times that of paddy in 1989. Out of nine regions, Bandundu ranked second in per capita production with Bas Zaïre 8th, these two regions together producing some 22% of the total for 1989 (Table 2).

A summary of FAO fertilizer trial data conducted between 1978/86 on 522 sites in 4 regions was prepared by the author (FAO 1985). The national average yield for local varieties under traditional farming methods was 8.6 t/ha (range: 3.8 in Shaba to 12.9 in Haut Zaïre). This differs from the national average usually quoted in official reports, that is 7 t/ha which resulted from the *Band Sud* survey (see Shapiro and Tollens 1992). With low rates of chemical fertilization, usually 50-50-50, the average was 13.2 t/ha (range: 5.3 in Shaba to 16.6 in Haut Zaïre) and for higher rates, 100-100-100, the average was 16.8 t/ha (range: 11.2 in West Kasai to 20.1 in Bas Zaïre)(Table 3). These data showed little difference in the level of response to chemical fertilizers between local and improved varieties, each responding to fertilization to a similar degree.

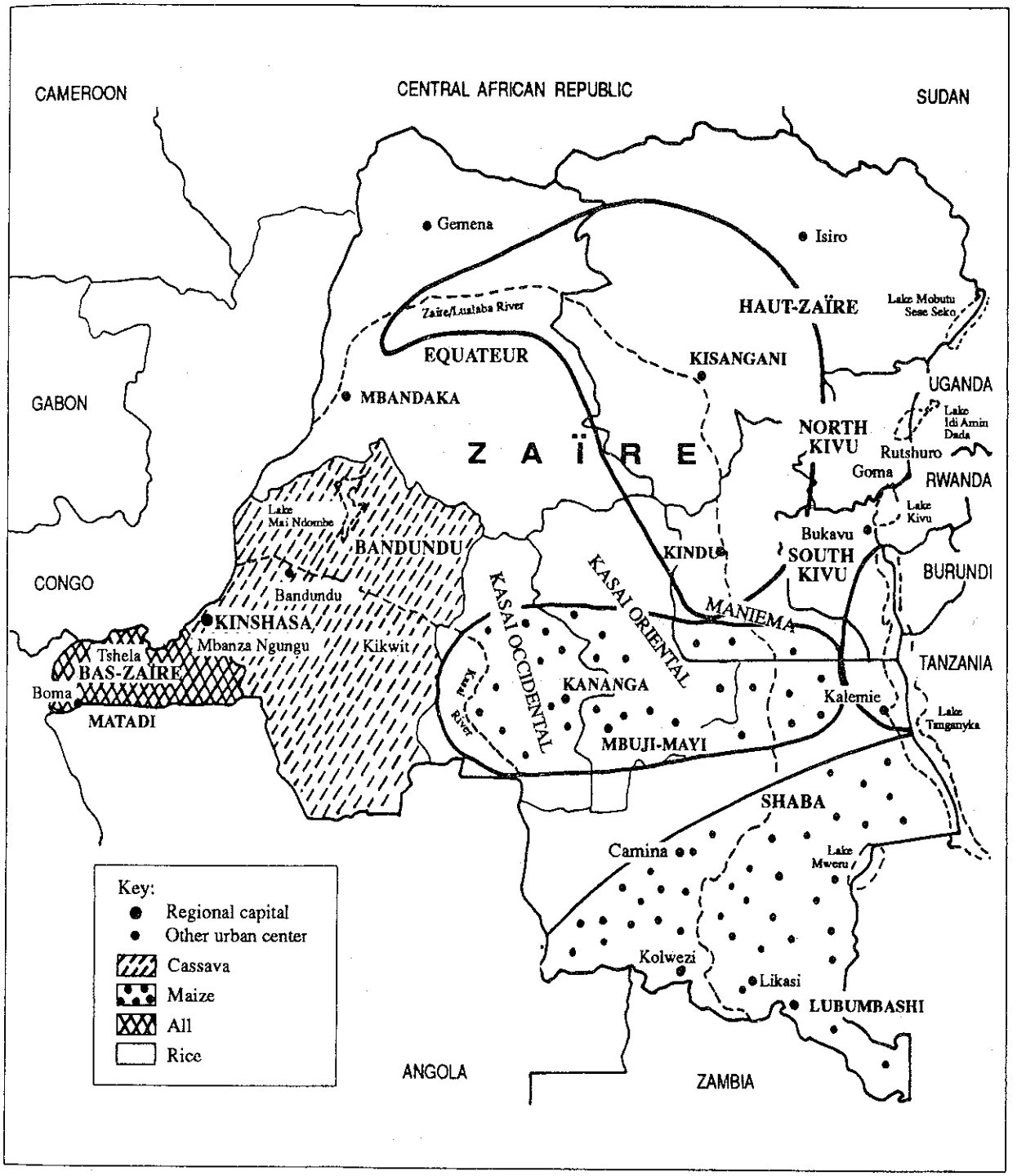
Research trials carried out by IITA in Bas Zaïre in 1988 gave an average yield from 7 sites of 6.4 t/ha for local varieties under traditional cultivation compared to 16.5 and 24.6 t/ha for low(150kg) and high (300kg) rates of fertilization with improved varieties (IITA 1988). The FAO results from 77 sites in Bas Zaïre with trials carried out in 1981/82 using the same improved varieties Kinuani and F100 gave average yields of 8.4, 13.7, and 17.5 t/ha, respectively(FAO 1985). The average for Bas Zaïre from 24 sites in 1985/86 was very similar (FAO unpublished and Table 3). The FAO results were rather lower than those of the IITA trials. This variability in yields is common given the large number of variables that can influence output.

Map 1. Administrative and major food crop areas of Zaïre.



Source: World Bank 1988.

Map 1. Administrative and major food crop areas of Zaïre.



Source: World Bank 1988.

Table 1. Cassava production in Zaïre, 1971-90.[a]

Year	Production (000t)	Index	Population (000)	Index	Per capita production (t)	Index
1971	10,330	100	19,990	100	0.520	100
1975	11,840	115	22,580	113	0.520	100
1978	11,780	114	24,674	123	0.477	92
1980	13,090	127	26,380	132	0.500	96
1981	13,170	127	28,046	140	0.470	90
1984	15,040	146	30,730[b]	154	0.489	94
1985	15,490	150	31,651	158	0.490	94
1990	17,960	174	36,692	184	0.490	94

Source: 1971-1978 (Département de L' Agriculture 1986); 1979-1989 (Shapiro and Tollens 1992); 1990 production figure calculated by the author using r=3.2%/year, 1979/89.

[a] *Figures rounded to nearest 10,000 (production and population) and 0.01 t per capita.*

[b] *The actual Institut National Statistique figure was 30,729,443 quoted in Shapiro and Tollens (1992). The population figures were calculated using a 3%/year growth rate backwards and forwards from the Census estimate for 1984 except for the 1975 and 1980 figures quoted in Shapiro and Tollens.*

Table 2. Per capita production of cassava by region in Zaïre, 1989.

Region	Production (000t)		Population (000)	Per capita (t)	Production (kg/yr)	Rank
Kinshasa	520	(3%)	3,099	0.168	168	9
Bas Zaïre	870	(5%)	2,316	0.376	376	8
Bandundu	2,958	(17%)	4,382	0.675	675	2
Equateur	1,740	(10%)	4,132	0.421	421	6
Haut Zaïre	1,914	(11%)	4,987	0.384	384	7
Kivu	2,958	(17%)	6,270	0.472	472	5
Shaba	2,264	(13%)	4,595	0.493	493	4
Kasai Occidental	2,262	(13%)	2,779	0.814	814	1
Kasai Oriental	1,914	(11%)	3,064	0.625	625	3
Total	17,400	(100%)	35,624	0.488	488	

Source: The final population from the 1984 Census (30,729,443) was taken from Shapiro and Tollens (1992), as was the 1989 regional distribution of total production. A 3% growth rate per year was then used to obtain the estimated population for 1989 as 35,623,847. This total population was then distributed by region using the same percentage distribution per region as Shapiro and Tollens for the 1984 population rounded to the nearest 1,000. Kivu today is seperated into three regions: North, South, and Maniema.

Table 3. Cassava yields of fresh roots (t/ha) in Zaïre.

Site/date	No. sites	Variety[b]	Fertilizer	Average yield[a]	Source
Bas Zaïre	7	Mpelolongi(L)	0	6.4[c]	
(1988)		Kinuani(I)	0	11.2[c]	
		F 100(I)	0	11.4[c]	
	18	I	150-300kg	16.5 - 24.6	IITA 1988
Bas Zaïre	270	L	0	10.3	
(1978/84)			40-40-0	15.9	
			60-60-0	20.1	FAO1985
(1981/82)	77	I	0	8.4	
			40-40-0	13.7	
			60-60-0	17.5	FAO 1985
(1985/86)	24	L	0	7.2 - 8.0	
			50-50-50	12.7 - 13.7	
			100-100-100	16.1 - 17.8	FAO unpub
Haut Zaïre	40	L	0	12.9	
(1981/83)			50-50-50	16.6	
			100-100-100	19.4	FAO 1985
Kasai Occidental	144	L	0	4.9	
(1981/83)			50-50-50	8.0	
			100-100-100	11.2	FAO 1985
Shaba	23	L	0	9.0	
(1978/80)			60-60-60	14.7	
			100-100-100	17.4	FAO 1985
(1985/86)	21	L	0	3.8	
			50-50-50	5.3	
			100-100-100	6.7	FAO unpub

[a] *averages calculated by the author.*
[b] *L= local variety and I = improved.*
[c] *Yields taken 18 months after planting, this data is unknown for all others.*

Results from two village level surveys on 25 households in Bandundu region carried out in 1988 were as follows:

- Bulungu zone, average yield 6.1 t/ha roots harvested 13 months after planting (MAP) (Greene 1989); and,
- Idiofa, a drier zone, average yield 2.4 t/ha of roots harvested at 16 MAP (Greene 1989a).

Estimated average household production of *cossettes* from a survey of 1,305 housholds throughout Bandundu region over the period 1988/89 carried out by the Department of Agriculture and the University of Louvain under the Marketing of Agricultural Products Project (MAPP) was 3.1 t or 8.2 t of roots from an unspecified hectarage (*Département de L'Agriculture* 1989a/1989c).[2] If we assume the average of 1.13 ha found in the *Band Sud* study for Bandundu (*Département de L'Agriculture* 1987), we obtain an average of 7.2 t/ha of roots, from this survey.

Benefit/cost ratios

IITA found benefit/cost (B/C) ratios less than one for fertilizer application either for leaf or root production in their studies in Bas Zaïre during 1988 (IITA 1988). The ratio from 21 sites scattered in Shaba region and conducted by the FAO fertilizer project during 1985/86 was 0.5 (FAO 1985) and this was with a fertilizer price subsidized at 55 Zaïres/kg or US$ 0.92/kg (US$=59.6

[2] Hereafter refered to in the text as the MAPP or the Marketing Project. This project covered 2 regions: Bandundu and Bas Zaïre and also looked at Kinshasa.

Zaïres).[3] Other FAO results during 1985/86 from 396 sites in Bas Zaïre using unspecified cassava varieties, but assumed to be improved varieties and local mixed, gave an average B/C ratio for low fertilizer rates of 6.4 and for high rates of 4.9 (averages calculated by the author using unpublished FAO data obtained from the FAO office in Kinshasa). In Bas Zaïre at that time, the farmer price for roots was 5 Z/kg or US$ 0.08/kg and fertilizer was provided by the project at 32 Z/kg or US$ 0.54/kg. The author estimated that the subsidy was around 60% (Greene 1989). With the unsubsidized cost, the B/C ratios would have been nearer 3.8 for low and 3.1 for high rates. It would appear that using fertilizer would have been attractive in Bas Zaïre, but not in Shaba region. For every kg of fertilizer applied at low rates in Bas Zaïre, the farmer would have produced 35-45 kg more than with no fertilizer and at high rates, 29-33 kg more of tubers.

Micro-level studies on 25 households in Bulungu (B) zone of Bandundu region gave a B/C ratio of 3.5 for production of *cossettes* under traditional methods and no fertilization while a similar study in Idiofa (I) zone, a drier area where product price was double that of Bulungu, was 5.2 (Greene 1989). Traditional cassava production appears to be profitable in most areas. When low rates (150 kg) of fertilizer were used, the B/C ratio became 0.6 (B) and 0.5 (I) with the subsidy and 0.4 and 0.3 with no subsidy, respectively, while at high rates of fertilization (300kg), the B/C ratios were 1.2 in B and 1.1 in I (Greene 1989).

It appears from these few micro studies that farmers would have had to apply the higher rates of fertilizer in order to cover the added input costs associated with the higher extra production. Unfortunately, fertilizer is generally unavailable in most rural areas.

Constraints

Research on cassava in Bas Zaïre during 1988 identified a large number of factors affecting varietal choice by farmers such as:

- soil type, e. g., *Mpelolongi* was suitable for heavy soils, *Kinesekele* on medium, and *Kidamu* on sandy soils; villages in the study area of the Cataractes sub-region had for example on average 6 different varieties of cassava including at least one sweet, one bitter, and one early maturing (IITA 1988);
- slope and location of the field;
- water and cyanide content of roots that affected quality of by-products;
- attractiveness of leaf coloration affected consumption;
- early flowering which affected leaf pickings for consumption through the year;
- degree of plant branching which influenced spacing and weeding;
- numbers of cuttings produced for planting;
- age of maturity, i. e., late maturing varieties stored better than early in the ground; and,
- degree of sweetness or bitterness which influenced the extent of damage from foraging animals and insects as well as the type of by-products processed.

The results of a survey of 100 households in 44 villages in Kwilu sub-region of Bandundu region during August/September 1988 showed that 45% practiced a 5-year fallow period, 17% less than 4 years, and 20% a 7-year period (Adelaki et al. 1989). This is the most important cassava producing area of Bandundu.

A study in Kalobo zone of Kasai East carried out by IITA in 1988, a humid savanna zone, reported fallow periods commonly of only 2 to 3 years. Declining soil fertility was seen with low plant vigour and poor leaf coloration. Other constraints in this area were infestations of weeds (*Imperata cylindrica*), cassava mealy bug causing wilting of young plants, irregular rainfall, and poor soils (IITA 1988). Even more serious problems were uneven land distribution as well as insufficient land. This was also reported in Bas Zaïre where large private and government corporations were said to have occupied the best lowlands forcing small holders to plant on hillier lands.

[3] The official exchange rates - Zaïres per US dollar (the parallel rates in brackets) were: 1982: 5.78 (12.00); 1983: 5.96 (24.00); 1984: 36.34 (35.85); 1985: 50.65 (46.20); 1986: 57.64 (60.00); 1987: 120.80 (142.50); 1988: 184.00 (230.00); 1989: 397.20 (410.00); 1990 (Dec): 2,000.00 (2,200.00); 1991 (July): 7,300.00 (15,000.00) (Shapiro and Tollens 1992).

Table 4. Food crop production (000 t) by region in Zaïre, 1989.

Region	Cassava	Rice/(paddy)	Maize	Peanuts	Beans/peas	Plantain	Banana	Pineapple
Kinshasa	520	3	17	9	7	36	4	6
Bas Zaïre	870	7	25	17	11	252	61	28
Bandundu	2,958	24	127	98	16	162	81	20
Equateur	1,740	58	119	51	12	486	77	13
Haut Zaïre	1,914	95	135	68	30	324	61	18
Kivu	2,958	95	118	55	52	396	81	18
Shaba	2,264	7	127	47	4	54	20	11
Kasai Occidental	2,262	24	93	43	24	36	12	14
Kasai Oriental	1,914	27	85	38	23	54	8	13
Total	17,400	341	846	425	179	1,800	404	142

Source: Shapiro and Tollens (1992) and Annuaire de Statistiques Agricoles 1986-1989 (1990). Unfortunately, the data have to be taken as very rough estimates only, since local production figures are increased by officials to match a 3% annual growth in population in many cases, at least this was the author's personal experience for official figures in Bandundu region.

Table 5. Composition of the average diet, Kinshasa, Zaïre, 1986.

Item	kg/person/month	%
Starchy foods	5.10	30.0
Cereal based	2.99	17.7
Vegetables	2.41	14.2
Alcoholic drinks	1.54	9.0
Fish	1.06	6.3
Oils	0.85	5.0
Meats	0.82	4.8
Grain legumes	0.51	3.0
Sugar	0.44	2.6
Spices	0.34	2.0
Soft drinks	0.34	2.0
Fruit	0.26	1.5
Milk	0.24	1.4
Nuts	0.04	0.2
Total	16.93	100

Source: Shapiro and Tollens 1992.

Serious problems affecting agricultural production including cassava have been listed in many studies on Zaïre and these are well known (see e.g., Thomas and Reintsma 1989; World Bank 1988). Some of these include the following:

- unavailability of small tools, chemical fertiliers, and insecticides;
- unavailability and shortage of formal credit for farmers or traders in rural areas, e.g., less than 3% of rural households surveyed in a study conducted by the Department of Agriculture and Ohio State University in Bandundu in 1990 had received institutional credit (Ohio State University 1990); substantial sums of money were however collected by informal associations of households and the informal loan sector was flourishing;
- degradation of the road network;
- underutilization of the river network;
- rail services essentially limited to one line from Matadi Port in Bas Zaïre to Kinshasa;
- low and declining purchasing power among rural households (*Département de L'Agriculture* 1986); the

MAPP estimated an average annual net income of US$ 142 for Bandundu rural households with figures for the most productive sub-region of Kwilu showing 55% of households earning between $30 and $185 (*Département de L'Agriculture* 1989);

- poor supply of consumer items in rural areas;
- lack of transportation in rural areas including trucks, bicycles, push carts or animal power; also inadequate and expensive diesel supplies, hazardous situation with spare parts; one study estimated that 70% of the trucks on the roads in 1984 were used in and around Kinshasa and that 60% of these were over 5 years old (Smits Eng Africa and STABO 1987);
- low government investment in the agricultural sector reported as 0.4 to 1.3% of the overall recurrent budget of the government of Zaïre in 1990 (Shapiro and Tollens 1992);
- complex taxation of agricultural produce;
- inconsistent government policies such as over valued exchange rates, protective tariffs, price liberalization policies and excessive taxation, small versus large farms (Block et al. 1987);
- high rural to urban migration. In 1930 about 96% of the population was classified as rural compared to 60% in the 1984 census (Shapiro and Tollens 1992). The urban growth rate has been estimated at 5%/year with about 28% of the population concentrated in the capital Kinshasa, i.e., 10.3 million (UNDP 1991); and,
- environmental constraints. A study of 120 farm households in 8 villages in 4 regions in 1986 linked declining yields, high dependency ratios due to out-migration and highly variable fallow periods with the need to encourage a shift toward more commercial mixed with fallow farming systems, oxen ploughing to replace lost manpower and more fertilizer inputs to halt the decline in soil fertility and yields (World Bank 1986). Shapiro and Tollens (1992) put these problems into perspective by stating that the cost of opening new areas for production will include the destruction of forest and the degradation of soil resources. The high population growth rate (around 3%) and high urban growth rates emphasize the need to encourage agricultural production to become more productive per unit of land and labor.

Potential production

Assuming an average yield for cassava of 8.6 t/ha and estimated production of 19 million tons in 1992, estimated total hectarage would be around 2.2 million ha. In spite of all the difficulties of using one average to represent production in Zaïre, a country more than 5 times the size of France and one with a broad range of ecosystems, one can use the modest yield increase suggested by the World Bank of 12 t/ha (World Bank 1988) with this hectarage to realise a potential production of 26 million tons for 1992, that is a 37% increase. Or, one can use the higher figure of 15 t/ha to give a 74% increase over the 1992 figure to produce 33 million tons.

If we assume an increase in the national average yield of 0.5%/year as suggested by Dorosh (1988), it could take 7 years to go from 8.6 to 12 t/ha and 13 years to reach 15 t/ha. This is an arithmetic calculation based on the original assumption. Given the very real and widespread problems existing in rural Zaïre as well as the recent disruptions to trade and presumably every other facet of national life, one would probably be safe in assuming that any increase in national average yields will be minimal, if any. However we would expect some increase in total production to meet increasing population demand. This would be the production figure previously mentioned of around 24 million tons by 2000.

A closer analysis needs to done regarding the expected degree of diffusion of chemical fertilizers into areas producing a surplus of cassava, i.e., to small holders. Current use of fertilizers is confined primarily to commercial corporations producing export crops and to government projects. One study by a private contracting firm estimated that in 1985 about 76% of all fertilizers imported into Zaïre had been used by commercial agro-industries (Smits Eng Africa and STABO 1987). In 1985, the *Programme National Engrais* (PNE) had imported 6,000 t (24%) and private agro-industries 19,400 t (76%). This means that the PNE, presumably in charge of all imported fertilizers, used their share on such projects as the FAO fertilizer project and other government projects like *Project National Riz, Mas et Manioc* (PNE 1987). *Gécamines-Développement*, a large government corporation in Shaba, used about 40% of all imported fertilizers on maize production; another large consumer was the national railway (SNCF) maize project, both in Shaba region (Shapiro and Tollens 1992). Assuming 5% of rural households to be involved in one or the other government project (called *encadre*), another 5% to be classified as small and medium enterprises (PMEA) with access to government subsidized inputs, the remaining 90% of rural farmers have no

access to fertilizers. Since cassava is grown by small farmers and not by commercial large farmers, where and how will any increase in cassava production take place?

In fact, it will be small farmers who expand the area of cassava production where possible to meet a growing demand. As mentioned by several authors, the combination of declining soil fertility due to shorter fallow periods and high population growth rates on the one hand, and high rural urban migration on the other hand, will combine to encourage a shift toward more commercial input use among growers (World Bank 1989), assuming of course that the necessary inputs become available in the villages and that the crop-to-fertilizer price ratio encourages adoption. Perhaps the most important of these is fertilizer and there are problems of availability. A very thorough discussion of these problems was presented by Williams and Schultz (1990) where they suggest an initial policy of importation of fertilizer requirements. The structural adjustment program of the government supported by the World Bank is aimed at just this problem. Other requirements are well known and understood, such as improved marketing facilities including the transport system, credit, relevant research, and improved extension services (TVA 1975). Some activity is taking place in each of these areas but generally of a very limited nature. Farmers were responding to higher maize prices in the Kongolo rural road project area of North Shaba and to rice market liberalization policies around Kisangani town in Haut Zaïre. Traders were generally facing severe fuel and credit problems (Thomas and Reintsma 1989).

Consumption

In a preliminary assessment of food needs for Zaïre carried out by the United States Agency for International Development (USAID) in 1990, the only major food crop for which there was no deficit was cassava (USAID 1990). In any case, the average national daily calorie consumption for Zaïre is 2,163 which is about the same as that of other Sub-Saharan countries (Shapiro and Tollens 1992). The National Nutrition Planning Center reported that cassava provided 71% of the theoretical requirement of calories and only 18% of the proteins. When mixed with maize and peanuts, as in Zaïre, these figures went up to 83% and 42%, respectively (*Département de L'Agriculture* 1989c). A serious problem therefore exists with proteins. Foods that are common in the national diet are common to Africa (Tables 4 and 5). Strong indications of malnutrition were found in one survey carried out by the USAID with the School of Public Health in Bandundu region as seen by high prevalence of low birth weights and severe levels of malnutrition among children registered in preschool clinics (Zaïre School of Public Health 1989). In a study comparing two different areas in a humid ecosystem in Nigeria, Nweke et al. (1988) suggested that children in those areas where 70% of the daily diet consisted of cassava were more likely to suffer from severe malnutrition, particularly in the dry season when there was a shortage of vegetables and other foods, than in those areas where the staple was yam. A similar situation would appear to be the norm in Zaïre.

Fresh roots from sweet varieties can be eaten raw or boiled while roots from bitter varieties are fermented for a few days and then processed into a variety of forms including *pat*, a wet paste, a heavy solid paste called *chikwangue*, or solar-dried to produce *cossettes* or hard chunks. The latter form, easily stored and marketed, can then be ground into flour to make a porridge called *foufou*. The protein content of *chikwangue* is four times that of the fresh tubers and twice that of the flour while its lipid content is five times that of the tuber and double that of the flour. In the MAPP in Bandundu region, 67% of households cultivated sweet cassava mainly for home consumption but production was only 5% of the amount of bitter varieties produced mainly to make *cossettes* (*Département de L'Agriculture* 1989c).

Regional and Urban

The relative importance of cassava in relation to other foods can be seen by looking at estimates of production per region. The importance of other foods varies by local climatic conditions, by region (Table 4) and by season but in general terms, the most commonly available other foods consumed with cassava would be rice, maize, groundnuts, beans and peas, plantain and other bananas, yam, pumpkins and gourds, and a variety of local fruits such as avocado, *pomme rouge*, citrus, pineapple, mango, coconut, and oil palm products. Meat and fish consumption vary by location.

Estimates of annual consumption of cassava *cossetes* per person varied from a low of 32 kg in Shaba, a major maize growing area, to 120 kg in Bandundu region (Table 6). Estimates for urban centers varied from a low of 24 kg in Lubumbashi, Shaba, to 144 kg in Bandundu town and 152 kg in Bukavu, Kivu (ZTE/Cogepar 1987). The Department of Agriculture has carried out a survey of consumption as part of a broad survey for each region based on consumption estimates for seven days (for example, see *Département de L'Agriculture* 1987). Unfortunately, these results were not available to the author.

Ethnic group

A detailed study was made by Houyoux in 1986 and quoted in one of the reports of the MAPP as follows: group 1 (non-European foreigners) 5.6 kg/month; group 2 (Bakongo mainly Bas Zaïre) 4.4; group 3 (Bandundu and lower Kasai) 6, group 4 (Equateur) 4.3; and group 5 (E. Zaïre and Shaba) 3.4 kg/month (*Département de L'Agriculture* 1989). This apparently refers to the amount of cassava flour per person per month for residents of Kinshasa. The actual percentage distribution of these different consumer groups was made in 1975 when the population of Kinshasa was around 1.5 million but has not been made since then. The average consumption of *cossettes* was estimated by the MAPP in Bandundu as 222 kg of tubers/person/year which was equivalent to 60 kg of flour per year or about 5 kg of flour per month (1 kg fresh roots = 0.27 kg flour; *Département de L'Agriculture* 1989a). These figures were based on estimates of annual production. No mention was made of using cassava to make local beer which could explain some of the difference. One would expect rural consumption to be greater than urban.

Revenue

As expected, the income elasticity of demand for cassava (feculants) was very low and estimated to be around 0.10 by Houyoux in 1986 (quoted in *Département de L'Agriculture* 1989). Estimates of consumption by income group in Kinshasa were available only for 1970 and reported as: 66-100 kg/person/year for low incomes, 114-130 for medium, and 136-91 for high income groups. Negative income elasticities of demand appeared with higher incomes. The actual range of incomes was not reported and the figures presumably refer to flour consumption (*Département de L'Agriculture* 1986).

Trends

An excellent discussion of factors influencing cassava consumption in general is found in Dorosh (1988). Population growth is naturally important but also the level of urbanization in turn affecting the form of cassava demanded in terms of ease of storage and processing. Some shifting of consumer habits occurs as incomes rise in urban areas, as we have seen with the low to negative income elasticity of demand. However, the majority of the urban population in Zaïre, i.e., low income groups, continue and will continue to depend on cassava products as their staple food as long as supplies can be transported into urban areas. The response of consumers to a rise in price of cassava products, the price elasticity of demand, is minimal due to this fact. The relative price of other available staple foods such as maize, rice, and bread also affect urban cassava consumption to some extent depending on the income and ethnic composition of the group and hence their consumption habits. New technology using gums to replace wheat gluten allows the production of a good cassava flour bread (New Scientist 1988). A lot of work

Table 6. Regional and urban consumption (kg/year) of cassava *cossettes* in Zaïre, 1986/87.

Region	Per capita	City	Per capita
Kinshasa	81	Kinshasa	60
Bas Zaïre	64	Matadi	55
Bandundu	120	Bandundu	144
		Kikwit	124
Equateur	113	Mbandaka	112
Kasai Occidental	56		
Haut Zaïre	64	Kananga	125
Kivu	48	Kisangani	116
Shaba	32	Bukavu	152
		Lubumbashi	24
		Kolwezi	34

Source: Regional estimates (Département de L'Agriculture 1986), November; urban estimates (ZTE/Cogepar 1987; figures for all feculants including cassava).

has also been done on using cassava flour in bread by IITA. This should encourage greater use of cassava flour in local bread production, for example. On the other hand, energy supplied by cereal imports was estimated to provide only 8% of the energy supplied by local cassava in Zaïre in 1979/81 (Dorosh 1988). This level can vary whenever there is a change in the ease with which marketing into Kinshasa takes place.

Tshikala and Lumpungu (1989) estimated a slow decline in cassava tuber (meaning actually the processed flour) and leaf consumption of 0.2 to 0.4% per year over the period 1971 to 1984 based on national production statistics. Using these trends, a supply and demand balance was estimated to give a surplus of 124,000 t cereal equivalent in the year 2000. This in turn would increase the possibility of shifting consumption to other by-products and industrial raw materials, such as an ingredient in animal feeds, or to produce fructose syrup or sugar to save on direct foreign exchange costs of imported refined sugar and to make industrial starch which can be done at the village level (Dorosh 1988). The study by Houyoux quoted in the MAPP estimated a decline in cassava consumption (fresh roots and *chikwangue*, not *cossettes*) from 67% of the staple food diet for Kinshasa residents in 1969 to 58% in 1986 or a decline of about 5% per year over the period 1975 to 1986. This decline was matched by an increase in the importance of other foods in the urban diet such as from 7% to 13% for rice (which requires no milling by the household), 3% to 4% for maize, 15% to 20% for bread, and 3% to 5% for plantain (*Département de L'Agriculture* 1989). The deficit in national production of rice and maize is particularly noticeable in urban areas where an over-valued exchange rate and an import policy has been used to try to fill this gap. The estimated value of imported food items was US$ 1,350 million in 1987 with meats, fish, and sugar making up 90% of the total, and wheat grain and flour 6% (Greene 1989).

If the transport network were to be improved, one would expect the potential marketed surplus of cassava *cossettes* to increase thereby encouraging a shift to local processing as previously mentioned. The increase in surplus would also depend on availability of inputs at the farm and village level and the extent of household motivation and adoption of these inputs.

Marketing

As we have already seen, there are many forms of cassava used for consumption. The fresh roots spoil within days and are therefore usually consumed locally. The roots are generally partially fermented by soaking in water over a number of days and then used to make a number of by-products such as wet paste, dry firm *chikwangue*, and for storage and marketing solar-dried roots or *cossettes*. The latter can then be ground into flour which is used to make a sticky porridge called *foufou*. *Chikwangue* can be saved for about a week while the *cossettes* last over many months.

Cossettes are transported or stored in sacks weighing around 75 kg, depending on the area. Traders generally bring sacks into a village and these are filled by selected families. Households transport roots into the village from fields by hand power since there are no other means of transport available for the majority of households. Bicycles are not common due to their high cost. In some cases, households will use a bicycle to support a sack which they then push into town from nearby fields. Most carry loads on their back using a head strap as in Nepal. Sacks are also filled and sold by the road or river side. Marketing in bulk therefore depends on available transport and a marketing system that includes a road or river or rail network.

Percentage marketed

The quantity marketed will depend to a great extent on location with regard to the transport network and the quality of transport. Thus, the majority of *cossettes* marketed in Kinshasa are collected from villages in the surrounding areas of Bas Zaïre (a rail line and one macadamed road into Kinshasa) and Bandundu (one main all weather but very rough road from Kikwit into Kinshasa). One study in 1984 surveyed the volume of foods flowing into Kinshasa from 13 major producing zones in Bas Zaïre and 19 in Bandundu, plus on the rivers (two major rivers). Excluding imported foods (386,584 t), tonnage by road was double that of the river (251,530 t compared to 121,042), and over three times that by train from Bas Zaïre (74,954 t). Cassava tonnage made up 32% of the total in 1984. There had been a decrease of 13% in the tonnage of cassava brought in from Bas Zaïre and an increase of 103% in that brought in from Bandundu over the period 1974 to 1984 due to the extension of the asphalted road from Kenge to Kikwit, about 200-400 km (Flouriot 1986). This study reports the estimated volumes of major food crops shipped from each zone and each port. The striking fact is how much more produce was transported by a very limited road system as compared to that by the very large river network.

Very detailed studies on the marketing of agricultural products into Kinshasa from surrounding regions

have been made. One such study included detailed maps and exhaustive analyses and descriptions of population, administration, economic factors, production, infrastructure, farming operations, marketing circuits, and prices at all levels from 1959 to 1980, price and other agricultural policies (*Département de L'Agriculture* 1982). This study remarked that the main factor that had prevented a famine taking place in Kinshasa, due to the very rapid increase in urban population (a growth in population of 70% between 1974 and 1984 was reported), had been the uncontrolled operation of small retail traders all linked by family, clan, and ethnic group which had led to margins between wholesalers, semi-wholesalers, and retailers. This added value generates income for each individual involved even if a small amount.

The most detailed study on the production and marketing of cassava was carried out under the MAPP by the Department of Agriculture and the University of Louvain between October 1987 and September 1988 with a sample of 1,305 households in Bandundu region. Some of the average results were:

- 51% of production was consumed (about 2 million tons);
- 46% of production was marketed (1.842 million tons);
- 7% of production was wasted (0.273 million tons); and,
- 4% of production was bought (0.169 million tons) (*Département de L'Agriculture* 1989c).

This same study reported that:

- 99.5% of households cultivated cassava;
- 92% of households marketed some cassava;
- 65% of households sold to traders coming from Kinshasa;
- 83% of the total value of cassava sold was from *cossettes*;
- 8% of households bought some cassava;
- on average households made a sale once every week over the whole year regardless of the season;
- 92% of households sold their cassava within a month of lifting it from the field; and,
- 25% of households sold 50% of total sales.

In sum, households used the sale of cassava, primarily as *cossettes*, to stabilize their income over the year. Most storage was done by leaving the crop in the ground. Sales actually went up during the rainy season, in spite of drying problems and subsequent higher losses, mainly due to higher farmgate prices. For this sample as a whole, the majority of production was sold as *cossettes* (88% average, with 97% in Kwilu and 93% in Kwango sub-regions, both favourably situated to dirt roads and having a good climate); some as wet paste (5% average with 23% in Mai-Ndombe sub-region, an area seperated from the road network by a river); *chikwangue* (4% average and 14% in Mai-Ndombe); and, fresh roots (1%) or as flour (1%). About 46% of production was marketed and very little stored by the household.

In a report produced in 1981, it was estimated that only 6.5% of total cassava produced in Zaïre was actually marketed (*Département de L'Agriculture* 1986, *janvier*). Another study estimated 7.7% (*Département de L'Agriculture* 1988, *avril*). This was low when compared to estimates of 29% of total maize production marketed and 30% of total rice production.

Income

In the MAPP in Bandundu, annual income from the sale of three main food crops was estimated. Sale of cassava earned 71% of this total compared to 15% for peanuts, and 14% for maize. A large number of households surveyed (41%) earned less than 10,000 Zaïres/year (US$ 50) from the sale of cassava, 45% earned between US$ 50 and 152, and only 15% earned more than 30,000 Zaïres/year (US$ 152; US$ 1 = 197 Zaïres, average figure for 1988; World Bank 1988).

Margins

The MAPP in Bandundu estimated a margin of 44% for the wholesaler in Kinshasa and a further 31% margin for retailers (price to farmer was 13 Z/kg, wholesale price was 35.1 Z/kg and the retail price was 51 Z/kg on average during 1988). Thus the farmers were getting about 25% of the final sale price of cassava *cossettes* (*Département de L'Agriculture* 1989b).

Data collected by the Division of Prices (DMPCC) in the Department of Agriculture based on the averages

from 9 markets in the Kinshasa urban area estimated a margin of 90% for wholesalers over the farm level price in Bas Zaïre and 50% for that in Bandundu for the fourth quarter of 1988. The mark up was then about 55% between this quarter and the first quarter of 1989. In the case of cassava, the wholesaler sells by the truck load and a semi-wholesaler or *demi-grossiste* usually sells by the sack. The percentage increase in the current retail price between the last quarter of 1988 and the first quarter of 1989 was estimated at 48% (DMPCC 1989). Prices were keeping pace with currency devaluation and inflation.

A detailed micro study was carried out by the author using data collected from traders in Bulungu town in July 1989. The price off the back of the truck in a market in Kinshasa was estimated to have been 68% above the price paid to the farmer in Bulungu town (Table 7 and Greene 1990). This compared to an estimate of 10-16% for peanuts. Fuel and operating costs were estimated to be 25% of total marketing costs as compared to official and unofficial taxes of 5%. In spite of 9 check points on the roads between Bulungu town and Kinshasa, this petty thieving would not have been enough to impede traders. However, any change in the cost for fuels, oils, and spare parts would have a serious impact on trading.

Market integration

A detailed study on the variation in current retail prices between major markets in Kinshasa has been carried out by the Department of Agriculture but the results are not available to the author. However, one aspect of the problem has been shown above in the quite large increases in price between the wholesaler (or semi-wholesaler) and the retailers. Those consumers without transport are forced to pay higher prices for a sack of *cossettes* than those with transport. The positive aspect of this value added is that it allows a large number of individuals to earn income in the process. The negative aspect is the higher price some consumers have to pay.

A detailed study of one Kinshasa market showed that for some products, the chain from village to market was controlled by certain ethnic groups. This led to some monopoly power for wholesalers but not for retailers who were too numerous (*Département de L'Agriculture* 1989d). While the market may seem to be operating in anarchic conditions, in fact it was very organized with specialization taking place with regard to gender (women more involved in marketing staple foods including cassava), tribe (marketing products from their region), age, quantities handled (small amounts leading to easy entry), methods of finance (based on traditional methods). This market was typical of most markets in Kinshasa and, except for some problems with regard to inter-market information and infrastructure (shelter, water), was characterized by high levels of competition among sellers and buyers, the absence of barriers to entry or exit, and the large numbers of retailers.

The Bandundu Market Project reported a much higher correlation between market prices for cassava than for peanuts or for maize and as expected, this was more significant along the better roads and the rivers due to ease of access (*Département de L'Agriculture* 1989b). There was a significant variation in the level of margins due to seasonal variations in the level of spoilage or damage and due to the rainy season.

Producer prices

Real prices to producers on the average varied between a high of 11 Z/kg for *cossettes* in January to a low of 8.5 Z/kg in August or a total variation of 23% over the year studied, September 1987 to October 1988 (*Département de L'Agriculture* 1989b). As already mentioned, the farmer received on average 25% of the final wholesale price in the Kinshasa market. This compared to 32% for maize and 37% for peanuts.

A weighted average price to the producer was 13 Z/kg in Bandundu varying up to 25% between sub-regions. The urban prices in the same sub-regions were 130% higher for Bandundu town and 90% for Kikwit town showing the deficit supply and resulting high demand and prices in these towns. The retail market price in Kinshasa was reported to be 51 Z/kg at this period that was 65% higher than in Bandundu town (about 400 km from Kinshasa) and 105% higher than in Kikwit town (700 km from Kinshasa).

The real price of cassava *cossettes* to the producer was reported to be around 3.5 Z/kg up to 1982 (or 0.60$/kg in 1982 when 5.78 Z = US$ 1) when a movement towards price and market liberalization was made, and around 6 to 10 Z/kg between 1983 and 1986 (or 0.20$/kg in 1986 when 57.6 Z = US$ 1) (Shapiro and Tollens 1992). This higher relative price (and lower real price) presumably demonstrated the benefits of the liberalization policies. Higher local current prices for maize and rice were also reported in other local areas (Thomas and Reintsma 1989).

Some further aspects of marketing in the Bandundu region were:

Table 7. Profitability of marketing cassava from Bulungu Zone to Kinshasa, July 1989.

Product/item	Quantity	Unit cost/revenue	Cost/revenue per week (000 Z)
A.- **Costs**			
cossettes	150 sacks	2,000 Z/s	300
sack	150	100Z/s	15
collection charges	150 sacks		5
truck	700 liter of fuel	200Z/lit	140
	1 liter of oil	1,000Z/lit	1
	2 drivers	10,000/month	5
	2 helpers	10,000/month	5
	"other"[a]	4,000 X 6	24
	insurance	300,000/year	6
	unofficial taxes		5
	market tax	50 Z/sack	8
	parking tax	1 full sack	6
losses	1-5 sacks	2 sacks	12
sub-total			530
Cost of credit	1%/week		5
Total costs			535
B.- **Returns**			
Sale in Kinshasa	148 sacks	6,000/sack[b]	890
C.- **Profit**			
	Returns less costs		355
	as % of total costs		66%
	Benefit/cost		1.66 : 1

Source: Estimated from information collected in Bulungu town by the author (Greene 1990).
[a] *Other helpers.*
[b] *The average price for the first quarter 1989 semi-wholesale in Kinshasa was 79Z/kg; 79 X 75 kg/sack=6,000 Z/sack.*

- 66% of income earned from cassava sales was earned by women;
- 4% of sales were transported on bicycles;
- 60% of income earned took place less than 10 minutes from the house;
- 12% of sales took place outside the village; and,
- 4% of sales took place along the road (*Département de L'Agriculture* 1989e).

Consumer prices in Kinshasa

The Bandundu Market study No. 12 used a series of average monthly unweighted figures collected by the Institute for Economic and Social Research of the University of Kinshasa by sampling markets 4 times a week. The average of these monthly figures was then calculated and used as the average annual price over the period 1961-88. The accuracy of this data is open to question. However, the trend showed an increase of 4% per year between 1961 and 1970, a decrease of 0.25% per year between 1970 and 1980, and a decrease of 1.7% per year between 1980 and 1988 (*Département de L'Agriculture* 1989). These results were for cassava *cossettes*. The index of real prices for cassava in Kinshasa using 1980=100 was 87 in 1988 compared to 77 for maize and 71 for peanuts (Shapiro and Tollens 1992). The declining consumer prices presumably demonstrated the benefits of the liberalization policies.

A more detailed study was carried out by the MAPP using these monthly prices. The results for cassava *cossettes* showed a fairly regular price cycle lasting from 3 to 5 years with a diminishing amount of variation between the high and low prices in the Bandundu market study after 1981. Higher prices occur in December and January and are related to the rainy season which

comes in October and results in more labor being used for other crops and less with producing *cossettes*. The lower prices are in July and August, and reflect the availability of more labor time and greater supply on the markets (*Département de L'Agriculture* 1989f).

Trends

Market liberalization policies were introduced by the Government in 1982. The intention was to encourage greater competition among traders thereby increasing the price offered to farmers and in turn encouraging greater production and hence supply for the Kinshasa urban center. As we have seen in our discussion, there has been a general increase in the real price to the producer and a small decrease in current price and a decrease in the real price to the Kinshasa consumer. However, in a study carried out by the *Service des Etudes et Planification (SEP)* of the Department of Agriculture in Bandundu and Shaba regions over the period December 1988 to June 1989 in which 309 farming households, 26 traders, and 200 urban consumers were surveyed, it was reported that many practices were still being followed that, as before, were contrary to the price liberalization policy of the central government. These included the control of marketing campaigns by local authorities; the restriction of credit to selected traders thus ensuring minimum prices to producers and the formation of cartels; excessive regional taxes on traders and producers; and forcing producers to cultivate a fixed amount of crops for sale through the head of the collectivity (local administrative area) and/or forced sale to selected agro-industries (*Département de L'Agriculture* 1989). A number of these policies are directly related to pre-independence colonial policies. Priority recommendations were to: strenghten the price liberalization policies through further dissemination of information; loosen the control of local authorities; restore roads and bridges in local areas in order to open areas and to facilitate the entry of traders; and, stop the policies of forced sales. Appropriate monetary and trade (i.e., import) policies were to be encouraged as well.

Conclusion

Earlier recommendations made by a UNDP/FAO project on methods of encouraging production and marketing were being addressed by the government but covered so many facets of socio-econmic life that, in fact, the problem of economic development itself was being addressed. And Rome was not built in a day. The overall objective appears to be to diminish urban supply deficits and high prices which encourage inflation and political instability by encouraging an increase in local production and the regular sale of this production through marketing channels into urban areas. The list of problem areas is endless but includes a number of inter-related elements such as: the definition of a national policy; the development of marketing infrastructures including transport networks and facilities such as trucks, fuel, and spare parts; improvement of credit facilities; and the training of personnel and the introduction of control measures that help rather than restrict the marketing system (FAO 1986).

Problems exist at every point in the marketing chain from production through the transportation network to the urban consumer markets. This is what economic and social development is about. In a discussion on sustainable agricultural development in Africa, Plucknett (1992) mentions the need to redress declining soil fertility by increasing the use of organic or chemical fertilizers in spite of current problems of high prices and unavailability; improving protection from yield losses as, for example, the success of biological control of cassava mealybug; increasing the number of options available to local farmers by which they can overcome limiting constraints to their production through the improvement of agricultural research and its applications; and, the urgent need for governments to give high priority—in fact rather than in fiction—to agricultural development. The impact of macroeconomic policies on sustainable, environmentally-positive economic devlopment is summarized by Berg (1992) and includes such problem areas as: over-valued exchange rates; trade policies; subsidization of inputs; and the role of other public policies such as price liberalization and stabilization, and fiscal policy.

Assuming that political conditions return to normal in the not too distant future in Zaïre, then one would expect pre-existing trends to continue. The potential for further excess production of cassava remains. The potential for local use of this excess in agro-industrial development remains as well. An increase in real producer prices may occur especially with the growth of agro-industries. The decline in urban consumer prices may also continue as long as constraints in the marketing system are improved and increased production is marketed in urban areas. A slow diffusion of new varieties of cassava can be expected along with a slow adoption of organic or chemical fertilizers in order to increase productivity per unit of land and labor. The overall importance of cassava throughout Zaïre both as the main source of calories and as a means of stabilizing incomes ensures its continued development.

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Sweetpotato in African Food Systems

Gregory J. Scott and Peter Ewell[1]

Abstract

Sweetpotato production in Sub-Saharan Africa doubled during the last three decades. Nevertheless, most scientists agree that the crop's potential has yet to be fully realized. This paper analyzes past trends and future prospects for sweetpotato in African food systems by presenting a synthesis of secondary data, a review of the available literature and results of unpublished research reports. Major emphasis is given to overcoming postharvest constraints in the area of marketing, processing, and storage as they, along with the availability of improved germplasm, will strongly influence the possibility of any future increases in sweetpotato production and utilization.

Key words: production marketing, consumption, constraints, Sub-Sahara, technology, processing, prices.

Introduction

Much of the commentary on the food situation in Africa over the last three decades has been sobering at best. As one observer noted, "During the 1960s, the continent's food production per person fell 7%, and during the seventies another 15%" (Norman 1987). Some have suggested that the lack of investment in agriculture has been one fundamental cause of this predicament (Whitaker 1986). Others have indicated that while taking into consideration successful strategies to overcome food problems elsewhere provides provocative points of comparison with Africa's evolving situation, the peculiar features of the continent's own resource base — most notably the absence of widespread irrigation and the limited supply of modern inputs — require the development of distinct approaches (Eicher 1986).

Sweetpotato, a root crop of South American origins, has recently attracted growing attention. Produced and eaten in Africa for a century or more, sweetpotato has not received nearly the research support of other crops such as maize, cassava, or potato by national and international agricultural institutes in spite of many attributes that make it highly suitable for local conditions. This paper briefly reviews recent trends in production, marketing, and utilization for sweetpotatoes in Sub-Saharan Africa with periodic reference to the status of the crop in other developing-country regions. After identifying the principal constraints to increased output and use of sweetpotato, the paper concludes with some future scenarios for the crop in different agro-ecologies.

Production

Sweetpotato is grown in every country South of the Sahara; the number of African countries producing the crop exceeds that of any other continent (Scott 1992). According to FAO statistics, total production averaged 6.4 million tons over the three years 1989/91, roughly double the level three decades previously (Table 1). The area planted reached 1.3 million ha in 1989/91 — the increase over 30 years was the fourth largest among the fifteen major food crops of Africa. Nevertheless, average reported yields fell by 10% to 4.8 t/ha over the same period.

Like most official statistics on root crops in developing countries, these average figures are subject to wide margins of error. They are a composite of widely

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Table 1. Sweetpotato production in Sub-Saharan Africa, 1961-91.

	1989/91[a]			Change (%)[b]								
				Production			Area			Yield		
	Prod. (000 t)	Area (000 ha)	Yield (t/ha)	1	2	3	1	2	3	1	2	3
Uganda	1,746	413	4.2	240.2	-6.7	217.5	235.7	-21.6	163.1	2.9	16.7	20.0
Rwanda	807	154	5.2	35.3	17.0	58.2	21.6	71.1	108.1	11.6	-32.5	-24.6
Burundi	668	93	7.2	-2.6	45.9	42.1	4.5	32.9	38.8	-7.1	10.8	2.9
Kenya	580	59	9.8	72.0	124.8	286.7	30.8	73.5	126.9	31.0	28.9	69.0
Tanzania	541	257	2.1	135.8	8.2	155.2	454.8	49.4	729.0	-57.4	-27.6	-69.1
Madagascar	485	92	5.	23.4	27.6	57.5	22.4	29.6	58.6	1.9	-1.9	0.0
Zaire	375	76	4.9	3.1	23.4	27.1	22.0	24.6	52.0	-15.3	-2.0	-16.9
Nigeria	260	20	13.0	27.9	32.0	68.8	23.1	25.0	53.8	4.2	5.7	10.2
Angola	170	19	8.9	57.1	3.0	61.9	12.5	5.6	18.8	39.4	-3.3	34.8
Cameroon	153	31	4.9	24.3	10.9	37.8	-7.0	-22.5	-27.9	34.6	40.0	88.5
Ethiopia	150	19	7.9	51.3	24.0	87.5	50.0	26.7	90.0	1.2	-2.5	-1.2
Sub-total	5,935	1,233	4.8	72.6	16.8	101.5	104.4	10.7	126.2	-14.8	4.3	-11.1
Others	536	103	5.2	11.2	10.5	22.9	1.1	7.3	8.4	10.9	2.0	13.0
Africa Sub-Sahara[c]	6,471	1,336	4.8	64.7	16.2	91.4	89.1	10.4	10.8	-13.2	4.3	-9.4

Source: FAO Basic Data Unit, unpublished statistics.

[a] Three year averages.

[b] 1=(1975/77 vs 1961/63); 2=(1989/91 vs 1975/77); 3=(1989/91 vs 1961/63).

[c] Africa - [Algeria, Egypt, Lybia, Morocco, Tunisia] - [South Africa].

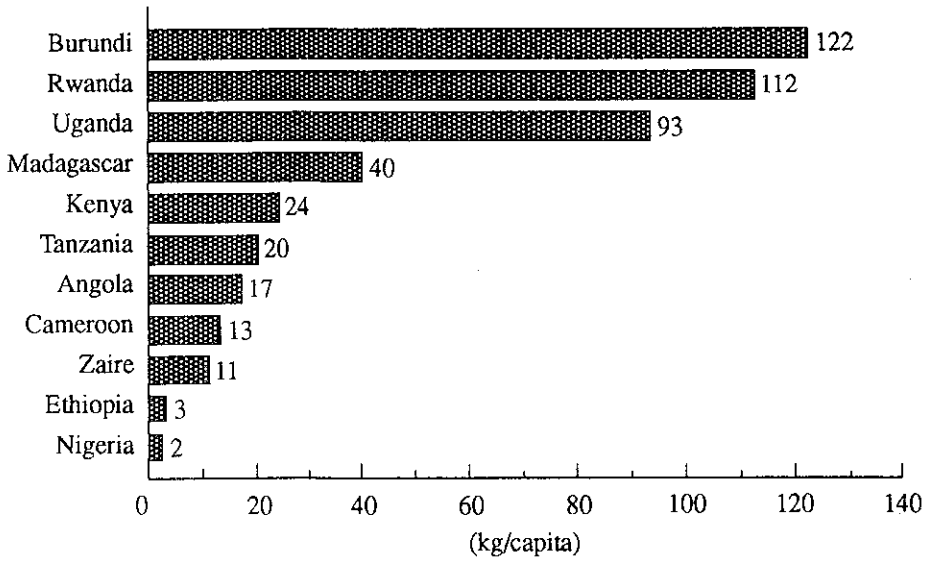
divergent tendencies among a large number of countries over a long period of time. Sweetpotato is grown in small plots on millions of small farms.The harvest is commonly either consumed directly within the farm households, or part is sold in small scale, unregulated markets from which accurate data are scarce. It has proven difficult for National Statistics services, the FAO, or anyone else to collect reliable figures. Nevertheless, FAO data provide a useful basis for broad comparisons between countries.

Five countries in eastern and Central Africa account for almost 70% of total sweetpotato production in Sub-Saharan Africa. Uganda alone registers an output of 1.7 million tons — nearly 30% of the total for Africa. Rwanda, Burundi, Kenya, and Tanzania account for another 2.5 million tons.

The role of sweetpotato in this sub-region is quite different in two types of food systems. In the first, the crop is a co-staple in a diet based on starchy staples: bananas, sweetpotato, cassava, potatoes, cocoyams in some areas, plus beans. This pattern is found in the densely populated highlands of central Africa north and west of Lake Victoria — in Uganda, Rwanda, Burundi, and adjacent parts of Zaïre and Tanzania (Ewell and Kirkby 1991). The relative importance of root crops relative to grains has increased significantly over the past 70 to 100 years, as population pressure has gone up and average farm size has declined (Jones and Egli, 1994). Average recorded sweetpotato production per capita is currently 122 kg in Burundi, 112 kg in Rwanda, and 93 kg in Uganda (Fig. 1). Actual per capita consumption is as much as 200 kg per capita in parts of Rwanda — very high by any standard (Tardif-Douglin 1991).

In Kenya, most of Tanzania, Ethiopia, Madagascar, Angola, and in southern Africa, the diet is based on grains, primarily maize. Sweetpotato is an important secondary food crop. It plays critical roles in rural diets in certain areas, in the "hungry months" when maize and other foods run short, and in years of drought or other catastrophe. Pockets of concentrated production are

Figure 1. Sweetpotato production per capita in Sub-Saharan Africa 1989/91.



Source: FAO Basic Data Unit, unpublished statistics.

found in western Kenya (Gor 1989; Magenya and Smit 1990) and in southern Sudan (Ali 1991). Average production per capita is 24 kg in Kenya, 20 in Tanzania, and 17 in Angola.

The five top producing countries are responsible for 80% of the increase in output since the early 1960s. Uganda and Tanzania alone account for 70% of the growth in area planted, with nearly all of this increase coming by the mid-1970s (Table 1). In fact, Uganda's 1990 agricultural statistics show a 50% drop in production and a 25% fall in area planted since the mid-1980s (Venegas and Bashaasha 1991). Nevertheless, among the ten largest sweetpotato producing countries in Sub-Saharan Africa, all but Cameroon registered an increase in area cultivated over the last three decades. In most cases, the trend was increasing for the latter half of the period (Table 1).

Major factors leading to expanded area planted and production of sweetpotato include: i) pressure on land due to population growth and declining farm size; ii) ease of propagation; iii) minimal production costs and cultural practices; iv) the crop's ability to do well on even marginal soils and under semi-drought conditions; v) its highly flexible planting dates; and vi) its short vegetative cycle (Doku 1989; Von Braun et al. 1991; Ewell and Kirkby 1991; Tardif-Douglin 1991). For most countries, average yields either stagnated or dropped modestly as sweetpotato cultivation spread into less favorable agro-ecologies; pests (e.g., weevils, moles) became more destructive; and the development and diffusion of higher-yielding sweetpotato varieties continued to be handicapped by the limited resources available for research on the crop (Horton et al. 1989). Noteworthy exceptions were Kenya, where yields increased 70% as area planted expanded by more than 125%, and Uganda where output per hectare rose 20% as production jumped 163% (Table 1).

Sweetpotato production occurs in a wide range of agro-ecologies in West, East, Central, and Southern Africa (Doku 1988; Ewell and Kirkby 1991). Cultivation is most intense, particularly in the highlands of East and Central Africa, in a diverse set of environments located between 800 m and 1,900 m (CIP 1991; Tardif-Douglin 1991: 15-16). In contrast, potato production is concentrated above 1,500 m (Scott 1991).

Sweetpotatoes are also planted at lower altitudes (<800 m). In Cameroon, the highest experimental yields are reported at sea level (Ngeve et al. 1992) although the bulk of production is in higher altitude zones (Pfeiffer 1982). In Ethiopia, sweetpotato was first established in lowland and mid-elevation areas (Doku 1989). Isolated pockets of sweetpotato production can also be found above 1,900 m in some parts of East Africa. Cooler temperatures, however, prolong the plant's

vegetative cycle and tend to diminish yields. Optimal average growing temperature is about 25°C, with well distributed rainfall between 750-1,250 mm (FAO 1988).

Sweetpotato cultivation typically is rain-fed in Sub-Saharan Africa. However, cuttings usually are planted on mounds or heaps in bottomland or swamps in the dry season where residual soil moisture serves as a source of water to insure proper establishment and development of the crop. In West Africa, sweetpotato is frequently grown before rice to avoid exhausting soil nutrients (Gura 1991). Hillside production begins with the rainy season. As sweetpotato serves as a supplement to the rural household's food intake, or a form of household food insurance, the crop is planted and harvested several times during the year (Fig. 2). These growing seasons often coincide with the rainy season for hillside production and with drier periods for crops grown in lower-lying areas. Cuttings from the lowland plots serve as seed for hillside plantings (Gass and Lekunze 1990; Tardif-Douglin 1991).

Sweetpotato producers in Sub-Saharan Africa are most often small, resource-poor farmers (Ewell and Kirkby 1991). Production takes place on tiny plots, rarely more than half a hectare in size. Total area planted per farm per year is typically less than one hectare, although some larger scale commercial producers have emerged in certain parts of Kenya (Mutuura 1990). Sweetpotato production is often dominated by women (Mutuura et al. 1992; Tardif-Douglin 1991; Odaga n. d.).

Production technology is basic. Cuttings serve as seed material. Planting, weeding, and harvesting is done manually or with hand tools. Chemical fertilizer and pesticides are too costly or unavailable for use on sweetpotato (Venegas and Bashaasha 1991; Tardif-Douglin 1991).

A recent survey of National Program personnel in Africa found that sweetpotato weevil, drought, scarcity of planting material, and too-late maturing varieties were among the most important, production-related constraints to increased output and use (Table 2). However, a number of the respondents identified several postharvest factors to be of equal, if not greater, importance.

Marketing

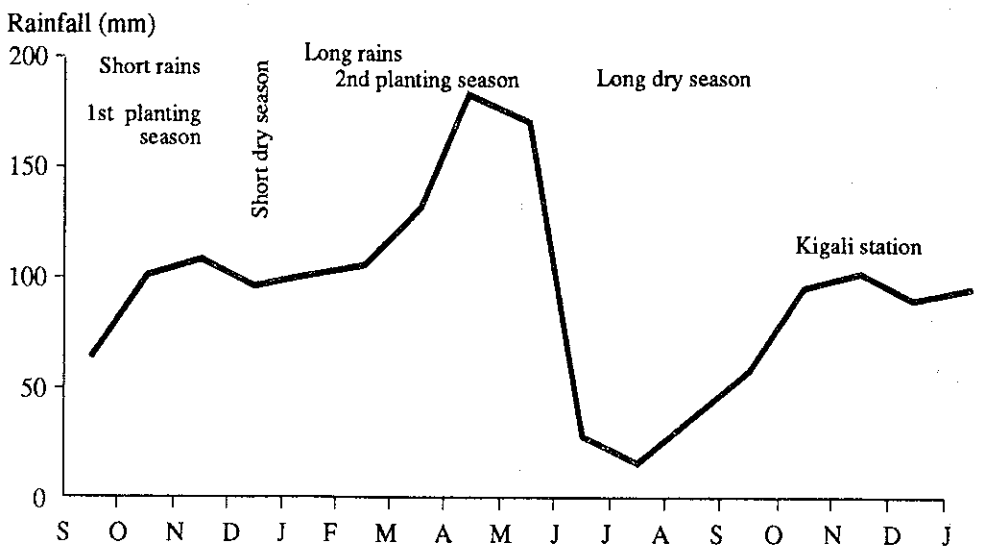
Sweetpotato is overwhelmingly grown as a subsistence crop in Sub-Saharan Africa in contrast to much of South America where it is cultivated principally for sale (Achata et al. 1990; Maggi 1990). Nevertheless, many African households also utilize sweetpotato as a supplementary source of income. A few roots are dug up and sold to pay for household necessities (e.g., salt); or, to barter for other food commodities. While these sales provide an important source of cash to the rural poor, sweetpotato is seen predominantly as a subsistence crop. One detailed farm survey in Rwanda found that just 34% of the 495 interviewed sweetpotato producers reported selling any roots (Tardif-Douglin 1991:48). Most (80%) had no excess production to sell (Ibid.). Therefore, household needs rather than market prices tend to be the most important factor influencing the timing of sweetpotato sales. Although the available evidence is extremely limited, the prevailing sense of the literature is that sweetpotato growers probably sell no more than 10% of total production per year — if that. As a point of reference, potato producers in many of these same countries sell 25-45% of production (Scott 1991).

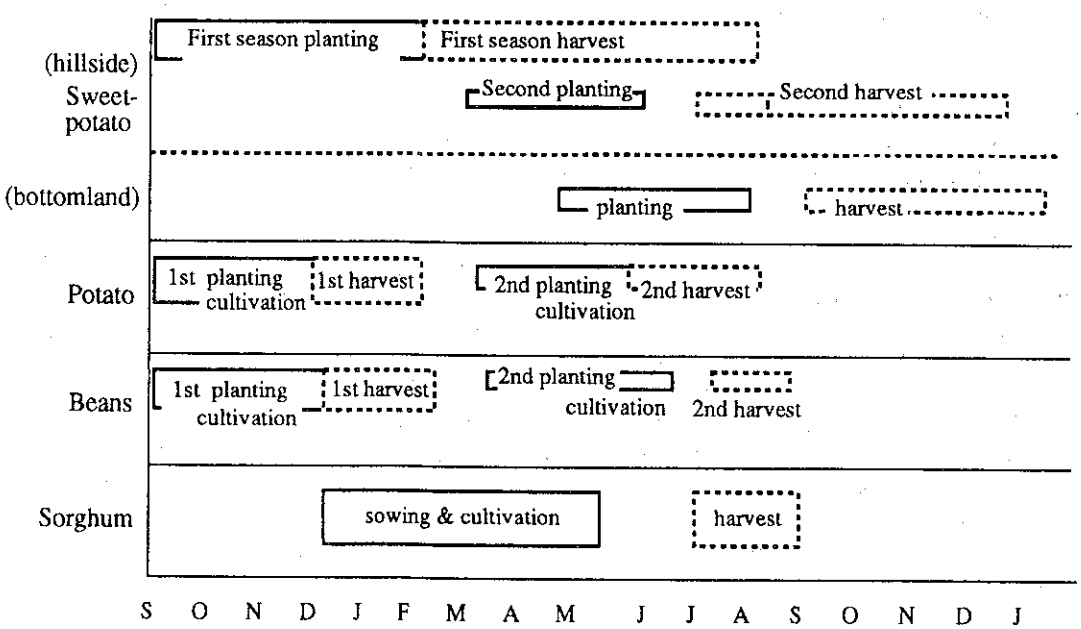
Few African countries imported (or exported) sweetpotatoes during the last two decades (FAO 1992). Food Balance Sheet Data for 1988/90 indicate that the region imported less than 1,000 t in total, virtually no change from 1961/63. Official potato imports for 1986/88, in contrast, exceeded 61,000 t up from 44,000 t in 1973/75 (Scott 1991). Given the bulkiness and perishability of the crop, international commerce in sweetpotato is confined to cross-border trade or barter intended to take advantage of local commercial opportunities. In light of the average size of most of these transactions (50-100 kg) and the long open borders in most African countries, foreign trade in sweetpotatoes—albeit small relative to other commodities—no doubt is under-reported in official statistics.

Most sweetpotatoes, particularly in East and Central Africa, are sold in local, rural markets. Several studies report prices for sweetpotatoes in a number of major, urban markets, e.g., Bujumbura (Bergen 1990), Dar-es-Salaam (Ndunguru 1992), Kigali (Scott 1988), Nairobi, and Mombasa (Gor 1989). However, volumes sold in these locations are generally considered to be a minor fraction of local production and, in aggregate terms, much less important than the quantities sold in local, rural markets (see Tardif-Douglin 1991:68). Both supply and demand factors account for the predominance of rural commerce in sweetpotato.

On the supply (i.e., rural assembly) side, growth in rural to urban sweetpotato trade, particularly over long distances, is discouraged by the bulkiness and

Figure 2. Growing season for sweetpotato and other crops in the Central Plateau of Rwanda.





Source : Tardif-Douglin 1991.

Table 2. Constraints to sweetpotato production and use in Africa.

CIP Region	East Africa[a]		West Africa[b]		Total	
Sites	15		5		20	
Production (000t)	2,451		16		2,467	
	Mean[c]	Std. Dev.	Mean[c]	Std. Dev.	Mean[c]	Std. Dev.
Production problems						
Varieties	0.9	0.6	0.0	0.0	0.8	0.6
Planting material	1.6	0.6	0.5	0.0	1.6	0.6
Fungal & bacterial diseases	0.2	0.3	0.0	0.0	0.2	0.3
Virus diseases	2.0	0.9	0.0	0.0	2.0	0.9
Nematodes	0.4	0.5	0.0	0.0	0.4	0.5
Insects	0.7	0.2	0.0	0.0	0.7	0.2
Environment	1.2	0.4	1.6	0.0	1.2	0.4
Postharvest problems						
Storage	1.0	0.9	1.6	0.0	1.0	0.9
Marketing	1.7	0.9	2.3	0.0	1.7	0.9
Demand	0.6	0.5	1.3	0.0	0.6	0.5

Source: CIP constraints survey.

[a] Includes responses from Burundi, Ethiopia, Kenya, Uganda, and Zaïre.

[b] Includes responses from Cote d'Ivoire and the Gambia

[c] These are weighted arithmetic averages with corresponding standard deviations, where 0=constraint not present or no information; 1=constraint of minor importance; 2=constraint important; and 3=constraint very important. See CIP 1989 Annual Report (Thrust X) for additional information.

perishability of the crop. Such trade is also handicapped by the geographic isolation of growing areas resulting from poor rural road networks and rainy season traveling conditions at harvest time. Marketing costs are therefore comparatively high.

On the demand side, sweetpotatoes do not have the broad consumer appeal among urban households as, for example, bread or potatoes. Hence, prices for sweetpotatoes are often low relative to more preferred substitutes (see, e.g., Scott and Muvira 1991). All other things being equal, low prices leave less of a margin for prospective traders to cover their costs and make a profit. Hence they are discouraged from seeking out additional supplies as well as ways to overcome existing marketing difficulties.

Four types of markets, with their associated participants, have been identified for sweetpotatoes: (i) rural retail; (ii) urban retail; (iii) rural wholesale; and (iv) urban wholesale (Tardif-Douglin 1991; Ndunguru 1992). In rural retail markets, sweetpotatoes are often bought and sold directly by members of local (5-10 km radius) farm households. Middlemen are not involved in these transactions. Moreover, women often do most of the selling (Tardiff-Douglin 1991; Odaga n.d.). Sellers may outnumber buyers at these locations. Urban retail markets are characterized by the presence of producers and small-scale traders both of whom engage in the retail sale of sweetpotatoes. Some producers prefer to sell to retailers in bulk at a lower price than in small quantities at a higher price directly to consumers.

Rural wholesale markets are assembly points where rural assemblers/shippers purchase baskets of sweetpotatoes from numerous, individual producers in order to supply truckloads of produce to distant urban centers. Relatively big cities such as Bujumbura (Scott and Muvira 1991), Dar-es-Salaam (Ndunguru 1992), and Kigali (Tardif-Douglin 1991) have wholesale terminal markets where assemblers sell their sweetpotatoes to local wholesalers or directly to retailers by the basketload. Rural and urban wholesale markets are linked by regular shipments involving established rural assembler/shippers. In the case of Rwanda, Tardif-Douglin (1991) estimates that rural retail markets handle roughly 80% of the sweetpotatoes sold, urban retail markets handle approximately 15%, and rural-to-

urban wholesale markets about 5%. Similar percentages would appear to prevail in most of the major sweetpotato producing countries in Sub-Saharan Africa.

Sweetpotato trade is largely informal. Established grades, weights, and units of sale are in evidence only on rare occasion. Roots to be sold to urban consumers receive more careful grading and packaging. For example, retail transactions are typically on a per mound or pile basis rather than per kilo. These lots vary considerably in weight. Sales are invariably for cash; or, in the case of barter, on the basis of agreed upon terms of exchange. Prices are most frequently set after bargaining between buyers and sellers at the time and place of sale.

Sweetpotato quantities sold and price movements appear to vary considerably from country to country. In Dar-es Salaam, sweetpotatoes are only available seven months a year (March-September), prices are highest when volumes shipped are also at their peak (March-April), and within year price changes are fairly modest (Ndunguru 1992). Consumers in this market have a strong preference for the crop during Ramadan (March-April); and, apparently, after June when annual government salary increases are announced. Seasonal monthly retail price patterns are more evident in Bujumbura, where from (1982-89) they generally fell during April-June (Bergen 1990). In Mombasa during 1980-87, monthly wholesale prices tended to reach a peak in the middle of the year (April to August), then taper off (Gor 1989). These price movements correspond to local production patterns and the high demand during Ramadan. Weekly sweetpotato prices (1987-88) in four Rwandese markets were flat in Butare and Nyaruteja, erratic in Nyamata and were 100% higher after mid-April in Gitarama (Tardif-Douglin 1991). Nairobi wholesale prices for sweetpotatoes have also been erratic (Gor 1989). Variable weather conditions, the thin volumes traded, location-specific tastes, and preferences of consumers would all appear to contribute to these diverse price movements.

Analysis of both monthly (1976-87) and weekly (1987-88) prices for sweetpotatoes in selected markets in Rwanda showed that trade tends to be poorly integrated, i.e., correlation coefficients for pairs of prices in different markets were considerably lower than those for beans or potatoes (Tardif-Douglin 1991). Furthermore, unlike cassava, sweetpotato trade showed little improvement over time. The relatively underdeveloped state of the market reflects the bulkiness and perishability of the crop, and the ". . . inability of the market, in its current form, to successfully address these problems" (Ibid.).

Estimates of marketing margins for sweetpotatoes in Sub-Saharan Africa are rare. Vanegas and Bashaasha (1991) cite an FAO report that lists the marketing margin for sweetpotatoes—here defined as the difference between the price received by growers and the price paid by consumers taken as a percentage of the retail price—in Uganda (1984) as 45%, in Burundi (1982) as 40%, and Gabon (1982) as 67%. Detailed field work in Rwanda permits a more disaggregate picture.

Most Rwandese sweetpotatoes are sold in local retail markets in rural areas. The marketing margins of relevance therefore are those of producers who sell directly to other producers, or those of retailers who buy from producers and sell to consumers. Tardif-Douglin (1991) estimates the marketing margin of products in five rural markets to be 8%-17%. He reports a marketing margin for local retailers of 38%. Hence, sweetpotatoes sold through retailers to consumers have a total margin of roughly 50%. The small volumes sold per transaction (e.g., 10-20 kg per transaction for producers, 560 kg per month for retailers), the risks involved in selling a perishable commodity, and the labor-intensive nature of this type of trade are what account for these price spreads (Ibid.).

Principal marketing constraints for sweetpotatoes include: (i) the bulkiness and perishability of the crop; (ii) the shortage of information about potential processed products to reduce the water content and increase the value added while lowering the volume of sweetpotatoes sold; (iii) the small size of market transactions which increase labor and transport costs per quantity sold; (iv) uncertain availability of transport; (v) inadequate market information; (vi) the volume-versus-value-based taxation schemes in many countries; and, (vii) limited information about how the sweetpotato can be cooked so as to take advantage of its culinary and nutritional attributes (Tardif-Douglin 1991: 187-188; Ewell and Kirkby 1991; Gura 1991).

Consumption

Sweetpotato has been eaten in Sub-Saharan Africa for over a century. Nevertheless, its varied role in the diet is sometimes still misunderstood. More importantly, the potential for expanded sweetpotato consumption has yet to be fully realized. Sweetpotato presently constitutes a minor percentage of average annual intake of carbohydrates and protein in Sub-Saharan Africa. How-

ever, this obscures the numerous ways in which sweetpotato can and does contribute to African food consumption and nutrition.

Sweetpotato currently serves as a staple food in parts of Burundi (central plateau), Cameroon (West and Northwest Provinces), Kenya (Western Highlands), Madagascar (Northwest Coast), Rwanda (Central Plateau), Sudan (Southern Region), Tanzania (western and southern shores of Lake Victoria, slopes of Mt. Kilimanjaro), Uganda (Eastern Region), and Zaïre (Kivu Region). In many of these same locations, sweetpotato has grown in importance as a major source of carbohydrates due to rapid population growth and the crop's ability to produce massive amounts of energy in short periods of time (e.g., Von Braun et al. 1991).

Sweetpotato is also eaten as a minor, complementary vegetable to diversify consumption patterns in areas adjacent to the prime-production zones in these same countries. Relatively minor consumption of sweetpotato as a complementary and/or seasonal vegetable occurs in other parts of Sub-Saharan Africa.

Sweetpotato is also seen as a catch-up crop or seasonal quasi-staple in the hungry-season before the main staple food is ready for harvest (Tardif-Douglin 1991).

Many African households plant sweetpotatoes as a food security or famine prevention crop as well. Sweetpotatoes are viewed in this instance as a form of insurance in the event of drought, political turmoil, or other food-supply-threatening event.

Sweetpotatoes have also served as a famine relief crop in parts of Sub-Saharan Africa e.g., in Ethiopia (Doku 1989; Behehu 1989). Given the limited inputs required, rapid growing period, and minimal cultivation practices, famine-stricken rural households will consume sweetpotatoes till the more traditional forms of food become available. In light of these different uses,

Table 3. Proximate composition of sweetpotato roots and other plant foods (per 100 g).

Food	Moisture (%)	Energy (kcal)	Energy (kJ)	Protein (g)	Lipid (g)	Total carbohydrate (g)	Dietary Fiber (g)	Ca (mg)	P (mg)	Fe (mg)
Sweetpotato										
Boiled	71	114	477	1.7	0.4	26.3	2.4	32	47	0.7
Baked	64	141	590	2.1	0.5	32.5		40	58	0.9
Flour	12	336	1,406	2.4	0.7	79.2		70	98	3.2
Cassava										
Flour	13	341	1,427	1.5	0.5	83.4		99	92	3.3
Rice										
Boiled, white	68	135	565	2.3	0.3	28.0	0.8	8	36	0.3
Flour	12	365	1,527	6.8	0.7	80.0		17	135	1.6
Noodles cooked	79	88	368	1.0		20.3		7	7	0.6
Maize										
Porridge	81	76	318	1.8	0.8	15.6		4		0.6
Tortilla	48	210	879	4.6	1.8	45.3		196	138	2.6
Meal	12	354	1,481	9.3	3.9	73.6		19	237	3.3
Wheat										
Chaphati	46	202	860	7.3	1.0	43.7	3.4	60		2.1
Bread	33	278	1,163	8.7	1.6	55.7	2.7	24	98	1.3
Noodles, cooked	75	108	452	2.7	2.1	19.4		21	25	0.8
Pasta, cooked	66	132	552	4.1	0.7	26.7		8	59	0.5
Sorghum										
Porridge	80	85	356	2.7	0.5	17.0		4	31	1.7
Meal	11	343	1,435	9.5	2.8	75.5		28	238	10.0
Beans (*Phaseilus vulgaris*)										
Boiled	69	118	494	7.8	0.5	21.4	7.4	38	10	2.4

Source: Adapted from Woolfe 1992.

estimates of annual per capita consumption vary considerably both within and between countries.

Average per capita sweetpotato consumption is highest in Sub-Saharan Africa in Rwanda (119 kg), Burundi (118 kg), and Uganda (95 kg) according to FAO statistics (Ewell and Kirkby 1991). More modest levels prevail in Madagascar (42 kg), Kenya (15 kg), Tanzania (13 kg), and Zaïre (12 kg); figures for the other countries all average less than 5 kg per annum (Ibid.). These nation-wide averages, however, mask considerable differences between regions. For example, Tardif-Douglin (1991) reports per capita sweetpotato consumption at over 300 kg/year in parts of the Central Plateau of Rwanda. Furthermore, given the tendency in many countries to consume sweetpotatoes at particular times of the year, national even regional averages underestimate the importance of the crop.

Sweetpotato's contribution to the African diet is highly complex. While it accounts for less than 5% of the average daily per capita supply of carbohydrates, it represents 15% or more of energy intake in Burundi, Rwanda, and Uganda according to recent estimates (Scott and Muvira 1991; Tardif-Douglin 1991). These percentages are certainly higher in areas of intense production and during seasonal periods of high consumption resulting from the shortage of other food commodities. Sweetpotato roots also provide protein, vitamins, and minerals. According to Woolfe (1992), they contain "substantial sources of ascorbic acid (vitamin C); moderate amounts of thiamine (B_1), riboflavin (B_2) and niacin; and, . . . variable and sometimes large quantities of the contenoids which act as precursors of vitamin A (Table 3)." Sweetpotato leaves are also good — and in Africa underexploited —sources of several vitamins: betacarotene (provitamin A), thiamine (B_1), riboflavin (B_2), folic acid, and absorbic acid (C). (Ibid.). It should also be noted that sweetpotato consumption tends to be concentrated among the poor and marginalized groups in most countries (Ewell and Kirkby, 1991; Von Braun et al. 1991).

In East, Central, and Southern Africa, consumers typically eat sweetpotato roots. The range of culinary practices involving sweetpotatoes is quite limited. In most instances, it consists of simply boiling the unpeeled roots whole, either alone or mixed with other foods, such as beans. In Kenya, sweetpotatoes are occasionally served roasted or fried as chips (see, e.g., Mutuura et al. 1992). Grilled sweetpotatoes are sometimes eaten as a snack in Rwanda (Tardif-Douglin 1991), or sold by street vendors in Dar-es-Salaam, Tanzania (Ndunguru 1992). In West and parts of Southern Africa, the tender tips and new leaves of sweetpotato vines are boiled and served as sauce on other foods, e.g., rice (Ewell and Kirkby 1991). Consumption of sweetpotato leaves is rare in the highlands of East Africa. Sweetpotato leaf is eaten by some consumers on the Kenyan coast (Mutuura et al. 1992) and is commonplace in Dar-es-Salaam (Ndunguru 1992).

Recent developments in a number of countries suggest considerable potential for processing of sweetpotato for human consumption. In Nyanza in Western Kenya and in Western Tanzania, tubers are peeled, sliced, dried, and then made into flour with sorghum or maize to make *ugali* or *uji*, a porridge-like dish (Tardif-Douglin 1991). In Burundi, the substitution of raw, grated sweetpotato for imported wheat flour (12%, approximately, on a dry weight basis) in bread has proven highly successful among bakeries and consumers in Bujumbura (CIP 1992). A similar recipe has also been adapted in Bamenda, Cameroon (Odaga n.d.). Several bakeries, market vendors, and other local enrepreneurs in Cameroon have begun using sweetpotato flour to make biscuits, donuts, and croissants (Ibid.). Applied research involving a variety of products in a number of countries is currently underway (see e.g., Mutuura et al. 1992).

Although utilization of sweetpotato for animal feed has expanded rapidly in a number of developing countries, most notably China, during the last two decades, such use is currently limited in Sub-Saharan Africa (Scott 1992). The sparse reports available indicate that nearly all fresh roots are needed for human consumption. Only damaged ones are fed to livestock (see, e.g., Ndamage 1988). However, in Kenya, Mozambique, Rwanda, and Uganda vines and/or foilage are utilized as green fodder for cattle principally, but also for pigs and other small animals (CIP 1988). Recent experiments suggest that considerable potential exists for expanding utilization of sweetpotato for animal feed in Africa (see, e.g., Tewe 1992).

Tastes and preferences of consumers with regard to sweetpotato roots have only recently surfaced as a topic of interest to researchers in Africa. Some observers contend that it is the sweetness of the roots that discourages greater consumption; hence, it is that characteristic that must be modified (e.g., through processing) to facilitate greater consumption (Almazan 1989). However pilot/consumer surveys in Dar-es Salaam, Tanzania (Ndunguru 1992), and in rural Rwanda (Tardif-Douglin 1991) found that floury and sweet roots are actually preferred by consumers.

Major constraints to expanded consumption and utilization of sweetpotato include its low status as a food commodity in abundant supply for poor people (Csete 1989); bulkiness and perishability encumber transport to urban consumption centers or densely populated rural areas where the crop is not now grown (Tardif-Douglin 1991); storage pests, particularly weevils, that deter prolonged consumption after harvest (Gass and Lekunze 1990; Mutuura et al. 1992); the underdeveloped processing sector for this commodity that limits use to a few known products; the shortage of information about products and processing techniques found in other developing regions (Gura 1991); the limited local research infrastructure and trained personnel to exploit the potential for technology transfer from abroad; and the lack of baseline assessments of the commercial and technical feasibility of alternative processes and products so as to prioritize postharvest initiatives in light of the limited available resources (see e.g., Vanegas and Bashaasha 1991). Yet, while the perception of sweetpotato roots as a poor man's food discourages its more widespread use, particularly in areas with currently high levels of production and consumption, it is the crop's rustic nature and limited production costs as well as nutritional value that suggest a far greater potential for incorporation into the average African diet.

Future Prospects

Trends in sweetpotato production and use in Sub-Saharan Africa suggest three different future scenarios. In the densely populated, medium altitude (800 m - 1,900 m) areas of East, Central, and Southern Africa with abundant rainfall, sweetpotato production seems likely to increase as continued population growth, shrinking farm size, and problems with declining soil fertility (due to erosion, shorter fallow periods) favor expanded cultivation of the crop. The introduction of improved germplasm with the promise of higher yields will provide an added incentive to growers. Similar tendencies seem likely to occur in mid-elevation sites with comparable demographic characteristics in West Africa (e.g., Cameroon). Improved agronomic practices and low-cost pest control measures could facilitate this increase by helping to raise yields currently less than 50% of the developing country average (Scott 1992).

Prospects for sweetpotato at lower altitudes (<800 m) also seem good for similar reasons. However, limited (or lack of) rainfall (Sahelian countries), competition from established staples like cassava (Zaïre) and/or yams (Ghana, Nigeria), high humidity, and pests present a more formidable combination of limiting factors to overcome. Nevertheless, recent developments such as the prohibition of wheat and maize imports in Nigeria, and the reduction in the import subsidy for wheat flour in Cameroon (Odaga n.d.) suggest established production and consumption practices may bow to economic reality as countries seek alternatives to existing food production and/or utilization patterns.

Sweetpotato seems less likely to expand production into higher altitude growing areas where higher value crops, such as potatoes, are currently flourishing. Furthermore, lower temperatures extend the crop's vegetative cycle and hamper root development thereby lowering yields (Ngeve et al. 1992) and as a result reducing sweetpotato's comparative advantage vis-à-vis other crops.

Introduction of appropriate processing techniques and new processed products accompanied by the appropriate germplasm and improved storage practices offer the promise of greatly expanding the potential for sweetpotato in the region beyond the growth in output for fresh consumption. Prospects for substitution of sweetpotato in various forms (i.e., grated fresh, or as a flour) for imported wheat look particularly good in light of the importance of bread in urban diets and high migration rates to the cities and towns. Expanded utilization of sweetpotato as livestock feed is another possibility. Given these and various other processed sweetpotato alternatives, priorities are urgently needed to accelerate efforts in support of technologies with the greatest potential. Such priority-setting exercises should serve to stimulate greater interest on the part of both the public and private sector by generating information that would both reduce the risk (i.e., by identifying not just a range of products, but some hard analysis of which ones are most viable) and increase the probability of success through inducing appropriate policy initiatives.

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Sweetpotato: A Source of Income for Low-income Rural Families in Uganda

B. Bashaasha and R. O. M. Mwanga[1]

Abstract

Sweetpotato is a major staple food in Uganda, with the bulk of output produced by small farmers. The crop is extensively marketed, particularly in and around urban areas where prices compare well with those of other crops. Significant market activity also takes place in rural areas though prices in these markets are rather low. Sweetpotato marketing in Uganda is still constrained by factors such as the bulkiness and perishability of the crop; poor means of transport, storage facilities, and marketing information systems; and the absence of processing. These factors are partly responsible for the large marketing margins noted. The national demand for sweetpotato is high and increasing as the income elasticity of sweetpotato is positive. Even under low external input levels, the profitability of sweetpotato is quite high and could more than double with improved technology. The competitiveness index of sweetpotato in Uganda is slightly above that of cassava though it is lower than that of bananas. Thus, Uganda has a comparative advantage in sweetpotato production.

Key words: production, demand, sweetpotato.

Introduction

Uganda is a major sweetpotato producer. It produces about 1.7 million t/year of sweetpotato from 400,000 ha. Sweetpotato is a major staple food and it ranks third in total output after bananas and cassava. The bulk of production is by small-scale, resource-poor farmers using little or no external inputs. Sweetpotato is produced primarily for home consumption. Hence, the food, rather than the cash, contribution of the crop has traditionally been emphasized. However, contrary to this traditional classification, it appears that sweetpotato is a major source of income for rural households. The main objective of this paper is to show that sweetpotato is — and can continue to be — a significant source of income for rural households.

Production trends, marketing, supply and demand, as well as elasticities, pricing, profitability, and competitiveness of sweetpotato production are discussed.

Unfortunately, no comprehensive economic studies have been done on sweetpotato production and utilization in Uganda. Consequently, empirical studies on sweetpotato marketing and the value of the crop as a source of income are rather scarce. On-farm production costs of sweetpotato were estimated by Aldrich (1963) and MacDonald (1967). These studies showed that sweetpotato production can be profitable.

Methodology

Most of the data and information used in the analyses in this paper are from secondary sources—mainly from the Ministry of Agriculture. However, some data were obtained from the on-going national sweetpotato survey. The survey has been completed in four districts, but some of the information obtained appears to be true across the nation and generalized conclusions could be made based on this information. Most of the analyses

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were done using a computer. Personal discussions held with farmers, extension workers, policy makers, and marketing agents also provided some of the information included in this paper.

Production

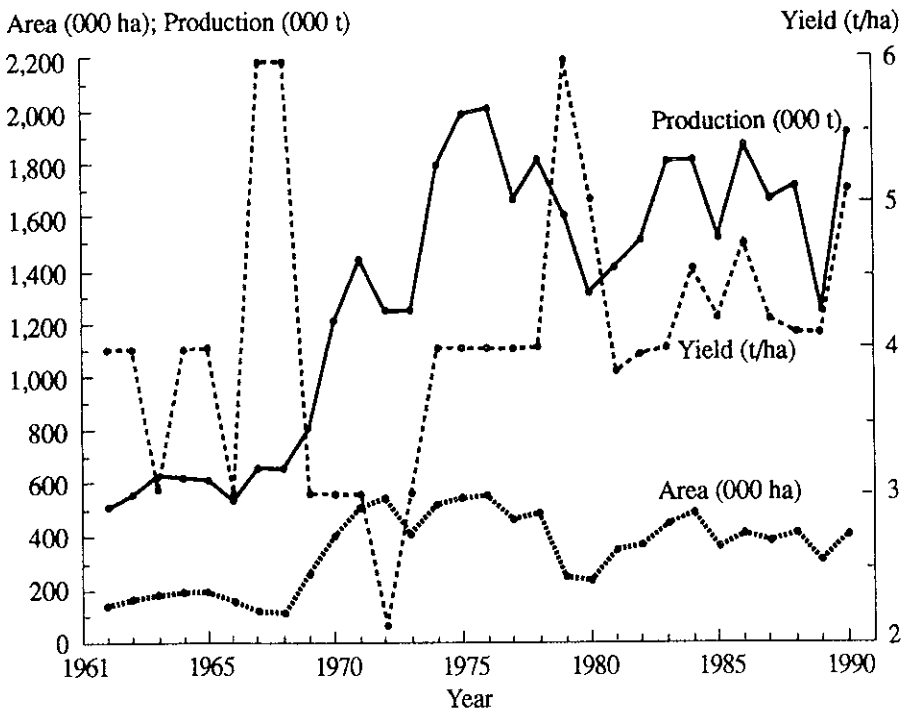
The area and production of sweetpotato in Uganda have been rather erratic (Fig. 1) reaching a peak in 1976 when over 2 million t were produced. For the period 1961-90, sweetpotato production experienced a growth rate of 4.2% per year. The period 1985-90 also shows a positive growth rate of 4.3% per year. Since 1961, production appears to have fluctuated. However, output figures have been subjected to irregularities in the collection of data due to civil strife. How much year to year changes reflect actual shifts in production therefore is not known.

In Uganda, the average yield of sweetpotato, 4.5 t/ha, is relatively low. With new varieties and better production methods being introduced, yields are expected to rise to over 15 t/ha (Vanegas and Bashaasha 1991).

Marketing

Currently, the extent of sweetpotato marketing is not well understood, though it is known that the crop is extensively marketed in almost all parts of Uganda. The most common method of selling is that in which small quantities of sweetpotato are sold by women in rural markets. However, a more economically significant sweetpotato marketing business goes on in urban areas. In this case, lorries, pick-up trucks, and bicycles collect sweetpotatoes from accessible areas of the country and wholesale them to retailers. The most common retail units of measure are heaps, baskets, and tins, though in some urban areas sweetpotatoes are sold by kilogram or sacks. Proceeds realized from the sale of sweetpotatoes are used to purchase a variety of household necessities such as salt, soap, clothes, paraffin, and medicine as well as to pay school fees.

Figure 1. Sweetpotato yield, area, and production levels in Uganda, 1961-90.



Source: Ministry of Agriculture.

Supply and Demand

Sweetpotato production has differed widely from year to year due to considerable variations in both area planted and yield. There is preliminary evidence of a response in sweetpotato production due to price changes. The short run price elasticity (SRE) for sweetpotato is 0.33. This means that a 10% change in the price of sweetpotato would lead to a 3.3% change in production. Hence, sweetpotato supply in Uganda seems to be reasonably price responsive.

Estimated cross elasticities with the price of cassava are 0.18. This suggests that cassava and sweetpotato producers do switch relatively easily between the production of the two commodities. This tendency could explain why in some areas of Uganda cassava production seems to be increasing while sweetpotato production appears to be decreasing.

The 1991 national sweetpotato demand was estimated to be 1.9 million t. National production in 1990 was approximately 2 million t. To avoid a deficit, 1991 production will have to be close to that of 1990. The price elasticity of demand for sweetpotato is -0.01, meaning that an increase in price for sweetpotato is accompanied by a decrease in demand. The estimate of the income elasticity for sweetpotato is positive, though low, at 0.14. This indicates that in Uganda sweetpotato is not an inferior good.

Pricing

Compared to production costs, the price of sweetpotato remains low. The fact that sweetpotatoes are not easy to transport, both in terms of unit cost and conservation, creates relatively independent pricing systems in each district of Uganda. Due to perishability problems and insufficient market information, the farmer assumes the position of a price taker. The farmer's position is further weakened because sales are often small and are made for immediate cash needs. The national average rural market and retail prices for sweetpotato are shown in Table 1.

Profitability

Using net income per hectare as a measure of profitability, under the current low external input technology the profitability of sweetpotatoes is Uganda shilling (U.Sh) 40,730/ha (U.Sh 200 = US$ 1) and could rise to as much as U.Sh 109,059/ha with improved technology. This represents an increase of 168% and underscores the importance of improved technology at least as far as profitability is concerned. The corresponding profitability figures for cassava (the major substitute) are U.Sh 23,696/ha at present technology and U.Sh 73,951/ha with improved technology, that is a 212% increase.

Marketing Constraints

Various marketing constraints affect the profitability of sweetpotato in Uganda, especially in getting the crop to urban markets. The impact of marketing constraints appears to be significant on the level of marketing margins and retail prices. These constraints stem to a considerable extent from sweetpotato's high perishability and bulkiness.

The rail and road system in most areas of Uganda is very poor. Hence, transport charges are high. Procurement depends upon a small number of old vehicles which often have no spare parts. Poor storage and processing technology constrain sweetpotato marketing. Poor communication, lack of market information, and lack of a standardized method of selling also constrain marketing. Sweetpotato marketing in some regions of Uganda suffers from prejudice, especially in urban areas where it is regarded as a food for low-income families. There is also a lack of cooperation in marketing because sweetpotato marketing basically remains individual.

Comparative Advantage

Competitiveness

The competitiveness index (net returns in Uganda shillings per domestic resource cost (non-traded input costs)) for sweetpotato was U.Sh 2.1 in 1990, while the respective figures for cassava and bananas, the two major starch foods, were U.Sh 1.7 and U.Sh 4.7.

The index for sweetpotato is very close to that for coffee at U.Sh 2.5. The sweetpotato index demonstrates that the crop can significantly contribute to the improvement of the Ugandan Gross Domestic Product (GDP). Figure 2 shows the competitiveness indices for the ten main crops of Uganda.

Conclusion

Sweetpotato is an integral component of the traditional food system in Uganda. It is widely grown by small-scale farmers primarily for home consumption with limited but significant market contact. Sweetpotatoes yield well in various climates, show some drought and

Table 1. Sweetpotato prices in Uganda (U.Sh/t), 1970-90.

Year	Average rural market price		Retail price		Ratio of real rural market price To retail price
	Nominal	Real	Nominal	Real	
1970	2.7	180.0	3.0	200.0	0.90
1971	2.8	164.7	3.6	211.8	0.78
1972	3.7	205.6	4.0	222.2	0.93
1973	3.2	160.0	10.2	510.0	0.31
1974	6.3	185.3	8.8	258.8	0.72
1975	7.7	189.0	10.2	248.8	0.76
1976	14.7	245.0	23.0	383.3	0.64
1977	21.0	185.4	47.4	419.5	0.44
1978	23.5	152.6	42.2	274.0	0.56
1979	26.0	53.4	42.2	86.7	0.62
1980	76.1	139.9	193.0	354.8	0.39
1981	2.1	92.1	144.6	144.6	0.64
1982	80.3	68.8	326.2	279.5	0.25
1983	180.4	116.5	496.6	320.6	0.36
1984	264.3	121.4	590.5	271.2	0.45
1985	749.3	128.2	2,041.8	349.3	0.37
1986	1,751.2	129.2	2,666.6	198.7	0.65
1987	7,540.0	114.3	8,170.0	186.7	0.61
1988	20,000.0	152.9	36,590.0	279.7	0.55
1989	24,097.0	132.1	12,367.1	253.6	0.52
1990[a]	46,700.0	135.1	20,059.4	246.0	0.55
Growth rate (%)					
entire period	49.4	-2.5	47.7	-0.4	-2.1
1985-89	93.8	2.3	62.2	-3.0	5.1
Coefficient of variation (%)	68	7	59	7	57

Source: Ministry of Agriculture, Ministry of Planning and Economic Development.

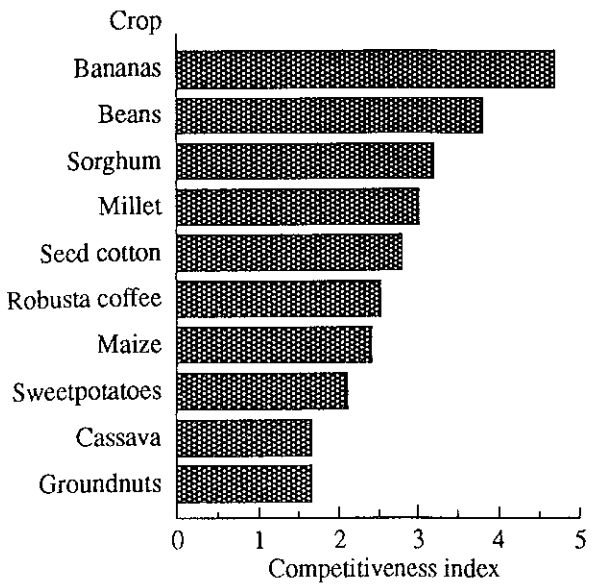
[a]Estimate.

disease tolerance, store in the soil for a reasonable period of time, and lend themselves to piece-meal harvesting. Sweetpotato is one of the crops small farmers regularly turn to in case of immediate cash needs.

While the crop is a valuable source of income for poor families, the marketing system remains underdeveloped, transport costs are high, losses extensive, storage inadequate, and processing inefficient. The small farmer who, though dependent on the market, has an amount of produce too small to negotiate at favorable prices.

While on-farm profitability is reasonably high, the marketing margins are also high and estimated to be no less than 50% of retail price. This is a reflection of high transportation and marketing costs. Therefore, the difficulties of expanding sales of sweetpotatoes in towns—the area where the potential demand is concentrated—are considerable.

Figure 2. Competitiveness indices (net returns in Uganda shillings per domestic resource cost) of ten major crops at Uganda, 1990.



To the Ugandan small farmer sweetpotato is a source of food for the family, a famine reserve, and a source of cash income. The increased role of sweetpotatoes in the areas mentioned would require attention and support to at least the same level as that available to other crops such as corn, beans, coffee, etc.

While sweetpotato prices are low, direct government intervention is neither possible nor desirable. Producer prices cannot be either fixed or regulated when marketing is mainly or entirely in the hands of the non-formal private sector. The improvement and maintenance of rural roads serving regions with high production potential are a prerequisite for lowering marketing margins and supplying Ugandan towns regularly and cheaply. This could lead to increased urban consumption of sweetpotato. Provision of a means of transport and storage facilities accompanied by credit facilities can help both farmers and operators to market sweetpotato cheaply and efficiently. It appears that in the development process of Uganda, sweetpotato yields will increase; marketing, transportation, and storage systems will improve; losses will decline; and price margins will shrink. Industrial use and an accompanying development of sweetpotato products will increase and the Uganda small-scale farmer will earn more from sweetpotato.

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Sweetpotato in Rwanda

David G. Tardif-Douglin[1]

Abstract

This paper provides an overview of the sweetpotato sector in Rwanda. It focuses on how, where, and why sweetpotatoes are grown, their importance and placement in production systems, the extent and nature of demand for them, and how they are marketed. The sweetpotato is suited to Rwanda and has gained an increasingly important place in its food system. With the exception of the Northwest, production is high and well distributed throughout the country. Levels of consumption are high both absolutely and relative to other starchy staples in rural areas. Demand among the urban poor would continue to grow if sweetpotatoes could reach them in reasonable condition and at reasonable prices.

Key words: production, consumption, urban demand.

Introduction

Sweetpotato production has grown faster in Rwanda than the other important crops (banana, beans, and sorghum) and as fast as potato, which has benefited from a much more intensive and well-funded research program. According to the average production of principal food crops in 1984-86, ranked according to the amount of calories they supply (Table 1), sweetpotato follows banana in gross production of calories and provides roughly the same amount as beans. On less than 13% of total cultivated area it produces 16% of total gross food energy coming from crop agriculture. Sweetpotato ranks fourth in area, but third in gross calorie production. Although banana provides more calories, because bananas are usually consumed as wine, up to one-half of their calories are lost to human consumption (Rwanda 1988). The wine-making process results in calorie losses. Consequently, sweetpotato is considered Rwanda's principal source of dietary energy (Ndamage 1988).

The sweetpotato has had one of the fastest rates of growth in production between 1966 and 1985. This is shown in Figure 1, which is drawn on a semi-logarithmic scale to facilitate direct comparison of rates of growth. The growth of sweetpotato, cassava, beans, and banana production are shown separately; important cereals: sorghum, millet, and maize are grouped. Rates of growth are contrasted with population growth over the same period (measured on the right-hand axis). Most crops have grown at roughly the same rate as population, but a few have grown faster. Sweetpotato production has grown at an average annual rate of 7%, within the same general level as potato, but substantially greater than that for beans, cassava, banana, and the cereals.

Most of the increase has come from extensification rather than intensification of production; cultivated area has increased by 6% annually, yields, by only 2% (Rwanda n.d.). As increasingly marginal land is brought into cultivation, yields can be expected to decline. This is not to say that all the additional land brought into sweetpotato cultivation has been previously uncultivated or uncultivatable. The data also indicate shifts away from cereals and grain legumes in favor of the higher-yielding staples, banana, cassava, potato, and sweetpotato.

The rapid growth in sweetpotato production has helped keep per capita calorie availability steady throughout the 1970s and 1980s, in spite of the demands placed on the food system by a rapidly growing popula-

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Table 1. Production, area, and yields of key food crops of Rwanda, 1984-86.

Crop	Area (000 ha)	Yield (t/ha)	Production (000 t)	Grain equivalents (000 t)	Food energy (bil. Kcal)	Food energy %
Banana	249	9.0	2,247	449	1,571.5	31
Sweetpotato	129	7.0	895	248	868.0	17
Beans	321	0.8	271	232	812.0	165
Sorghum/millet	175	1.2	202	202	707.5	14
Cassava	52	10.2	524	163	570.5	11
Maize	82	1.2	97	97	339.5	7
Potato	42	6.9	289	58	203.0	4
Total	1,050	--	--	1,449	5,072.0	100

Source: Ministry of Agriculture.

tion. Since 1965 population has grown at an average annual rate of 3.3%, reaching 6 million in 1987, and an expected 10 million by the year 2000 (World Bank 1989). During the 1970s and 1980s, agricultural production grew at an average annual rate of 5%, slowing down towards the end of that period, but remaining three times as rapid as the rate of growth for Sub-Saharan Africa (Ibid.). Consequently, agricultural production per capita has grown at an annual rate of a little over 1%, slowing down somewhat in more recent years. Daily per capita calorie availability remains fairly steady, around 1,800 to 2,000 Kcal. (Rwanda 1988).[2]

The sweetpotato's adaptability to Rwanda and its ability to meet the food energy requirements of a large and rapidly growing population have been incorporated into long-term planning. The extent to which this is so is evident from Figure 2, which is derived from projections made in Rwanda's 1986 Five Year Plan, "Plan Quinquennal". Production levels in the figure have been converted to grain equivalents, a measure of their food energy content, which allows for direct comparison and aggregation. If population grows by 4 million between 1986 and 2000, as is expected, the production level, in grain equivalents, will have to grow by 1.3 million tons over the same period. Projected increases in root and tuber crops, specifically sweetpotato and cassava, would make up the bulk (50%) of the necessary increase. Sweetpotato production is projected to nearly triple between 1984-86 and 2000, most of the increase coming from intensification. Yields are expected to nearly double while area is expected to increase by less than one-fifth. The only other important crops where yield improvements are being counted on so heavily are potato, sorghum, and, to a lesser degree, cassava.

Production

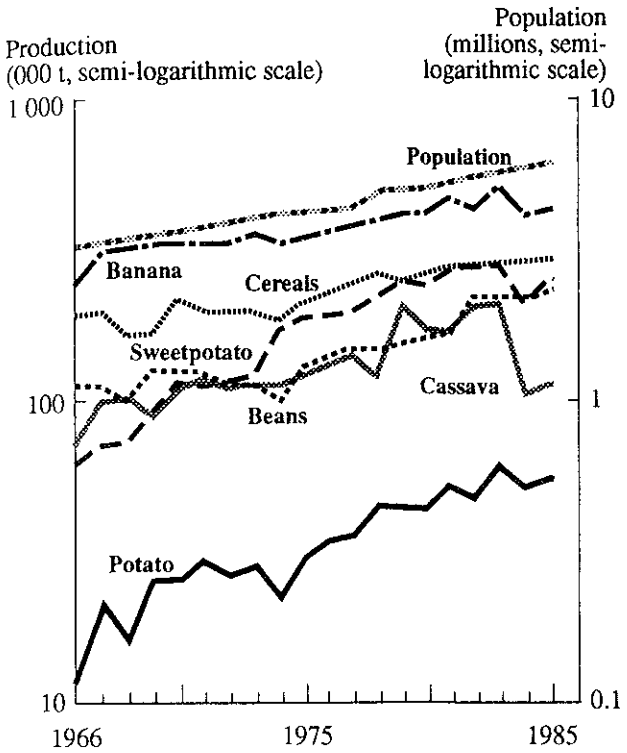
Sweetpotato is considered a famine-reserve or a cash crop to be cultivated when land and labor allocated to crops having more demanding planting and harvesting schedules are freed up.[3] Consequently, minimal labor is expended on it. Its primary advantage, from the point of view of producers, is its ability to be left in the ground to be harvested as needed. Only a small part of annual production is placed on the market, and that is usually for local trade.

Nine out of 10 farm households cultivate sweetpotatoes. This varies, in some cases greatly, by region (Rwanda 1985). In the middle elevation zone, all households grow some sweetpotato. In the high elevation zone, only a little more than two-thirds do. Sweetpotato cultivation is considered women's work,

[2] In Sub-Saharan Africa, excluding Nigeria, population growth rates have averaged 2.5% between 1965 and 1987 while agricultural production has grown by only 1.3% per annum. Consequently, production per capita has actually fallen by about 1% annually.

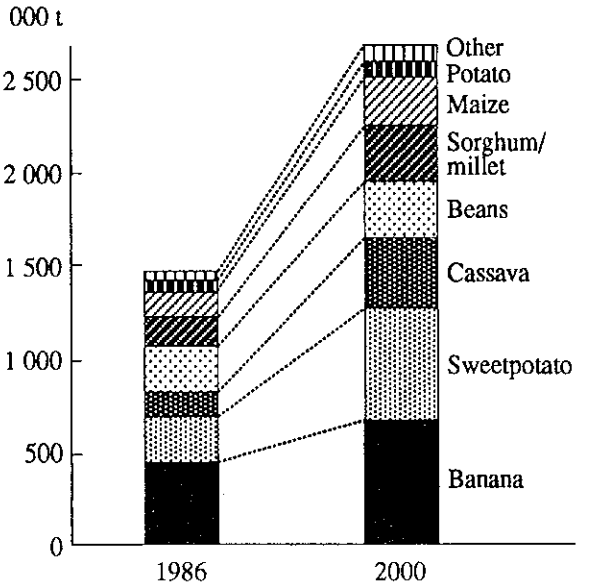
[3] A cash crop is one that is relatively quick-maturing and is often planted to ensure against the eventuality of crop failure of the more seasonally important crops.

Figure 1. Rate of growth of production of key groups in Rwanda, 1966-85.



Source: Rwanda, Ministry of Agriculture, Annual Report.

Figure 2. Projected change in production and composition of production, 1986-2000.



Source: Rwanda, Ministry of Planning, Strategie Alimentaire au Rwanda: Objectifs chiffres et programmes d'actions, no. 3, 1983, from Scott 1988.

although men are often responsible for field preparation and help decide when and where the crop should be grown (Ibid.). The small proportion of farm households that do not cultivate sweetpotato are the richest in land, cattle, and other indicators of wealth.

Sweetpotato is usually planted and harvested throughout the year, with little seasonal differentiation or specificity. First season planting is most frequently done on hillside fields between September and January, and second season planting is usually done between February and May, which permits harvesting throughout most of the year. Households that have access to bottomland fields in addition to hillside fields can plant from May to July, and thereby ensure a year-round supply of sweetpotatoes (Ndamage 1988a).

Sweetpotato cultivation is usually given a relatively small amount and percentage of household farmland. Farms are small, averaging a little over one ha, broken into five fields averaging 24 ares each (Rwanda 1985). Average farm size varies between 0.9 and 2.0 ha, number of fields, between two and seven, and average field size, between 14 and 96 ares, depending primarily on the level of population density in the region. Since sweetpotato production is most associated with the more densely populated areas, sweetpotatoes are more likely to be found on farms no larger than one ha. A survey by Rwanda's agriculture research institute, Institut des Sciences Agronomiques du Rwanda (ISAR), of 72 farmers in 8 of the 12 agroclimatic regions found that, on average, 0.12 ha were used for sweetpotato cultivation, and that the range in size was from 0.01 to 0.63 ha (Alvarez and Ndamage 1985). Elsewhere it has been estimated that 0.1 to 0.3 ha are used (Ndamage 1988). The results of the National Agriculture Survey (ENA) conducted by the Ministry of Agriculture in 1984 were that average annual household production of sweetpotatoes was 725 kg, and per hectare yields were between seven and eight tons. These data suggest that the typical household uses 0.1 ha for sweetpotato cultivation.

Methods of Cultivation

Sweetpotatoes are propagated vegetatively. The seedstock is vines that usually come from other, just-harvested fields owned and cultivated by the household. Careful planning is necessary for a household to ensure that proper balance and coordination is maintained between harvesting and planting, so as to minimize loss of expensive planting material. Cuttings have a high value, especially at planting time, and there is a thin but high-price market for them.[4] Shortfalls in production have been attributed as frequently to insufficient planting material as to pest infestations or diseases. Seedstock is often in short supply because most farmers plant at very high densities as a crop insurance strategy (Ndamage 1988a; Pffeifer 1988). According to a producer survey (hereafter, ENQPAT) the author conducted with the assistance of the Ministry of Agriculture, most households acquire their seedstock from their own fields although a sizeable minority must either buy or receive cuttings as gifts (Tardif-Douglin 1991):

Source of seedstock	Percentage of households for whom primary source
Own fields (hillsides)	52
Own fields (bottomlands)	34
Gifts	9
Purchases	5

Once planted, relatively little attention is given to the sweetpotato crop. Almost no farmers apply fertilizer; fewer than one-third weed their fields, and then only once (Ndamage 1988a). This probably constitutes a rational use of household labor, but it also reduces sweetpotato yields and production. Sweetpotato fields are left to grow with little intervention.

Limited intervention extends to pest and disease control. Other than choosing varieties that are most resistant, farmers do little to actively combat disease and pest infestations, in spite of the extensive damage caused by them. The virus complex (sweetpotato virus disease) and alternaria are the two most important sweetpotato diseases; sweetpotato weevils and defoliating caterpillars the most serious pests. George Ndamage, the head of root and tuber research at ISAR, has conducted research on the extent of disease and pest infestation. He reports that a 1984 study by ISAR found that an estimated two-thirds of all sweetpotato fields were affected by alternaria, one-half by the virus complex. Pest damage also appeared to be widespread, caterpillar damage being found on nearly half the fields, and weevils infesting one-third of them (Ndamage 1988a). Actual rates of infestation may be higher; symptoms are often masked where soils and other growing conditions are good.

Market Orientation of Producers

The amount of sweetpotatoes entering the market is influenced by farmers' perceptions about when, how, and how much of their crop to harvest and by their in-ground storage practices. Sweetpotato sales represent a small part of production in aggregate as well as for the average producer. The ENQPAT survey suggests that only about one-third of producing households sell any of their crop.

Households most likely to sell sweetpotatoes are those that seem, by certain criteria, to be the poorest. These criteria are low area-to-household-size ratio, and thatch rather than tin or tile roofs on their houses. The vast majority of households (80%) that do not sell sweetpotatoes simply have no excess production to sell. A sizeable minority (13%) could sell but choose not to because they have other sources of income, and only 5% are deterred from selling by low prices (Tardif-Douglin 1991).

Sweetpotato sales by producers do not tend to be responsive to the market. Most sales are made, instead, when households have a pressing need for cash for school fees or medical bills rather than when prices are favorable. Most households (75%) appear never to take market conditions into consideration when making their production plans. One-third of all households that sell admit to having their harvest schedules and amounts influenced by market price. Of these, however, only half base their harvest decisions directly on prevailing market prices. Where price has no apparent influence on harvesting or marketing, harvest decisions are based primarily on food and cash needs rather than on crop maturity (Tardif-Douglin 1991):

[4] There are no records of prices paid for cuttings, but the author was told on numerous occasions that, by weight, cuttings are equivalent in price to tubers.

Reason for harvest	Percentage of households for whom it is the primary reason
Food needs	50
Cash needs	15
Crop maturity	32
Other reasons	3

Finally, that nearly three quarters of all selling households sell their sweetpotatoes regardless of the prevailing price shows that market price is not yet an important determinant of sweetpotato sales.

Consumption

Sweetpotato is a highly important component of the diet in rural areas but is substantially less important in the diet in urban areas, where it seems to be eaten primarily by people of modest or poor means. Sweetpotato consumption represents 13% of the value of food consumed by rural households, but only 4% of the value of food consumed by their urban counterparts (Rwanda 1985a, 1988). Nationally, levels of consumption are high, the contribution to caloric intake great, but importance declines with increases in income. While levels differ, patterns of consumption differ little between rural and urban consumers. Methods of procurement, however, differ as do degrees of responsiveness to prices. Rural households eat sweetpotatoes primarily from their own fields. Urban households buy nearly half of what they consume (Rwanda 1988). From the perspective of market analysis, it is the evolution of urban demand and consumption that is most challenging and interesting.

Levels of Consumption

The two most important foods in traditional rural diets are beans (for protein) and sweetpotato (for calories). The typical meal in the countryside usually includes both. Sweetpotatoes are prepared very simply for the average meal, usually the unpeeled tuber is boiled and served directly with beans. In some cases the tuber is peeled and mashed prior to being served, and in still others it is grilled and eaten as a snack. Consumers prefer their sweetpotatoes starchy (floury) and sweet (Tardif-Douglin 1991):

Sweetpotato characteristics	Percentage of households preferring each characteristic
Starchiness/flouriness	44
Sweetness	27
White fleshed	5
Blandness	4
Yellow fleshed	1

Between 1982 and 1986, Rwanda's Ministry of Planning conducted a budget and consumption survey (ENBC) of rural households (November 1982-December 1983) and urban households (October 1984-January 1986). Most of the consumption data reported here come from the ENBC study. Unfortunately the urban segment had not been completed at the time of writing, and hence the lack of clear estimates of urban demand elasticities, among others.

For the rural part of the survey the base sample was 1,170 households, 13 from each of 90 *secteurs* selected from 90 rural communes. From a subsample of 270 households, three each from the 90 *communes*, it was estimated that annual consumption was 203 kg (556 Kcal per day) per adult equivalent (hereafter AE),[5] and that it varied from 300 kg (821 Kcal/day) in the North-central part of the country, where it reached as much as 400 kg (1096 Kcal/day) for one-fourth of the households, to 130 in the East and Northwest, where nearly half the households consumed less than 100 kg (274 Kcal/day) (Rwanda 1988).[6] Although these results are from a study of rural households, they provide reasonable estimates of national averages because the urban population is so small that it does not substantially alter aggregate or average levels. Average annual consumption of sweetpotatoes for all households was estimated at 865 kg; for households actually consuming sweetpotatoes the estimate was 895 kg. Ndamage suggests that overall per capita consumption (not just adult equivalent) is roughly 120 kg nationally, which would convert to 600 kg per household (Ndamage 1988a).

[5] The expression adult equivalent (AE) is used to discount the calorie requirements of the very young and the very old. At the time of the survey in question the adult equivalent population was roughly 4.5 million, or three quarters of the total population of 6 million.

[6] North-central, east, and northwest are three of the five geographical zones by which the country is divided. They have little relation to agroclimatic regions, and the only reason they are used here is because they are the regions for which the Miniplan data we have cited have been disaggregated. The north-central zone corresponds roughly with middle elevation, although it also includes some of the high altitude Buberuka Highlands. East is synonymous with low elevation, high temperatures, and low rainfall, and Northwest with high elevation, low temperatures, and high rainfall.

The ENBC study estimated that in 1983 sweetpotato accounted for 17% of the average household's calorie intake, making it, after beans which provided 32%, the second most important source of calories. Sweetpotato was a distant second, after beans, in the provision of protein, providing 8% versus 65% of the protein in the average diet (Rwanda 1988):

Percentage of calories and protein supplied by each crop in the typical diet.

	Calories	Protein
Beans	32	65
Sweetpotato	17	8
Cassava	12	5
Sorghum beer	9	4
Cooking banana	8	1
Banana wine	5	na
Maize	4	4
Potato	9	3
Other	4	10

In addition to regional differences, there are some important demographic and socioeconomic factors affecting the level and relative importance of sweetpotato consumption. One factor that seems to have an important effect on the amount of sweetpotato in the diet is the profession or employment of the head of household. Households in which the head of household is a craftsman (artisan), for example, consume about half as much sweetpotato per capita as those engaging entirely in farming. Since women are the principal agriculturalists in Rwanda, what is implied when the male head of household has a profession or employment other than farming is that there is a greater source of cash income. Households with greater cash income tend to switch to cassava, much of which is probably purchased, and their sweetpotato calories decline to about one-half the average level (Rwanda 1985).

Households with more farmland (another indicator of well-being) also tend to rely somewhat less on sweetpotato than do their counterparts with less area. This suggests that it is the poorest who rely most heavily on sweetpotato. There is also an apparent positive relationship between the extent to which households consume only what they produce, and the relative importance of sweetpotato in the diet. The ENBC study classified households according to the share of their diet that came from purchased foods, and found that households that bought only one-fourth to one-sixth of the food they ate relied twice as much on sweetpotatoes as their counterparts that bought nearly half of their food (Rwanda 1985).

Effect of Income on Consumption Level

Although it is only at the highest income levels that sweetpotato consumption actually declines, its relative importance in the diet diminishes as income grows. Sweetpotatoes are most important in the diets of people of modest or poor means. The ENBC study of rural households analyzed the structure of food purchases, sales, and consumption as a function of household calorie intake, a proxy for nutritional status (and, equally, income/wealth levels). Average daily calorie intake per adult equivalent in each household was broken down into five categories or quintiles (Rwanda 1985):

Calorie intake quintile	Range (Kcal/AE/day)
First	Less than 1,706
Second	1,706 - 2,105
Third	2,106 - 2,510
Fourth	2,511 - 3,050
Fifth	Greater than 3,050

The importance of sweetpotato as a source of calories for the first intake quintile (25% of all calories) was found to be more than twice what it was in the fifth quintile (12%) (Rwanda 1988a).

The same study found that the average rural household consumes what amounts to the equivalent of $US 60 worth of sweetpotato each year, most of that coming from the household's own production (Ibid.):[7]

Source	Value in Rwandese francs	Percentage
Own production	5,071	92
Purchases	272	5
Gifts	166	3
Barter	24	<1
Total	5,533	100

[7] Here and in subsequent computations conversion from Rwandese francs to U.S. dollars has been made at the rate of 90 francs to 1 U.S. dollar. Since most sweetpotatoes never enter the market, there are some problems with valuing their consumption at the prevailing market price. By so doing, more is assumed than is warranted about the state of supply and demand.

If only those households actually making sweetpotato purchases are considered, the results are somewhat different. According to ENBC, one-third of all households purchase sweetpotatoes, spending on average the equivalent of $US 10 (Rwanda 1985a). The results of the ENQPAT survey indicate that half of all rural households buy sweetpotatoes, but that purchasing rates vary by prefecture, being highest where there are fewest producers (Ruhengeri and Gisenyi) and lowest where households rely most heavily on sweetpotato (Gikongoro) (Tardif-Douglin 1991):

Prefecture	Households buying sweetpotato (%)
Gisenyi	64
Ruhengeri	60
Byumba	53
Gitarama	51
Kibungo	46
Butare	44
Cyangugu	43
Kibuye	43
Gikongoro	26
Kigali	28
Average	46

The ENBC study analyzed demand for different goods as a function of the value of per capita consumption of all products, by household, and other household characteristics (Rwanda 1988a). The independent variable used to estimate demand elasticities was the annual value of per capita consumption of all products by household (a proxy for income or household well-being). The dependent variable was the percentage of the household budget allocated to particular consumption categories (food, sweetpotatoes, and so forth). From the demand and consumption relationship were computed demand elasticities similar to the commonly used income elasticities of demand. The rationale for using value of total consumption rather than the more commonly used income level was that the value of consumption can be more precisely measured than income, and that consumption levels in developing countries tend to be more stable from season to season than income (Rwanda 1988a). Rather than be considered as normal income elasticities, the elasticities derived by the study are, more strictly, expenditure elasticities, since the dependent variable is a monetary value rather than a physical quantity. The elasticities differ from expenditure elasticities, however, in that the values of total consumption as well as the consumption of specific goods include the value of goods purchased as well as those produced by the household itself.

The study found that as the value of total consumption increases, the value of sweetpotato declines in importance, and there tends to be a shift away from sweetpotatoes and other low cost foods, towards more expensive sources of calories. The relatively low (0.14) income elasticity of demand of rural households for sweetpotatoes suggests that while total consumption increases with income, because demand is elastic, albeit only slightly, sweetpotato's share of the food bill becomes smaller. A 1% increase in overall household consumption results in only a 0.14% increase in sweetpotato consumption. The table below, also from ENBC, lists the income elasticities of sweetpotato and key competing starchy staples in descending order (Rwanda 1988a):

Food	Income elasticity
Potato	1.45
Banana	0.77
Sorghum	0.67
Beans	0.63
Cassava	0.42
Sweetpotato	**0.14**
Processed foods	1.85
All food	0.85

The relatively high elasticities of demand for potato and banana suggest that consumption of them will increase nearly proportionally with overall household consumption (or income), and if consumption levels increase, the share of potato and banana will grow at the expense of products with lower elasticity. The extremely high demand elasticity for potato reflects its status as a luxury food among rural households. Potatoes have come to be viewed, perhaps because their consumption was associated with Belgian colonialists, as part of the sophisticated diet of the well-to-do. As value of consumption (income) grows, more potatoes tend to be bought and consumed.

Sweetpotato consumption does not increase proportionately with increases in personal income (total consumption). This has two ramifications.

Sweetpotato represents an especially important component of the diet for primarily the poor, or for those with low levels of consumption overall in value terms. But this brings up a difficulty with the measurement used. Values rather than actual quantity consumed have been used to determine income elasticities, and it is not completely clear whether households that are better off in terms of higher value of food consumed eat less sweetpotato or whether because their food bill is larger,

as a result of eating more expensive items, a similar amount simply represents a smaller share of total consumption.

Secondly, the relative importance of sweetpotato in the average diet is not much affected by total consumption or income. The sweetpotato is truly a Rwandan staple.

Although no price elasticities of demand are available for rural or urban consumers, general estimates can be derived from income elasticities. They must, however, be interpreted with caution. Estimates of income elasticity set the lower limit on price elasticity. Consequently, the absolute value of price elasticity can be placed at no less than |-0.14|, and because of the existence of substitutes such as cassava, banana, potato, and other root crops, it is probably higher. Nonetheless, demand for sweetpotato is almost certainly inelastic with respect to its own price. A 1% drop in price will result in a 0.14 to, perhaps, 0.20% increase in consumption for the average household. Richer households would have lower price elasticities, poorer households, somewhat higher price elasticities of demand.

It is as difficult to ascribe meaning to price elasticities as to income elasticities in the rural semisubsistence setting that characterizes most of Rwanda. Income elasticities are computed on the basis of imputed values of consumption because most food, especially the sweetpotato, does not enter the market. Overall low market orientation poses problems for the interpretation of estimates of price elasticity. If a household does not get any of its sweetpotatoes on the market, prices do not influence consumption directly, but indirectly through sales or substitution decisions. Nonetheless, the seemingly low price elasticity suggests that the key to promoting sales and demand for sweetpotato and sweetpotato products is to process them into a product that has advantages such as high value as well as easy storage and preparation traits normally associated with processed foods. It is worth noting that the income elasticity of demand for processed foods (principally locally processed) has been estimated at 1.85.

Growth in Urban Demand and Consumption

The consumption and demand patterns of urban consumers differ from those of rural consumers. There is a greater selection of foods from which to choose, and consumption is more directly tied to cash income and product prices. Because average urban income is higher, it is likely that the income elasticity of demand of urban households for sweetpotato is generally lower than that of their rural counterparts. There are, nonetheless, two primary reasons urban demand for sweetpotato is likely to increase in the future:

- Population increases are rapid as Rwanda begins to urbanize in earnest; and,
- At least half, probably more, of the sweetpotatoes eaten in urban households will have to come from the market.

According to the urban component of ENBC, conducted between 1984 and 1986, food consumption represents just under half the average urban household's total annual consumption of all goods and services (Rwanda 1985). Most of that is purchased. Since the households are urban and, by definition, have limited access to land, it is remarkable that a little over one-tenth of households' food needs are produced by the households themselves.

Sweetpotato ranks fifth, along with banana, in value of starchy staples consumed by the average urban household. It represents 4% of the value of all food consumed, a little under one-tenth the value of starchy staples, including beans and peas, and about one-sixth of all roots, tubers, and bananas consumed. Roughly half the sweetpotatoes consumed are bought (Rwanda 1985):

Average annual value of urban household consumption

Source of sweetpotatoes	Rwandese francs (FRw)	Percentage
Own production	1,762	51
Purchases	1,692	49
Barter	11	<1
Total	3,465	100

More than 90% of all households eat sweetpotato, and an only somewhat smaller proportion (85%) buy them.

Based on the value of annual sweetpotato consumption among urban households (3,465 francs versus 5,533 francs for their rural counterparts), and on an estimated per kilogram price of 11 francs, we have estimated that urban households consume on average 315 kg of sweetpotatoes annually. They consume a little less than half the quantity of sweetpotatoes eaten by rural households, but they purchase greater amounts than their rural counterparts. Urban households purchase 49% of what they consume, spending on average 1,700 francs for 150 kg, while rural households spend

on average 290 francs for them annually (Rwanda 1985, 1988a). Among households actually buying sweetpotatoes, urban households spend 2,000 francs each year, while rural households spend only 930 francs.

The rapid growth in the urban population, and the likely ramifications of that growth, has been treated above. Income elasticities are assumed to be smaller among urban households than among rural households. Price elasticities, on the other hand, may be larger in spite of the normal association between price and income elasticities, because of the availability of a wide range of substitutes for sweetpotatoes in urban markets. Substitutability between the root and tuber crops and bananas is high (field notes). The homogeneity condition suggests that own-price elasticity is likely to be high since income elasticity is low and cross price elasticities appear to be high.[8]

Nearly half the sweetpotatoes consumed by urban households are supplied through the market. Rwanda's urban population was estimated at 420,000 in 1988 (World Bank 1989). If urban households are indeed eating 315 kg of sweetpotato each year, of which 150 kg are bought, then roughly 13,250 t must be brought into urban markets. The average annual rate of urbanization between 1980 and 1987 has been 8%, which means that for the sweetpotato to retain its position in the urban diet, the amounts brought into urban markets will have to increase by 6,200 t, an increase of roughly 50%, over the next five years.

With increased urbanization there will be less space on which to grow the kitchen gardens that have heretofore enabled urban consumers to supply up to half of the sweetpotatoes they consume. More of what is consumed in the cities will have to come from the outside via the market. If, for example, the self-sufficiency ratio of urban consumers falls from 50% to 25%, the additional amount of sweetpotatoes that will be needed on the market within five year's time will be roughly 10,000 t.

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[8] The homogeneity condition is based on the observation that the sum of income elasticity, own price elasticity, and cross price elasticities is zero.

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Trends and Prospects for the Potato South of the Sahara[1]

Gregory J. Scott[2]

Abstract

Potato production in Sub-Saharan Africa has increased by nearly 150% since 1961—faster than any other major food crop except yams and rice. Moreover, both African and international potato scientists agree that future increases in productivity are technically possible. This paper reviews present production, marketing, and consumption patterns for potatoes in an effort to identify priority constraints and initiatives to overcome them. Particular attention is paid to the seven countries that produce over 80% of the region's potatoes. The results emphasize the need for renewed efforts to raise productivity using improved quality seed with attention as well to minimum input packages for farmers who use little, if any, chemical fertilizers and pesticides. The potential for postharvest and marketing improvements based on combining traditional practices and modern science supplemented by better access to market information and credit is also noted.

Key words: production, marketing, consumption, prices.

Introduction

Inadequate food production has frustrated development efforts in Sub-Saharan Africa for decades. It is the persistent and growing imbalance between food supplies and population growth, however, that has gradually transformed the nature of this problem. No longer simply a stumbling block to economic growth, the ability of many countries to feed their rapid growing population has become an issue of human survival. As a result, local and international concern has focused added attention on new strategies to meet this challenge. Interest in the potential of the potato—a crop not normally associated with traditional cropping patterns or established eating habits in this area—arises in this context. While both local and foreign biological scientists agree that considerable increases in productivity are technically possible, there is a growing realization that accelerated development in potato production and use will depend on more fully integrated efforts to improve production, marketing and consumption. Questions about the current role of the potato in the food systems of Sub-Saharan Africa therefore merit closer consideration.

Production

Potato production and area planted increased faster than any crop in Sub-Saharan Africa during the last 30 years except yams and rice (Table 1). Area currently cultivated is about 390,000 ha; an increase of over 140% since 1961 (Table 2).[3] Over 80% of this total is in seven countries of East (Ethiopia, Kenya, Tanzania and Uganda), Southern (Madagascar and Malawi), and Central Africa (Rwanda) (Map 1, Table 3). These countries also account for nearly all of the expansion in area planted. In Malawi, area planted in potatoes increased by 66,000 ha; in Kenya by 24,000 ha; in Tanzania by

[1] This is a revised version of a paper originally presented at the workshop on production, postharvest technology, and utilization of potato in the warm tropics, held in Reduit, Marutitius, 23-27 1990, in collaboration with the African Potato Association.

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[3] These are FAO statistics; past experience suggests that due to intercropping, multiple cropping, small farm size and geographic isolation, potato production, area and yield levels are probably underestimated (see Horton 1988:10-12).

Table 1. Food crop production in Sub-Saharan Africa, 1961-91.

	1989-91			Change (%)[a]								
	Production	Area	Yield	Production			Area			Yield		
	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
Cassava	67,187	8,715	7.7	46.2	42.3	108.0	25.3	22.3	53.2	16.7	16.4	35.8
Maize	20,036	16,575	1.2	62.1	34.0	117.3	21.9	29.8	58.3	33.0	3.3	37.3
Yams	19,473	2,130	9.1	54.1	59.2	145.4	26.3	53.4	93.8	22.0	3.8	26.6
Sorghum	12,677	17,093	0.7	1.0	27.0	28.3	6.4	25.5	33.5	-5.1	1.2	-3.9
Millets	10,513	14,890	0.7	15.5	31.7	52.1	8.9	16.1	26.4	6.0	13.5	20.3
Rice, paddy	9,689	6,059	1.6	64.9	70.2	180.7	50.0	46.9	120.4	9.9	15.9	27.4
Sweetpotatoes	6,473	1,339	4.8	64.6	16.3	91.4	89.9	10.5	109.8	-13.3	5.3	-8.8
Bananas	5,533			49.0	30.8	94.9						
Groundnuts in shell	4,621	5,723	0.8	1.5	-8.9	-7.5	14.4	-15.8	-3.7	-11.2	8.3	-3.8
Potatoes	2,329	390	6.0	96.8	24.3	144.8	101.5	22.5	146.8	-2.3	1.5	-0.8
Wheat	2,121	1,376	1.5	44.3	62.4	134.2	-6.6	24.6	16.4	54.5	30.3	101.3
Beans, dry	1,671	2,497	0.7	56.9	12.4	76.4	37.6	16.4	60.2	14.0	-3.4	10.1
Tomatoes	1,469	167	8.8	82.5	61.0	193.9	91.2	43.4	174.3	-4.6	12.2	7.1
Barley	999	987	1.0	4.7	22.4	28.1	-14.6	19.2	1.8	22.7	2.6	25.9
Broad beans, dry	322	353	0.9	42.9	1.5	45.0	19.3	22.5	46.2	19.8	-17.2	-0.8
Soybeans	288	358	0.8	75.0	112.8	272.4	24.4	41.3	75.8	40.7	50.6	111.9
Chickpeas	179	300	0.6	-0.8	41.1	40.0	11.4	37.6	53.3	-10.9	2.5	-8.7
Cabbages	123	8	15.4	93.4	56.4	202.5	50.0	33.3	100.0	29.0	17.3	51.2
Lentils	34	62	0.6	7.0	-15.6	-9.7	-9.7	-17.4	-25.4	18.5	2.2	21.1

Source: FAO Basic Data Unit, unpublished statistics.
[a] 1 = (1975-77 vs 1961-63); 2 = (1989-91 vs 1975-77); 3 = (1989-91 vs 1961-63).

27,000 ha. In contrast, potato area in much of West and Southwest Africa remained extremely limited with the exception of Angola (6,000 ha), Nigeria (3,000 ha), Chad (2,500 ha), and the Cameroon (17,000 ha).[4]

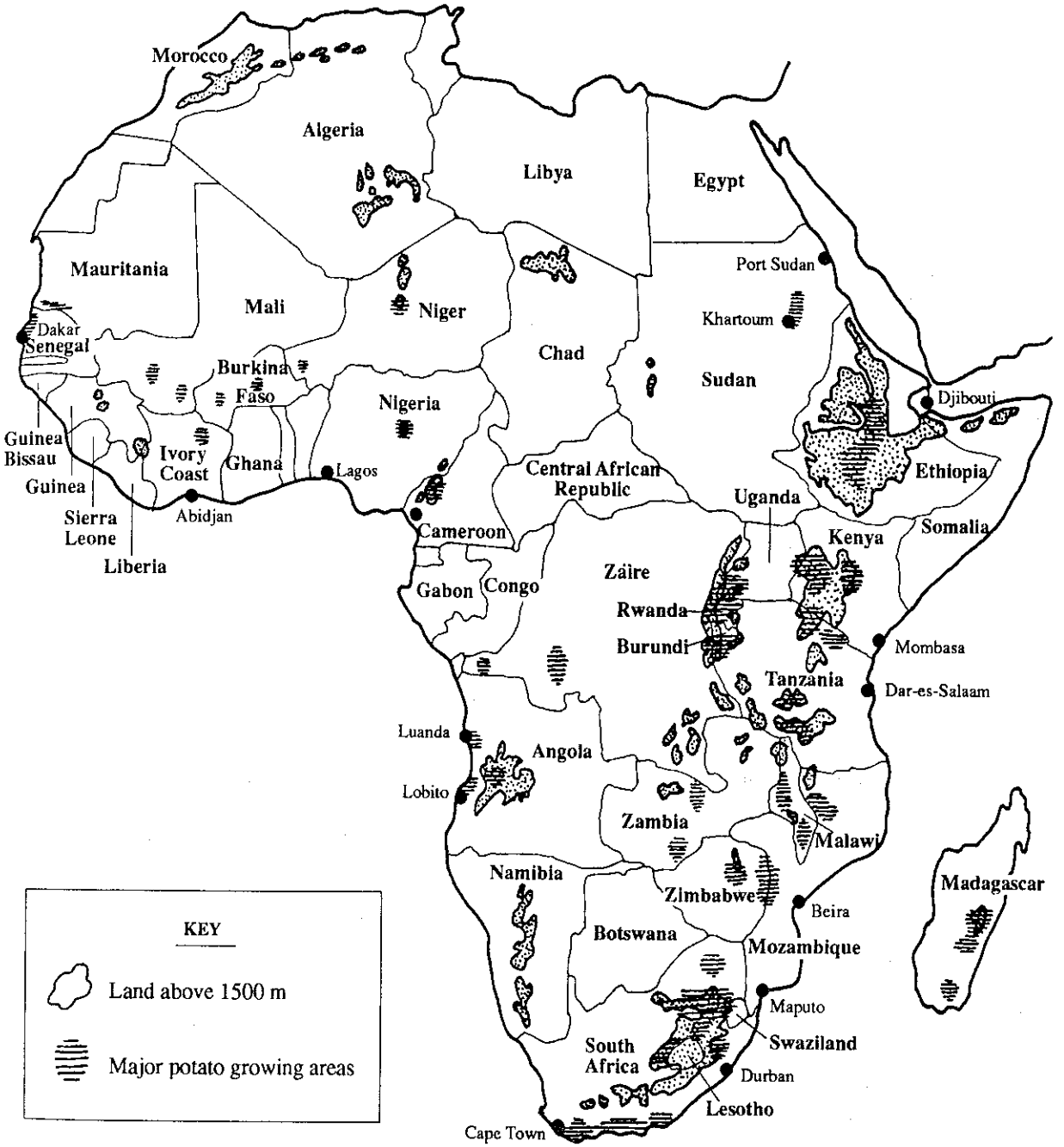
Population increases at higher altitudes, the potato's comparative advantage in terms of yield per hectare under highland agro-ecological conditions and its short vegetative cycle have been the principal contributing factors to expanded cultivation (Dürr and Lorenzl 1980; Rasolo et al. 1987; Scott 1988). Yields average about 6 t/ha across the continent (Horton 1988); however, they can reach twice that in the highlands of Ethiopia (Börgel et al. 1980) and as much as 30 t/ha in the volcanic region of northeast Rwanda (Vander Zaag et al. 1984).

Potato production in Sub-Saharan Africa is largely concentrated above 1,500 m. This includes the crest of the Zaïre/Nile Divide that runs through Burundi, Rwanda, and northeast Zaïre (Scott 1988) as well as the highland areas of Kenya (Dürr and Lorenzl 1980), Ethiopia (Börgel et al. 1980), Tanzania (Macha et al. 1984), Uganda, and Madagascar (Rasolo et al. 1987). In Cameroon, potatoes are cultivated in the western and northwestern provinces at 1,000 m and higher; similarly, in Nigeria, production is located on the Jos Plateau (1,200-1,400 m). Oases-like pockets of potato production are found at lower elevations in several countries (e.g. Chad, Mali, Mauritius, Niger), but high temperature, humidity and a shortage of irrigation water discourage more extensive cultivation.[5]

[4] 22 of the 47 countries in Sub-Saharan Africa produce less than 1,000 t of potatoes according to FAO figures.

[5] Information about potato production at lower altitudes is taken from Rhoades (n.d.).

Map 1. Major potato production areas in Sub-Saharan Africa.



Source: Based on Gutteridge (1983) with modifications from Ravuna (1991).

Table 2. Potato production, area, and yield in developing countries by regions, 1961-91.

	1989-91			Change (%)[a]								
	Production	Area	Yield	Production			Area			Yield		
	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
Africa[b]	5,925	657	9.0	86.7	73.4	223.8	97.9	41.3	179.6	-5.6	22.7	15.8
(Sub-Saharan)[c]	2,329	390	6.0	85.5	32.0	144.9	95.6	26.2	146.8	-5.2	4.6	-0.8
Asia[d]	62,192	4,825	12.9	89.9	63.8	210.9	42.7	47.1	110.0	33.0	11.3	48.1
(China)	32,887	2,885	11.4	88.5	35.1	154.8	42.0	41.7	101.2	32.8	-4.6	26.6
Latin America[e]	12,476	981	12.7	34.5	29.2	73.7	2.5	-6.3	-3.9	31.2	37.8	80.8
Total	80,593	6,463	12.5	76.0	57.9	177.8	34.8	34.8	81.8	30.6	17.1	52.8

Source: FAO Basic Data Unit, unpublished statistics.

[a] *1 = (1974-76 vs 1961-63); 2 = (1989-91 vs 1974-76); 3 = (1989-91 vs 1961-63).*

[b] *Africa not including South Africa.*

[c] *Africa - (Morocco, Algeria, Tunisia, Egypt, Libya) - (South Africa).*

[d] *Asia - (Israel, Japan) + Oceania - (Australia, New Zealand).*

[e] *North and Central America + South America - (Canada, USA).*

Rain-fed agriculture accounts for the vast majority of potatoes produced in Sub-Saharan Africa, although in many countries at least one planting relies on residual soil moisture or irrigation. Typically, potato cultivation is spread out over more than one period with dry season production occurring in moist bottom-land, along receded lake or river banks, or in locations where irrigation is available, e.g., small dams in Botswana, wells in Mali.

The vast majority of potato producers in Sub-Saharan Africa are small farmers. The typical household plants less than one ha per year. Moreover, production frequently consists of various plantings in separate plots for each of the growing seasons. Larger commercial farms have emerged in Kenya, Mauritius, Rwanda, Swaziland, Tanzania and Zimbabwe. In Zambia, virtually all of production is by large, commercial growers.

Differences in agro-ecological conditions, the extent of geographic isolation, and the supply and price of agricultural inputs mean that there is considerable variation in the type of technology utilized. As a general rule, however, potatoes are frequently intercropped, for example, with maize, beans, or sugar cane. Soil preparation, weeding, and harvesting are all done with hand tools, although draft animals are used by some growers in Ethiopia and Malawi. Tractor hire is a common practice in Kenya and Swaziland. Chemical fertilizers and, to a lesser extent, pesticides are used by some growers in several countries, but most farmers find that such modern inputs are unavailable or too expensive. In West Africa, growers often plant seed imports from Western Europe; while those in the southern tip of the continent use seed from South Africa. Seeding rates vary tremendously from 0.5 t to 3.0 t/ha in Zaïre.

Principal production constraints include the shortage, cost, and timely availability of good quality seed; diseases such as late blight and bacterial wilt; declining soil fertility (particularly in the mountainous areas of Central, East and southern Africa); and the limited resources of National Programs.

Marketing

Potatoes are often characterized as a "cash crop" by policy makers and interested observers in Sub-Saharan Africa. Evidence gathered in a number of countries suggest this statement is only partly true. While potato farmers typically sell at least some potatoes, the vast majority of growers in the principal potato-producing countries utilize the largest share of the harvest for on-farm consumption and seed. For example, Burundese growers sell about 10% of the potatoes that they produce (Ndmira and Christensen 1983). Potato producers in Rwanda and Zaïre sell approximately 45% and 25% of total output (Scott 1988); in Madagascar and Kenya, they sell roughly 35% of annual production (Dürr and Lorenzl 1980; Rasolo et al. 1987). In countries of West (e.g., Senegal, Burkina Faso, Chad) and Southern Africa (e.g., Botswana, Zambia) that produce minor quantities of potatoes, production is highly market-oriented. Nevertheless, the limited information available indicates that even in these locations many growers also eat potatoes (Rhoades n.d.).

Table 3. Potato production in Sub-Saharan Africa, 1961-91.

	1989-91			Change (%)[a]								
	Production	Area	Yield	Production			Area			Yield		
	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
Africa Sub-Sahara[b]	2,329	390	6.0	96.8	24.3	144.8	101.5	22.5	146.8	-2.3	1.5	-0.8
Ethiopia	380	48	8.0	32.7	35.7	80.1	32.9	36.2	81.0	-0.2	-0.4	-0.5
Malawi	335	87	3.9	303.2	34.0	440.3	254.8	18.6	320.9	13.7	12.9	28.4
Madagascar	272	40	6.9	62.3	102.0	227.7	85.7	83.1	239.9	-12.6	10.3	-3.6
Kenya	257	51	5.1	74.3	-24.1	32.2	70.8	8.6	85.4	2.1	-30.1	-28.7
Uganda	244	35	7.0	160.3	-12.2	128.4	234.2	-10.3	199.9	-22.1	-2.2	-23.8
Rwanda	240	35	6.8	109.7	44.7	203.4	20.6	38.2	66.7	73.9	4.7	82.0
Tanzania	227	33	6.9	513.1	109.2	1182.8	288.0	50.0	482.0	58.0	39.5	120.4
Mozambique	69	6	11.4	229.8	68.8	456.9	124.7	0.0	124.7	46.8	68.8	147.8
Nigeria	42	3	14.0	59.6	38.5	121.1	0.0	50.0	50.0	59.6	-7.7	47.4
Angola	40	6	6.7	94.6	12.1	118.2	45.2	12.6	63.5	34.0	-0.4	33.5
Zaire	33	7	4.5	98.0	1.0	99.9	100.0	22.2	144.3	-1.0	-17.3	-18.2
Burundi	32	10	3.2	36.3	-30.2	-4.9	32.1	-9.1	20.0	3.2	-23.2	-20.8
Cameroon	32	17	1.9	66.7	-20.8	32.0	95.6	13.3	121.6	-14.8	-30.1	-40.5
Zimbabwe	31	2	15.5	1.5	40.9	43.1	-16.5	19.8	0.0	21.6	17.7	43.1
Sub-total	2,233	379	5.9	100.6	23.8	148.4	101.3	22.3	146.1	-0.4	1.3	0.9
Others	96	11	9.0	34.9	37.3	85.2	92.4	28.1	146.4	-29.9	7.2	-24.8

Source: FAO Basic Data Unit, unpublished statistics.

[a] *1 = (1975-77 vs 1961-63); 2 = (1989-91 vs 1975-77); 3 = (1989-91 vs 1961-63).*

[b] *Africa - (Morocco, Algeria, Tunisia, Egypt, Libya) - (South Africa).*

During 1988-90, 28 countries in Sub-Saharan Africa imported some 70,000 t of potatoes annually with a total value of US$ 27 million (FAO 1990).[6] Two-thirds of these potatoes were imported by only six countries (Senegal, Côte d'Ivoire, Botswana, Angola, Mauritius, and Mauritania). Another 22 countries imported 0.1 t to 4.0 t each. Scattered facts suggest that the bulk of these imports consisted of seed with the Netherlands, United Kingdom (Scotland), and France serving as the principal sources of supply (Gutteridge 1983).

Exports of potatoes totaled 3,500 t at a value of US$ 0.9 million during the same period. Nearly all these exports were made by four countries (Ethiopia, Botswana, Kenya, and Cameroon). Several other countries (e.g., Rwanda, Zaïre, Zambia) are involved in exporting potatoes but, given the modest size of these shipments, they may not always be recorded in official statistics (see Scott 1988; Scott and Muvira 1991). Burundi, Madagascar, and Mauritius—among others—have expressed interest in expanding potato exports. However, freight rates, handling losses, unit costs of production, phytosanitary restrictions, and the absence of straightforward regulations governing foreign trade in potatoes discourage this type of commerce (Gutteridge 1983).

Potato sales are an important source of cash income for African growers. Potatoes are often found in major urban markets across the continent partly for that reason. Nevertheless, in the principal potato producing countries, it appears that the sum total of tubers sold in rural markets is far superior to that sold in cities and towns. Demography, the physiology of the crop and existing marketing infrastructure are the principal rea-

[6] According to FAO data, potato imports for these countries totaled 59,000 t valued at US$6.1 million in 1970-72.

sons. Unlike Latin America, for example, the overwhelming majority of the population in Sub-Saharan Africa lives in rural areas.[7] The potato's bulkiness and perishability combined with poor rural road networks discourage rural-urban trade, whereas rural demand provides a ready outlet for available surpluses. In much of West Africa and in countries such as Botswana and Zambia on the southern tip of the continent, however, potatoes are grown largely if not exclusively for nearby urban markets (see Rhoades n.d.).

Potato marketing is not characterized by a rigid division of labor (Fig. 1). The small volumes handled by most traders—a few 100 kg a week—preclude specialization. Wholesalers exist only in major urban markets like Kigali, Nairobi, Antananarivo, and Kinshasa. Trucker/traders are key marketing agents in a number of countries (e.g., Burundi, Kenya, and Madagascar) in large part because they provide a transportation/commercial link between geographically isolated growing areas and major market centers. Producer marketing organizations have also emerged in several countries (e.g., Burundi, Rwanda, Zaïre, Zimbabwe), but they have had mixed success at best. The tendency has been to overestimate the profits and underestimate the logistical/financial problems associated with private trade in a perishable commodity like potatoes (see, e.g., Scott 1988).

Potato marketing tends to be informal throughout the region. Potatoes typically are sold with minimal grading, although high income, urban consumers frequently require a more uniform, attractive product (and package). Negotiations are generally done at the time and place of sale. Sales are almost always for cash—though barter is not uncommon in the more isolated growing areas—and without any receipt. Packages vary in form and size from 15 kg bamboo boxes (Zaïre) to 50 kg baskets (Rwanda), to 84 (Kenya) and 100 kg (Burundi) sacks. In Cameroon, potatoes are sold in bags that weigh from 10 to 100 kg.

Governments participation on potato marketing is minimal.[8] In fact, government regulation of the sale of substitute crops in Burundi and Madagascar has encouraged switching into potato production according to World Bank observers. Potato prices are set by supply and demand.[9] However, local authorities frequently impose an assortment of taxes on marketing participants. Trading permits are also often required. Import/export regulations are difficult to enforce due to long, open borders between countries.

The limited information about potato prices and marketing margins indicate that annual and within-year price fluctuations appear largely to reflect supply and demand conditions (see Scott 1988; Dürr and Lorenzl 1980; Börgel et al. 1980; Loveridge 1988). However, within-year price movements have been erratic in some instances, e.g., in Rwanda potato prices rose during certain months in some years and declined in others (see Dürr 1983). Spatial price comparisons indicate greater integration between major urban markets than between small, rural markets (see, e.g., Ndimira and Christensen 1983; Bergen 1984).

Sharp seasonal price movements, the high cost of transportation, and the potato's perishability have generated interest in processing in a number of countries including Cameroon (Diop and Mbakwa 1991), Kenya (Kabira 1990), Madagascar (Rasolo et al. 1987), Mauritius (Wong Yen Cheong et al. 1991), and Zaïre (Ravuna 1990). Meager available information suggests that with few exceptions, e.g., a potato chip plant in Malawi with a capacity of 800 t/yr of raw material (Gondwe 1986) and similar operations in Kenya (Dürr and Lorenzl 1980), and Zimbabwe (Joyce 1986), industrial potato processing remains negligible. Efforts in Kenya in the early 1980s to introduce intermediate-scale processing to produce dehydrated mashed potatoes proved uneconomical (Kabira 1989).

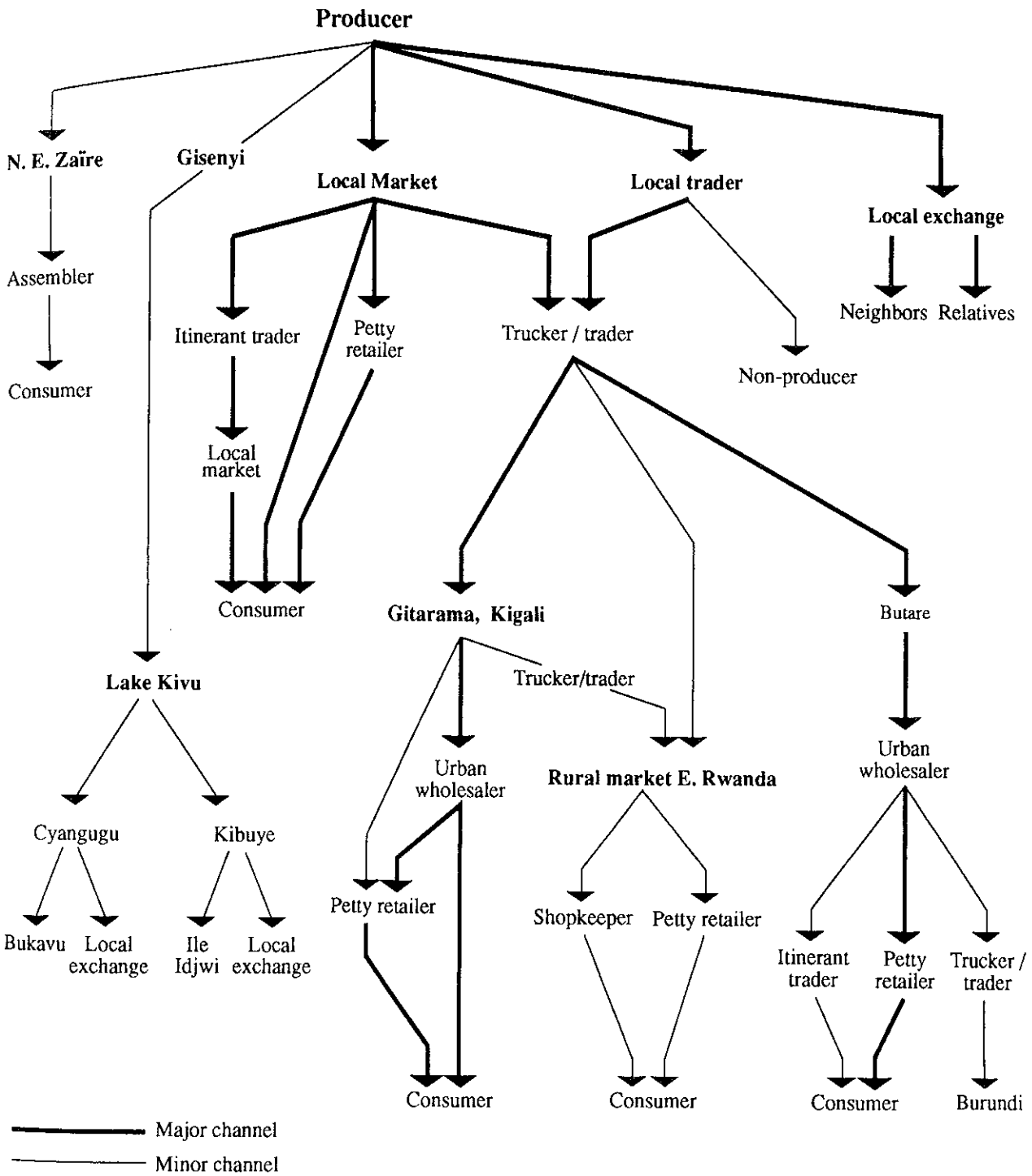
Recent research in Kenya using small-scale units to make potato flour appears promising, but only in competition with alternative flours such as cassava. Maize and wheat flour are 20-60% cheaper than flour made from solar dried potatoes (Kabira 1990:235). A feasibility study for establishing small-scale, solar drying units for potatoes in North Kivu, Zaïre, also showed positive results, but for the moment work remains at the experimental stage (Ravuna 1990). While a number of other countries have tested the technical viability of small-scale solar drying of potatoes including Cameroon, Ethiopia, and Sudan, the high cost of the raw material

[7] In Burundi, Rwanda, and Zaïre (Scott 1988) and Madagascar (Rasolo et al. 1987), potato production tends to be concentrated in those rural areas with the highest population densities.

[8] In a number of countries, potatoes have been or are currently marketed through government parastatals or marketing boards (e.g., Benin, Botswana, Lesotho, Mauritius, Tanzania).

[9] Notable exceptions to this rule are the National Produce Marketing Corporation in Lesotho that sets prices (see Rhoades n.d.) and the Potato Marketing Board in Mauritius that pays a guaranteed price until storage capacity is filled (Govinden and Chong 1989).

Figure 1. Principal marketing channels for potatoes in Rwanda.



Source: Scott 1988.

combined with the value added from processing restricts potential sales to a relatively small niche in the market for dehydrated food products.

Less is known about the cottage industries that have sprung up in nearly all the major potato producing countries to supply potato chips or french fries to urban consumers in rapidly growing metropolitan areas where the African equivalent of a fast food industry has become increasingly apparent. The number of restaurants and snack bars that serve french fries in Bujumbura, for example, has expanded considerably since the early 1980s in spite of the relatively high price of potatoes (Scott and Muvira 1991). This type of processing merits closer attention in future research, although improving the availability of potatoes in rural areas, where the vast majority of African consumers live, deserves top priority. Work on storage is frequently mentioned in this regard.

Improvements in on-farm storage have been the focus of considerable effort in Kenya and to a lesser extent in Burundi, Rwanda, Madagascar, Ethiopia, and Cameroon. These activities have focused on three areas: improved ware (table potato) storage; improved seed storage; and evaluation of clonal material for good storage characteristics. Many African farmers store table potatoes in the ground in the form of multiple cropping, staggered planting (Nyangitu 1986), periodic harvesting from the same plant —especially in N. Kivu, Zaïre (Scott 1988), and delayed digging of entire plants (Börgel et al. 1980:86). Rainfall and temperature requirements allow multiple-cropping to serve as a strategy to permit consumption/sale of fresh potatoes over several months, if not the entire year. As growers typically divide production for any given cropping period into the cultivation of several plots, staggered planting is an alternative way of stretching the availability of potatoes. Harvesting the most mature tubers and leaving the smaller tuberlets in the ground for several weeks or months is another practice. Depending on weather conditions, prices, or availability of other food stocks, potatoes may also be left in the field as soil conditions, insect populations, and planting dates for subsequent crops permit. Ware storage after harvest for more than a few days typically consists of small quantities of potatoes being kept either on the farm in low-cost structures/containers made for this purpose, in the farmhouse itself, or in pits (Dürr and Lorenzl 1980). Both rural and urban traders will also keep potatoes, but usually just a few days to accumulate enough tubers for a major shipment or until the stock on hand has been sold. Unlike South Asia where millions of tons of potatoes are kept in refrigerated cold stores (Srivastava 1980; Scott 1988a), potato storage in Africa is done, with few exceptions (Govinden and Chong 1989), under rustic conditions.

Growers receive about 40% of the retail price in the capital cities of Burundi, Rwanda, and Madagascar (Scott 1988; Rasolo et al.1987). They receive less than 10% of the consumer price in Zaïre.[10] The largest margins are received by petty retailers in Burundi (13.5%) and Kenya (20-39%); trucker/traders in Rwanda (29%) and Madagascar (33%); and air freight companies in Zaïre (34%). Although the available evidence is thin, these margins appear to reflect the limited physical infrastructure and formal financial support for such activities available in each of the countries, the small volumes marketed by most traders, and the risks associated with buying and selling a perishable product like potatoes.

Principal marketing constraints include the shortage of market information; the poor, rural road network—especially in Madagascar; limited physical infrastructure in markets themselves; scarce public credit for small-scale marketing ventures; weak post-harvest extension; and poor-quality seed material.

Highly dispersed, rural settlement patterns are a special challenge in Burundi, Kenya, and Rwanda. Potato marketing in southern Tanzania is handicapped by the geographic isolation of growers from major markets at home or abroad. Poor seed material and multiple, often premature, harvests are also important marketing constraints in a number of countries (e.g., Zaïre).

Consumption

Potatoes have been eaten in parts of Sub-Saharan Africa for over a century, although consumption began to accelerate most rapidly in the last several decades. Potatoes currently comprise a minor portion of the average daily intake of calories across the continent. However, they are a much more important component of regular food intake in the potato-producing regions of Central, East, and parts of Southern Africa. Furthermore, in several countries, e.g., Burundi, Madagascar, potatoes sustain household food stocks before the harvest of basic staples.

[10]The estimates of the growers' share of the retail price range between 24% and 70% in Ethipia (see Borgel et al. 1980:123-141).

Annual per capital consumption ranges from 2 kg in Burundi and 4 kg in Zaïre to nearly 50 kg in Rwanda, with major potato-producing countries such as Cameroon, Kenya, Madagascar, Tanzania, and Uganda between 15 and 25 kg/year. These averages mark considerable variation within each country. For example, Durr's survey of five potato producing areas in Kenya resulted in an estimated consumption of 116 kg/yr (Dürr and Lorenzl 1980). Poat's pilot consumption study in Rwanda found some producer households in the volcanic region eating over 300 kg/yr (Poats 1981). Pockets of high potato consumption also exist in other potato production centers such as North Kivu, Zaïre, the Vakinankaratra region of Madagascar, and the Western and Northwestern provinces of Cameroon.

In the principal potato producing countries, potatoes are consumed by a much broader segment of the population than is generally believed. In addition to rural households that produce the tuber, wealthy, local, urban consumers and resident expatriates also eat potatoes. Low-income consumers eat some potatoes as well but can only afford to do so on special occasions. Urban consumption is more widespread in places like Rwanda because recent production increases and new roads have lowered the price of potatoes in major cities and towns. In much of West Africa and in the southern end of the continent, potato consumption is largely confined to the wealthy, urban elite. High prices for potatoes discourages more widespread use.

Most African consumers like the taste of potatoes. In the highlands of Central Africa, they especially like tubers with a high dry-matter content. Preferences for a particular size, color, or shape of tuber are not pronounced in Burundi, but have begun to emerge in certain markets in Rwanda. In Kenya, a distinct preference exists for red-skinned potatoes (Dürr and Lorenzl 1980). In Burkina Faso, white or yellow-skinned tubers are preferred (Rhoades n.d.). Grading and appearance are important only among the urban elite and expatriate consumers. Potatoes are typically boiled in rural households and served as french fries in urban restaurants and hotels. Potatoes are not used for industrial processing, animal feed or in the preparation of packaged food products with the exception of cottage industry preparation and sale of potato chips (see, e.g., Rasolo et al. 1987). The principal reasons for this are the costs and logistical problems associated with rural assembly from numerous, highly dispersed, small farms; the absence of varieties ideally suited for processing; the shortage of basic industrial infrastructure in rural areas; and the availability of cheap substitutes.

Principal consumption constraints are the potato's availability, particularly far from the main production centers, and its high price relative to other foods in urban markets. In addition, many consumers, especially those in rural areas far from potato growing regions, rarely see potato; hence they are not familiar with its culinary and nutritional attributes.

Future Prospects

Recent trends in potato production, marketing and consumption in Sub-Saharan Africa suggest two distinct scenarios for the crop. In the principal potato producing countries of East (Ethiopia, Kenya, Tanzania, Uganda), Southern (Madagascar, Malawi), and Central Africa (Rwanda), potato output has risen sharply in the last two decades. Practically all of this increase has been due to expansion in area planted, rather than increases in yields (Table 3). The limited evidence suggests further that the biggest increases have come in those ecological niches most ideally suited to potato production (see, e.g., Scott 1988). As good quality seed and improved agronomic practices are introduced into more marginal areas, the resulting rate of increase in production is likely to be lower. Hence, renewed efforts for technological improvements in the more favored growing areas will be required if the increase in potato production is to keep pace with the accelerating growth in food requirements. In that regard, greater attention might be given to minimum input packages as many farmers use little, if any, chemical fertilizer and pesticides.

One additional way to promote continued, and perhaps even faster, growth in available surpluses for either on-farm use or sale is improvements in postharvest technology and marketing. In fact, storage losses resulting in shortage and high prices have been noted in a number of countries including Cameroon (Toet 1982), Ethiopia (Börgel et al. 1980), Kenya (Dürr and Lorenzl 1980), and Madagascar (Rabakoarihanta and Rakotondramanana 1984). While several countries have built modern stores in an attempt to overcome this constraint, these structures often have been underutilized or simply left idle (see Rhoades n.d.). Coursey (1982) argues that considerable potential exists for improving existing traditional storage practices. However, since many small farmers sell their potatoes at harvest because they need cash for household necessities or to finance a subsequent crop, the creative fusion of traditional technology and modern science will require the added catalyst of improved market information and credit if it is to have impact. Similarly, rather than blame middlemen for periodic gluts and shortages, potato pro-

gram leaders would do well to encourage policy makers to provide the private sector—that includes many growers who sell their own potatoes—with the types of incentives mentioned above so as to alleviate potato marketing problems.

Policy makers in many of these countries frequently express concern over who will eat these potatoes as well as the future demand for this commodity should additional surpluses be forthcoming as a result of introducing yield-increasing, improved technology. They need only to be reminded, perhaps, that population growth rates in the principal potato producing countries are all over 3% with those in Kenya (3.9%), Malawi (3.5%) and Rwanda (3.8%) considerably higher. Furthermore, the very small number of detailed studies indicate a strong correlation between rising incomes and the demand for potatoes amongst low-income households in both urban and rural areas (see Dürr and Lorenzl, 1980; Von Braun et al. 1991).

Thus, temporary gluts that develop due to bumper crops, particularly in certain areas where new technologies are introduced or commercial potato production emerges, should not distract policy makers and program leaders from the urgent task of sustaining increases in food production in the medium- and long-term. Nor should biological scientists underestimate the future demand for improved technology. The convergence of population expansion and shrinking agricultural frontier in many of these countries is already generating pressure on rural households to improve productivity and incomes so as to maintain existing living standards. Program leaders may be in a better position to secure resources to meet this challenge to the extent that they are capable of marshaling the available information to support their claim for additional potato research.

The situation in many of the other potato producing countries in Sub-Saharan Africa is somewhat different. Potato production is largely a garden crop grown for sale to local urban consumers in much of West Africa and parts of the southern end of the continent (e.g., Botswana). In the arid and semi-arid countries, the expansion of irrigation facilities will be a key determinant in the expansion of potato production. Another will be efforts to introduce low-cost seed material adapted to prevailing agro-climatic conditions. Recent developments in rapid multiplication offer some promise here. Given the costs and risks associated with potato production, several observers have suggested an assessment of market requirements would be highly worthwhile (see Waldstein 1983; Reust, 1987). Potatoes do have certain advantages over other vegetables, (e.g., they are less perishable and travel better) that should favor their production over other crops.

Urbanization in West and Southern Africa is proceeding at a breakneck pace. Moreover, potatoes are considered a high-status, luxury food in all of these countries. Hence, the extent to which they can be made available at a more modest price, through lowering unit production cost and improved marketing practices, is likely to result in rapid increases in consumption.

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III. Assessment of Processing Potential

Perhaps the most critical stage in all of product development concerns the initial evaluation of different possible products and processes. The most appropriate region or area to begin such work and the final market to be targeted are among the principal questions that need to be answered. Often this task is all the more intimidating because little information of this nature is readily available for root and tuber crops in most developing countries. Furthermore, once a decision is made, the resources available must be concentrated on the development of the most promising alternative. Under such circumstances, a user-friendly approach to identify the product or process with the greatest potential can considerably enhance the chances of success.

This section addresses the issues of market, technical, political and social potential for product development for root and tuber crops in two ways. First, it presents a framework for conducting such assessments. Second, examples of work done in a number of countries provide an indication of what such assessments entail.

As Christopher Wheatley and Gregory J. Scott point out in **Identification of Product Opportunities**, options for processing and marketing products made from roots and tubers often are more numerous than initially realized. They go on to present a systematic approach to opportunity identification considered to be thorough, yet inexpensive and designed for rapid generation of results. Their paper includes an inventory of possible processed products and a checklist for helping to determine those with the greatest potential. An abbreviated version of an evaluation of potato processing in India illustrates the application of the procedure.

Cassava serves as a staple food for roughly 160 million people in sub-Saharan Africa. It is most frequently consumed in processed form. In **Traditional Cassava Processing in Sub-Saharan Africa and Research Implications**, Felix I. Nweke describes the wide variety of processed products that are made from cassava in different countries. By utilizing results of the Collaborative Study of Cassava in Africa (COSCA) country surveys, he then estimates that about 70% of total cassava root production is processed. He also goes on to note that labor—not water or fuelwood—constitutes the principal constraint to traditional cassava processing.

Given the importance of cassava in diets in sub-Saharan Africa and that most cassava consumed is eaten in processed form, one specific objective of the first phase of the COSCA study was to quantitatively and qualitatively characterize the nature and distribution of cassava processing systems. In **COSCA Phase I Processing Component**, researchers at the Natural

Resources Institute (NRI) clarify the relative importance of basic product types (e.g., flour, roasted granules) based on results from detailed surveys in six African countries: Côte d'Ivoire, Ghana, Nigeria, Tanzania, Uganda, and Zaïre. They then go on to identify (both common and divergent) patterns in cassava processing as regards seasonality, gender, mechanization, fuel use, and fermentation comparing survey results across countries, e.g., West African countries possess the most mechanized processing systems.

In Africa, before cassava is consumed as human food it is frequently processed to eliminate the toxic effects of the cyanogenic glucoides present in the roots and to convert the highly perishable commodity into a storable and soluble product. Cassava processing is essentially a manual operation. Based on survey results in six different countries (see above) that formed part of the Collaborative Study of Cassava in Africa (COSCA) project, B.O. Ugwu and P. Ay analyze the **Seasonality of Cassava Processing in Africa and Tests of Hypotheses**. They begin by providing a list of 80 different cassava products that they categorize into nine different product types (e.g., cooked cassava, cassava flour, roasted granules). Ugwu and Ay then go on to examine the gender role in cassava processing. Among their principal findings are that men are seldom involved in cassava processing operations; however, as mechanical processing equipment is acquired, men's participation in cassava processing tends to increase.

Cassava and cocoyam production in Nigeria is dominated by small-scale operators. In **Technological Change and the Economics of Product Development in Cassava and Cocoyam in Nigeria**, N.O.A. Ezeh, O.B. Arene, S.O. Odurukwe and L.S.O. Ene initially provide an overview of statistics on area planted and productivity for root and tuber crops. They then briefly describe the root crop products developed by the National Root Crops Research Institute (NRCRI). Technical and commercial aspects of cassava root meal as an input in poultry feed formulations are treated next. Cocoyam soup thickener is analyzed in similar fashion. While both types of products show real promise, their further development is handicapped by a shortage of funds to support research and extension efforts.

Although sweetpotato has been a food security, famine prevention crop in many developing countries for centuries, its nutritional properties and potential contribution to diets have only begun to be studied and documented. In **Sweetpotato - A Versatile and Nutritious Food for All**, Jennifer Woolfe analyzes the nutritional content of sweetpotato roots and leaves in both cooked (fresh) and processed form. Her results indicate a remarkable richness in terms of not just calories but also vitamins and proteins. She then goes on to describe a variety of processed products that might well serve to help expand consumption of sweetpotato particularly in Sub-Saharan Africa.

Research into storage and processing is probably the single most important contribution that can be made to the expansion of sweetpotato utilization in Rwanda. In **Product Development for Sweetpotato in Rwanda**, David G. Tardif-Douglin points out that both underground and mound storage technologies appear technically feasible. Solar dried sweetpotato chips for milling into flour also appear promising according to Tardif-Douglin's cost estimates. Storage and processing research therefore merit closer attention in the future development of the sweetpotato sector.

Although sweetpotato has long been eaten as a subsistence crop by producers in rural areas, relatively little is known about **Consumer Demand for Sweetpotatoes in Dar es Salaam, Tanzania**. Nevertheless, as Gabriel T. Ndunguru explains, consumption of sweetpotato appears to have risen with the increasing number of street vendors operating in the city. He argues that

this indicates that the crop has high potential for commercial expansion. Results of the survey conducted by the author indicate that 97% of the households (n=303) interviewed eat sweetpotato roots, while 84% consume the leaves. He estimates that annual availability of the roots is only 40% of total demand suggesting ample opportunity to increase sales. In that regard, Ndunguru recommends, among other things, the weekly broadcast of sweetpotato prices so as to make growers aware of the market opportunities available for sweetpotato in Dar es Salaam.

In **A Rapid Appraisal of Sweetpotato Marketing in Uganda**, M. H. Fowler and A. M. Stabrawa provide a concise review of recent production trends before describing postharvest activities. Census data indicate, for example, that sweetpotato is the third most important food crop in terms of total production on a fresh weight basis after cassava and bananas. Sweetpotato is mainly consumed fresh either boiled or steamed. Storage is typically done by delayed harvest. Farmers, rural traders including small-scale retailers, urban wholesalers and retailers are the typical market participants. Lack of or unpredictable markets, transport, perishability as well as poor storage and market facilities constitute the principal constraints to expanded commercialization of sweetpotato in Uganda.

Identification of Product Opportunities

Christopher Wheatley and Gregory J. Scott[1]

Abstract

Options for processing and marketing products made from roots and tubers often are more numerous than initially realized. This paper reviews the potential objectives, participants, constraints, and opportunities involved with alternative forms of product development for the purposes of determining those with the greatest probability of success. An inventory of possible processed products is presented. The technical aspects of some basic processing operations are reviewed. An initial checklist for final screening of products is described. The paper concludes with an illustratory evaluation of village-level potato processing in India.

Key words: product opportunities; processed products; processing techniques; procedures for evaluation.

Introduction

This paper presents methods used to generate and evaluate ideas for new or improved products from root and tuber crops. It deals with how the objectives and constraints of such projects affect the choices made, describes the product possibilities and process options available, and presents a checklist for gathering the information used to select the best option from a range of product ideas. The overriding theme is the importance of the market and consumer in the product development process; in other words, the technical aspects of the exercise cannot be carried out in isolation from the real world.

Definition of Objectives

Before considering which products made from root and tuber crops can be taken through the product development process, it is necessary to define the objectives of the exercise clearly. This is important because product development is, almost by definition, something that involves a number of actors—from farmers to research scientists. It is important that there be some overlap in the objectives of the participants; otherwise, the project is certainly doomed. Three basic types of organizations, each with its own set of objectives, can be identified as national research institutions, local development and extension agencies and farmer groups, and commercial enterprises.

National Research Institutions

Their objectives are to provide solutions to priority problems at a national level, as determined by the government. Examples of these objectives include:

- generate foreign exchange earnings;
- substitute imports;
- slow migration to urban centers;
- increase small farmer incomes;
- develop specific regions;
- improve nutritional status of population; and,
- reduce costs of basic foods (control inflation).

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Local Development and Extension Agencies and Farmer Groups

The objectives of these groups are focused on a particular region or province of a country. They attempt to provide solutions to problems directly affecting the local target population groups; some examples of problems are:

- increase incomes of small farmers;
- provide employment for landless laborers;
- improve markets for traditional crops;
- improve nutrition of rural and/or urban populations;
- improve market efficiency/reduce losses;
- protect environment: control erosion, reduce pollution, etc.; and,
- improve the position of women in agriculture.

Commercial Enterprises

Although the prime objective of a private company in developing products using root and tuber crops is undoubtedly commercial, such firms are also interested in long-term profitability. This implies a concern for the local environment and community, which provides scope for interest in social welfare objectives.

Many of the objectives of these different actors do overlap. For example, provision of employment for landless laborers will slow migration to urban centers. However, the importance given different objectives may vary and could be a source of conflict. If the overriding national priority is the generation of foreign exchange, this may be difficult to reconcile with a development emphasis on small farmers and appropriate processes. It is important for all participants to agree on the main objectives; differences in emphasis and focus can usually be accommodated. The various institutional agendas must therefore be made explicit, for hidden agendas can cause friction later in the process.

Project Assumptions and Constraints

In addition to the objectives of each institution involved in a product development project, the constraints facing each may also play a decisive role in determining the type of projects undertaken. Constraints can exist in the following areas.

Institutional Mandate

- Crop/raw material used (e.g., cassava or sweetpotatoes only).
- Type of processing organization (cooperative, small business).
- Farm size (<20 ha).
- Location (specific province, watershed, irrigation district, etc.).

Financial Constraints of the Institution

- Research facilities available.
- Technical expertise available.
- Cost of research project.
- Process scale.

Financial Constraints of the Farmers and Processes

- Capital investment required.
- Credit availability and conditions.
- Technical complexity of process.

Legal Constraints

- Compliance with government regulations for product nutritional or sanitary standards.
- Licensing requirements.

Certain institutional assumptions are made on the basis of an analysis of these constraints; and, it is important that these also be made explicit from the start of the project. It is possible that some of these constraints can be removed at a later date; for example, an externally funded research project could provide the needed research equipment. Making these constraints explicit at an early stage will help to clarify which market and technological options fall within the framework of manageable solutions to the problems and opportunities presented.

Identification of Market and Technical Opportunities

Based on a clear definition of the problems to be overcome and the constraints that are present during this process, a search for possible product options based on market and technical opportunities can be initiated. These ideas are then screened according to criteria based on project constraints and market- and process-related factors important to the project's success.

In order to identify a range of possible market opportunities for root and tuber crops, the present status and future trends in society's use of food, feed, and other industrial products should be known. Demographic changes over the last 30 years or more have resulted not only in dramatic population increases in many developing countries but also in an ever greater concentration of this population in large, urban centers. In Latin America over 75% of the population resides in urban areas, compared to 30% and 35% in Asia and Africa, respectively. The growth rates of urban areas in Africa are especially high. The combination of migration and urbanization has often led to dramatic changes in food consumption habits due to the more diverse number of foods available in an urban environment. Income increases associated with a move to urban areas can also lead to dietary changes. These changes have often adversely affected root and tuber crops, whose bulky, perishable nature is not well suited to transport and marketing in urban situations. Traditional foodstuffs have therefore tended to lose out to more convenient, non-traditional foods, especially where government subsidies for certain cereals and indiscriminate food aid have artificially reduced the price of imported goods. Nevertheless, this process has led to the development of a local food industry in many countries.

Many governments are now reducing subsidies on foodstuffs and agricultural inputs, and it can be expected that market competition will increasingly be allowed to develop in the food and agricultural sectors of developing countries. Therefore, the withdrawal of subsidies to other crops may provide an opportunity for root and tuber crops to enter into the food industry as a locally available source of starch, protein, and vitamins. The challenge is to foster the use of such raw materials by the local food industry, which developed using other, frequently imported, raw materials.

As incomes increase, consumption of animal products also increases. The poultry and pork industries in many countries have shown rapid growth rates. An opportunity exists for root and tuber crops to become an accepted carbohydrate source for a range of animal feeds. This has happened in the case of cassava exported from Southeast Asia to Europe; but, with one or two exceptions (e.g., China), has yet to develop on a large scale in the animal feed industries of tropical countries. Root and tuber crops are used for animal feed in many traditional on-farm feeding systems, especially fresh or ensiled roots, but the increasing intensification and use of purchased feedstuffs will necessitate the use of processed (dried) root and tuber products.

Finally, a range of opportunities exists in non-food industries—for example, textiles, paper, glue, and plywood—which currently use other sources of starch or flour. In Ecuador and Peru, heavy subsidies on imported wheat flour resulted in its use in plywood manufacture as it was the cheapest available flour. This is now declining as subsidies have been withdrawn.

Information required to identify market opportunities often can be obtained using secondary sources. For a specific country or region, the following topics and sources can be considered.

Crop production, yield. Food and Agriculture Organization of the United Nations (FAO); Ministry of Agriculture; regional rural development agency; extension workers; and, growers associations.

Food, feed, and other industries. Chambers of commerce; associations of flour millers; cereal producers; poultry, egg, swine, and cattle producers; animal feed companies, etc.

Consumer information. Census data; household expenditure, food and nutrition surveys of major cities (ministries of planning, agriculture, etc., universities); quick surveys of products available in major shops and supermarkets give a good idea of products currently being made, raw materials used, and the existence of gaps in the market.

Technical Opportunities

The market characteristics outlined above help identify possible areas where root and tuber crops could be used. These must be checked against the technological possibilities of each crop, and the current processes used to transform them. A list of possible products is shown in Table 1.

A wide range of processes are also used to make the different products. Since some processes may be inappropriate in certain situations, summaries only are given in the table.

Table 1. List of possible products using root and tuber crops.

Fresh roots, human consumption: Traditional product improved and value-added by:
- Grade and clean to produce high quality
- Package to increase shelf life
- Pre-peel, to give convenient, fresh prepared product (cold store)
- Chemical treatment to prevent microbial deterioration

Fresh roots, animal feed:
- Non-commercial fresh roots left over from fresh market
- Fresh roots, as main product
- Fresh boiled roots (removes anti-nutritional factor)
- Ensiled roots for use out of usual harvest period

Fresh leaves:
- Human consumption, vegetable
- Fresh or ensiled leaves, animal feed

Fried products:
- Chips, crisps
- Add flavorings

Dehydrated products:
- Sun dried, traditional products (chips, root pieces, slices)
- Flakes, granules, cubes (convenience foods)
- Chips for animal feed
- Leaf meal for animal feed

Flour used as raw material in food industry for:
- Bakery products
- Soup, sauce bases
- Processed meats
- *Pastas*, noodles
- Beverage bases

Flour used in other industries (quality specifications differ):
- Glue and plywood
- Raw material for animal feed rations (flour or pellets)

Starch used in traditional food products and by food industry:
- As for flour, in many products
- As feedstock for derived products (glucose, alcohol, etc.)

Starch also used by other industries:
- Textile
- Paper
- Animal feed (especially fish, shrimp)

Fermented products:
- Whole root; e.g., *tape* (Indonesia)
- Starch; e.g., *almidón agrio* (Colombia), *polvilho azedo* (Brazil)
- Flour; e.g., *gari* (Nigeria)

Frozen:
- Root pieces, often parboiled
- *Purée*

Vacuum packed:
- Root pieces, parboiled and sterilized

Canned:
- Root pieces
- Leaves

Bottled products:
- Jams
- Sauces
- Beverages, juices

By-products from industrial processing:
- Peel, fiber used for animal feed
- Fiber, feedstock for citric acid production

Processes Used in Transformation of Root and Tuber Crops

A discussion of the detailed processes used with root and tuber crops is beyond the scope of this paper. Briefly, the main options are:

Storage

Wound healing or curing processes can be accelerated in all crops, under the correct environmental conditions, to prolong storage life. In addition, treatments such as paraffin wax coating and packing in moist containers can also work well. It is important to differentiate among different objectives for storage when deciding the method to use:

- on-farm storage for seed use;
- on-farm storage for human consumption;
- storage during normal marketing (transport, distribution, sale, and at-home storage (2-3 weeks);

- storage for several months to smooth imbalances in supply and demand due to seasonal harvests;
- storage for export; and,
- storage at processing plants (stockholding).

A comparison of the last two points is worthwhile. Storage for export will require excellent product presentation and raw material quality control; but storage or processing/treatment costs will be high. Storing roots prior to industrial processing must be low cost, yet some loss of yield or quality may be acceptable. These different needs should be reflected in the design of the storage technology.

Selection and Cleaning

Roots may be selected and cleaned before, during, or after storage depending upon their intended use. Selection involves the removal of unacceptable roots (rotting, deteriorated, excessively mechanically damaged, too small, or immature) and also any foreign matter (stones, sand, woody material). The criteria for selection or rejection depend upon the end use. Cleaning is usually carried out by washing or brushing roots. This operation may not always be necessary (harvested roots are cleaner during drier periods). Washing can be manual or mechanical, and may be combined with peeling.

Peeling

It is important that peeling be efficient in order to minimize the loss of raw material. Peeling losses can be very high if roots vary greatly in size and shape. Grading before peeling may help to reduce losses in batch processes. Other factors influencing losses include depth of eyes and length of storage for potatoes. Peeling can be manual or mechanical, by abrasion, lye, or steam.

- Manual peeling, can be inefficient and result in high losses.
- Mechanical peeling, by abrasion in a rotating drum with water added to flush loose peel.
- Lye, roots immersed in solution of sodium hydroxide.
- Steam, roots exposed to steam under pressure.
- Combination of lye and steam peeling.

The end use of the raw material will determine whether costs can be lowered through shorter peeling times. For example, in the case of cassava, abrasive peeling for 3 min is sufficient to remove most of the outer, barky peel while leaving the white inner peel largely intact. For starch extraction this is sufficient; for other purposes longer times for complete peeling may be needed, at a greater cost and with higher losses. In many cases, the peel by-product can be dried and used as an animal feed.

Sulphiting

Potatoes and other tuber crops may be immersed in sodium meta bisulphite to avoid enzymic discoloration if further processing is not carried out immediately.

Size Reduction

Almost all processes involve some type of size reduction of the whole peeled or unpeeled roots and tubers. Some of the alternatives are to:

- slice, for snack food products;
- chip, for french fry cut and for later natural or artificial dry (traditional dried root products may use quite large root pieces cut manually); and,
- grate, for starch extraction and some traditional products (*gari, farinha*, etc.).

For potatoes, it is important to keep all chips, slices, etc. under water to prevent discoloration.

A vast array of chipping, grating, and slicing machines have been developed for root and tuber crops, from manually operated chippers (output of 1-200 kg/hr) to the continuous process equipment used in large starch extraction plants, capable of processing 200 t/day.

Blanching

Raw material is subjected to boiling or near boiling temperatures for short periods in order to inactivate enzymes, as well as cook the tissues partially, rendering the cell membranes more permeable to moisture transfer. By blanching, more rapid and complete drying is obtained and the texture of rehydrated products is improved. Partial sterilization is also achieved. The temperature should be above 80°C. Blanching time depends upon the dimensions of the root pieces, the amount of raw material to be added, and the temperature of the water. Blanching is mainly used with potatoes for products destined for human consumption. For potato slices, 3-4 min will suffice. The more complex alternative of steam blanching results in less loss of nutrients.

Additives to improve flavor, appearance, and texture may be added during or after blanching, e.g., sodium bisulphite, citric acid, and pro-phosphate are often used to reduce browning during storage. The blanched product must be cooled before drying can commence.

Drying

Root pieces may be dried either with or without prior blanching. Drying is achieved by the evaporation of moisture from the surface of the pieces and by migration of moisture from the interior to the surface. Adequate air movement around the drying pieces is important to prevent the accumulation of humidity in the surrounding air which slows the drying process. Drying speed depends on the dimensions of the root pieces, rate of air movement, atmospheric humidity, and air temperature. The moisture content of the final product must be low enough to prevent the growth of microorganisms during storage (especially *Aspergillus*) and to eliminate tissue metabolic processes that could affect product quality. This critical moisture content level varies for different crops (e.g., potatoes, 8-10%; cassava, 14%).

Natural or sun drying is the cheapest method. Chips can be dried on concrete floors, trays, or even flat roofs of houses. Drying can only occur during reasonably dry and sunny weather, especially for larger operations. Drying may be carried out by the small, subsistence farmer or by a large, commercial operation (e.g., 35,000 m^2 drying areas per factory for cassava in Thailand).

Natural drying results in possible contamination of the product by dust and microorganisms during the two days or longer that it takes. A solar collector may be feasible to harness solar radiation to reduce drying times, although few working examples of these have proven feasible thus far.

Artificial drying—which permits the rapid drying of root crops with good hygiene, outside the dry season, or in areas with constant rainfall—does increase costs. Batch driers, which can be constructed simply and cheaply, can be powered by locally available sources of fuel (e.g., coal, diesel, plant by-products, etc.). The drying temperature should not exceed the gelatinization point of the starch contained in the roots, about 50-60°C. For cassava, artificial drying results in a final product with a higher cyanide content than a naturally dried one.

Drying using continuous processes is rarely profitable, except where a high value product is being made in large volumes.

Starch Extraction

After grating, starch can be extracted through a simple process of adding water, mixing well (usually in a rotary system with water injection), and then separating the extracted starch from the fiber and other root components. Separation may be through centrifugal action, sedimentation in tanks, or in a system of channels. The separated starch is then dried, either naturally in small-scale operations or using a flash drier in large-scale plants. *Sago* is a product derived from starch, involving partial gelatinization of small globules or flakes of starch with an intermediate moisture content.

Fermentation

A variety of fermented products are made from root crops, mostly by traditional processes. These are destined to be used in traditional food products. Fermentation may be in the solid state, after grating, or after starch separation (*tapé, gari*, and sour starch—traditional cassava products from Indonesia, Nigeria, and Colombia, respectively). Natural fermentation is the rule, except for *tapé* where *rasi* a powdered inoculum consisting of *Amylonices rouxii* is used. Fermentation changes the taste of final products, and in the case of starch, also modifies their baking properties. Natural fermentation, however, may take 2-3 weeks to fully modify starch.

Milling and Grading

Dried root pieces can be processed into flour through milling and grading or sifting stages. Milling can be a large- or small-scale operation. Small-sized cassava chips can be successfully milled in a normal wheat flour roller mill, with very high conversion rates (90% or more). Small-scale hammer mills generally give lower conversion rates. The grading of flour depends on the end use. For pellet production or direct use for animal feed, the entire milled product is used. For a high-quality flour for bakery use, several milling and sifting stages may be necessary to reach the required standard.

Other Processes

These may be used to make products of less general application or to manufacture derived products from the basic flour or starch products described here.

Initial Selection of Products

By considering the range of technological options for root and tuber crops together with the market characteristics discussed earlier, the initial range of product ideas can be selected. These can be summarized as:

- improving the traditional fresh product (better storage, convenience; a fresh prepared product; precooked or parboiled; instant products; fast and snack foods);

- animal feed uses (stable, dried products for marketing; or ensiled/fresh roots for local use);
- flour for food or industrial uses (substitution of wheat and other flours); and,
- extraction of starch for food and industrial uses (substitution of maize and other starches).

Other possibilities exist but with a less general application; for example, dried chips for human consumption, beverages, and fermented products.

Selection of Region

In order to screen and evaluate the different opportunities that exist, it is necessary to obtain information about the markets, products, and industries already present. This obviously requires that a region where the project is to be developed has already been chosen. The next task is to select the area where the project is to be located. Regional selection needs to consider the following criteria:

Root and Tuber Crop Production

- The region should have sufficient production or potential to permit the establishment of a rural agro-industry.
- Prices should be low enough to permit processing as an option (i.e., no dominant fresh market).
- Production should not be concentrated into one very short harvesting period.
- Institutional support in crop production is necessary (research, extension).

Markets

- A major urban center should be located in or relatively close to the project area (for human food markets).
- Food or feed industries should be within a reasonable distance.

Social Factors

- A rural population with experience in root crop production and with a clear need to improve economic well-being.
- Successful local experience with cooperative or small business organizations.
- Institutional support and financial assistance to such groups should be available.

Clear support for the idea of improving rural welfare through interventions in root and tuber crop production, processing, and marketing should be available from local and regional state and private sector organizations working for rural development.

Idea Screening

The product ideas developed through a consideration of the technical possibilities of the crop, the region in which the project will be focused, and the markets available or potential in that region can now be screened to pinpoint those with the best chances of success. Screening is a two-stage process. First, those products that are clearly incompatible with the objectives of the project or the constraints imposed on it are deleted. This leaves a narrower range of possibilities, which then need to be subjected to further consideration.

Initial Screening

If the objectives of the project are to improve the welfare of small farmers through adding value to root and tuber crops via rural processing, then products that entail processes unsuited to these objectives will be eliminated. For example, freezing, canning, and vacuum packing are relatively high technology processes with a capital-intensive, large-scale processing bias. It is difficult for a small-scale rural industry to develop using this type of technology. Similarly, if project objectives are to improve the nutritional status of low-income urban consumers, this same group of technologies would also be discarded because of their high cost, which would result in a product accessible only to higher income consumers. Using the socio-economic objectives of these projects and the financial limitations within which they must work, the number of possible options can be reduced to a feasible number for more detailed study.

The remaining options will normally belong to those products requiring relatively simple, low-cost processes, resulting in products with a large potential market. These will be in the categories of fresh, prepared or stored products, flour, and starch. Considering that flour includes products suitable for animal feed, human food, and industrial use, it is necessary to subdivide these categories further. Each potential use will require specific quality or product specifications, which in turn affect the process and the cost of the final product.

Final Screening

Each product/market category remaining under consideration can be screened in greater detail using a checklist approach. Such a brief, but systematic consideration of basic facts relating to raw material supply, potential demand, etc., is preferable to a large and costly research project that will certainly be very time consuming. Table 2 gives the points that should be considered.

The time required to obtain answers to these questions will depend on the supporting data that already exist. Secondary data sources will provide much information, and a brief visit to the project region will often help fill in any gaps. It is not necessary to conduct an elaborate formal survey; but, it is important to think carefully about all assumptions made since popular knowledge is frequently mistaken. For example, cassava drying is now commercially successful in areas originally considered to have excessive rainfall.

With answers to the checklist, it is then possible to assess the favorable and unfavorable responses and decide which of the several initial product ideas can be taken for further study and development. The individual researcher must use this checklist with great flexibility. For one product, a single negative response to one crucial question may be sufficient to kill that product. For another product, many negative responses to certain questions may not be critical at all. Given financing, training, or time, such negative aspects can be changed.

An additional benefit of proceeding through the checklist is the generation of alternative product ideas. For example, by considering each of the items on the list, suggestions or observations may surface that can be useful in modifying the original idea; e.g., selling a powder-like potato product to industrial clients rather than a dried wafer or chip directly to consumers. Or, a totally different product may come to mind, e.g., for animal, not human consumption.

By working through the checklist in Table 3, four product ideas can be evaluated: (1) storage to provide potatoes out of season; (2) snack foods for high-income consumers; (3) chips for animal feed; and, (4) starch for food and other industries. The most favorable option shown is to store potatoes for sale in the off-season when prices are higher. In fact, such a project could develop several processed products for human consumption based on the project objectives, which could be to maximize rural employment, not farmers' incomes. Processing activities generate much labor, and this is considered to be an essential element in any product development activity.

Concept Testing

This is a simple procedure that can be used to define further the product idea. Information from the checklist has provided better knowledge of the market, and consumer characteristics and needs. These can be used to elaborate a series of concepts relating to the way the product will be used by different consumer groups (Table 3). Concept testing involves presenting the different concepts to consumers (or industrial clients) and receiving feedback from them. The advantage is that this can be done without having the product, but through using photographs and text to describe the product and its characteristics. Consumers can then be asked to comment on the concept (if they understand it) as to if the benefits of the product are relevant to them, how they would use the product, tentative purchase intentions, etc. This process is a very cost-effective, rapid method of defining product characteristics based on consumer needs, and it helps to eliminate those ways of presenting or using a product that are unattractive to consumers.

Conclusion

At this stage, a product with potential for benefitting the target population has been identified, as well as the region in which the project will develop. The next stage is to undertake market and technical research required to define the product characteristics, the process to make the product and the marketing strategy to be used.

Table 2. **Checklist for final screening of products.**

Demand
- Define target market (city, region, etc.).
- How many consumers (total, % who could purchase)?
- How much product per person/yr?
- Is purchasing power increasing or not?
- Are consumption, food purchase habits changing?
- Does product fit these changes?
- If product is novel, will acceptance be good?
- If product is competing against others, will price and quality be better than competitors?
- For industrial markets: What is the volume of purchases and the price of competing raw materials by industries concerned?

Raw material supply
- Volume of production in target region.
- Demand in other markets for this production.
- Seasonality of production and demand in other markets.
- Price fluctuations/cycles.
- Characteristics of both traditional and new varieties (growth cycles, quality, yield).
- Potential for and constraints to increasing production (diseases, erosion, drought, etc.).

Physical factors: Determine harvest times and feasibility of natural drying systems.
- Rainfall (dry and wet seasons).
- Does dry season coincide with harvest time?
- Temperature.
- Relative humidity.
- Is there ready access to clean water (for starch extraction especially)?

Organizational aspects
- Are farmers market- or subsistence-oriented?
- Are farmers willing to experiment?
- Has there been a positive experience with coops?
- Is institutional support available for coops/small businesses?
- Is credit available?
- Are capital requirements manageable?
- Is a separate distribution entity needed? Is technical and financial support available for this?
- Will many institutions be involved? Is inter-institutional coordination satisfactory?

Existence of similar activities
- Is small farmer processing novel or a continuation of existing practices?
- What are the strengths and weaknesses of existing operations?
- How can weaknesses be corrected?
- Are there any existing facilities that can be utilized to reduce capital outlay?

Consumer acceptance
- Is this crop accepted in the diet (fresh, processed)?
- Is image good or not?
- Is this product being made already? If not, why not?
- If an existing product, what improvements can be made?
- If a novel product, is this crop accepted in other foods or is it a food accepted with other ingredients?

Capital requirements
- Amount, conditions of loan (interest rate, period of grace, etc.).
- Requirements for collateral (land holdings, etc.).
- Standard banking arrangement or special loan scheme for small businesses, cooperatives.

Labor
- Costs.
- Availability (seasonality).
- Educational level.
- Gender issues: replacing manual operations by machinery often reduces the women's role and can have negative social consequences.

Technology
- Is it already developed, or is further research required; if so, how much and what are the chances of success?
- Imported or local? If imported, are spares, etc., available?
- Can it be managed by farmer group if necessary?
- What training will be required (process operation, business, marketing, etc.); who can provide and finance training activities?
- Can local labor and materials be used in construction?

Benefits
- How well will the product fit project objectives?
- Who will benefit and by how much?
- What is the risk of failure? Who suffers if project fails?
- How much; i.e., economic feasibility?

Table 3. Example of selecting product ideas using a checklist: Potato processing in North India.

Factor	Product			
	Fresh storage	Dry processed	Chips (animal feed)	Starch
Demand	Good, fills gap in market (out of season); traditional product, good acceptance across incomes	Novel product for high income (10% population)	Depends on price, unlikely to be competitive	Depends on price of raw material & starch yield; uncertain
Raw material supply	Excellent; buy at a low price & sell when high	Limited to June-March, when main harvest/low prices operate		
Physical factors	Need to store during hot season; technology development needed?	Dry season coincides with harvest; good for natural drying		Water availability poor
Organizational aspects	Family level or coop	Small business	Family level or coop	Small business
Existence of similar activities	Storage of other crops carried out	Processing well known & accepted		Not in this area
Consumer acceptance	Good if quality ok	Good at upper income levels	Industrial market; depends on price	
Capital requirements	Moderate	Moderate	Low	Moderate to high
Labor	Little used	Much needed; some skilled	Unskilled only	Much needed; some skilled
Technology	Needs some work, but simple	Needs some work; rather complex	Simple	Known; relatively simple
Benefits:				
Farmers	+++	+	++	+
Processors	none	+++	++	+++
Consumers	++	+	none	+
Economic feasibility	+++	++	+	+

Traditional Cassava Processing in Sub-Saharan Africa and Research Implications

Felix I. Nweke[1]

Abstract

About 160 million people in Sub-Saharan Africa eat cassava as a staple food. Cassava is most widely consumed in processed form. Based on research in six African countries, this paper describes traditional processed products and processes. It highlights the importance of chips and flour as the most popular forms of processing fresh cassava roots. It also analyzes the relative importance of characteristics such as color, texture, and taste.

Labor as a key constraint to cassava processing (and production) is highlighted next. The impact of mechanization on the length of the fermentation period is also analyzed, noting the possible disadvantages associated with the introduction of this type of improved technology. Suggestions for future research include labor saving technology, product quality, and the role of fermentation in cassava processing.

Key words: traditional technologies, products, product characteristics, constraints, fermentation.

Introduction

Using the International Institute of Tropical Agriculture (IITA) definition of a staple food as one that accounts for more than two hundred calories per day in the diet of an individual, cassava is the second most important staple food in Sub-Saharan Africa (IITA 1988). About 160 million people, or 40% of the population of sub-Saharan Africa, consume cassava as a staple food. There are some countries such as Zaïre, Congo, Gabon, and Mozambique, among others where, on an average basis, people derive about 1,000 food calories or about 50% of total food calorie per day from cassava. The cassava is used mostly in processed form; in Africa, unlike parts of Latin America where humans only consume unprocessed cassava, most cassava is consumed after going through several days of processing. The question is whether with appropriate changes in technology, policy, and price if cassava could play an even greater role in improving urban diets and increasing rural income (Berry 1993)?

The objective of this paper is to describe methods of processing various traditional cassava products. The key questions addressed are:

- What qualities are sought in processed products?
- Is "bitter" or "sweet" cassava type preferred for processing?
- How much of total cassava production is processed and how much is used as fresh roots?
- What are the key constraints in traditional cassava processing: fuelwood, water, or labor shortage?
- What is happening to fermentation in cassava processing; is it increasing or decreasing?

The paper is based on the information collected as part of the Collaborative Study of Cassava in Africa (COSCA).

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Method of the COSCA Study

The COSCA study is funded by the Rockefeller Foundation. The objective is to collect authoritative information on cassava production and processing methods, market prospects, and on consumption patterns in order to guide research on the cassava crop (Nweke 1988). The study is conducted in 6 countries namely Côte d'Ivoire, Ghana, Uganda, Tanzania, Zaïre, and Nigeria which together produce 70% of cassava in Africa.

It is executed in phases; the first phase is a broad characterization survey of cassava producing areas of Africa which was conducted in 1989; the second phase is a detailed production survey conducted in 1991. There is also a third phase which includes a detailed survey to gather information on a wide range of postharvest issues.

Climate, demographic pressure, and market access infrastructure form the bases for sampling for the COSCA study (Carter and Jones 1989). Areas with growing season daily temperature mean of above 22°C, range of less than 10°C, and less than four months of dry season are classified as lowland humid climate zone. A month of dry season is that with a total rainfall of not more than 60 mm. Areas with growing season daily temperature mean of less than 22°C, range of less than 10°C, and less than four months of dry season are classified as highland humid climate zone. Areas with growing season daily temperature mean of above 22°C, range of 10°C, and four to six months of dry season are classified as subhumid. Other areas with growing season daily temperature mean of above 22°C, range of above 10°C, and four to nine months of dry season are classified as nonhumid.

All-weather roads, railways, and navigable rivers were derived from the 1987 Michelin travel maps and used to create a market access infrastructure map of Africa. This map was divided into good and poor zones according to the density of the roads, railways, or navigable water ways. Population data from the United States Census Bureau (unpublished data), projected forward to 1990, were used to calculate population densities and to create a population map of Africa. This map was divided into high and low demographic pressure zones, the former comprising areas with 50 or more persons per square kilometer and the latter comprising areas with less than 50 persons per square kilometer.

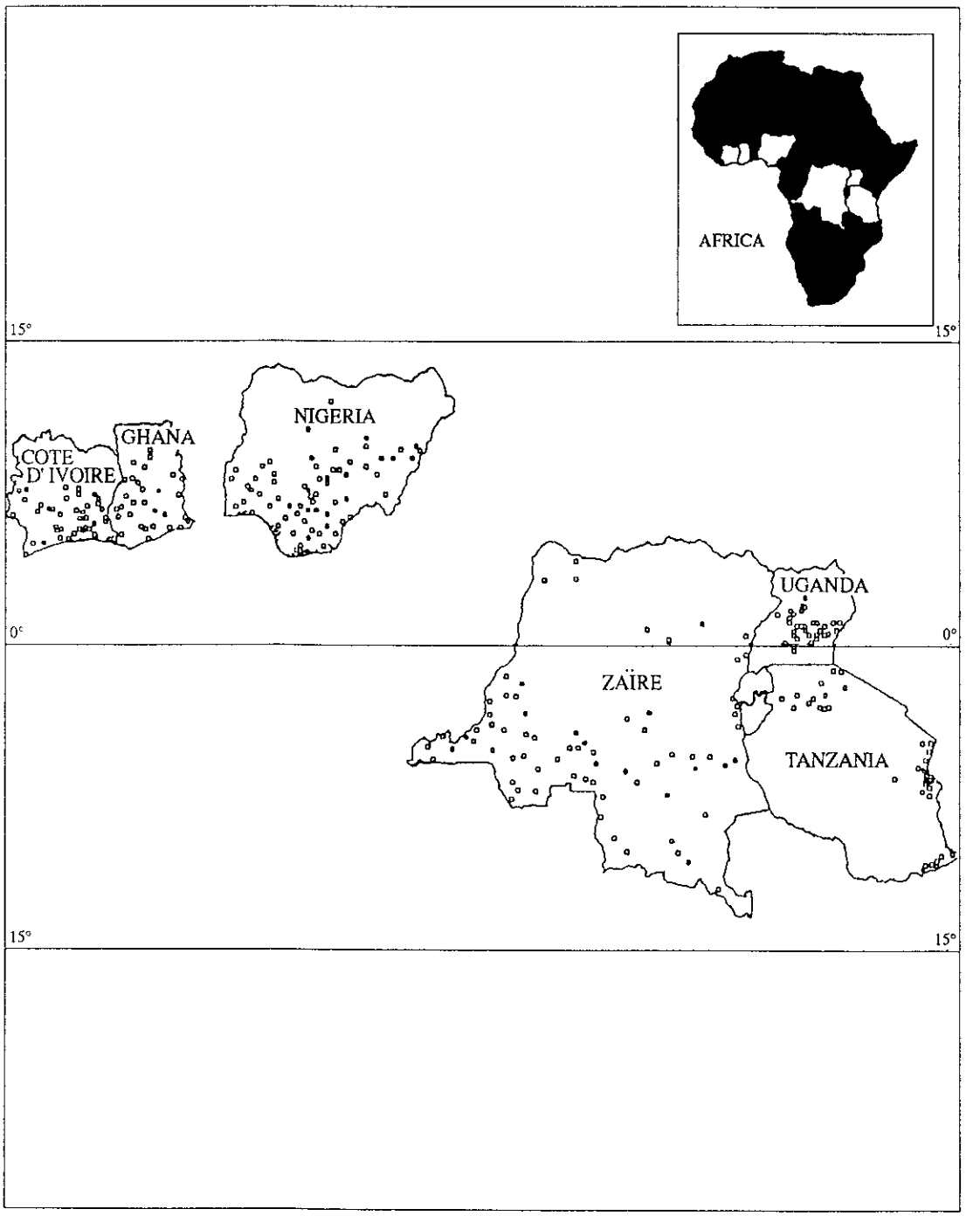
The three maps of climate, population density, and market access infrastructure were overlaid to create zones with homogeneous climatic, demographic, and market access infrastructure conditions of the cassava producing areas. Each climate/population density/market access infrastructure zone with less than 10,000 ha of cassava in each country was excluded as unrepresentative of cassava growing areas. The remaining areas which formed the potential survey regions were divided into grids of cells 12' latitude by 12' longitude to form the sample frame for sites selection. A certain number of cells distributed among the climate/population density/market access infrastructure zones in proportion to the zone size were selected in each country, depending on the size of the country, by a random method; the total for the six countries is approximately 300. One village was selected, by a random method, within each of the cells (Map 1).

In each selected village a list of farm households was compiled and grouped into 'large', 'medium', and 'small' smallholder units with the assistance of key informants. Farm units which cultivated 10 ha or more of all crops were excluded. One farm unit was selected from each stratum by a random method. Information was taken from all the fields, including cassava and non-cassava fields, of selected farmers.

For the Phase I survey, the rapid rural appraisal technique was employed in which farmer groups consisting of men and women with a wide age range were constituted and interviewed in each village. Hence, in Phase I of the COSCA study, the unit of analysis was the village site. The groups in each village were interviewed for qualitative information on the following aspects among many others: (1) various production practices including cassava varieties grown at present and in the past, crops grown and their relative importance in the cropping system; (2) cassava processing methods including cassava products processed, their relative importance in terms of quantity produced, desired quality characteristics of each product, the cassava variety ("bitter" or "sweet") which gives the best quality of each characteristic, steps followed in processing each product, duration of each step at present and in the past, whether the step is mechanized or not, and sources of water and energy; and (3) cassava marketing, including cassava products marketed, points (field, rural or urban market places) of sale of fresh cassava roots, and buyers (middlemen or consumers) of fresh roots from the farmers.

For Phase II, information was collected at the field level as the unit of analyses. The information taken from each field included distribution of total production by proportion to be processed and proportion to be used fresh and field size, among other information.

Map 1. Location of survey sites.



The investigators who are leaders in cassava research in the national agricultural research systems in each country, and who administered the survey instruments, are very knowledgeable in the cassava production system of the country and hence well qualified to collect these types of information.

Needs for Cassava Processing

Traditionally, cassava roots are processed by a variety of methods into many different products and used in diverse ways, according to local customs and preferences (Hahn 1989). However, processing serves certain purposes in cassava production; such purposes can be summarized as quality improvement and market expansion for cassava products.

According to Hahn, there is need to process cassava into various products that have increased shelf-life, are easier to transport and market, contain less cyanide, and have improved palatability. Fresh cassava roots cannot be stored for long because they rot within 3-4 days after harvest. Being bulky, with about 70% moisture content, transportation of the roots from rural to urban areas for marketing is very difficult and expensive. Both root and leaf contain varying amounts of cyanide which is toxic to humans and animals. The raw cassava root and leaf are not palatable (Hahn 1989).

Reliance on cassava as a low cost food staple in urban centers and as a source of steady real income for rural households will to a large extent depend on how far it can be presented to the urban consumers in an attractive form at prices which are competitive with those of alternative grains (Berry 1993) and, in West Africa, yams as well.

Expenditure elasticity estimates for southeast Nigeria show that the domestic market potentials for cassava are high (Nweke et al. 1992). Among the low expenditure households the estimates are such that should their disposable incomes increase, they would spend proportionately more than their incomes increase on cassava. Among the high-expenditure households the expenditure elasticity estimates are such that, should their disposable incomes increase, they would spend more on *gari* (cassava) although proportionately by less than their income increase. However, the proportionate increase in their *gari* (cassava) expenditure would be substantially higher than the increase in their yam expenditure. Thus, among the people of southeastern Nigeria, although cassava may be considered an inferior commodity in certain forms, in other forms it is far from being inferior, and could even be superior to yam.

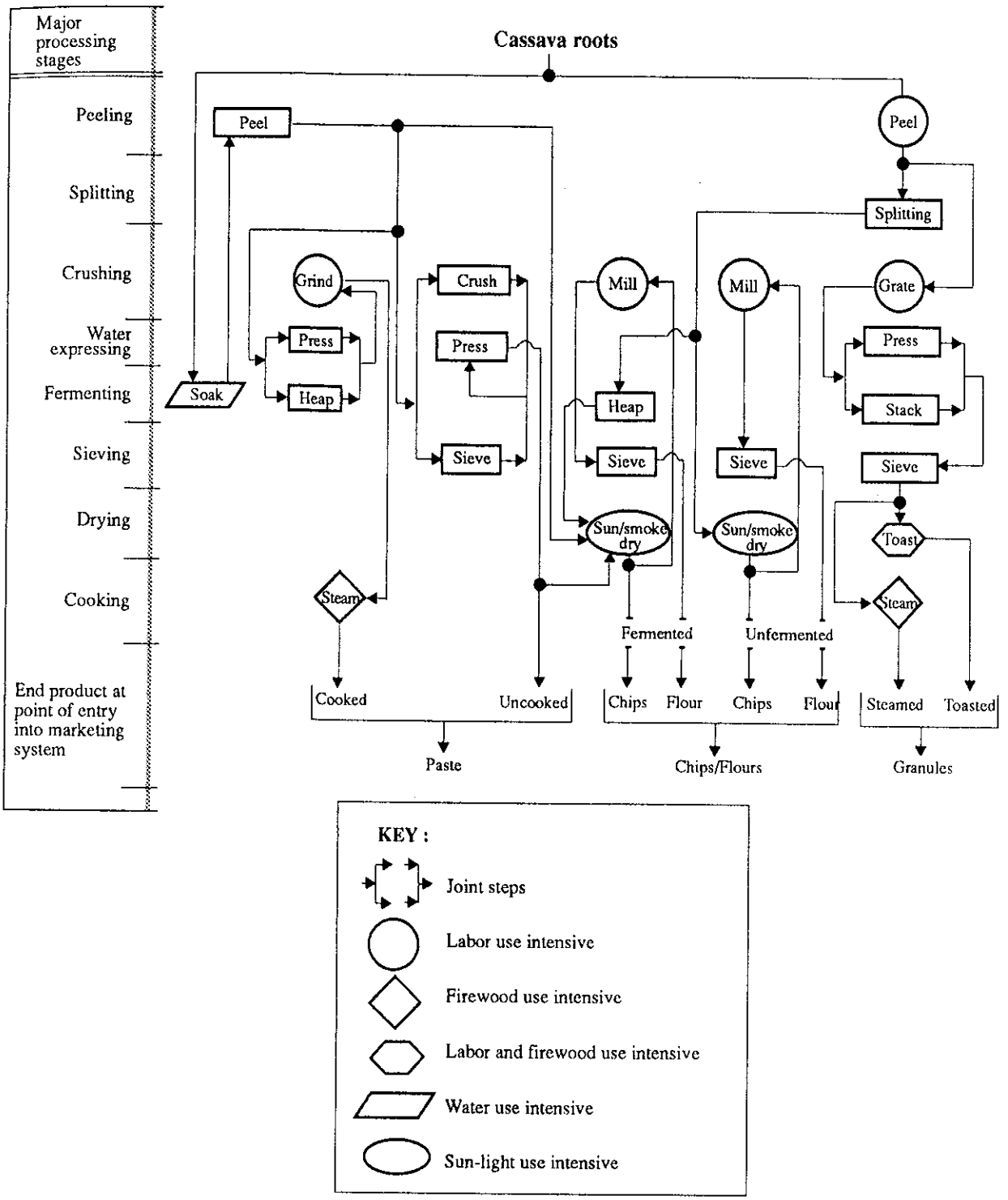
These observations imply that the market for certain processed cassava products is largely limited to low income groups. Other forms of cassava, especially *gari*, have a significant market among the high income population. The extent to which the potential market for cassava may be expanded would, therefore, depend largely on the degree to which the quality of the various processed products oan be improved to make them attractive to the high income consumers, without a significant increase in the processing costs, which are already high. The observation implies that the development of appropriate and cost effective farm-level processing technologies is critical for expanding the market for cassava in the future.

Traditional Processing Methods and Products

The processing methods involve combinations of activities which are performed in stages. Such activities are (a) peeling, (b) crushing, milling, slicing, or grating,(c) water expressing by pressing, decanting, sun or smoke drying, or frying, (d) fermenting by soaking in water, heaping, stacking, or sedimentation, (e) sieving, and (f) cooking, boiling, or steaming. The combinations and the sequences of these activities vary with the product being made from the cassava roots. This sequence of activities creates a wide range of intermediate products some of which meet certain of the processing objectives, thus further processing activities can be postponed until need arises. Hence, it is not always easy to distinguish intermediate and end products of processed cassava. In addition, some of the processed products need further cooking at meal preparation. Others are so final that they are ready to eat without further cooking sometimes making it difficult to distinguish between a processed product and prepared meal of cassava. The following analysis will be based on those end products which enter the marketing system. This will include some intermediate products which are ready for consumption but not prepared cassava meals. Some of the major ones among these products and steps involved in producing them are shown in Figure 1 and described as follows:

Steamed paste. This product is called *chikwangue* in Zaïre, *placali* in Côte d'Ivoire, *myondo* or *bobolo* in Cameroon. To make it, whole roots are immersed in water (stream, puddle, or water in container) for three to five days where they are softened and fermented. They are taken out of water and peeled. Fibers are removed from the pulp, which is heaped on a rack for further fermentation or covered with leaves and pressed

Figure 1. Traditional cassava processing methods in Africa.



Source: Collaborative Study of Cassava in Africa (COSCA) project.

with heavy objects to drain off excessive liquid. The pulp is then ground on a stone or pounded in a mortar. The fine pulp is wrapped firmly in leaves and steamed. Sometimes peeling is done before soaking. This improves attractiveness of the end product. But it also makes the product more expensive because peeling of fresh roots is labor intensive relative to peeling of soaked roots. These products which are ready to eat are included as part of a meal without further cooking. The making of cooked paste is expensive because it involves numerous stages and virtually every one of the stages is intensive in the use of one or another resource. The soaking step is water use intensive, grinding and sieving are labor intensive, while steaming is fuel-use intensive. The process is so labor intensive because the product consists of very fine particles. Only areas with abundant supplies of water, labor, and fuelwood would have comparative advantage in the processing of cassava into cooked pastes by traditional methods.

Although the product is heavy it is not bulky and hence is relatively easily transportable. In addition, the double fermentation process involving soaking and heaping as well as the steaming impart long shelf life. Consequently, the product is suitable for production in remote areas with abundant supplies of water, fuelwood, and labor, for transportation to distant markets in major consumption centers. The double fermentation process however imparts a strong, cheese-like flavor which is liked only by people who are brought up in the culture of eating the product. Perhaps the high production cost and the strong flavor has restricted the production and consumption of this product to limited areas.

Unsteamed (wet) paste. This product is called *akpu* in Nigeria, *agbalima* in Ghana, and water *foufou* in Cameroon. The steps of making wet paste are similar to those for the making of steamed paste except that wet paste is not cooked. These products are not ready for eating as wet pulp and they have to be steamed in the preparation of a meal. Just as in the case of steamed paste, the fermentation step is water-use intensive, but the joint crushing and sieving steps are not as labor intensive since the particles need not be very fine in the case of wet paste preparation. In addition, fuel is not required in the preparation of wet paste although it will eventually be needed in cooking the paste during the meal preparation stage. The palatability of wet paste meal varies depending on the quality of water used in the fermentation process and on the duration of the fermentation.

Although shelf-life and bulk reduction are improved in relation to fresh roots, wet paste is still bulky and perishable compared to other processed cassava products. Hence, production of wet paste is concentrated in remote areas where production is more for subsistence than for market and where there is an abundant water supply. Among exceptions are parts of Nigeria with good market access infrastructure where this product is transported over relatively long distances in truck loads and retailed in urban markets in small units packaged in plastic or polypropylene bags (Hahn 1989).

Chips and flour. Flour is often made at home by final consumers from cassava chips so that chips are an important intermediate product making up a major proportion of marketed cassava in Africa (Berry 1993). Chips and flour are called *kokonte* in Ghana; *lafun* in Nigeria; *cossette* or *unga* in Zaïre; *chinyanga*, *ugali*, *makopa*, *abutega*, *omundyenge*, *udaga*, *chikondole*, *bada*, *dimwehe*, *uhu*, *udunule*, *mbute*, *makonga*, *obusanobwe*, or *kivunde* in Tanzania; *obuite*, *udilimbe*, *habalogala*, *ajobo*, or *malwa* in Uganda.

Chips and flour are made by a wide range of alternative traditional methods. For example, soaked roots can be converted into chips by sun or smoke drying either directly after peeling or after crushing, sieving, pressing, and balling. Alternatively, chips are made directly from fresh roots in one of two ways; one, sun or smoke drying of peeled fresh roots. This is the simplest traditional method of cassava processing which is not water-, fuel-, or labor-use intensive except at the peeling stage. However, the product contains a considerable amount of cyanide (Hahn 1989) and the method is used for the processing of "sweet" varieties (TFNC and ICH n.d.). The alternative method of making cassava chips involves fermentation by heaping prior to sun or smoke drying. Chips made in any of the foregoing traditional methods are converted into flour by milling.

Making of chips and flour may be water use intensive depending on the method employed. The peeling step is labor intensive also depending on the method of processing. However, irrespective of whichever traditional method is employed, the milling step is labor intensive by traditional methods because it is manual using pestle and morter. But above all, making cassava chips and flour is most efficient in dry climates.

The fermentation process whether in water or in heaps serves to reduce hydrocyanic acid (HCN) and to impart palatability to the product while fermentation in heaps has an additional advantage of improving the nutritional value of the product. The mould growth associated with the heaping increases the protein con-

tent of the resulting product by a factor of six to eight (TFNC and ICH n.d.). On the other hand, the drying process reduces bulk and extends shelf life considerably and therefore facilitates marketing of the product. Consequently, remote areas from urban centers in nonhumid climatic zones would have comparative advantage in the production of cassava chips and flour.

Toasted granule. This product is widely called *gari* in West Africa except in Côte d'Ivoire where it is called *atoukpou*. Fresh roots are peeled and grated; the grated pulp is put in sacks and the sacks are placed under heavy objects for 3-4 days to express excess liquid from the pulp while it is fermenting. The dewatered and fermented lumps of pulp are sieved and the resulting fine pulp is roasted in a pan. Palm oil is often added during roasting in order to prevent burning of the pulp. This has additional effect of changing the color of the product from white to yellow. The individual who is carrying out the roasting is in constant contact with smoke and heat and probably also with cyanide, although the quantity is likely to be small (Hahn 1989).

Gari-making is expensive because of the labor intensive nature of most of its processinging steps (IITA 1988). In addition to this, a large quantity of fuelwood is needed for roasting, so *gari* is normally produced in the forest or savanna areas where fuelwood is cheap. Fermentation imparts an acid taste to the product; dewatering, sieving, and roasting reduce bulk and weight while roasting extends shelf life so that the product is easily transported to distant urban markets.

Other products. Pastes, chips/flour, and granules are the major processed cassava products which were reported in the representative villages. Other processed products which were also reported are starch, alcohol, and *abacha*. In addition to processed cassava products cassava roots are also widely used in fresh form in all the countries while cassava leaves are also eaten usually in fresh form throughout Zaïre and in parts of Tanzania out of the six countries. *Abacha* is commonly produced in parts of southeast Nigeria but rare elsewhere. Its production involves boiling peeled roots, then slicing the boiled roots into small flat pieces using perforated graters. The sliced pieces are soaked just over night to make wet *abacha* and sun drying the wet *abacha* to make the dry one. Although the process of making *abacha* is straightforward involving relatively few steps, the process is expensive because virtually all the steps are water-, fuelwood-, and labor-use intensive. The boiling and the overnight soaking eliminates HCN and the drying in the case of the dry product reduces weight and bulk and extends shelf life significantly. Dry *abacha* can store as long as or even longer than some grains because it is not attacked by known weevils. The product is attractive with bright white clean color and hence highly marketable. It is not clear why its production and use are restricted to such a limited area.

Distribution of Various Processed Products

The above products are made not only by farmers but also by middlemen who buy fresh roots from farmers, then process and sell processed products. About 90% of the representative villages sold fresh roots. Sixty percent sold to traders, processors, and marketing cooperatives; and 30% sold direct to consumers as their primary buyers. The processors, marketing cooperatives, and some of the traders process the roots into various products before selling to consumers. These middlemen are more involved in cassava processing in areas which have relatively good market infrastructure and high population density.[2]

Chips and flour—which were reported as the most important cassava products in 45% of the representative villages—are the most widely used forms of cassava roots in Africa (Table 1). Relative to other cassava products, chips and flour are made with a wide range of techniques some of which are straightforward and cost effective. In West Africa, granules are also used. Fresh roots are the widely used form of cassava roots in Côte d'Ivoire, Ghana, and Uganda, but not as much in Nigeria, Zaïre, or Tanzania.

Granules and fresh roots are more frequently used as the major forms of marketing cassava roots in relatively well developed areas than in the areas of poorly developed market access infrastructure (Fig. 2). Granules are also more frequently used as the major forms of cassava products in high than in low population density zones. Chips, flour, and pastes are more frequently used as the major form of cassava products

[2] Areas where farmers go to their main markets by motor vehicles represent areas of well developed market access infrastructure. Other areas, where farmers go to their main markets by foot over long distances (above 10 km), represent areas of poorly developed market access infrastructure.

Table 1. Distribution (%) of villages by major forms of cassava used.

Major form	(% Villages)	
Fresh roots	21	
Pastes	12	
steamed		(6)
unsteamed		(6)
Chips/flours	45	
Granules	22	
steamed		(7)
toasted		(15)
Total	100	

in the poorly developed areas than in the areas having relatively well developed market access infrastructure. They are also more frequently used as the major form of cassava products in the areas of low than high population density. These observations would suggest that granules are more associated with commercialization than the other processed cassava products.

Desired Characteristics for Processed Products

Farmers distinguish two sets of cassava varieties. One set consists of roots which can be eaten without preprocessing. Varieties in this set are conventionally referred to as "sweet" varieties. A second set of cassava varieties includes those which if eaten raw, or even boiled or roasted without prior processing, are presumed by the farmers to be dangerous to humans and animals. This set of varieties are conventionally referred to as "bitter" varieties. This convention is adopted in this report.

There are more sweet than bitter cassava varieties in all the representative villages. But land area allocated is even, approximately 50% for each. A distribution of the representative villages, by most important cassava product they use, shows that fresh roots represent the most important cassava product eaten in 28% of the representative villages who grow only sweet, in 10% of those who grow both the bitter and the sweet, and in none of those who grow only the bitter cassava types (Table 2). Fifty percent of the villages grow both the bitter and the sweet, 45% grow only the sweet, and only 5% grow only the bitter varieties. Flours, pastes, and granules were frequently reported as the most commonly used cassava products in villages irrespective of the

Figure 2. Distribution (%) of villages by market access zone by major cassava products produced.

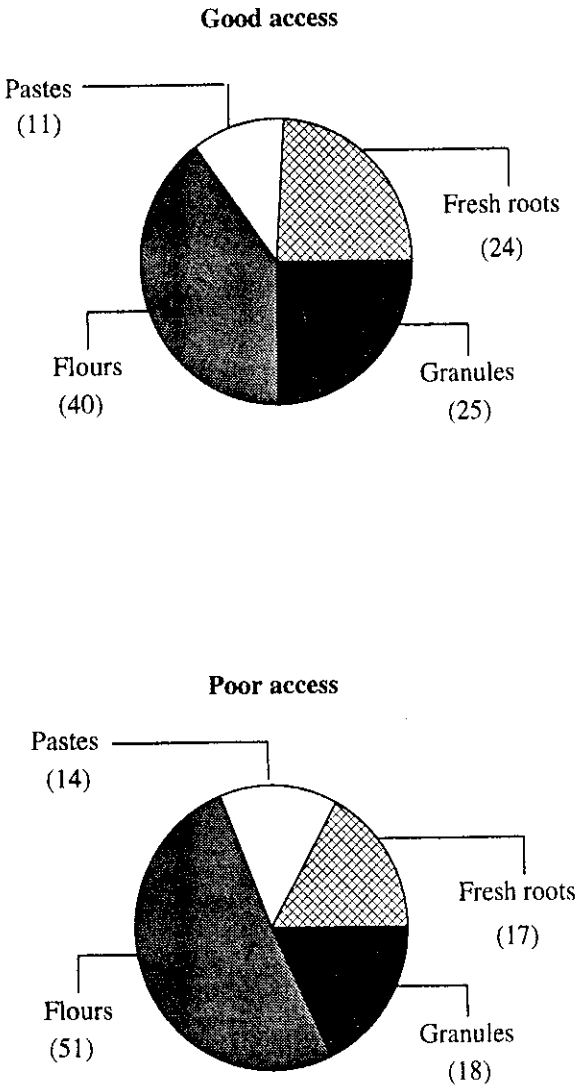


Table 2. Distribution (%) of villages by most important cassava product used by cassava variety produced.

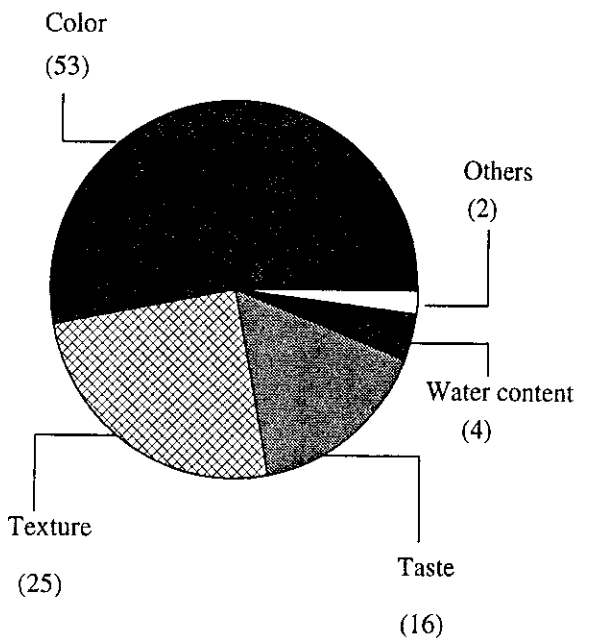
Product	Sweet only	Bitter & sweet	Bitter only
Fresh roots	28	10	0
Flour	33	55	65
Paste	6	11	21
Gari	18	18	14
Steamed granule	11	5	0
Others	5	2	0
Total	100	100	100

type of cassava grown. The implication of these observations is that the HCN, or its potential in cassava, can be eliminated at a stage in the transformation process or reduced by breeding.

Groups of farmers interviewed during the rapid rural appraisal phase of this study were asked the local name of the variety that gives them the best quality for each of the processed products and subsequently whether that variety was bitter or sweet cassava. Analysis of this information for those villages which grow both the bitter and the sweet show that almost 60% of such villages indicated that bitter and only 40% indicated that sweet cassava varieties give the best quality for the various processed cassava products. Farmers in the Kwango-Kwilu are explicit about their reasons for preferring bitter varieties. These varieties contain more starch; give a better quality finished product such as *luku* or *chikwangue*; and, because the *cossettes* (intermediate product) can be more easily stored (Fresco 1986). In the Kwango, sweet varieties were considered inferior and children are laughed at if they eat sweet cassava (Adriaens 1951). This shows that most villages consider bitter cassava superior to sweet cassava for processing. This is however true only for the major products namely pastes, chips/flour, and granules. Among the villages which produce both bitter and sweet cassava, all of those which process alcohol reported that sweet cassava gives the best quality of this minor processed product. Some villages in Uganda produce only bitter cassava which they use for making beer.

A frequency distribution of the quality characteristics of the various products desired by the processors shows that color or appearance was the most important quality characteristic for more than 50% of the villages.

Figure 3. Distribution (%) of villages by desired quality characteristics of cassava products.



Texture or consistency was considered most important for about 25%; taste for about 15%; and, other quality characteristics for less than 10% of the representative villages (Fig. 3). Color or appearance is the most important in so many villages because of commercial production; the product has to be visually attractive to the buyer.

Cassava production in Africa is highly commercialized with as much as 45% of total output marketed. This amount is marketed as different products including fresh roots and leaves, dried chips, flour, roasted granules, pastes, alcoholic and nonalcoholic beverages, starch, and many others. Only about 3% of the villages representative of cassava producing areas of Africa did not sell any cassava product. One of the villages in this category was an oil palm plantation community in Zaïre. About 21% of the villages sold one or two cassava products; 45% sold three or four; 20% sold five or six; and, 3% sold seven or more cassava products.

The regions of Bandundu and Bas-Zaïre are the main suppliers of cassava products namely *cossette*, *pondu*, and *chikwangue* to the urban population of Kinshasa. Average tuber yields per hectare are slightly higher in Bandundu (7 t) than in Bas-Zaïre (5 t). The Kinshasa market prefers products from Bas-Zaïre

which are whiter. The brownish tint to Bandundu *cossettes* has been traced to the color of water in the streams in which the tubers are soaked. The proximity of Bas-Zaïre to Kinshasa also gives the region a greater share of the *pondu* market in the capital city (Osiname et al. 1988).

The texture of processed cassava food products is an important consideration in many villages because of an eating style which is widespread in sub-Saharan Africa. It consists of rolling pasty food into balls and swallowing without chewing. In the rolling, which is done with fingers, the food has to stay together and not fall apart; hence, texture (and consistency) is an important consideration. Food eaten in this way is called *fufu* or *foufou* in West and Central Africa, *ugali* in East Africa, and *nsima* in Southern Africa. In West and Central Africa *fufu* is made from yam and various cassava products. In East and Southern Africa, *ugali* or *nsima* is made from grains. In Nigeria, a similar food made from cassava toasted granules (*gari*) is also called *eba*.

For consumers who eat processed cassava products in the form of *fufu* or *eba*, flavor or taste is largely irrelevant since the *fufu* eating style is to swallow without chewing. However, not all cassava processed products are swallowed without chewing. In fact, *chickwangue*, *placali*, *myondo*, or *bobolo* are eaten in the same way as bread. These products are fermented twice: first by soaking and second by heaping; in the process they acquire a strong flavor which is liked only by people who grew up in the culture of eating them. In addition, commercial *gari* processors in Nigeria ferment for different durations, depending on the market. For example, processors in Edo State of Nigeria, a major commercial cassava producing state, ferment for three or less number of days *gari* meant for markets in the eastern states and for five or more for *gari* meant for markets in the western states. The strong acid taste in *gari* acquired from a long period of fermentation is appreciated by the Yoruba people of Western Nigeria but not by the Ibos who make up most of the people of Eastern Nigeria.

Taste is a very subjective concept. What is flavor and cherished by some people could be odorous and repulsive to others. Double fermentation of steamed pastes, such as *chickwanque*, *mboung*, *mangbele*, *myondo*, or *bobolo*, first by soaking and second by heaping is aimed at imparting this strong taste. Depending on the variety of the root used, the length of the fermentation period, and the amount of oil used in cooking, a wide range of flavor is possible and consumers are often very selective in their purchases (Jones 1959).

These observations would tend to suggest that flavor is an important quality characteristic of processed cassava products in a relatively few villages; yet, imparting of it is likely to be at least part of the objective of fermentation in cassava processing.

Constraints in Traditional Processing

Traditional cassava processing techniques are flexible in their use of various processing resources. For example, while the techniques of making cassava pastes are mostly water-use intensive, the techniques of making cassava granules are mostly fuelwood-use intensive. Some techniques of making chips and pastes are water-use intensive and others require a lot of sunshine for drying. Figure 4 shows that frequencies of some of the processed products as major cassava products in the representative villages have definite climatic trends. Villages in each climate zone concentrate on making products for which the zone is endowed with the necessary resources. For example, the relative frequency of paste as a major cassava product made with water-use intensive techniques declines from the humid climate which has abundant rainfall to zero in the dry climate zone where rainfall is limited. On the other hand, the relative frequency of chips/flour which requires abundant sunshine for drying decreases from over 80% in the dry climate zone—where sunshine is most abundant, to only about 25% in the humid climate where sunshine is most limiting among the three climate zones.

Water. Berry (1993) argues that to assess cassava's potential for increasing food production and food security in semi-arid areas, it is important to know how far the advantages of cassava's tolerance of drought, poor soil, and irregular labor inputs may be outweighed by the fact that processing is dependent on availability of water; that the importance of water for processing is potentially a serious constraint for increased reliance on cassava both as a source of local food security in times of drought, and as a source of steady real income for rural households. In areas where water is available for only a few months out of the year, the possibility of relying on piecemeal harvesting and processing of cassava to even out seasonal variations in income and food supply may be significantly reduced. Hence, apart from ecological constraints to increased production, develop-

ing cassava as a source of food security in semi-arid and/or drought-prone areas may depend in part on people's willingness to grow and consume fresh roots of cassava varieties which are low in HCN (Berry 1993).

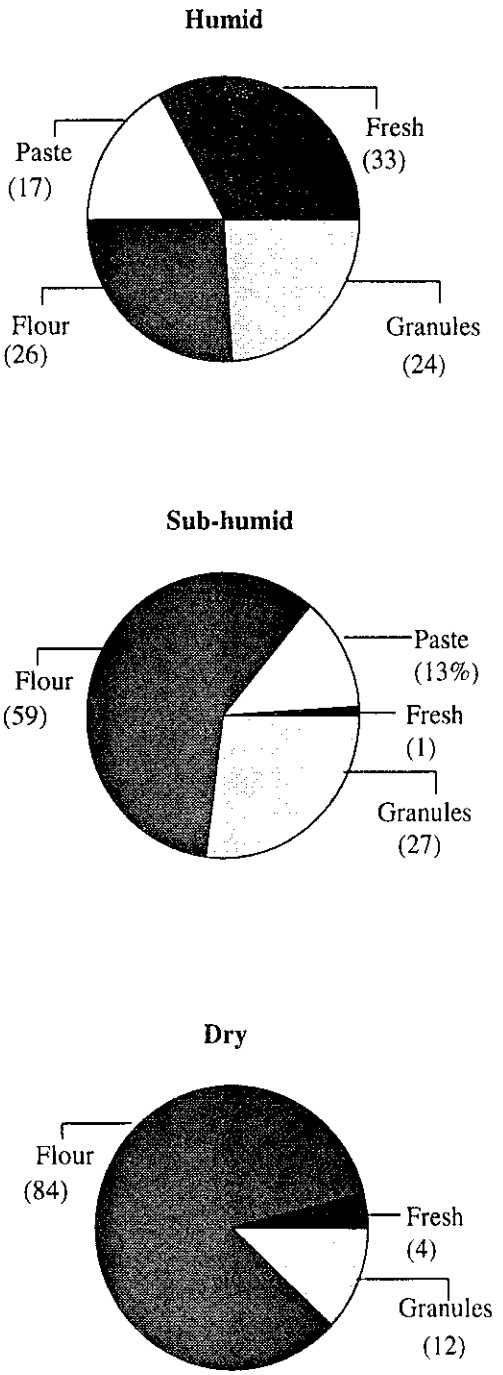
Figure 4 shows that the frequency of fresh cassava roots as the major cassava product in the representative villages declines from more than 30% in the humid to near zero in the dry climate zone. This suggests that level of cassava processing may not be higher in the humid than in the non-humid climate villages. There is a clear trend in the relative amounts of bitter and sweet cassava varieties produced in the different climate zones. Farmers in the dry climate zone produce relatively much more bitter cassava (nearly 70% of total cassava land) than the humid climate zone (about 32% of total cassava land). On the contrary, the farmers in the humid climate zone produce relatively much more sweet cassava (nearly 70% of total cassava land) than the farmers in the dry climate zone (about 30% of the total cassava land).

These observations would suggest that while water availability could affect the technique of cassava processing, it is not likely to affect the quantities processed. Therefore, it is not likely that the importance of water for processing is a serious constraint for increased reliance on cassava as a source of steady real income for rural households even in areas of low rainfall or in periods of drought without having to grow cassava varieties which are low in cyanide.

It is however likely that the importance of water for processing could be a serious constraint for increased reliance on cassava as a source of local food security in times of drought especially in the drought-prone, dry climate areas which produce more bitter than sweet cassava. It is possible that shortage of water could compel processors in such areas to make chips and flour, their most common major product, from bitter cassava which they produce most, with the technique of sun-drying without soaking or heaping. This technique is usually adopted for processing sweet cassava. If it was adopted for processing bitter cassava, it would result in products which contain a considerable amount of cyanide (Hahn 1989).

The method of direct, solar drying of cassava roots after peeling without soaking or heaping has little effect in reducing the cyanogenic glucoside. This is because the root tissue is not effectively disintegrated giving no chance for the enzyme linamarase to act on the cyanogenic glucoside to liberate hydrogen cyanide. The roots which are split into smaller pieces before solar

Figure 4. Distribution (%) of village by major cassava products used by agro-climatic zone.



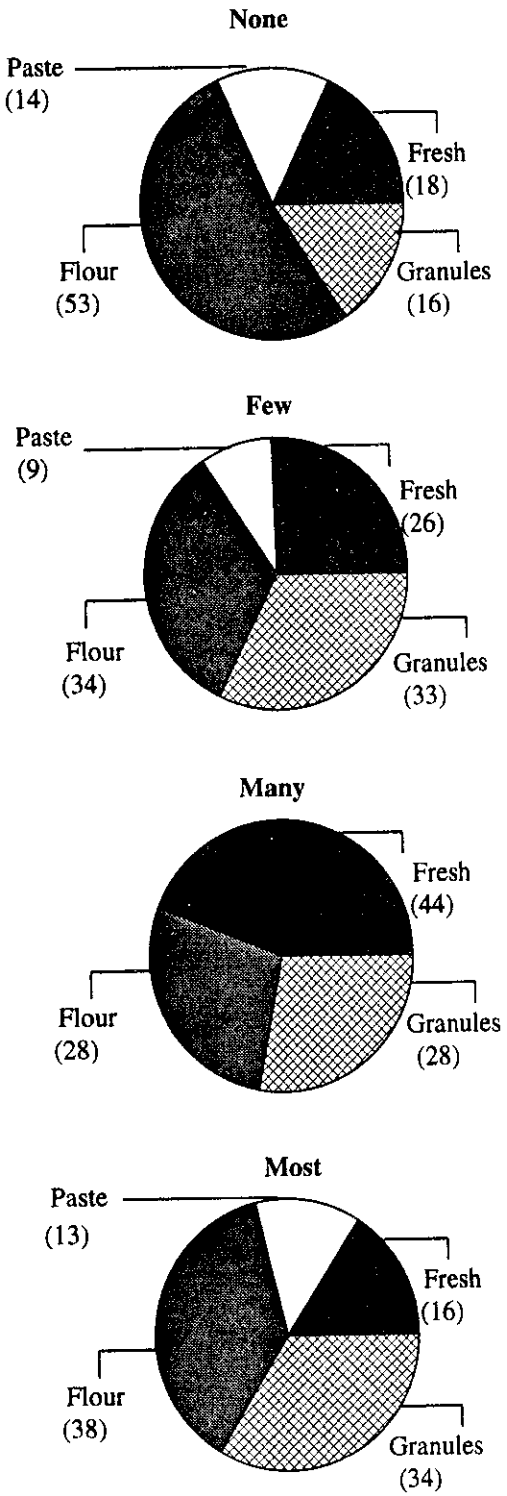
drying have an increased surface area which exposes more tissue of the roots thus enhancing the action of linamarase enzymes (TFNC and ICH n.d.).

Fuelwood. According to Hahn (1989) a large quantity of fuelwood is needed for making *gari* so the product is normally produced in the forest or savanna areas where fuelwood is readily available. Figure 4 confirms Hahn's observation that the frequency of granules as the major cassava product is significantly higher in both the lowland humid areas which in general correspond to the forest zone and in the subhumid areas which correspond more to the savanna than in the dry climate. However, further observations suggest that this difference is for a different reason than fuelwood availability. The groups of farmers interviewed during the rapid rural appraisal phase of the survey were asked to indicate the relative number (none, few, many, or most) of the people who buy fuelwood. The assumption is that fuelwood is most abundant where no one buys it and most scarce where most people buy it. It is also logical to assume that in Africa the level of commercial activities would be higher where most people buy fuelwood and lowest where no one buys fuelwood.

Figure 5 compares the frequency of granules as the major cassava product among the village group where no, few, many, and most people buy fuelwood. The figure shows that the relative frequency of granules as the major cassava product is more than double among the villages where most people buy fuelwood than what it is among villages where no one buys fuelwood. Although *gari* needs a large quantity of fuelwood to produce, it has minimal water requirements (just enough to boil), and sometimes none at all at the food preparation level. It is very easy to prepare into a meal and therefore convenient for medium income urban consumers who are willing to pay relatively high prices for it. Hence, processors in commercial areas are able to buy fuelwood for *gari* processing. Frequency of granules as major cassava products is higher in the humid and subhumid climate zones mainly because levels of commercial activities are likely to be higher in those zones than in the dry climate zone. Therefore, market availability is more important than fuelwood availability as a determinant of cassava processing into *gari*.

Labor. Increased reliance on cassava as a source of steady real income for rural households may however be reduced because of labor shortage for processing. All the processing techniques described in Figure 1 have at least one labor-intensive step. According to IITA

Figure 5. Distribution (%) of villages by major cassava products used by relative number of people buying fuelwood.



(1988), the labor required for processing cassava roots into *gari* is very high and equals the total labor input for production of the roots themselves.

Mechanized techniques of grating in the making of granules are available in 15% of the villages visited. Such methods involve the use of various types of mechanical cassava graters that are driven by electric, petrol, or diesel engines (Kwatia 1986). Other steps—which are also labor intensive, but not mechanized—are peeling and toasting.

Costs and return estimates for cassava root production and *gari*-making in southeast Nigeria show that high root yields attained through adoption of improved field practices including high yielding varieties would not have cost saving advantages at the processing level because traditional processing techniques employed are at small scales with low capital investments and hence may not lead to expanded production (Nweke et al. 1991).

Field production costs, i.e., the costs of planting materials and field operations' labor per unit weight of output, declined as yield increased, because most of such costs were constant per unit area, irrespective of the yield. Consequently, the percentage contribution of field production to total costs per unit weight of output declined as yield increased. Processing costs per unit weight of output were constant as yields increased, because the processing technique employed was traditional with a low level of capital investment. Consequently, the percentage contribution of the processing to total costs per unit weight of output increased as yield increased.

Hence, the cost-saving advantage of yield increasing technology may not fully translate into expanded production if there is no cost-saving technology at the processing stage. This is because the cost constraint is merely shifted to the processing stage. Some Nigerian farmers employing IITA's high yielding TMS 30572 variety to produce *gari* have been observed at certain seasons to drastically cut back on planting because they were unable to process the previous season's harvest (Nweke et al. 1988).

The mechanization of cassava processing is concentrated in West Africa—especially in Nigeria, where all three steps namely water expressing, milling, and grating have been mechanized in nearly 20% of the villages. The mechanization of cassava processing is not as widespread in East African villages and virtually non-existent in Zaïrean villages visited. Mechanization is also more widespread in the villages where granules are the major processed products than in others where pastes or chips and flour are the major processed products.

Mechanization of cassava processing appears to be driven by market forces. For example, mechanization of the various cassava processing steps is more common among villages which sell large, than among others which sell small, proportions of their total cassava production. It is more common among villages which have good, than among others which have poor, market access infrastructure.

According to Fresco (1993), one of the unique paradoxes of cassava is that its relatively low field labor requirements are not matched by its needs for processing labor, since both require about the same amount of labor under traditional techniques.

Where cassava as a market crop forms the key to agricultural growth, one would suppose the emergence of new labor-saving processing techniques, perhaps coupled with the use of hired labor. Where cassava is grown as a food reserve crop supplementing income or food production from other sources, investments in processing seem less likely. Increased income from cassava and improved marketing might encourage investment in processing equipment (Fresco 1993).

Level of Cassava Processing

On average, two thirds of the cassava produced in the representative villages is transformed into various processed products and only one third is used in fresh form. Although the proportion of total production processed is significantly higher among farmers who produce bitter cassava, more than 80% of the total production, the proportion processed by farmers who produce sweet cassava is still substantial, nearly 60% of total production. This is because consumption of fresh cassava is limited by the extreme perishability of the roots which may begin to deteriorate within 24 hours after harvesting. With present facilities for storage and transport, it is difficult to market fresh cassava roots at any distance from the place where it is grown. Processed cassava, on the other hand, is less bulky to transport and far less perishable than fresh roots. Perhaps for this reason, most cassava is eaten in processed form (Berry 1993).

Further analysis of the data shows that the level of cassava processing is substantially higher in villages which are remote from marketplaces such as where farmers go to market on foot over distances of more than

10 km (about 80%) than others where farmers go to market on foot distances of over 10 km or less (about 65%). This is because to sell people in remote areas have to process in order to reduce the bulkiness and extend the shelf life of the product. The proportion of total production processed is directly related to the proportion of total production marketed. Thus, the proportion processed increases from less than 60% among farmers who market 20% or less of total output through 65% among those who market 21-60% to nearly 80% among others who market more than 60% of total production.

There is no definite trend in the percentage processed from humid through subhumid to dry climate zones. While the proportion of total production processed is highest (about 80%) among farmers in the subhumid zones, the proportions are similar, about 60%, in both the humid and dry climate zones. This is in spite of the fact that both water and fuelwood which are important inputs in cassava processing are more easily available in the humid than in the dry climatic zones (Hahn 1989).

The proportion of total cassava production processed is not higher among farmers in the villages where no one buys fuelwood than among farmers in other villages where most people buy fuelwood. In other words, fuelwood scarcity does not make a difference in the proportion of total production of cassava output processed. Similarly, water scarcity does not make a difference in the proportion of total production of cassava processed; the proportion of total production processed is lower among farmers in the villages where the main source of water supply is rivers and hence where water is abundantly available than among farmers in the villages where the source of water is borehole and hence water is relatively scarce. Hence, while availability or scarcity of water or fuelwood may determine the type of processed products made from cassava roots, the availability or scarcity of those essential inputs does not determine the level of cassava processing. Cassava processing has many traditional technological pathways which are adapted to the use of locally available processing resources in the area. Where water for fermentation is scarce, the heaping or stacking fermentation technique is adopted. Where scarcity of fuelwood is a constraint to toasting or steaming techniques, solar energy is adopted for drying, and so on.

The wide range of technological pathways, however, leads to an equally wide range of products which vary from one another in taste, appearance, and in other quality characteristics. This could be a disadvantage as it creates product differentiation which restricts the market for each product only to people who are used to it. The ways in which cassava is prepared varies from tribe to tribe and from place to place. Differences in processing that sometimes seem unimportant, even accidental, to the outside observer may be sufficient to make the staple product of one community unacceptable in another because of subtle changes in taste, texture, appearance, or digestibility. The fragmented character of the African world, however, has resulted in an unusual diversity of tastes. This diversity has seriously impeded the development of low-cost mechanical processing of a standardized product (Jones 1959).

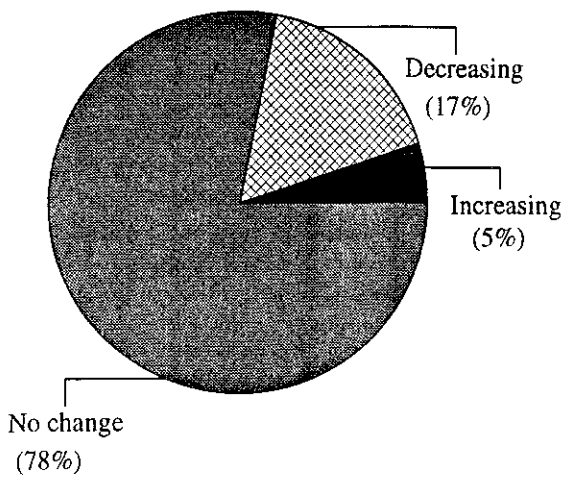
High labor requirements appears to be the only constraint to the level of cassava processing which none of the traditional techniques is able to circumvent. Improved technologies are therefore needed to resolve the labor constraint in cassava processing. The mechanized technique is available for only one of the three labor-intensive steps in the making of the granules.

Fermentation in Traditional Cassava Processing

Improved techniques of water expressing in the making of pastes and granules are available in about 30% of the villages visited. In some of the villages, processing is done using hydraulic elements, predominantly by a hydraulic jack mounted on a solid steel frame or using power screw shafts (Kwatia 1986). These are so effective in comparison with traditional methods that water expressing that otherwise would take three to five days to complete can be done in a matter of an hour or two. This can have disadvantages, however, as in the making of granules where fermentation is combined in an operation with water expressing. In this case, the adoption of the improved method of water expressing can result in a reduced fermentation period.

In those villages where major products are made with techniques which involve fermentation, nearly 20% reported that the fermentation period has declined in the last few years (Fig. 6). This decline seems to be related to the mechanization of cassava processing. The relative frequency of declining fermentation time is low for villages where no improved processing method is adopted compared with others where improved methods are adopted for different processing steps. It is highest in those villages where mechanized techniques have been adopted for grating. Grating is a step in the making of granules. Here water expressing and fermentation are a combined operation. Hence, adoption of an

Figure 6. Distribution (%) of villages by trend of fermentation time.



improved method which will reduce water expressing time from 4 or 5 days down to less than one day would reduce the fermentation period, if not eliminate fermentation entirely.

The relative frequency of a declining fermentation period is comparatively high among villages where mechanized methods of water expressing is adopted, although it is not as high as in villages where mechanized methods are also adopted for grating. The reason for this is that a mechanized method of water expressing is also adopted in making pastes where fermentation is carried out independent of water expressing. The relative frequency is even lower among villages where a mechanized method of milling chips into flour is adopted. Some chips are made following traditional technological pathways which do not involve fermentation. In addition, the same milling mechanized techniques for cassava converting chips into flour is also used to convert yam chips and grains into flour. Following these differences, the relative frequency of reported declining fermentation period is highest among villages which produce granules followed by those which produce pastes and lowest among others which produce chips and flour as their main products. The implication is that as mechanized processing techniques are adopted to replace traditional techniques the fermentation period will decline further.

The frequency of reported declining fermentation time is also higher for villages located close to market than among others which are remote from markets. It is also higher among villages in high than among others in low population density areas. The implication is that processing techniques could change in favor of less fermentation with increasing mechanization, commercialization, and population density.

Although the relative frequency of declining fermentation time is higher among villages which produce both bitter and sweet cassava types, or even among those which produce only the sweet types, the danger is that it is also declining among villages which produce only bitter cassava.

The relative frequency of declining fermentation time is higher among villages in the regions where cassava is the number one staple, and hence makes the bulk of the diet, than where it is not the number one staple. The implication of the declining fermentation period for the health of people who grow and eat bitter cassava is not clear because biochemists do not seem to agree that cassava contains cyanide or that fermentation is necessary for elimination of cyanide. Farmers, however, appreciate the fact that certain cassava types are dangerous to health if not properly processed.

Cyanogenic glucosides which release HCN are present in cassava. The cyanogens can be eliminated from cassava by two main mechanisms, namely, by leaching in boiling water and by hydrolysis to less stable compounds. Micro-organisms present during fermentation create conditions favorable to leaching and hydrolysis by inducing rating (Boganga 1992). This suggests that fermentation somehow has something to do with the elimination of the occurence of HCN in cassava.

As gas, the cyanogens evaporate when cassava roots are peeled, sliced, and crushed such as done in milling and grating operations. Sometimes the evaporation can reduce the HCN to below fatal levels. The frequency of the reported declining fermentation period is highest among the villages whose major cassava products are granules, especially *gari*. The crushing and the water expressing steps are more efficiently performed when mechanized and thus loss of linamarase more efficient than under traditional methods. This makes it easy to reduce the fermentation period without much risk of cyanide poisoning, if any.

Even if fermentation is not necessary for elimination of cyanide, and this is not certain, it is necessary for imparting taste to the product. Mechanization of processing techniques combined with population and market pressures which all contribute to the reduced fermentation period will also change the taste of cassava products. This situation will have implications for acceptance of new cassava products particularly in non-commercial areas where cassava serves food security needs.

Conclusion

About 70% of total cassava production is processed into a wide range of products including pastes, chips/flour, granules, starch, and alcoholic beverages. The proportion processed is positively and significantly related to the importance of cassava in terms of percentage of arable crop land and also to demographic pressure. It is significantly higher in the subhumid than in the humid and the dry climatic zones. It is also significantly higher among villages which produce only bitter cassava types than among others which produce only sweet cassava types. The proportion processed is, however, negatively and significantly related to market access infrastructure conditions, being lower in areas close to markets than in others not close to market centers. The objectives of processing cassava roots include bulk reduction and shelf-life extension in order to facilitate marketing. Therefore, the need for processing is greater in areas further away from markets.

Processing follows a wide range of traditional technological pathways adapted to the use of locally available resources such as fuelwood and water. The techniques involve several steps such as cooking/toasting which are labor, fuelwood, and/or sunlight use-intensive. They also include fermentation which may or may not be water use-intensive depending on the technological pathway adopted. The processors desire attractive color, texture, and taste qualities, in that order, in the processed products. Chips/flour are the most widely used cassava products followed by granules, fresh roots, and pastes in that order.

Available processing resources determine the types of products made from cassava roots but do not influence the level of processing. Labor-use intensity is the major constraint in traditional cassava processing. Peeling, crushing, and toasting are extremely labor-intensive, to the extent that high root yields attained through the use of the improved cassava varieties would not lead to expanded production to a significant degree because of labor constraints at the processing stages. However, the crushing step in *gari*-making has been mechanized in some areas of commercial production, mostly in West Africa.

The need for research on labor-saving technology for the various processing steps is a key issue arising from the results. Such processing steps are peeling of fresh roots, toasting of granules, and grinding of soaked roots in the making of pastes. The technologies must be cost effective at the farm level and must not depend on electricity or petroleum energy so that they would be adoptable by poor farmers most of whom lack access to electricity, while others face high costs for petroleum-based energy sources. The existing mechanized processing technologies for milling of chips into flour and grating of fresh roots in making granules are based on electricity or petroleum energy sources. There is a need for alternative technologies which will not depend on these scarce sources of energy to permit wide adoption of labor-saving technologies for the milling and grating steps in the making of flours and granules.

Another issue is the need to improve the quality of certain products. There is a wide variability in the quality of each product resulting from the use of diverse processing resources such as drying energy from various sources and particularly under a wide range of conditions. Although different peoples accept these different qualities perhaps out of habit, evidence suggests that there are desired standard quality characteristics for each product at least when intended for sale.

Traditional processing methods have positive values which could be lost if they are replaced by new processing methods. Such values include elimination of HCN through extended fermentation or water expressing periods. There may be a need for a clearer understanding of the role of fermentation in cassava processing. Similarly, certain traditional methods of fermentation also enhance the nutritive value of the cassava. If new technologies will eliminate these positive attributes of traditional processing, then there may be a need for research on how to enhance the protein value of cassava products without changing the desired quality characteristics and without increasing the cost of the product.

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COSCA Phase I Processing Component[1]

Natural Resources Institute[2]

Abstract

The first phase of the Collaborative Study of Cassava in Africa (COSCA) had as one of its specific objectives the characterization of cassava processing systems. This paper reports the results of baseline surveys carried out in six countries regarding the nature of processing activities. Among the principal findings are the identification of 623 products classified into 62 product types. Flours constitute the largest category of products with 45% of the total, followed by cooked roots with 17%, and fermented pastes with 12%. Roasted granules, fermented pastes and cooked roots are associated with rising trends in cassava production whilst flours occur disproportionately in villages with falling or static production. Women do most cassava processing. Men become more involved when machinery is present.

Key words: cassava, products, gender, machinery, ethnic group, fuel usage, fermentation.

Introduction

The first phase of the Collaborative Study of Cassava in Africa (COSCA) involved the collection of village level information from key informant groups in 233 villages across six African states.[3] This information has been assembled, using DBase III +, into a comprehensive database by COSCA staff based at the International Institute of Tropical Agriculture (IITA), Ibadan.

The phase I COSCA database is subdivided into four categories: production, marketing, consumption, and processing. The Natural Resources Institute (NRI), one of the participating organizations involved in COSCA, has the responsibility for analyzing aspects concerning processing.

The analysis of the first phase of COSCA is guided by a series of objectives and hypotheses set out in the first working paper.[4] The specific objective which relates to processing is "to quantitatively and qualitatively characterize the nature and distribution of cassava processing systems". This report interprets information contained in the phase I processing database to address this objective.

Phase I Product Definition

An observable characteristic of the phase I processing database is the use of a large number of different product names. Across the six countries, 147 different names (including spelling variations) are used to describe a total of 623 products. In most instances, these names refer to the same or similar types of products. This complicates the interpretation of information contained in the processing database.

In order to facilitate assessment of the information, there must be some means of identifying which products are synonymous or analogous, and defining their similarity.

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[1] Collaborative Study of Cassava in Africa (COSCA), Working Paper N° 7, International Institute of Tropical Agriculture (IITA). Ibadan, Nigeria. Reprinted here with the permission of the authors and Felix Nweke, Project Leader.

[2] Central Avenue, Chatham Maritime, Kent, United Kingdom, ME4 4TB.

[3] The six countries are: Côte d'Ivoire, Ghana, Nigeria (divided into East and West), Tanzania, Uganda and Zaïre.

[4] F. I. Nweke. 1988. COSCA project description. COSCA Working Paper N° 1. Resource and Crop Management Program, International Institute of Tropical Agriculture (IITA). Ibadan, Nigeria.

This problem was foreseen by the designers of the first phase of COSCA. A solution was attempted through the use of "product codes". These codes were designed to allow products to be defined by a prespecified code number. A list of 62 product codes was eventually drawn up, reducing the problem, but there were still too many categories of product to permit interpretation of the collected processing information. Further aggregation was necessary.

The next sections of this paper describe a system devised by the Natural Resources Institute to fit the various products encountered into unique aggregated categories, simplifying the interpretation of the data. These aggregated product categories were then used to analyze the information collected during phase I of COSCA, including the testing of various hypotheses.[5]

Developing Discrete Product Categories

During the first phase of COSCA, general information was collected on the five major cassava products processed in each village. Detailed information covering the sequence of processing stages of the three most important processed products was collected, although not all survey villages had three different processed cassava products. This detailed information constitutes the database on which this report was written.

Processed products are identified in the processing database using two different fields: the local name and the product code. Using the product codes, there are, as explained earlier, 62 different product types, which is a large number for critical interpretation. The number of product types had to be reduced and combined into broader categories to facilitate interpretation. The starting point for this procedure was the work of Peter Ay who defined a small number of broad but discrete categories for processed cassava products.[6]

Using Ay's definition of the essential processing stages required for each product category, DBase III+ programs were developed to assign each product to one of eight different product categories: cooked fresh roots, roasted granules, steamed granules, flours/dried chips, fermented pastes, sedimented starches, leaves, and drinks.

Separate programs for each product category worked by comparing the stages used in processing each product with the essential processing steps defined by Ay. For example, the fermented paste program searched for any product which was fermented then pounded or milled, then boiled.

After running these initial programs, it became obvious that, due to extensive variations in processing techniques, Ay's simple essential processing steps would not suffice to accurately categorize the large numbers of different products. For example, roasted granules *(gari)*, and steamed granules *(attieke)* were being defined as flours by the computer program since the two products shared the essential processing stages of fermenting and drying. In addition, ostensibly different (though similar) processing stages such as milling and pounding, or steaming and boiling were often being used interchangeably. As a further complication, some enumerators had included the food preparation stage[7] in the processing stage, with the result that flours and roasted granules were, in some cases, being categorized as fermented pastes as a result of the food preparation stage of adding boiling water to these products.

This problem was solved by using less equivocal definitions for each product type, plus the addition of "excluding" or "negative" conditions. These conditions stipulated that some products could be defined by processing stages which could not be used. Thus, to ensure, for example, that *a fermented paste* does not appear as a *roasted granule*, the paste is defined as being fermented, grated and pounded but not roasted. A list of definitions of product types appears in Appendix 1.

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[5] F. I. Nweke. 1988. COSCA project description. COSCA Working Paper N° 1. Resource and Crop Management Program, International Institute of Tropical Agriculture (IITA). Ibadan, Nigeria.

[6] P. Ay. Essential processing steps and their variations. Working draft, COSCA, Resource and Crop Management Program, International Institute of Tropical Agriculture (IITA). Ibadan, Nigeria.

[7] Food preparation stages are those stages used in preparing a processed product for immediate consumption (such as mixing *gari* with boiling water).

Examining Basic Product-type Patterns

Applying the revised product-type definitions to the phase I database, it is possible to categorize 602 of 623[8] recorded products. It is not possible to classify the remaining 21 products largely due to omitted processing steps, and possibly due to the esoteric nature of some of the products. Table 1 shows the distribution of the product types across the six COSCA countries.

Flours constitute the largest category of products, with 45% of the total, followed by cooked roots (17%), and fermented pastes (12%). Côte d'Ivoire accounts for 94% of steamed granules and 79% of sedimented starches. The production of drinks is limited to Uganda. Cassava leaves were only enumerated as a processed product in four instances, although the consumption database indicates that they were consumed in 132 of the 233 villages surveyed.

Table 2 shows the distribution of first ranked products only. It is apparent that the most important product in COSCA villages in Eastern Nigeria, Tanzania and Zaïre is flours, while in Uganda the preference is for cooked roots.[9] In Ghana and Western Nigeria, roasted granules *(gari)* is the most important product, while cooked roots and steamed granules vie for the position of the most important product in Côte d'Ivoire.

Using the IDRISI[10] mapping package, it is possible to gain an insight into the geographical distribution of the various products. Maps 1, 2, and 3 suggest that roasted granules and fermented products are typically a first or second ranked product near the coast, but tend to decline in importance the further north one goes. The converse is generally true for flours. It is also notable that fermented pastes are the most important product in southern/central Nigeria.

Table 3 shows the distribution of product type by agroecological zone, as defined by Carter and Jones.[11] Products are concentrated in the lowland humid and lowland semihot zones because almost 90% of the COSCA villages are themselves concentrated in these zones.[12] Only cooked fresh roots and flours are processed in lowland semi-arid and highland humid zones.

Table 1. Product type by country—first three ranked products.[a]

Product	Côte d'Ivoire	Ghana	Western Nigeria	Eastern Nigeria	Tanzania	Uganda	Zaïre	Total	%
Cooked roots	35	20		11	9	33		108	17
Roasted granules	7	19	18	24				68	11
Steamed granules	30	1					1	32	5
Flours/dry pieces	21	27	17	35	61	52	66	279	45
Fermented pastes	4	10	19	21	1		20	75	12
Leaves					1	3	2	6	1
Beers						6		6	1
Sedimented starch	22		3	3				28	4
Unclassified		5	4	4	2	2	4	21	3
Total								623	100

[a] The figures in the columns indicate the number of times a particular product type was ranked in the first three most important in the 233 villages surveyed.

[8] There were 623 products described in the database instead of 699 because some villages did not record a second or third ranked product. The three most important products in each village were used for this analysis.

[9] There was some confusion during the field administration of the Phase I questionnaire which resulted in some countries choosing not to record products which could be described as cooked fresh roots.

[10] A grid-based geographic analysis system produced by the graduate school of geography at Clark University, USA.

[11] S. Carter and P. G. Jones. 1989. COSCA site selection procedure. Working paper N° 2. Resource and Crop Management Program, International Institute of Tropical Agriculture (IITA). Ibadan, Nigeria.

[12] See Table 6.

Table 2. Product type by country—first ranked products.[a]

Product	Côte d'Ivoire	Ghana	Western Nigeria	Eastern Nigeria	Tanzania	Uganda	Zaïre	Total	%
Cooked roots	16	7			2	28		53	23
Roasted granules	1	12	14	8				35	15
Steamed granules	14						1	15	6
Flours/dry pieces	4	8	4	27	26	4	24	97	42
Fermented pastes	2	2		8	1		9	22	9
Leaves								0	0
Beers								0	0
Sedimented starch	3							3	1
Unclassified		1	3	1			2	7	3
Total								232	100

[a] The figures in the columns indicate the number of villages where the products were ranked first in the 233 villages surveyed.

Table 3. Product type by agro-ecological zones—first three ranked products.

Product	Low humid (A)	Low semi-hot (C)	Low continental (E)	Low semi-arid (G)	High humid (J)	Total
Cooked roots	70	15	2	1	12	100
Roasted granules	31	35	1			67
Steamed granules	24	5	2			31
Flours/dry pieces	124	88	7	15	19	253
Fermented pastes	41	31	1			73
Sedimented starch	15	11	1			27
Total	303	183	14	16	29	545

Table 4 illustrates the statistically significant relationship between population density and product type. For the purposes of the survey, population densities were defined as *high* when the number of people per square kilometer was 50 or more. The number of villages in the high and low density bracket was 115 (54%) and 98 (46%) respectively.[13] The concentration of steamed granules and sedimented starches in low density areas reflects the predominance of these product types in Côte d'Ivoire.

Table 5 illustrates a significant relationship between product type and the trend in cassava production (i.e. whether the production of cassava is said to be rising or falling). Cassava production was rising in 159 (70%) out of the 233 villages and falling or static in 67. Roasted granules, fermented pastes and cooked roots are associated with rising trends in cassava production whilst flours occur disproportionately in villages with a falling or static production trend.

The statistical significance of Tables 4 and 5 supports the contention that there is some underlying relationship between population densities and product type.[14] A possible relationship is that the highly marketable products (amongst which roasted granules must be the epitome due to extended storability) are associated with high population densities due to easier market access in high population density areas. Additionally, there may be some relationship between the

[13] Some of the 233 villages did not possess information on population density, the percentages relate to the 213 villages that did.

[14] The comparison of trends in cassava production and population density reveals a chi-squared figure of 15.33 (with DR = 1); a significant figure.

Map 1. Rank for roasted granules–West Africa.

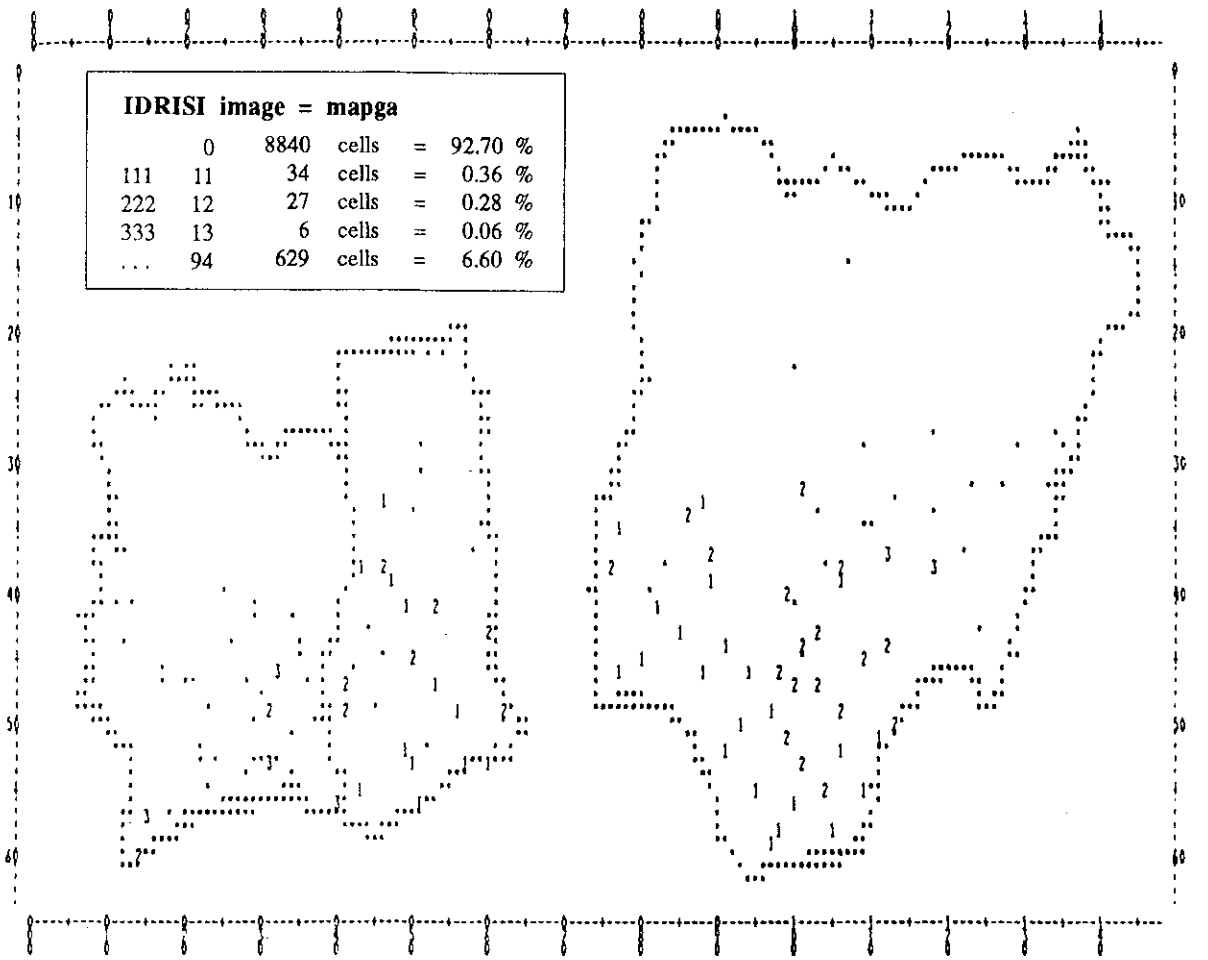


Table 4. Product type by population density.[a]

Product	Population Density				Total
	High		Low		
	number	%	number	%	
Cooked roots	51	50	51	50	102
Roasted granules	51	76	16	24	67
Steamed granules	1	3	30	97	31
Flours/dry pieces	121	48	133	52	254
Fermented pastes	50	68	23	32	73
Sedimented starch	4	15	23	85	27
Total					554

[a] Degrees of freedom 5; chi squared: 69.33.

Map 2. Rank for flours and dried pieces–West Africa.

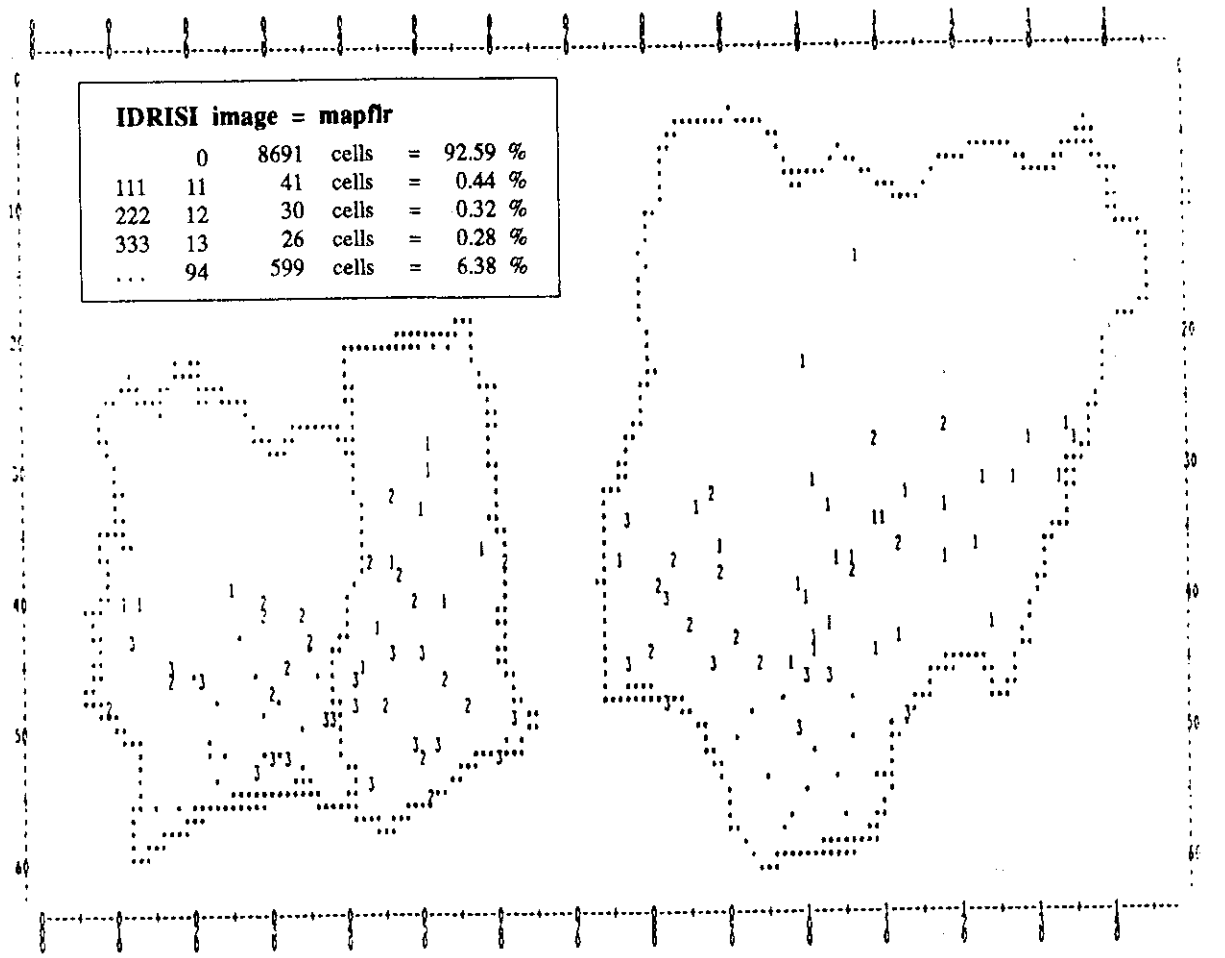
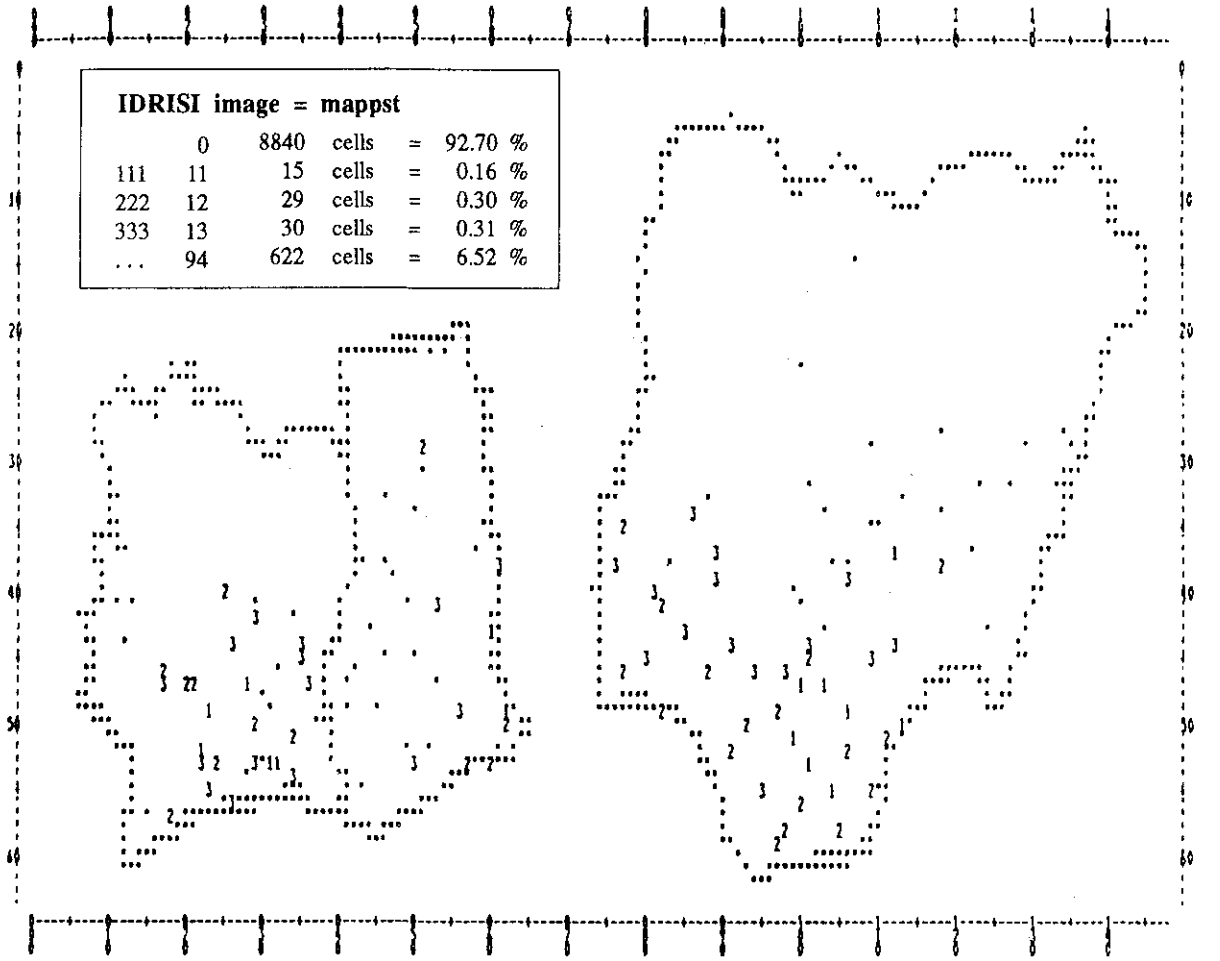


Table 5. Product types by cassava trend.[a]

Product	Production Trend				Total
	Rising		Falling/static		
	number	%	number	%	
Cooked roots	81	74	28	26	109
Roasted granules	65	96	3	4	68
Steamed granules	22	69	10	31	32
Flours/dry pieces	164	60	111	40	275
Fermented pastes	54	74	19	26	73
Sedimented starch	19	68	9	32	28
Total					585

[a] Degrees of freedom 5; chi squared: 36.18.

Map 3. Rank for fermented pastes–West Africa.



marketable, labor-intensive products (such as roasted granules) and high population densities due to their importance as a source of cash income where alternative employment, both on- and off-farm, is becoming more limited due to increasing population and resultant oversupply of labor.

Seasonality of Production

Seasonality data from phase I indicate that there are pronounced peaks and troughs in the processing of certain products. Before looking in detail at these patterns, it is necessary to make some clarifications.

The comparison of seasonality data can be misleading. Where seasonality data are aggregated, as in Figures 1 to 7, there is a possibility that distinct seasonal peaks and troughs may cancel each other out, giving the appearance of constant output. To minimize the chances of this occurring, comparisons should only be made on the basis of one key variable.[15] For example, to identify the seasonality of flour production, comparison might

[15] Usually the variable which is thought to be the major influence when specific products are processed.

Figure 1. Seasonality of processing in Côte d'Ivoire.

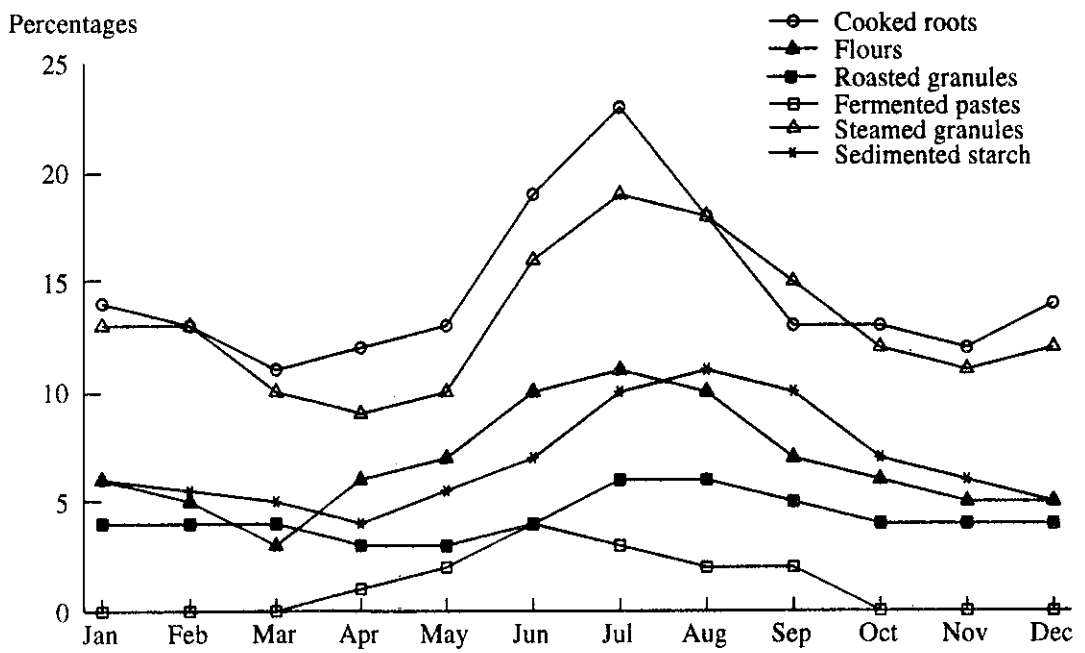


Figure 2. Seasonality of processing in Ghana.

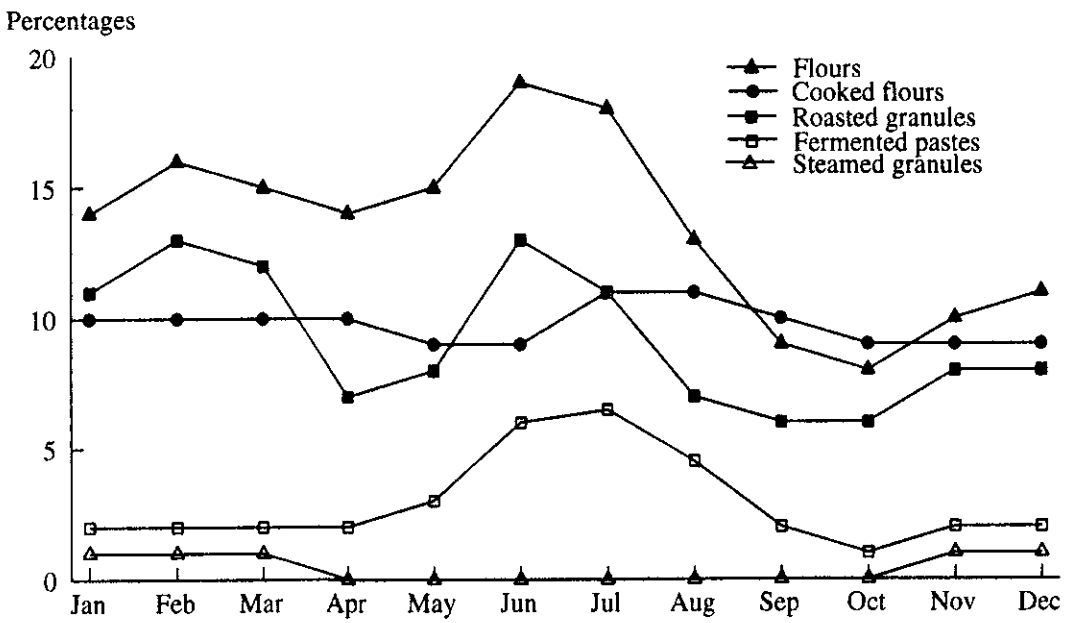


Figure 3. Seasonality of processing in Eastern Nigeria.

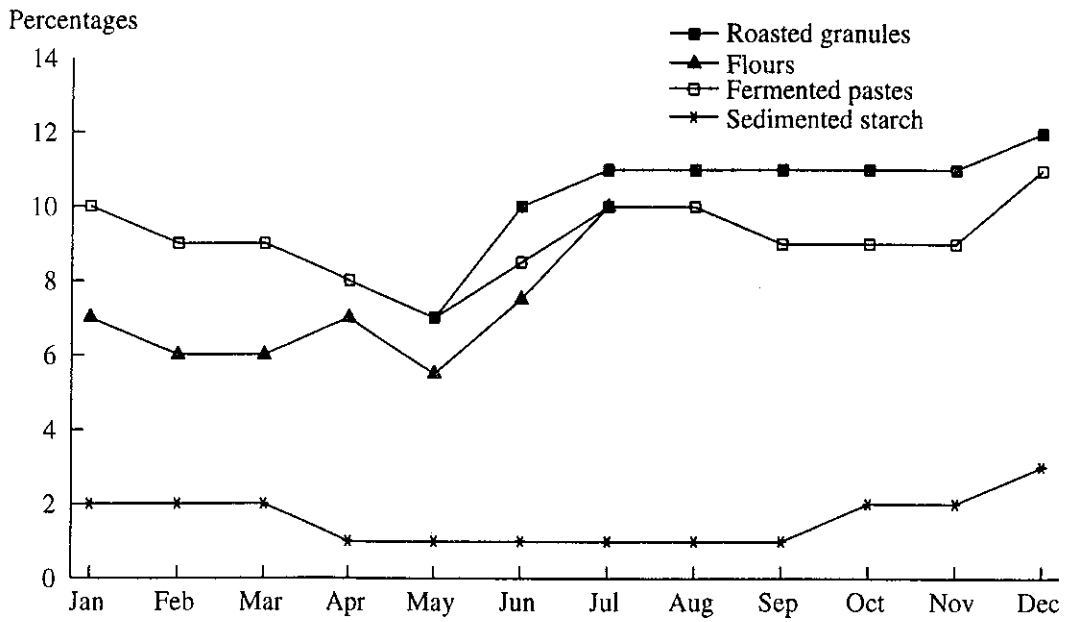


Figure 4. Seasonality of processing in Western Nigeria.

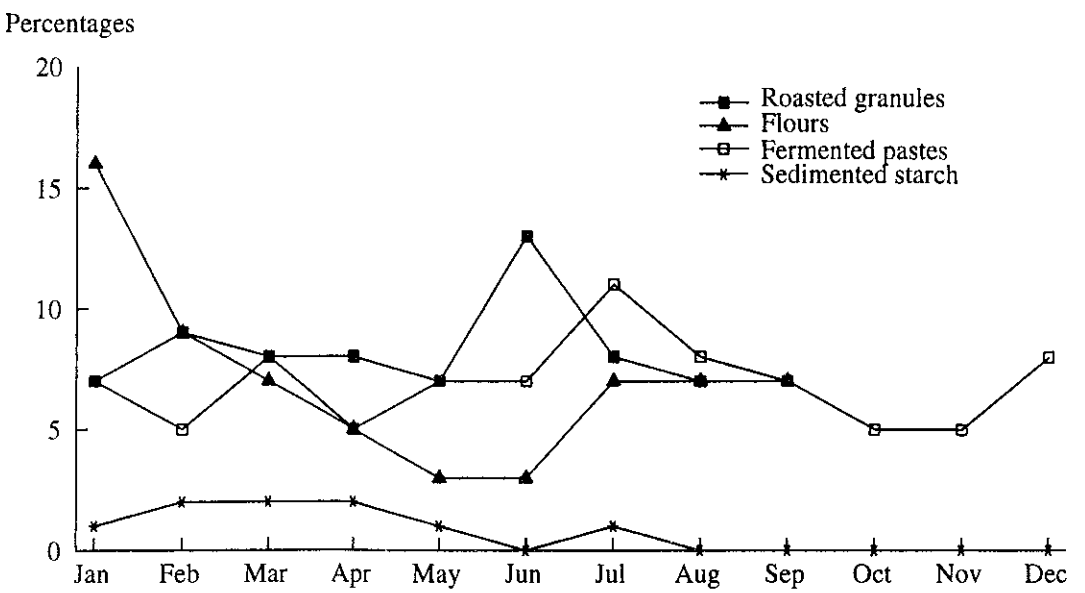


Figure 5. Seasonality of processing in Tanzania.

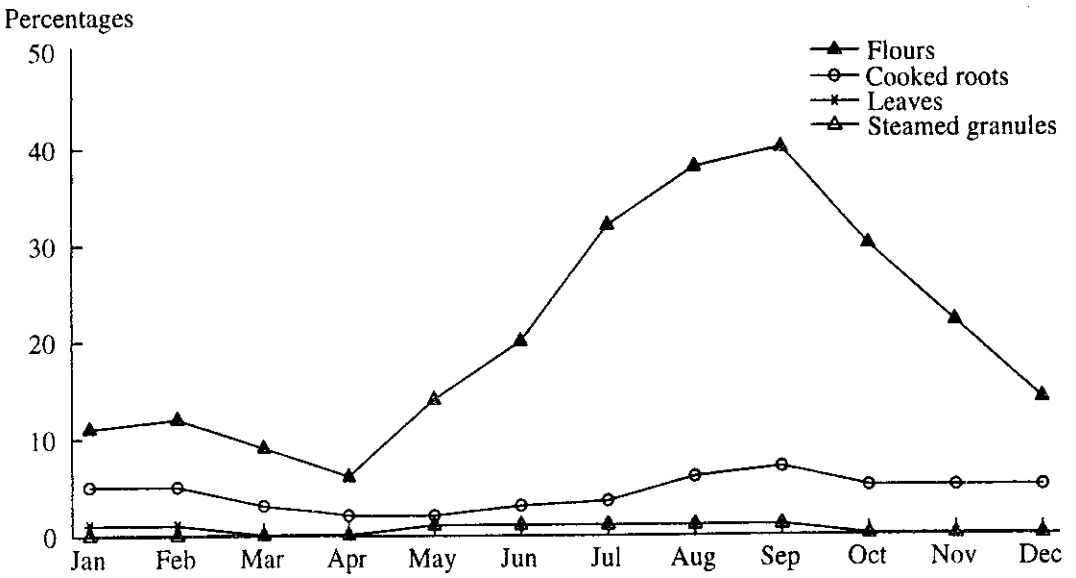


Figure 6. Seasonality of processing in Uganda.

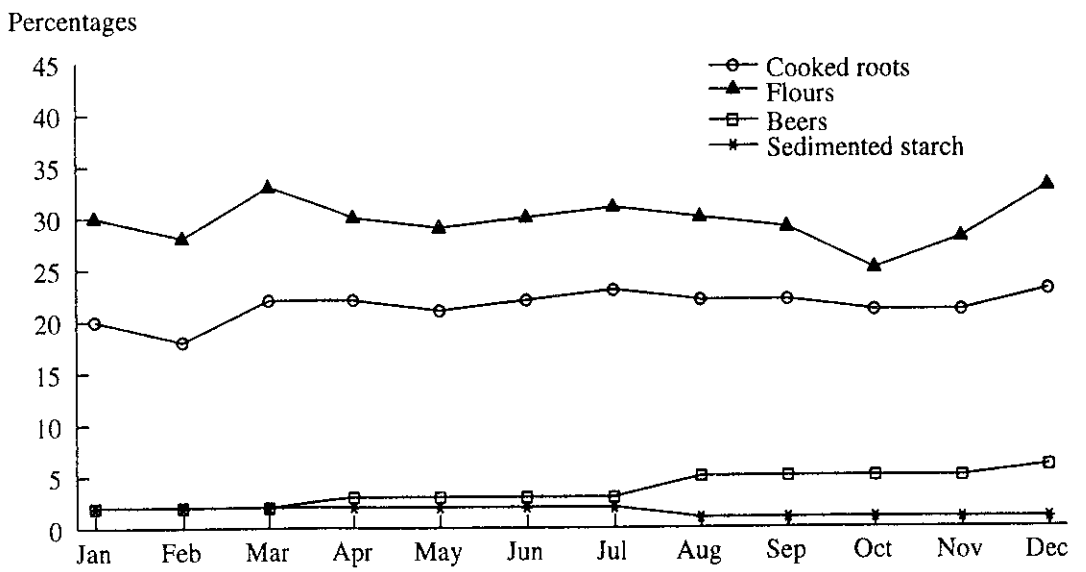


Figure 7. Seasonality of processing in Zaïre.

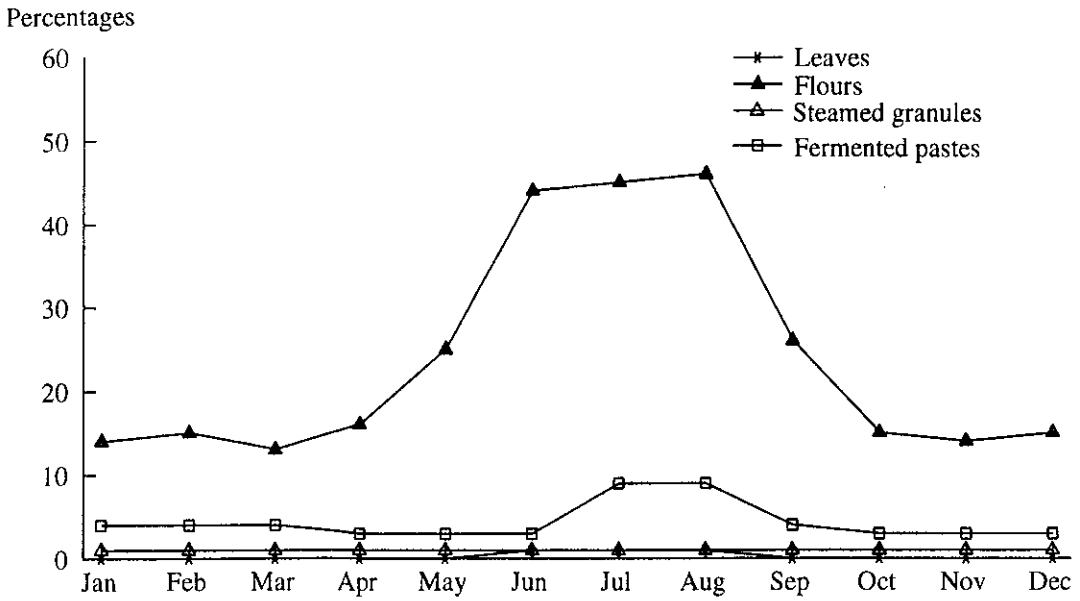


Figure 8. Seasonality of sales and processing of *gari* in Nigeria.

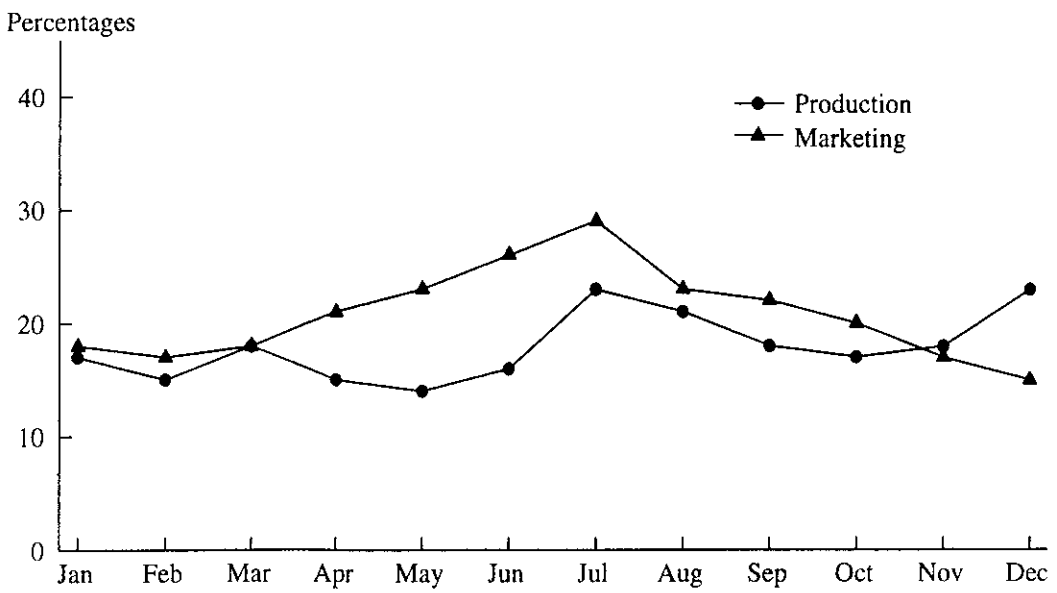


Table 6. COSCA villages by agro-ecological zones.

Country	Low humid (A)	Low semi-hot (C)	Low continental (E)	Low semi-arid (G)	High humid (J)	Total
Côte d'Ivoire	27	8	2	0	0	37
Ghana	17	9	0	0	0	26
Nigeria	20	41	2	2	0	65
Tanzania	3	13	0	5	0	21
Uganda	20	0	0	0	12	32
Zaïre	27	7	2	0	0	36
Total	114	78	6	7	12	217

be based on when the dry season occurs. Once such a variable is identified, comparison should take place between areas where the key variable occurs at the same time of the year. Otherwise, there is a risk of masking the true peaks and troughs of production.

To clarify further, take two areas, A and B, where flours are processed. The rainy season lasts from January to June in A, and from July to December in B. If flour production surges during the dry season, the separate graphs depicting seasonality of flour production in each country will show a peak for country A in the first half of the year and a trough in the second half, and a peak for country B in the second half of the year with a trough in the first half. If data on country A and B are now combined on one single graph, the peaks and troughs will cancel each other out, giving the appearance of constant output throughout the year.

Figures 1 to 7 are presented on a country basis in order to minimize these possible aggregation errors. Products are not compared across agroecological zones as variation in the key variables is likely to be greater between agroecological zones[16] than between countries. Nonetheless, substantial variations will still occur within each country, masking some of the seasonal effects. Looking at Figures 1-7, many products reveal a seasonal peak between June and August. This is demonstrated most clearly in the cases of Zaïre, Côte d'Ivoire, and (less clearly) Ghana. Interesting exceptions occur for flours in Eastern Nigeria (December/January peak), flours in Tanzania (June to November peak) and roasted granules in Western Nigeria (December peak).

Table 7 shows the extent of "zero seasonality" in production, that is, where production is said to be at a constant level all year round.[17] The figures must be interpreted with reference to Table 1, since the percentage figures give no indication of the sample size. Ugandan products appear to be subject to least seasonality, with 46% of the products exhibiting no change in output over the year. Western Nigeria, Eastern Nigeria and Côte d'Ivoire exhibit the greatest degrees of seasonality, although the graphs do not make this apparent. From the evidence of the Table 7, roasted granules show the greatest degree of seasonality.

Various hypotheses could be invented to explain the seasonality of products. Timing of rainfall, for example, may be the prime determinant of the timing of flour production. Similarly, labor demand in other household activities will influence timing. Unfortunately, the scope of phase I database means that there is no data which could be used to adequately test these hypotheses.

Data do exist, however, on the seasonality of marketing of products. Taking the product which, according to Table 7, showed the greatest degree of seasonality (or the least nonseasonality) and comparing its processing seasonality with the record of marketing seasonality of that product, a relationship may be dis-

[16] The main difference between the key "humid" and "semi-hot" zones (see Table 6) is the length of the rainy season, not when the rainy season occurs; "humid" is used where precipitation is over 60 mm per month for 0 to 3 months; "semi-hot" indicates a duration of 4 to 6 months.

[17] The wording of the question asked during the survey was "during what month(s) of the year is production of these cassava products highest? (enter 1 for highest)". Constant production, or "zero seasonality" is taken as occurring where a "1" has been entered against each month in the year. Products where a blank appeared for each month of the year were not counted as exhibiting "zero seasonality" since the likelihood is that it shows this part of the questionnaire was not filled in.

Table 7. Incidences of stable annual processing.

Product	Côte d'Ivoire %	Ghana %	Western Nigeria %	Eastern Nigeria %	Tanzania %	Uganda %	Zaïre %	% of Total
Cooked roots	23	60		18	44	42		37
Roasted granules	14	21	22	4				15
Steamed granules	20	0					100	22
Flours/dry pieces	14	26	6	9	31	46	26	27
Fermented pastes	0	0	32	5	0		30	17
Leaves					0	67	50	50
Beers						50		50
Sedimented starch	18		33	0				18
Percent of total	18	30	21	7	32	46	28	26
Total								232

cernible. Figure 8 shows the pattern for peak sales of *gari*/roasted granules in Nigeria as a whole, as well as the seasonality of the processing of *gari* reproduced from Figures 3 and 4. The result shows that one of the processing peaks for *gari* coincides with the marketing peak. Where lines diverge, such as in the November/December period, there is inferred storage, increased domestic consumption and decreased commercial demand.

In conclusion, the seasonality data illustrate that output of cassava products varies according to the season, but further work is necessary to generate estimates which will point to the factors that are the most important in determining the timing of production.

Testing Hypotheses

A major aim of the first phase of COSCA was to test some of the hypotheses set out in the first COSCA working paper.[18] Those which relate to the processing of cassava include hypothesis a8 ("there are no economies of scale in cassava processing"), hypothesis a10 ("high labor requirements for processing cassava is a major constraint to expanded production"), and hypothesis b10 ("gender roles in cassava processing change as we move to more commercial production"). Other hypotheses also contain references to processed cassava but are predominantly production or marketing questions which have their own sections elsewhere in the COSCA project.

Within the context of the phase I database, the above hypotheses cannot be fully tested. The hypothesis of the economies of scale can only be tested if there is information about the inputs and outputs from different processes. In phase I there is no such data. The hypothesis concerning the constraining effect of the demand for processing labor cannot be tested since there is no information in the database on processing labor time.[19]

The hypothesis concerning changing gender roles relates to the movement to "more commercial production". The nearest convenient proxy that can be used for degree of production commercialization is the question on why cassava is produced; for home consumption or for sale. Thus, a table (8) has been produced which

Table 8. Hypothesis b10 Gender roles and increasing commercialization.[a]

Cassava production objectives	Gender roles		Total
	Female	Male	
For home consumption	198	5	203
For sale	94	2	96
Total	292	7	299

[a] Degree of freedom 1; chi squared: 0.0.

[18] Nweke 1988, COSCA project description. COSCA Working Paper N° 1. Resource and Crop Management Program. International Institute of Tropical Agriculture (IITA). Ibadan, Nigeria.

[19] There is data on the time taken for processing stages which last a day or more, such a drying, but this is not the same thing as active labor input.

contrasts this information with the question of which sex has the greater role in production. The chi squared statistic is categorically not significant in this case, so the hypothesis goes unconfirmed.

The Role of Women in Cassava Processing

It is clear from the phase I database that women play a major role in processing cassava. In answer to the question: "What is the gender of those who do most processing of this product?" Only 9 instances are recorded where the answer was given as "males", and four of these involved the production of alcohol. In contrast, in 372 cases the answer was given as "females".

Unfortunately, the question "who does most processing?" was not asked for the first ranked, and hence most important, processed product. There is, therefore, the possibility that men may be responsible for most of the processing of the first ranked products if responses to this question alone are used to analyze gender roles.

Fortunately, additional information does exist. Table 9 summarizes the information on gender-differentiated processing tasks for all ranked processed products and demonstrates that 82% are performed mainly by women, with only 7% performed mainly by men. When comparable figures are assembled for first ranked products only, the proportions are almost identical, at 81% and 7% respectively.

From Table 9 it can be seen that in 75% to 91% of villages, women or women and children are responsible for the tasks of peeling, washing, pounding, roasting and frying. Men tend to assume significant responsibility only for the tasks of milling, grating, and fermenting in sacks —tasks which often involve the use of machines. Table 10 compares the relative frequencies of male participation in milling, grating, and dewatering, the three tasks which make the most extensive use of machinery. Figures for villages where machines are present ("mechanized vil-

Table 9. Gender roles in cassava processing.

Subprocess	(A) Women	(B) Men	(C) Others	A/A + B + C %	B/A + B + C %	Total
Washing	273	2	24	91	1	299
Peeling	318	11	60	82	3	389
Soaking	88	6	6	88	6	100
Slicing	173	9	20	86	4	202
Grating	48	35	16	48	35	99
Milling	44	24	6	59	32	74
Pounding	165	5	17	88	3	187
Sieving	187	5	23	87	2	215
Roasting	33	4	7	75	9	44
Sun-drying	179	13	21	84	6	213
Drying	52	3	5	87	5	60
Wrapping	25	0	1	96	0	26
Fermenting in sacks	106	24	26	68	15	156

Table 10. Comparison of gender responsibilities for selected mechanized processing stages.

Machine	Stage	(A) Mainly women	(B) Mainly men	(C) Others	Mechanized villages		All villages	
					Women (%)	Men (%)	Women (%)	Men (%)
Mill/grinder	Milling	36	22	6	56	34	59	32
Grater	Grating	12	32	5	24	65	48	35
Screw-press	Dewatering	19	6	0	76	24	68	15

lages") are compared with figures for all villages,[20] with the relative frequency of male participation in these tasks noted. The results show that the relative frequency of male responsibility is higher when a machine is present. In the case of grating, this frequency is almost twice the standard village level.

With respect to the marketing of cassava products, in 180 out of a possible 233 instances women are responsible for the selling of the products, whilst only 27 instances of men performing this task are recorded.

Product Types, Quality Preferences and Varietal Preferences

As shown in Table 11, color, texture and taste were the most frequently cited quality characteristics of product types by villagers. Color is a particularly important quality characteristic for flours and fermented pastes whilst texture and taste are most important for cooked roots.

In 60% of the phase I survey villages, the preferred cassava variety for processing is a sweet variety and in 40% the favored variety is bitter. Table 12 shows the relationship between product type and the bitterness or sweetness of the main cassava variety grown for processing. The relationship is statistically significant, and supports the observation that villagers tend to use sweet varieties for cooked fresh roots.

There is the possibility that the statistical significance noted in Table 12 is due to the unremarkable tendency for villagers to use sweet varieties as cooked fresh roots. It is, therefore, worth excluding cooked fresh roots from the tabulation to further test the relationship. As shown in Table 12, the relationship remains significant when fresh roots are removed, indicating a preference for sweet or bitter varieties extending into other product categories.

Table 11. Desired quality characteristics.[a]

Products	Color	Texture/ mealiness	Taste	Other
Cooked roots	16	43	35	6
Roasted granules	24	11	18	15
Steamed granules	7	6	8	8
Flours/dry pieces	166	47	30	29
Fermented pastes	44	17	3	11
Sedimented starches	7	8	5	3

[a] $v = 15$; $x^2 = 116.06$.

Table 12. Bitter/sweet varietal preferences.[a]

Product	Bitter	Sweet
Cooked roots	11	94
Roasted granules	32	32
Steamed granules	5	12
Flours/dry pieces	127	147
Fermented pastes	44	26
Sedimented starches	9	15
Total	228	326

[a] $v = 5$; $x^2 = 60.64$.

Mechanization of Cassava Processing

Table 13 shows the number of villages using machines to process cassava. Nigeria has both the highest number and the greatest diversity of cassava processing machines with 11 of the villages in Western Nigeria using grinders, graters and screw presses. In Zaïre, there is no mechanization of cassava processing, whilst in Tanzania and Uganda only mills or grinders are used, given the importance of flours in the two countries. The use of screw presses is restricted to Côte d'Ivoire and Nigeria.

Table 13. Extent of mechanized processing.

Country	Mills/ grinders	Graters	Screw press
Côte d'Ivoire	6	4	28
Ghana	24	5	0
W. Nigeria	14	18	13
E. Nigeria	22	16	7
Tanzania	9	0	0
Uganda	24	0	0
Zaïre	0	0	0
Total	99	43	48

[20] Figures for "all villages" are taken from Table 9.

Table 14. Mechanization of processing—total and relative frequency (% of total) of use.

Product	Country	Total product	Mill/grinder	Grater	Screw press
Roasted granules	Côte d'Ivoire	7	1(14)	1(14)	7(100)
	Ghana	19	14(74)	4(21)	0(0)
	Nigeria	42	21(50)	31(74)	17(40)
Steamed granules	Côte d'Ivoire	30	6(20)	3(10)	24(80)
Flours	Côte d'Ivoire	21	3(14)	4(19)	10(48)
	Ghana	27	23(85)	2(7)	0(0)
	Nigeria	52	36(69)	20(38)	14(27)
	Tanzania	61	16(26)	0(0)	0(0)
	Uganda	52	37(71)	0(0)	0(0)
	Zaïre	66	0(0)	0(0)	0(0)

Machines for peeling cassava roots were not encountered in any of the phase I survey villages despite the labor intensity of this processing stage.

Figures 9 and 10, derived from Table 14, show the use of machines for the production of particular products.[21] In the case of flours, Figure 9 shows that the majority of village production in Ghana, Nigeria, and Uganda utilizes a grinder or mill. Graters are only used for flour production in Ghana, Côte d'Ivoire, and Nigeria, countries which have alternate uses of these machines for the production of steamed and or roasted granules. Screw presses are only encountered in flour production in Nigeria and Côte d'Ivoire again reflecting their use in the production of other products (Fig. 10).

Figure 10 illustrates the different machine combinations used in the production of roasted granules in Côte d'Ivoire, Ghana, and Nigeria. Ghanaian production tends to make extensive use of mills or grinders and graters, with no use of presses. Nigerian producers make use of all three machine types, whilst Côte d'Ivoire producers make most use of screw presses.

Table 14 illustrates that 80% of *attieke* production in Côte d'Ivoire utilizes screw presses, whilst only 20% of production utilizes mills and 10%, graters.

Organization of Cassava Processing Units

Most cassava processing was conducted by households, with processing by individual commercial units in 22% of the survey villages. Although no cooperative processing of cassava was recorded, this may be due to cooperative processing having been equated with formal cooperative organizations. There were factories processing cassava in 15 of the 233 survey villages: six in both Tanzania and Uganda and three in Eastern Nigeria. All the cassava processing factories in Uganda were government owned. Since no definition of "factory" was specified, there may be inconsistencies between countries.

Fuel Usage

Table 15 presents data on the usage of different types of fuel for cooking and processing. This original question did not restrict itself to the processing/preparation of cassava and did not list firewood as a fuel. It is nevertheless clear from the table that kerosene/gasoline and crop residues are important fuels, whilst charcoal and gas are rarely used.

Distribution of Product Type by Ethnic Group

Table 16 presents cross-tabulations of product type by principal ethnic groups in each of the six study

Table 15. Fuel usage by number of users.

Fuel type	None	Few	Many	Most
Charcoal	159	58	4	4
Crop residue	141	20	23	40
Kerosene/gasoline	111	59	10	3
Gas	205	16	2	0
Other	192	3	0	10

[21] Figures 9 and 10 should be interpreted in conjunction with table 14 to gain a perspective of sample sizes.

Figure 9. Use of machines in the production of flours.

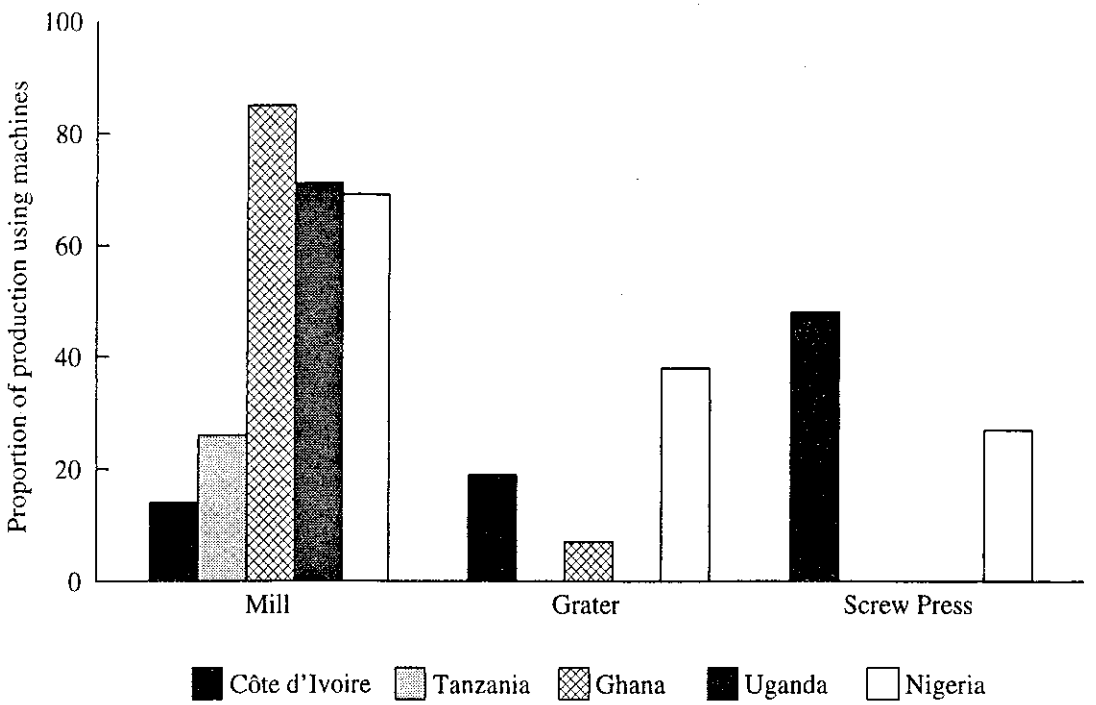


Figure 10. Use of machines in the production of roasted granules.

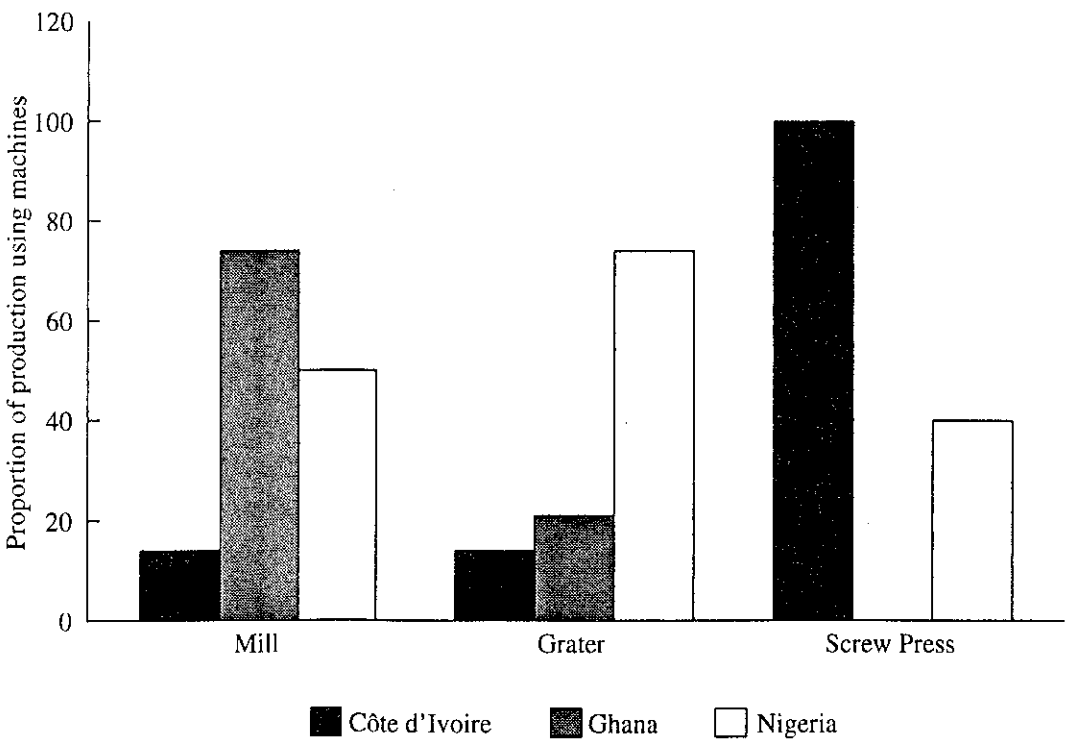


Table 16. Product type by ethnic group.

Country/Ethnic group	Product type*							
	1	2	3	4	5	7	8	9
CÔTE D'IVOIRE								
Agni-Ashanti	13	1	12	10	2	0	0	10
Krou	9	2	6	5	2	0	0	6
Mande du Nord	1	1	1	0	0	0	0	0
Mande du Sud	5	0	3	4	0	0	0	2
Koua	4	1	5	1	0	0	0	4
Mossi	2	1	2	1	0	0	0	0
GHANA								
Akan	14	11	0	15	3	0	0	0
Gouang	1	1	0	2	1	0	0	0
Ewe	1	2	1	1	3	0	0	0
Voltaic	2	2	0	4	1	0	0	0
Ga-Adangbe	1	2	0	3	2	0	0	0
Konkonba	1	0	0	1	0	0	0	0
Dagarti/Gagari	0	1	0	1	0	0	0	0
WESTERN NIGERIA								
Yoruba	0	11	0	13	12	0	0	1
Edo	0	3	0	1	4	0	0	0
Urhobo	0	2	0	0	3	0	0	1
Nupe	0	1	0	1	0	0	0	0
Igbirra	0	1	0	1	0	0	0	1
EASTERN NIGERIA								
Hausa/Fulani	1	0	0	12	0	0	0	0
Igbo	3	6	0	3	6	0	0	0
Ibibio	1	1	0	0	1	0	0	0
Tiv	0	2	0	2	2	0	0	0
Gwari	0	2	0	2	0	0	0	2
Katab	0	0	0	1	0	0	0	0
Jukun	0	0	0	1	0	0	0	1
Igala	0	3	0	5	3	0	0	0
Boki	1	1	0	0	1	0	0	0
Gwandara	0	0	0	1	0	0	0	0
Afo	0	1	0	1	0	0	0	0
Chip	0	0	0	1	0	0	0	0
Goemai	0	1	0	1	1	0	0	0
Eggon	0	0	0	2	0	0	0	0
Cheobo	0	0	0	1	0	0	0	0
Ichin	0	1	0	1	1	0	0	0
Dusang	1	1	0	0	1	0	0	0
Ekoi	1	1	0	0	1	0	0	0
Bisu	0	1	0	1	1	0	0	0

Table 16 *continued*

Country/Ethnic group	Product type*							
	1	2	3	4	5	7	8	9
TANZANIA								
Wassukauma	2	0	0	14	1	1	0	0
Wasubi	0	0	0	2	0	0	0	0
Wajaruo	0	0	0	5	0	0	0	0
Waha	0	0	0	3	0	0	0	0
Wazaramo	2	0	0	13	0	0	0	0
Wamakonde	0	0	0	9	0	0	0	0
Wamakura	0	0	0	3	0	0	0	0
Wazigua	1	0	0	1	0	0	0	0
Wajita	0	0	0	1	0	0	0	0
Wanata	0	0	0	1	0	0	0	0
Wadigo	0	0	0	2	0	0	0	0
Wasambaa	2	0	0	1	0	0	0	1
WaZanzibari	1	0	0	2	0	0	0	0
UGANDA								
Buganda	14	0	0	19	0	2	2	0
Tchouezi	1	0	0	1	0	0	1	0
Nyawanda	1	0	0	2	0	1	0	0
Banyoro	3	0	0	2	0	0	0	0
Alur	2	0	0	4	0	0	0	0
Bakiga	1	0	0	2	0	0	0	0
Basogo	4	0	0	11	0	0	0	0
Langi	2	0	0	3	0	0	1	0
Bagishu	3	0	0	4	0	0	2	0
Badama	1	0	0	2	0	0	0	0
Baruli	1	0	0	2	0	0	0	0
ZAÏRE								
Bakongo	0	0	0	31	13	2	0	0
Balunda	0	0	0	4	1	0	0	0
Code 6	0	0	1	8	4	0	0	0
Code 7	0	0	0	23	2	0	0	0

Key to products: 1 = cooked fresh roots
2 = roasted granules
3 = steamed granules
4 = flours/dried pieces
5 = fermented pastes
7 = leaves
8 = drinks
9 = sedimented starches

*6 = no class

countries. Since a total of 67 ethnic groups were encountered in the phase I database, it would be advantageous statistically if these are rationalized before further investigation on these variables is undertaken.

Duration of Fermentation Stages

The analysis of fermentation is complicated by the possible ambiguity of the sundrying and smoking processing stages. Sundrying and smoking may not be explicit fermentation stages but will nevertheless result in microbial growth, occasioning fermentation. Similarly, there are complications arising out of the definition of "dewatering": the database does not allow the processing stage "dewatering" to be distinguished from fermentation in sacks. The problem arises from the fact that fermenting in sacks invariably involves the loss of moisture whether the sack is weighted down with stones or simply left on a rack. Yet many households will use a press, for example, in addition to "dewatering" in the sack. In this report, dewatering and fermenting in sacks\baskets are, therefore, used interchangeably.

Bearing in mind these complications, four distinct methods of fermentation were identified during phase I:

- fermentation in sacks or baskets
- soaking in water for 1 day or more
- fermentation in heaps for one day or more
- sundrying or smoking of products for two days or more.

In this report, (a) and (b) are referred to as "acidic" fermentations and (c) and (d) as "air" fermentations. It should be noted in this definition that air-fermented products cannot be acid-fermented but that acid-fermented products may also be air-fermented (acid-fermented flours, for example, are frequently dried for more than two days).

Since there are seven different processing stages which could be deemed to involve microbial growth[22] total fermentation time will involve, in most cases, the combined duration of these stages. However, very different product qualities are imparted when different fermentation methods are used. For example, a product which is soaked for three days and dried for three days will have different properties from one which is merely dried for six days; that is, the mere comparison of times across the range of fermentation methods is not appropriate.

Nevertheless, some interesting pointers can be gleaned from the database on fermentation times. Figure 11 illustrates the differing "dewatering" times (i.e., fermentation in sacks) for steamed and roasted granules, predominantly *attieke* and *gari* respectively. The graph illustrates clearly that steamed granules appear to need less time to dewater than roasted granules. A possible explanation is that roasted granules may be allowed to dewater for longer periods to improve the drying/roasting efficiency, whilst the steaming of granules is less dependent on moisture content. A second hypothesis might be that the practice of adding a starter culture, ubiquitous in *attieke* production in Côte d'Ivoire, produces a more rapid fermentation which may accelerate the loss of moisture.

On the subject of physicochemical changes in the product and their relationship to water loss, Figure 12 taken from Table 17, shows the relationship between drying times for flours and the use of soaking as a processing stage. There is a slightly greater proportion of unsoaked flours in the one to six day categories than soaked flours. This is difficult to explain, indeed the reverse might have been expected due to the same physico-chemical changes postulated for the addition of starter cultures in the production of steamed granules.

Table 18 and Figure 13 show the duration of fermentation in sacks or baskets for roasted granules. Eastern Nigeria and Côte d'Ivoire seem to allow a large proportion (57% and 43% respectively) of roasted granules to ferment for only 1 or 2 days, although the techniques of production do not seem to vary to any great extent. There is little evidence to support the contention that climate will adversely affect the dewatering time. A possible explanation may lie in the selection of varieties for the production of roasted granules.

There are 279 instances of flours in the phase 1 data base, of which 150 are air-fermented and 113 are acid-fermented. The remaining 16 instances were deemed to be "unfermented". Twenty-one per cent of the acid-fermented flours were subsequently turned into pastes whereas no air-fermented flours were used to this end.

[22] Processing stages 03, 12, 29, and 30 to 33 (see Appendix 2).

Figure 11. Dewatering times for roasted and steamed granules.

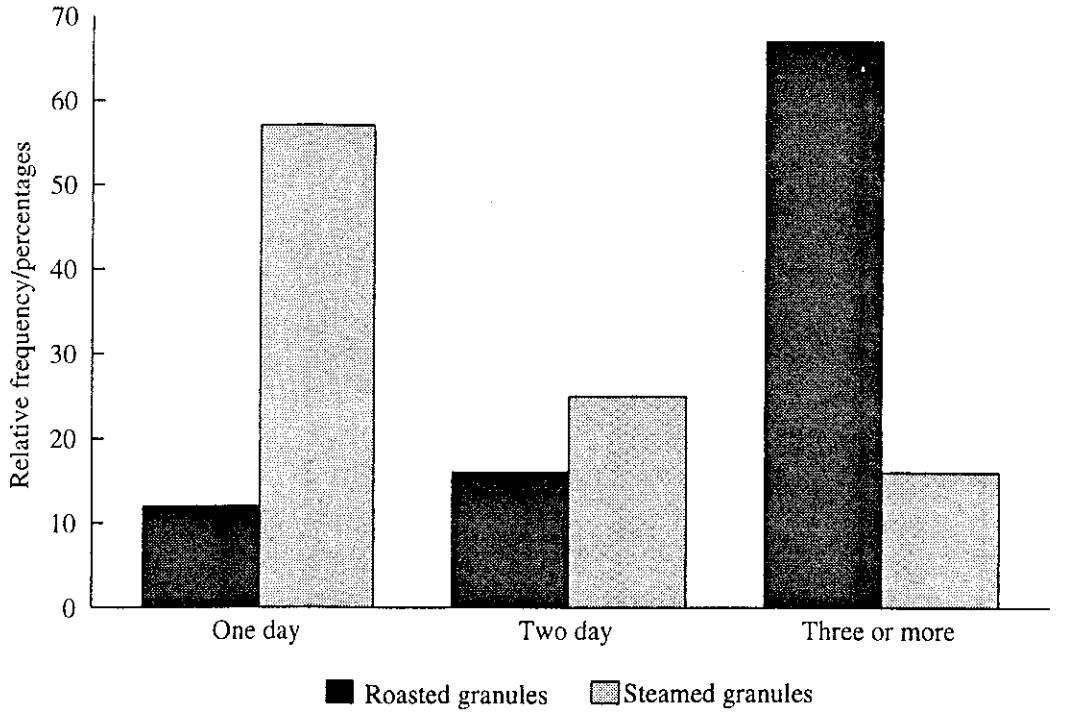


Figure 12. Relationship of drying time between soaked and unsoaked flours.

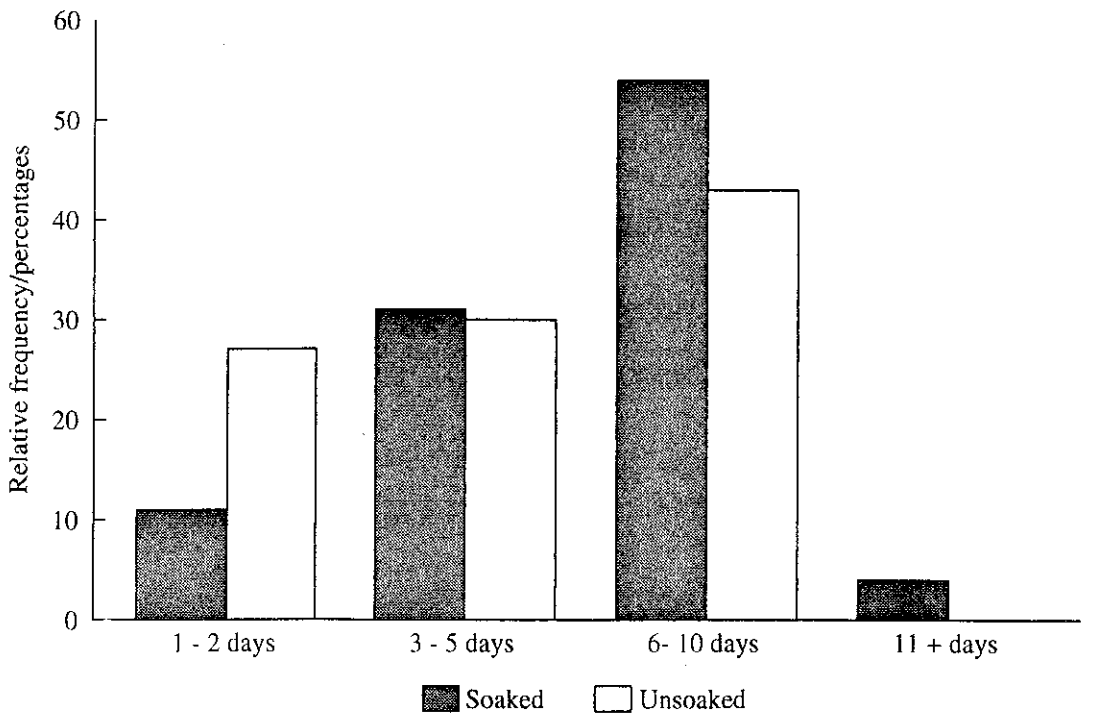


Table 19 and Figure 14 show the duration of what is effectively fermentation through sundrying for air-fermented flours. The tendency is for flours in Côte d'Ivoire, Ghana, and Uganda to be sundried for a longer period than those in Nigeria[23] and, to a lesser extent, Tanzania. In 21 cases out of 44, however,

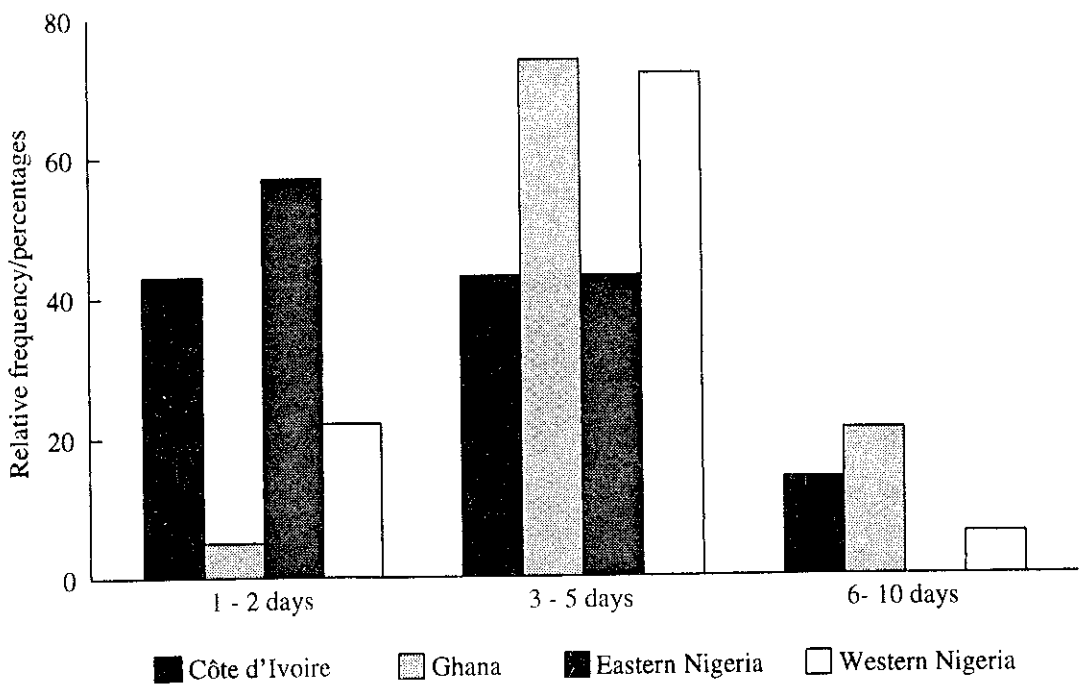
Table 17. Drying times for soaked and unsoaked flours (days).

Days	1-2		3-5		6-10		11 +		Total	
	n	%	n	%	n	%	n	%	n	%
Soaked	18	11	50	31	87	54	6	4	161	100
Unsoaked	22	27	25	30	35	43	0	0	82	100

Table 18. Dewatering/fermentation duration—roasted granules (days).

Country	1-2		3-5		6-10		11 +		Total	
	n	%	n	%	n	%	n	%	n	%
Côte d'Ivoire	3	43	3	43	1	14	0	0	7	100
Ghana	1	5	14	74	4	21	0	0	19	100
Western Nigeria	4	22	13	72	1	6	0	0	18	100
Eastern Nigeria	13	57	10	43	0	0	0	0	23	100

Figure 13. Duration of fermentation in sacks or baskets for roasted granules.

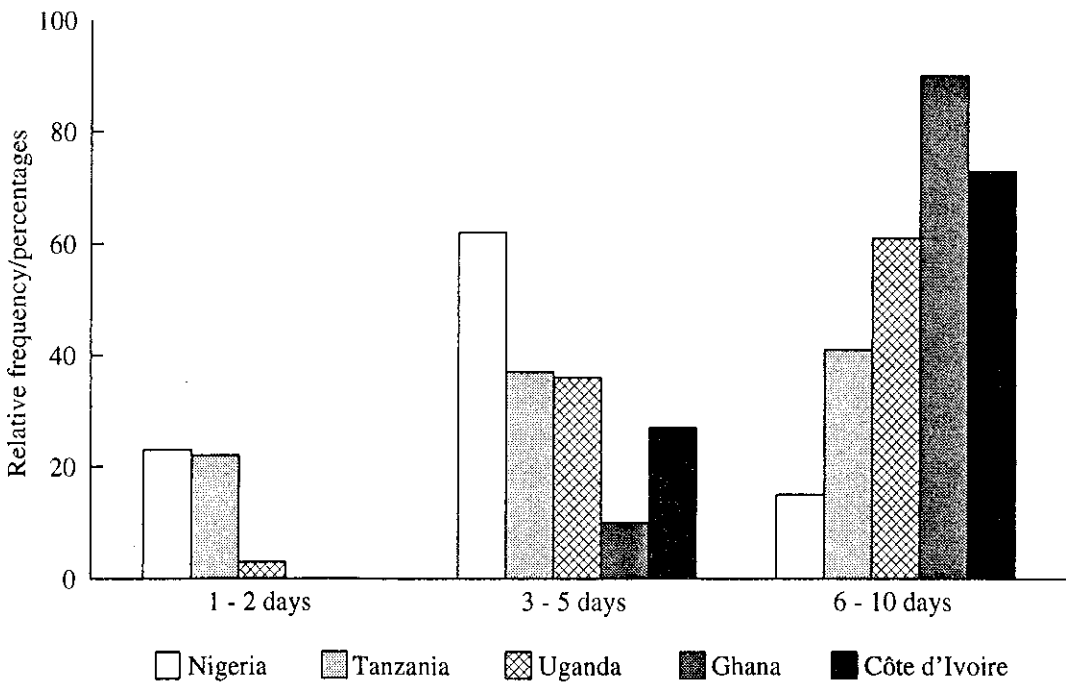


[23] Only 1 instance of air-fermented flour occurs in Western Nigeria.

Table 19. Duration of sun-drying—air fermented flours (days).

Country	1-2		3-5		6-10		11 +		Total	
	n	%	n	%	n	%	n	%	n	%
Côte d'Ivoire	0	0	3	27	11	73	0	0	15	100
Ghana	0	0	2	10	19	90	0	0	21	100
Nigeria	3	23	8	62	2	15	0	0	13	100
Tanzania	10	22	17	37	19	41	0	0	46	100
Uganda	1	3	13	36	22	61	0	0	36	100
Zaïre	1	50	1	50	0	0	0	0	2	100

Figure 14. Duration of sun-drying for air-fermented flours.



Tanzanian households also fermented their flours in heaps.[24]

Although the warning at the beginning of this section was that different types of fermentation are not directly comparable, it is instructive to analyze the total durations of the "fermentation" stages, if only to compare the time taken to produce the various products. From Table 20 and Figure 15 it is evident that the majority of starches, pastes, roasted granules, and steamed granules take from 1 to 5 days to "ferment". The majority of flours take 6 to 10 days to ferment, with over 10% taking 11 or over.

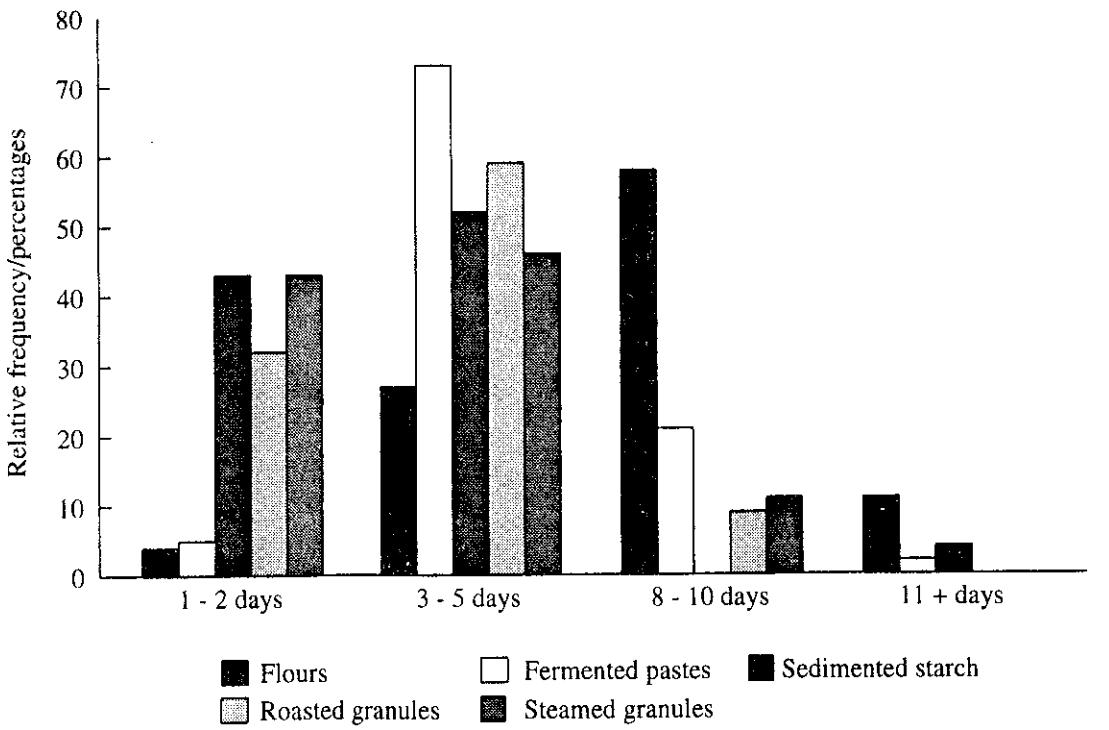
Table 21, and Figures 16 and 17, elaborate on Table 20, examining durations of fermentation on flours.

[24]There is a perception in some quarters that high cyanogen content in processed bitter cassava may be related to short "fermenting" duration, particularly for sundried products. There are many provisos to this view, not least of which is the question of the true relationship between drying time and cyanogen content, plus the question of exactly how the flours in question are stored and cooked.

Table 20. Duration of total fermentation—by product (days).

Products	1-2		3-5		6-10		11 +		Total	
	n	%	n	%	n	%	n	%	n	%
Cooked roots	10	83	1	8	1	8	0	0	12	100
Roasted granules	22	32	40	59	6	9	0	0	68	100
Steamed granules	12	43	13	46	3	11	0	0	28	100
Flours	11	4	70	27	152	58	30	11	263	100
(acid-fermented)	3	3	21	19	65	60	20	18	109	100
(air-fermented)	6	4	47	32	84	58	9	6	146	100
fermented pastes	3	5	48	73	14	21	1	2	66	100
Beers	0	0	2	40	2	40	1	20	5	100
Sedimented starch	10	43	12	52	0	0	1	4	23	100

Figure 15. Duration of total fermentation by product.



Again it is manifest that, comparing Eastern Nigeria with the rest of Western Africa, less time is spent fermenting in Eastern Nigeria.[25]

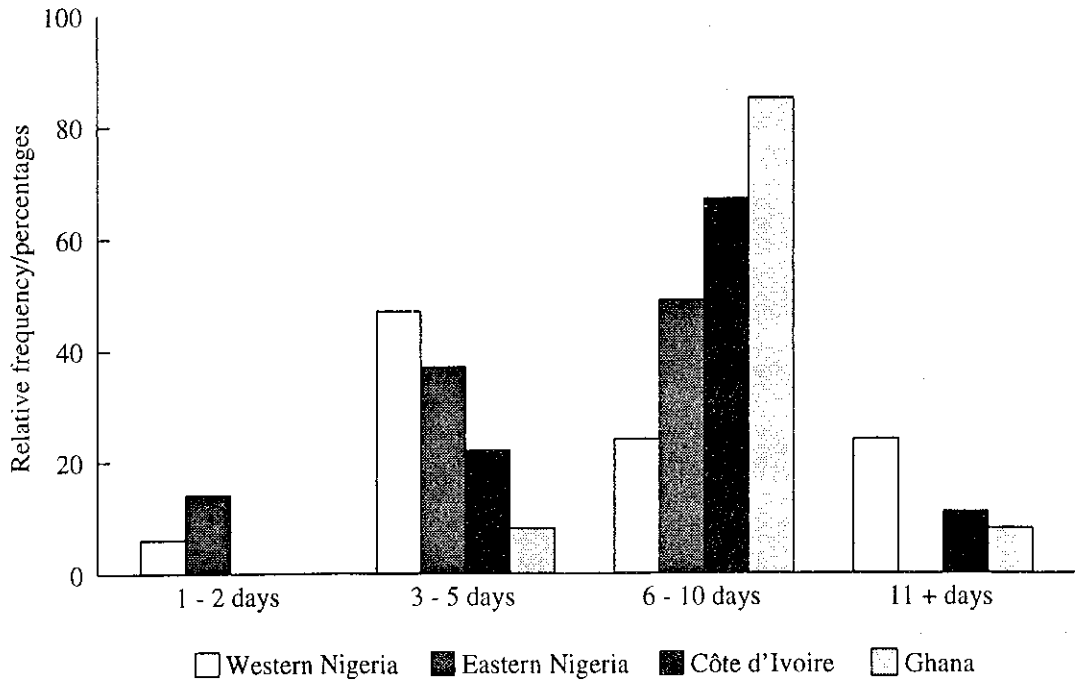
Starter cultures were used in 66 cases, 54 of which were in Côte d'Ivoire. Given the much reduced dewatering time for steamed granules (which tend to use starter

[25] Eastern Nigeria is the only area where no products are fermented for longer than ten days.

Table 21. Duration of total flour fermentation—by country (days).

Country	1-2		3-5		6-10		11 +		Total	
	n	%	n	%	n	%	n	%	n	%
Côte d'Ivoire	0	0	4	22	12	67	2	11	18	100
Ghana	0	0	2	8	22	85	2	8	26	100
Western Nigeria	1	6	8	47	4	24	4	24	17	100
Eastern Nigeria	5	14	13	37	17	49	0	0	35	100
Tanzania	4	7	21	36	27	47	6	10	58	100
Uganda	0	0	15	32	23	49	9	19	47	100
Zaïre	1	2	7	11	47	76	7	11	62	100

Figure 16. Duration of total fermentation by country in West Africa.



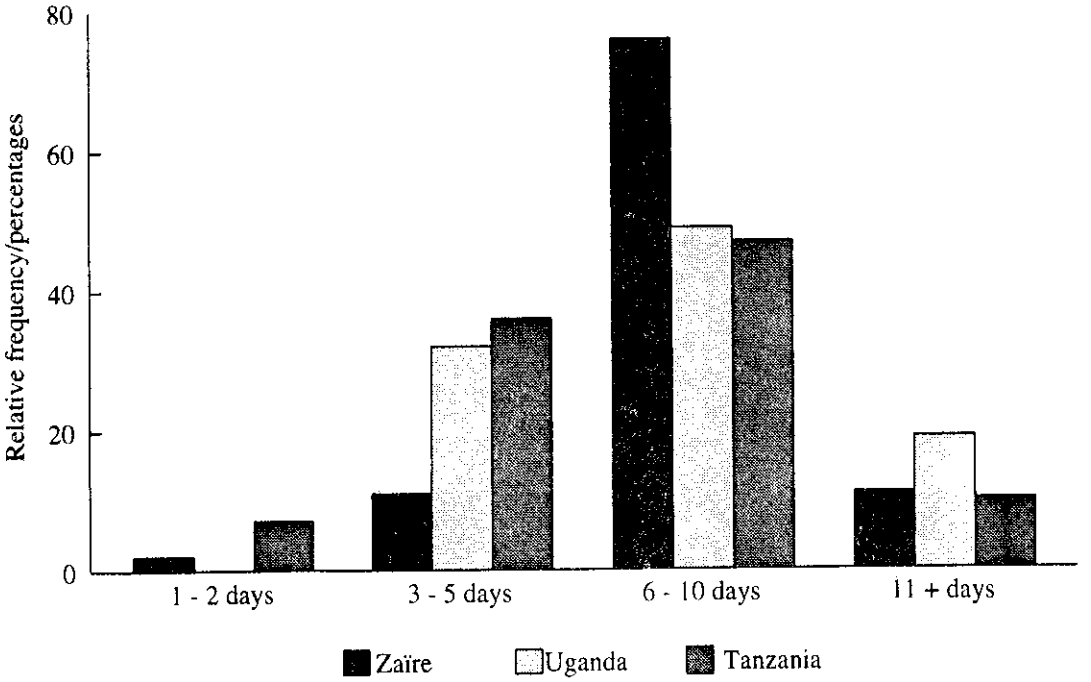
cultures) it would have been logical to compare the drying times for those products which had and those which had not used starter cultures. Unfortunately, there are only eight instances where products which use starter cultures have accompanying records showing the duration of drying; and of those, 2 were beers. Of the remaining six products (all flours) two were dried for one day, one for three days and three for seven days. With such a small sample it is not appropriate to make any inferences from the data.

Conclusion

Using DBase programming techniques, it has been possible to distinguish eight discrete cassava product categories. Using these categories the processing of cassava products in the six COSCA countries has been characterized.

The most common product encountered during the first phase of COSCA was "flour" (a composite category

Figure 17. Duration of total fermentation by country in East Africa.



of flour and dried pieces), which amounted to almost half of all products. Cooked roots accounted for another 17% and roasted granules a further 12%.

On a regional basis, West African countries tend consistently to produce a wide variety of products including cooked roots, granules, flours, pastes, and sedimented starches. Eastern and Central African countries, on the other hand, showed much more of an accent on flours, with relatively few pastes and starches and only one occurrence of granules.

Cassava products exhibit a certain degree of seasonality, most often around the months of June, July, and August. Alternate seasonal effects are discernible in the production of flours in Eastern Nigeria and Tanzania and roasted granules in Western Nigeria. The question why such seasonality should be encountered is one which cannot be answered from the information available in the phase I database. Nevertheless, the verified existence of seasonal effects on production has encouraged the adoption of questions for the third phase of COSCA which will allow some conclusions to be arrived at in explaining seasonality.

In common with the seasonality data, it proved difficult to apply some of the COSCA hypotheses concerning cassava processing to the phase I database. Attempts to test the gender hypothesis suggest that no relationship exists between the degree of commercialization and the gender of the processor.

Data from phase I confirms the view that African cassava processing is dominated by women. Where men took part in any significant numbers, there was a tendency for this to involve the use of machines. Thus, the introduction of machinery may have reduced the drudgery of some of the women's tasks, but the control of this machinery is not necessarily in their hands.

The West African states possess the most mechanized processing systems, although Côte d'Ivoire villages make little use of mills and graters. Tanzanian villages employ fewer mills than those in Uganda, but neither country employs graters or screw presses. This can be explained by the low technology requirements for the processing of flours, which represent the greater part of processed cassava output in these countries. Zairean villages made no use of machinery in the manufacture of cassava products.

The processing of cassava is marked by variations in the length of fermentation and processing techniques. While direct comparison across the complete database

is not possible, due to the technical connotations of different fermentation techniques; there are some clear differences in fermentation strategies between countries and between products. The production of steamed granules in Côte d'Ivoire contrasts with that of roasted granules in Nigeria through the shorter duration of fermentation in Côte d'Ivoire. This may be explained by the prevalent utilization of "tarter cultures" in Côte d'Ivoire.

Similar variations can be detected in the relatively short duration of fermentation of roasted granules in Eastern Nigeria and of flours in Côte d'Ivoire, Ghana, and Uganda. Taking the somewhat artificial figure for duration of total "fermentation"[26], flours require the longest interval, whilst roasted and steamed granules and sedimented starches require the shortest.

[26] As explained above in the sub-section entitled "Duration of Fermentation Stages".

Appendix 1. Product definitions.

Eight discrete product types were distinguished by the followed taxonomic processing steps:

Product Type (revised product or new codes)	Taxonomic processing steps (sub-process codes)
Cooked fresh roots (1000)	Don't sediment (10), roast (11), fry (13), sun dry(12), granulate (28), smoke (29), or ferment (30, 31, 32, 33, 03 for more than one day). Do boil (15) or wash (01) or peel (02).
Roasted granules (2000)	Don't sediment. Do grate (05), mill (06) or pound (07), THEN ferment in sacks (30 or 31), THEN sieve (09), THEN roast (11), or fry (13).
Steamed granules (3000)	Don't sediment, roast or fry. Do grate, mill or pound. THEN, ferment in sacks, THEN granulate (28) or sieve, THEN boil or steam (27).
Flours/D Pieces (4000)	Don't sediment or steam. Don't roast or fry unless this is combined with blending with other staples (19). Do sun dry, smoke or start with flour (40).
Fermented pastes (5000)	Don't roast, sun dry, fry, brew (20), distill (22), granulate, smoke or sediment (unless performed in combination with soaking). Do ferment, THEN, grate, mill, pound or sieve.
6000 no class	
Leaves (7000)	Do start with leaves (50).
Drinks (8000)	Do brew or distill.
Sedimented starches (9000)	Don't soak (03). Do sediment.
Unclassified (0999)	Any product left unclassified by the above steps.

Appendix 2. Processing codes

01 washing
02 peeling
03 soaking
04 slicing
05 grating
06 milling
07 pounding

09 sieving
10 sedimenting
11 roasting
12 sun-drying
13 frying
14 wrapping
15 boiling
16 molding/shaping
17 sprinkling with water
18 scraping
19 blending with other staples
20 brewing (beers and soft drinks)
21 making paste
22 distilling

25 adding a starter culture or inoculum
26 blending with spices, flavorings, colorings, salt
27 steaming
28 granulation (using curved board or bowl)
29 smoking
30 fermentation in sacks or baskets/ dewatering for less than one day
31 fermentation in sacks or baskets/ dewatering for one day or more
32 fermentation in water for one day or more

40 start with cassava flour

50 start with cassava leaves

Seasonality of Cassava Processing in Africa and Tests of Hypotheses[1]

B. O. Ugwu and P. Ay[2]

Abstract

One of the major advantages of cassava is the variety of uses to which the roots can be put. This study begins with a brief description of the different types of processed products that can be made from cassava drawing on the results of detailed surveys carried out in six different countries carried out as part of the Collaborative Study of Cassava in Africa (COSCA) project. Subsequently, the paper tests a series of hypotheses related to cassava processing including the role of gender, the degree of mechanization as well as the relationship between cyanide in cassava varieties, and the making of fermented and unfermented flours. The results indicate that women, and to a lesser extend children, perform most of the processing operations. As population density increases, cassava processing becomes more mechanized. A significant relationship was found between the proportion of low to high cyanide varieties and the presence or absence of fermented flour making.

Key words: agro-ecology, population density, gender, products, fermentation.

Introduction

Cassava (Manihot esculenta Crantz) was introduced to West and Central Africa from South America by the Portuguese more than 400 years ago. It is now grown throughout Sub-Saharan Africa[3] and is considered second in importance to maize as a human staple, accounting for more than 200 calories per day per person (IITA 1988). Estimates show that about 160 million people or 40% of the population of Sub-Saharan Africa consume cassava as a staple food (Nweke et al. 1988).

One of the major advantages which cassava has over other carbohydrate/starch crops is the variety of uses to which the roots can be put. In addition to being a major staple food for humans, it also has excellent potential as livestock feed (Best 1987) and in the textile, plywood, paper, and pharmaceutical industries. One major constraint, however, when dealing with cassava is that it is a highly perishable crop. Although mature cassava can be stored in the ground for up to six months or longer, once harvested, cassava deteriorates rapidly. The fresh roots must be transformed into more stable products within two or three days from harvest. This transformation requires various combinations of technology—peeling, grating, boiling, fermenting, drying, frying, and milling. A second constraint in utilizing cassava involves reducing the toxic levels of cyanogenic glucoside (linamarin and lotaustralin) found in cassava (Cooke 1982, Hahn 1987, Oke 1982).

The objective of this study[4] is to examine the seasonality of cassava processing, as well as the gender role in cassava processing, the degree of mechanized

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[1] Collaborative Study of Cassava in Africa (COSCA) Working Paper N° 6, reprinted here with permission of the authors and Felix I. Nweke, Project Leader.

[2] National Research Coordinator, Nigeria, COSCA project, and Sociologist, c/o International Institute of Tropical Agriculture (IITA), P.M.B. 9320, Ibadan, Nigeria.

[3] See COSCA Working Paper N° 5 for a map of the agroecological zones of cassava production in Africa, (Fresco 1991).

[4] The Collaborative Study of Cassava in Africa (COSCA) is being conducted in three phases; this study is part of phase one, which had

Table 1. Distribution of survey villages by country and climate zone.[a]

Country	Lowland humid	Highland humid	Lowland semi-hot	Lowland continental	Lowland semi-arid	Total
Côte d'Ivoire	27	0	8	2	0	37
Ghana	17	0	9	0	0	26
Nigeria	20	0	41	2	2	65
Tanzania	3	0	13	0	5	21
Uganda	20	12	0	0	0	32
Zaïre	27	0	7	2	0	36
Total N° of villages	114	12	78	6	7	217

[a]The climate zones for this study were classified in Cosca Working Paper N° 2.

processing and the relationship between the proportion of low and high cyanide varieties and fermented and unfermented flours. Added to the end of this report are two appendices: Appendix 1 is a classification of the different cassava processing steps; Appendix 2 is a list of more than 80 different cassava products found in the COSCA study countries.

Guiding hypotheses

The following hypotheses were tested.

- Gender role in cassava processing tends to change as processing becomes more mechanized.
- Women's role in cassava processing is greater with increasing commercialization of cassava production.
- As more cassava is produced for sale than for home consumption, processing becomes more mechanized.
- As population density increases, cassava processing becomes more mechanized.
- The more accessible the product-producing areas to the market, the greater the degree of mechanized processing.
- The period of fermentation is decreasing in areas where cassava processing is mechanized.
- The period of fermentation is decreasing in areas with good access to market.
- Flours from unfermented cassava are associated more with areas growing sweet than bitter varieties.

Study area

The majority of the villages in the survey were in the lowland humid tropics (53%) and lowland semi-hot (36%) ecologies, although five climate zones were represented (Table 1). The number of villages is almost evenly distributed between high and low population density areas, while access to roads is slightly skewed to the good side (Table 2).

The Seasonality of Cassava Production

On a global basis, millions of hectares of land are today occupied by standing, mature cassava (Onwueme 1978). Unlike other crops, cassava cannot be harvested all at once, because the roots cannot be stored for more than two or three days without rapid deterioration. Other estimates indicate that about 20% of the cassava hectarage is used for root storage (Phillips 1974). This scenario suggests that cassava is harvested in small sections, based on what the farmer needs for home consumption. However, if the cassava is sold to processors, then large quantities may be harvested.

Table 2. Percentage distribution of survey villages by population density and road access by country.

Country	Population		Road access	
	high	low	good	bad
Côte d'Ivoire	0	100	63	37
Ghana	65	35	58	42
Nigeria	83	17	66	34
Tanzania	33	67	48	52
Uganda	81	19	69	31
Zaïre	8	92	28	72
Total	49	51	57	43

Being a major staple food and a highly perishable crop, cassava is, generally, harvested all year round. Likewise, cassava processing continues throughout the year, however, the intensity of processing activities, however, depends on the availability of other crops.

Peak processing months. Processing trends appear fairly similar in all the climatic zones—with peak periods occurring more frequently between May and September (Fig. 1-4). The exception to this observation is flours in the lowland semi-hot zones and cooked roots in the highland humid zone. The peak processing periods correspond almost entirely with the hungry months in the study areas, which occur mainly between March and September in the high population density areas, and April to September in the low density areas (Table 3).

The second peak occurs between December and January, when processors, especially in West Africa, take advantage of favorable drying conditions, to process and store flour. The bulk of these products are consumed at a later date, however, because of the availability of other food staples, such as yams and grains, during this period.

Table 3. Frequency distribution of survey villages by hungry months and by population density, Africa, 1989/1990.

	Population density	
Month	high	low
January	14	12
February	16	16
March	30	19
April	48	26
May	51	35
June	53	50
July	41	49
August	24	31
September	19	25
October	10	24
November	8	21
December	9	13

Figure 1. Frequency distribution of monthly production peaks for cassava product types in the lowland humid climate zone.

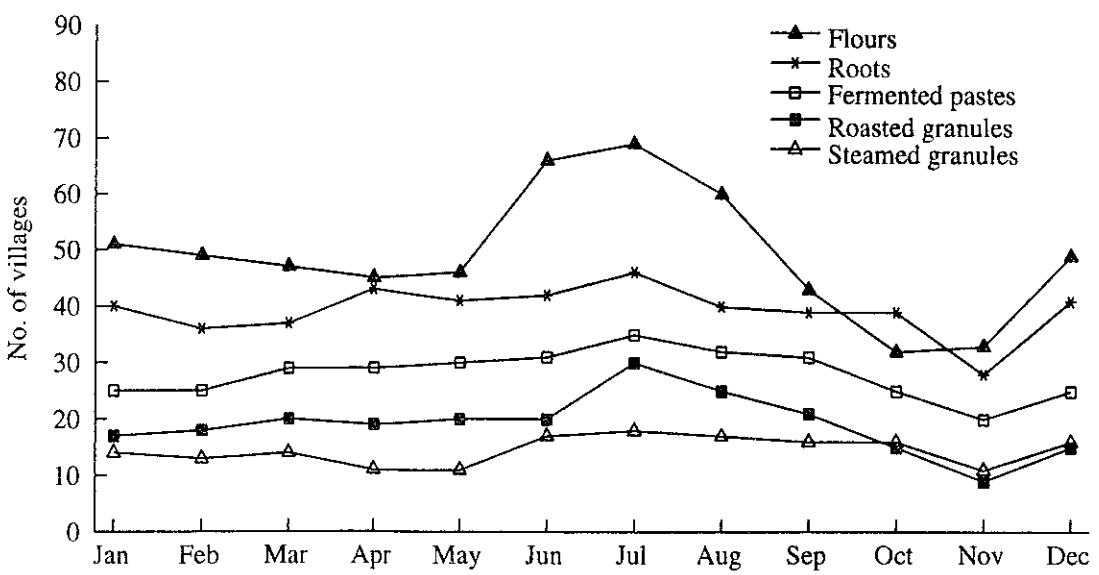


Figure 2. Frequency distribution of monthly production peaks for cassava product types in the lowland semi-hot climate zone.

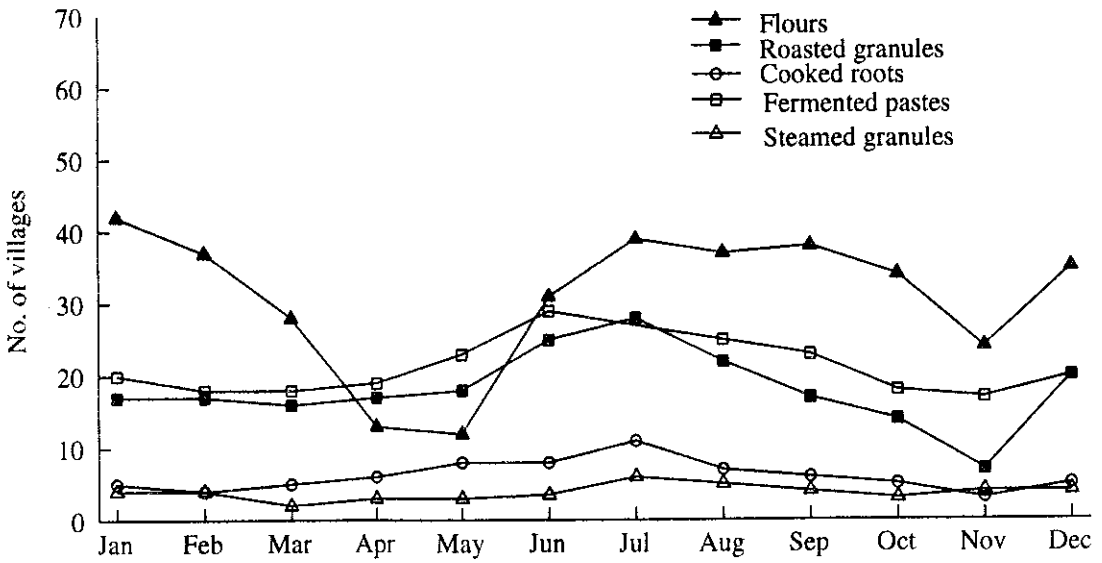


Figure 3. Frequency distribution of monthly production peaks for cassava flours and roasted granules in the lowland semi-arid climate zone.

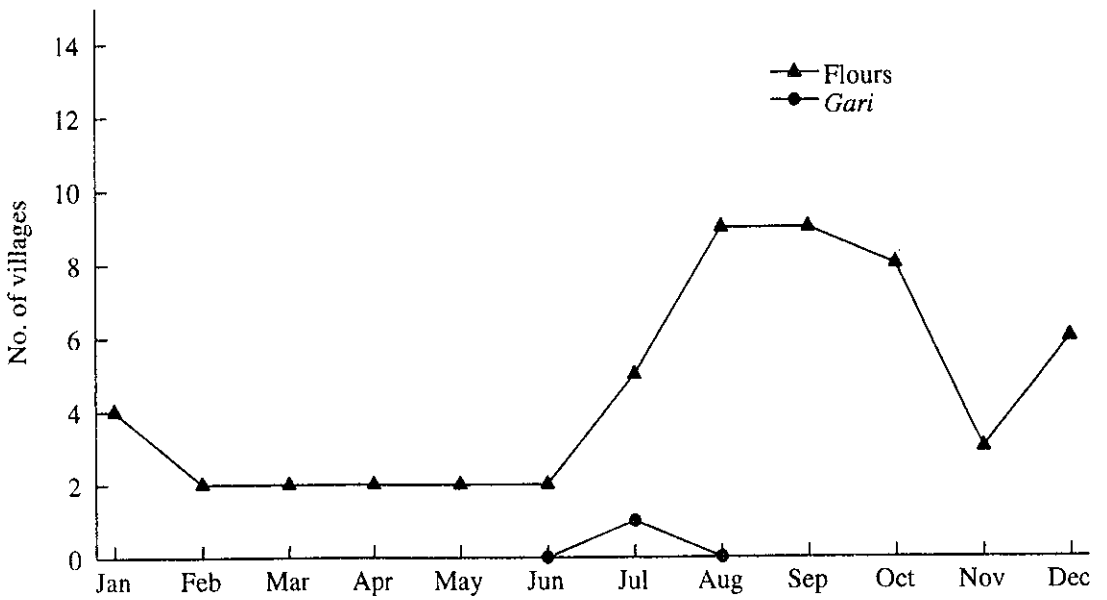
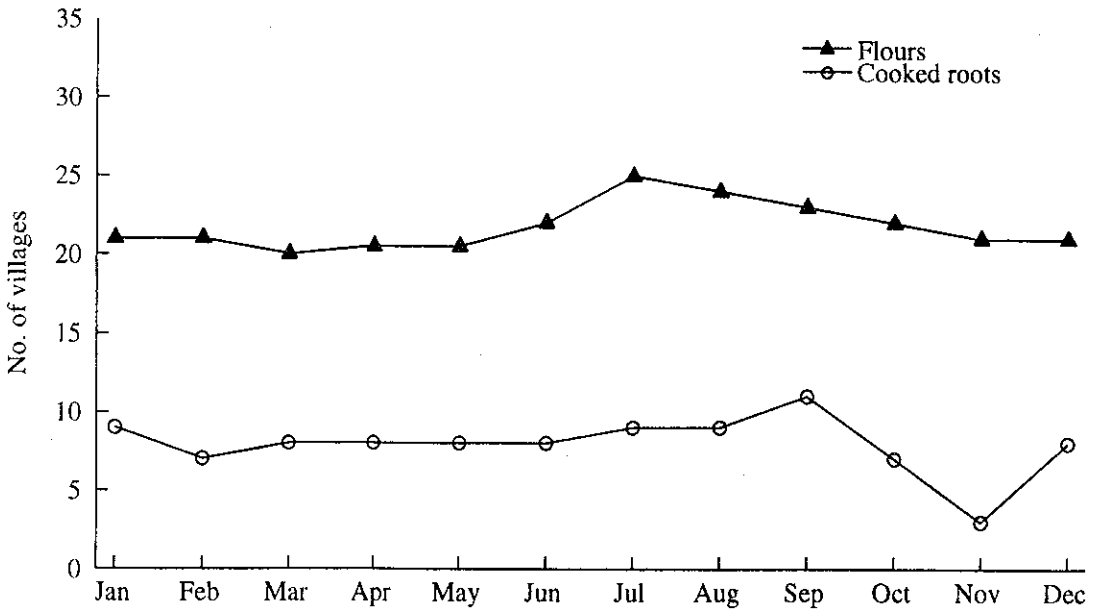


Figure 4. Frequency distribution of monthly production peaks for flours and cooked roots in the highland humid climate zone.



Production peaks for products. Production peaks for various products were evaluated for areas with low and high population densities (Fig. 5 and 6). The processing peaks follow a similar trend in both the high and low density areas. The frequency of peaks in the high density areas appears quite uniform for all processed products, except flours, which generally peak during the month of July. This trend probably indicates that cassava plays a more important role as a household food security crop in the high density than in the low density areas. The first peak for flour production occurs in January, and a second peak occurs in July.

Cassava Products and Postharvest Processing Activities

There is probably no other agricultural crop for which a similar range of postharvest processing activities exists as for cassava. Women use a wide range of processing techniques in order to transform fresh roots into foods and storable/marketable cassava products. As would be expected, there is some overlap in the classification where different names are used to describe the same product and also where similar or identical names are used for different products. (See Appendix 2 at the end of this report for a list of the 80 food items recorded during Phase I of the survey).

In order to distinguish the different product types and processing techniques, the cassava products were divided into subgroups based on the minimum number of processing steps by which a product type could be identified. Nine different categories emerged. The first six include food items made from the roots, while the remaining three categories include drinks made with cassava components, food made from the leaves and medicines.

- cooked fresh roots
- cassava flours: fermented and unfermented
- granulated roasted cassava (*gari*)
- granulated cooked cassava (*attieke, kwosai*)
- fermented pastes
- sedimented starches
- drinks (with cassava components)
- leaves (cooked as vegetable)
- medicines.

Figure 5. Frequency distribution of monthly production peaks for cassava product types in low density areas.

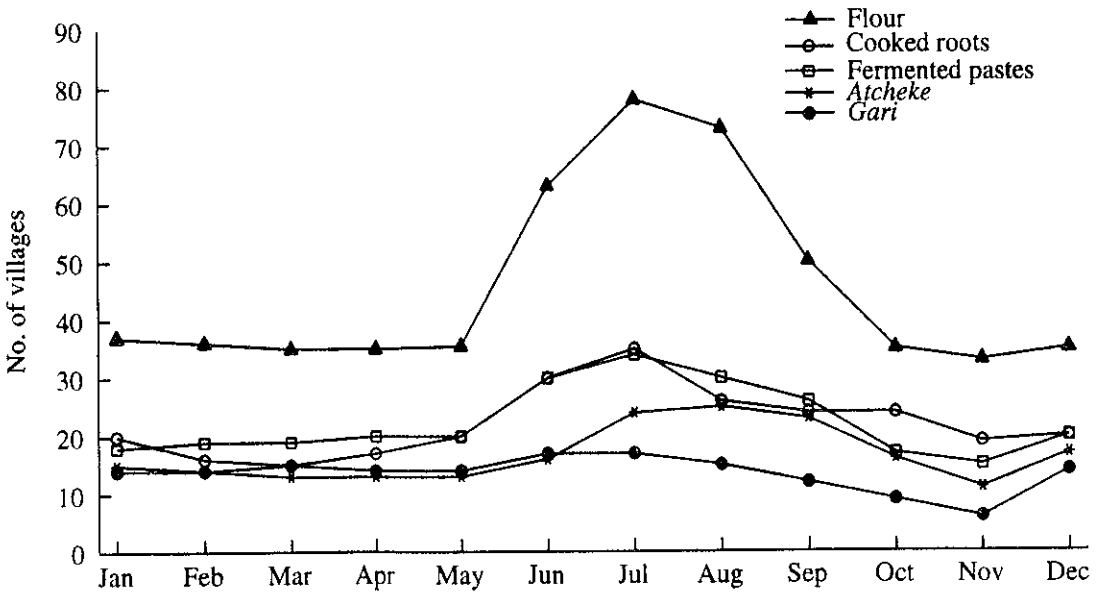
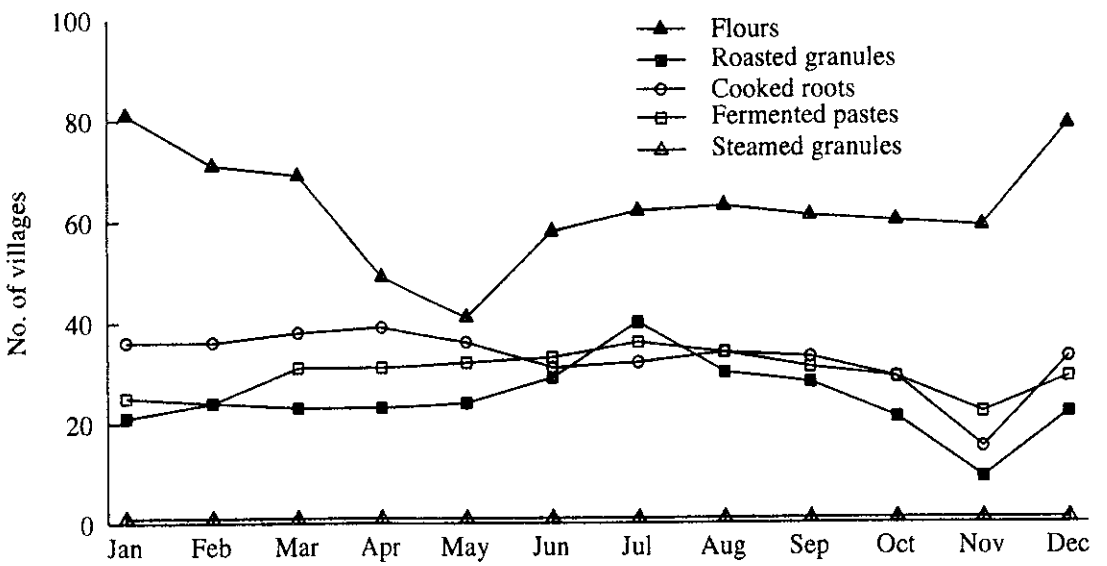


Figure 6. Frequency distribution of monthly production peaks for cassava product types in high density areas.



Food Types Prepared from Cassava in the Six COSCA Study Countries

Cooked Fresh Roots

i. ***Roasted cassava.*** The simplest way of preparing fresh cassava roots is roasting whole roots of sweet cassava varieties in the coals of burnt-down fires. Roasted cassava roots are often prepared and eaten by farmers during field work. When the root is cooked, the burnt peel is scraped off and the white steamed inner part of the roots is eaten alone or with palm oil or stew. Even in areas where bitter cassava varieties dominate, farmers plant at least some stands of sweet varieties for food during farm operations. The taste of roasted cassava is influenced by the length of time the roots remain in the ground before harvesting, and the variety of sweet cassava used. Roasted cassava is rarely made in the compound, as other methods of preparation are available.

ii. ***Boiled cassava.*** The roots from low cyanide varieties may be boiled fresh after peeling, washing, and cutting into small pieces. The pieces are usually submerged in boiling water and not steamed as is often done with yam or sweetpotatoes. Boiling in large quantities of water reduces or eliminates the small quantity of cyanide which is also present in the fresh roots of sweet varieties. Boiled cassava is eaten like boiled yam or boiled potatoes with stews or vegetable soups. Certain starchy varieties are also pounded and eaten like yam.

iii. ***Soaked boiled cassava (abacha).*** Another variation of boiled cassava can also serve as a storage technique, and is known as wet *abacha* in Eastern Nigeria. After the peeled cassava has been boiled, the water is poured off and the boiled pieces are covered in cold water and kept in a cool place. *Abacha* is eaten as a part of the main meal. By changing the water every day, the boiled cassava can be stored for two to three days before fermentation begins.

Cassava Flours

Cassava flours are the most widely spread food product made from cassava in Africa and are processed in a variety of ways. In the COSCA study countries a large number of methods were observed, but certain steps i.e., drying and milling are essential. Drying is either done in the sun or over low fires, and milling is done by manual pounding or grinding or by mechanical mills.

Cassava flours are generally eaten as a thick paste, which is obtained by mixing the flour with hot water. The paste is eaten with stews and soups. The flours are also used to prepare deep-fried, savory or sweet cakes and snacks.

Two major flour types exist: those derived from unfermented dried cassava roots and those obtained from fermented cassava. Different fermentation methods were observed: fermentation in water, open air fermentation, and fermentation with a specially prepared starter. Flours from unfermented cassava roots are more common in areas where sweet cassava varieties dominate.

i. ***Unfermented flours.*** In all the countries where unfermented cassava flour is prepared, the roots are peeled and cut into small chips immediately after harvest and spread in the sun for drying. In drier climates, like in the northern part of Ghana, the chips may sun dry in only a few hours. In the more humid forest zone, it is common, especially during the rainy season, to dry the chips over the fireplace in the house. Roots or cuttings dried in the smoke need to be cleaned and scraped before milling in order to obtain a nice white flour. The traditional methods for milling are pounding in a mortar or grinding on a grinding stone. Data from 233 villages in the COSCA study indicated that 86 villages had milling machines. After milling, the coarse fibers are sifted out to obtain a homogenous flour.

ii. ***Fermented flours.*** Where bitter cassava varieties are common, the fresh roots are fermented before they are dried and milled. Whole unpeeled cassava roots are submerged in water from 3 to 5 days depending on the taste desired and the weather. Warm weather intensifies and shortens the fermentation process. A longer or intensive fermentation produces a sour tasting flour which is preferred in some regions.

Many processors peel the cassava and submerge the roots in clean water for fermentation. This usually results in a whiter flour. The color of the cassava flour depends on the time used for sundrying. If the drying is not finished the same day, the product may start to ferment again or get mouldy. To shorten the drying time the fermented roots may be put in bags or baskets and pressed with stones or a screw press to remove excess water. In East Africa, fermentation is often done in heaps without adding water. Where sundrying is extended over several days fermentation takes place in open air. Therefore, drying for more than two days was classified as a special form of fermentation even though it is not seen as an additional or separate processing step.

Granulated Cassava

i. ***Roasted or gelatinized granules (gari).*** *Gari* is prepared by fermenting grated fresh cassava in sacks, squeezing out the excess water, and then frying the semi-dry granules in a minimum amount of oil to prevent sticking until a gelatinized crust forms. Yellow *gari* results when palm oil is used to fry the raw grated granules. The longer the period of fermentation the more sour the taste of the *gari*. Grating is either done manually, or mechanically, with motor-powered grating machines. Grated wet cassava is then bagged or put in baskets; the excess water is pressed out in a variety of ways: processors may use planks weighed down with heavy rocks, planks with car jacks or hydraulic presses. Frying is usually done in large round earthenware pots or iron pans. *Gari* can be stored up to three months in plastic bags or other containers, depending on the quality of the product.

Gari can be reconstituted with hot water and stirred to form a thick paste and eaten with soups and stews; it can also be mixed with cold water/milk and sugar and taken as a snack.

Cooked Granules

i. ***Steamed fermented granules (attieke).*** *Attieke* are semidried cassava granules which are processed by peeling, washing, mashing, fermenting, dewatering, granulating, and semi-drying in the sun. A starter culture is added to the cassava during mashing, which influences the taste and quality of the end product. The starter culture is prepared either by boiling, roasting, or cutting fresh roots which are then fermented for a period of about three days; or through the preparation of a filtrate from cassava which has been boiled, pounded, and squeezed through a cloth. The traditionally recommended fermentation period for *attieke* is three days; however, the COSCA survey data indicate that there is a trend towards shorter fermentation periods.

In Côte d'Ivoire, these semi-dried granules (*attieke*) are steamed and eaten with stews and soups. The Hausa in Nigeria use pressed, sieved, and fermented cassava granules mixed with onions, tomatoes, and spices to form cakes which are then deep fried in oil. These cakes are called *kwosai* and are eaten as a full meal or as a snack between meals.

Fermented Pastes

i. ***Boiled fermented pastes.*** The processing steps for preparing fermented cassava paste include: peeling, washing, grating, or cutting into finger-like pieces, fermenting in water, mashing or pounding and squeezing through a fine cloth or sieve. This raw paste is now boiled in water or steamed in wrapped leaves. The normal fermentation period is from 1 to 3 days, however, in Ghana, the grated cassava was fermented up to 7 days. Longer periods of fermentation result in a more sour taste, which is preferred by some consumers. One essential characteristic of all these fermented pastes (demanded by consumers in the COSCA study areas), is the white color and smooth texture of the boiled cassava paste. In some of the study countries, a starter culture obtained from previous processing was added during the fermentation period. Sedimented pastes can be stored up to two weeks, sometimes even longer, depending on how long the cassava was fermented. Longer fermentation is positively related to longer storability.

Sedimented starches

i. ***Tapioca.*** Cassava starch is made by peeling and grating fresh roots and stirring them in water in order to separate the fibers from the starch. The starch particles are allowed to settle on the bottom of the container, where it forms a white muddy cake. The water is then carefully skimmed off, and the cake is removed and further dried in the sun. The semi-dried starch may be roasted in iron pans until it is completely dry to form.

ii. ***Starch flour.*** Alternatively, the sundried starch cakes can be pounded or milled into a fine flour, which is used as a thickener in soups and stews. Part of this powder may be sold or used as laundry starch.

iii. ***Laundry starch.*** Where cassava is being processed into *gari* on a large scale the water which is pressed out during fermentation is collected in large basins and allowed to settle. The starch so formed is not considered clean enough to be eaten and is used as laundry starch. However, few processors seem to be taking advantage of this by-product at present.

Drinks with Cassava Components

Cassava is used as a substitute for maize and other grains in the preparation of local beer. It is also mixed with cereals to stretch out supplies and still arrive at a product which resembles the original cereal-based beer.

Consumers tend to give priority to high alcohol content over taste. The type of yeast used influences the quality of the end product, especially in the brewing of local beer. As the taste of distilled drinks is less affected by raw materials, the proportion of cassava can be higher, and even the lowest quality products, such as

mouldy or damp flours which are useless as food, can still be fermented to alcohol.

Cassava Leaves

The leaves from the low cyanide cassava varieties can be boiled and eaten like spinach. The leaves from high cyanide varieties are also consumed but they are boiled, squeezed out and reboiled to reduce the toxicity. High cyanide leaves are also boiled together with palm oil, which has the same effect.

Medicine

Various medicines are prepared from both the leaves and the peels of sweet and bitter cassava varieties.

Tests of Hypotheses

Gender role in cassava processing

Women, and to a lesser extent children, perform most of the processing operations (Table 4). As the opportunities for commercialization increase, the number of women involved in processing also increases.

The relationship between gender participation in cassava processing and the degree of commercialization of cassava production was significant at the 0.01 level (Table 5). Increased commercialization of cassava production may arise from favorable market opportunities for cassava and its products. Where this occurs, extra cassava is often planted by individuals (especially women) for personal gain, as distinct from family cassava. While men may participate, even if to a limited extent, in the production of family cassava, they may not do so at all with respect to the women's individual cassava that is meant for the market.

Men are seldom involved in cassava processing operations, but perform more of the heavy duty farm operations. It was observed, however, that as mechanized processing equipment (such as graters and mills) is acquired, men's participation in cassava processing tends to increase, as they often control and operate these machines. The hypothesis that gender role in cassava processing tends to change as processing becomes more mechanized, was accepted at 0.01 level of significance (Table 6).

While cassava processing is, to a large extent, stereotyped along sex lines, this is not the case with respect to age (Table 4). There are virtually no opera-

Table 4. Frequency distribution of men, women, and children involved in cassava processing by subprocess, COSCA countries, Africa, 1989/90.

Sub-process	Number of people in category							
	Form of cooperation							Total N° of people
	Men only	Women only	Men & children	Women & children	Men & women	Adults only	Children only	
Washing	2	210	0	116	22	1	1	352
Peeling	11	249	0	138	39	20	1	458
Soaking	6	101	0	26	6	0	1	140
Slicing	9	186	0	30	14	6	0	245
Grating	35	40	0	18	11	2	3	109
Milling	23	46	1	3	1	3	2	79
Pounding	5	155	0	41	11	0	6	218
Sieving	5	162	0	45	18	4	1	235
Sundrying	13	189	0	30	14	6	1	253
Boiling	0	101	0	17	3	0	0	121
Other	48	456	1	73	38	9	0	625
Total N° of people	157	1,895	2	537	177	51	15	2,835

Table 5. Association between gender role in cassava processing and the degree of commercialization of cassava production in COSCA countries, Africa, 1989/1990.

Gender	Cassava production objective		Total N° of people
	Sales > home consumption	Sales < home consumption	
Male	68	321	389
Female	568	1,874	2,442
Total N° of people	636	2,195	2,831

Table 6. Cross tabulation of gender role in cassava processing by degree of mechanized processing, COSCA countries, Africa, 1989/1990.

Gender	Degree of mechanization		Total N° of people
	One or 0 machine used	Two or more machines used	
Male	101	59	160
Female	2,175	496	267
Total N° of people	2,276	555	2,831

tions exclusively done by children, and only 1.8% of the operations were restricted to adults.

Degree of mechanized processing

Of the total number of machines in the study villages, 87% were located in Nigeria, Uganda, and Ghana. The remaining 13% were found in Tanzania and Côte d'-Ivoire. Mechanical processing is insignificant in Zaïre (Table 7). Mechanized graters were observed only in West Africa; Nigeria accounted for 81% of the stock, and the remaining 19% were found in Côte d'Ivoire and Ghana. Cassava presses were only found in Côte d'-Ivoire and Nigeria.

Areas where the population density is high, also have the largest share of cassava mills and graters. About 69% of the number of mills and 84% of the number of graters are located in the high population density areas. This supports the hypotheses that as population density increases, cassava processing becomes more mechanized, which was accepted at 0.01 level (Table 8).

The distribution of cassava presses between the low and high population density areas did not, however, seem to follow the same pattern as that of the graters and mills, since 70% of the presses are located in the low population density areas (Table 7). A further analysis of the data in Table 7 however, shows that Côte

Table 7. Frequency distribution of cassava processing machines (mills, graters, presses) by country and population density, COSCA countries, Africa, 1989/1990.

Country	Type of machine					
	Mill		Grater		Press	
	Low[a]	High	Low	High	Low	High
Côte d'Ivoire	7		3		28	
Ghana	8	12	0	5	8	0
Nigeria	8	28	4	31	3	17
Tanzania	3	1	0	0	0	0
Uganda	2	22	0	0	0	0
Zaïre	0	0	0	0	0	0
Total N° of machines	28	63	7	36	39	17

[a] Low and High refer to population density

Table 8. Relationship between population density and machine use, COSCA countries, Africa, 1989/1990.[a]

Population density	Degree of mechanization		Total N° of villages
	1 or 0 machine present	2 or more machines present	
Low	99	12	111
High	80	27	107
Total N° of villages	179	39	218

[a] $x^2 = 6.76$, significant at 0.01 level.

d'Ivoire alone, with all its sampled villages in the low population density areas (Table 2), accounted for 50% of the total number of cassava presses. When Côte d'Ivoire data are excluded from the analysis, the distribution of the presses then follows the hypothesized distribution, with 61% of the presses located in the high population density areas.

In addition to population density, there are other variables that were found to be significantly associated with mechanized processing. As road access to market improves, cassava processing tends to be more mechanized. This hypothesis was accepted at 0.04 level of significance (Table 9).

The length of fermentation is often much shorter where processors have access to a cassava press which dewaters the grated cassava mash. The relationship between fermentation and the presence of cassava presses was found significant at 0.002 level (Table 10). Using a press, it is now possible to complete all the steps in *gari* production in one day.

While the length of fermentation is significantly associated with the degree of mechanization, it did not seem to be affected by market accessibility. Thus, the hypothesis that the fermentation period is decreasing in areas with good access to market, was rejected at 0.05 level of significance (Table 11).

Cassava production objectives do not seem to be significantly associated with the degree of mechanized processing. Even if more cassava is being produced for sale than for home consumption, processing has not shifted to more mechanized methods (Table 12).

Relationship between the proportion of low to high cyanide cassava varieties and fermented and unfermented flours

Cassava flours can be produced by milling either fermented or unfermented dried cassava chips. Fermentation reduces the level of cyanogenic glucosides present

Table 9. Association between road access to market and machine use, COSCA countries, Africa, 1989/1990.[a]

Road access to market	Degree of mechanization		Total N° of villages
	1 or 0 machine present	2 or more machines present	
Poor	97	12	109
Good	97	27	124
Total N° of villages	194	39	233

[a] $x^2 = 4.08$, significant at 0.04 level.

Table 10. Association between machine use and fermentation period, COSCA countries, Africa, 1989/1990.[a]

State of mechanized dewatering/fermentation	Fermentation period		Total N° of villages
	1-2 days	3 or more days	
Cassava press used	31	38	69
Cassava press not used	71	246	317
Total N° of villages	102	284	386

[a] $x^2 = 13.66$, significant at 0.002 level.

Table 11. Relationship between road access to market and fermentation period, COSCA countries, Africa, 1989/1990.[a]

Road access to market	Fermentation period		Total N° of villages
	1-2 days	3 or more days	
Poor	34	46	80
Good	45	81	126
Total N° of villages	79	127	206

[a] $x^2 = 0.69$ Significant at 0.05 level.

Table 12. Relationship between production objective and machine use, COSCA countries, Africa, 1989/1990.[a]

Production objective	Degree of mechanization		Total N° of villages
	One or 0 machine used	Two or more machines used	
Sale > home consumption	44	14	58
Sale < home consumption	148	25	173
Total N° of villages	192	39	231

[a] $x^2 = 2.26$, significant at 0.05 level (Table 12).

Table 13. Relationship between the proportion of sweet to bitter varieties and bpe of flour, COSCA countries, Africa, 1989/1990.

Proportion of sweet to bitter varieties	Type of flour		Total N° of villages
	Unfermented flour	Fermented flour	
Sweet > bitter	125	8	133
Sweet < bitter	73	19	92
Total N° of villages	198	27	225

in the fresh cassava roots. As would be expected, flour made from unfermented cassava was found in areas where low cyanide varieties dominate; while flour from fermented cassava was found in areas where high cyanide varieties are mainly grown. A significant relationship ($x^2 = 9.69$) was found between the proportion of low to high cyanide varieties and the presence or absence of fermented flour (Table 13).

Conclusion

In Africa, cassava is a major staple food for man; it also has great potential as livestock feed and as an industrial crop. Before it can be used as human food, however, it must be processed. Processing not only eliminates the toxic effects of the cyanogenic glucosides present in cassava, it also helps to convert the highly perishable roots into stable, storable and marketable products.

A wide range of processing techniques are employed in transforming the fresh roots into numerous products. Different names and descriptions for similar cassava products exist across Africa, and these are largely location specific, reflecting the large numbers of ethnic groups. More than 80 different cassava products were recorded in the study areas. Nine different product types were identified: Cooked cassava, cassava flour, roasted granules, steamed granules, fermented pastes, starches, drinks, leaves (cooked as spinach), and medicine.

Cassava processing in Africa is essentially a manual operation. Women, and to a lesser extent children, do most of the processing. The number of women involved in processing tends to increase with greater commercialization of cassava production. As commercialization of production increases, women also begin to plant/buy their own cassava to process and sell. While men may participate in cassava production for

household consumption, they generally do not help in the processing of cassava intended for sale in the market. However, where machines are in use for activities such as grating, pressing and milling, the men often own the equipment. This seems to imply that the gender role in processing begins to change as processing becomes more mechanized.

As would be expected, the mechanization of cassava processing tends to occur where the population density is high and access to market is good and the demand therefore, is higher. Although only about 25% of the African population reside in the urban areas (Nweke 1988), the growth rate in urban centers is high, exceeding 5% per annum in most countries. This underscores the need to process cassava into products which are easy to store and prepare in the home. Mechanization reduces the amount of time needed to process the fresh roots into storable/marketable products. This may prove a health hazard, however, where high cyanide varieties are grown, as the levels of hydrocyanide present may be lethal if the fermentation period is reduced.

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Appendix 1. Essential processing steps.

Products types and subgroups	Essential processing steps (sequential)	Variations in essential steps	Manner in which prepared food is eaten
1. **Cooked cassava** a. Cooked fresh roots	1. Cook	1. (i) Boil (ii) Boil and pound (iii) Boil and soak in fresh water (iv) Boil/ferment and mix with vegetables (v) Roast	1. (i) Boiled cassava (ii) Pounded cassava (iii) Soaked boiled wet roots (wet *abacha*) (iv) Fermented boiled cassava (v) Roasted cassava
b. Dried Cooked Cassava (*abacha*)	1. Boil 2. Slice 3. Dry	1. _ 2. _ 3. (i) Dry in sun (ii) Dry over fire	1. _ 2. _ 3. (i) Soak in water, eat with coconut or palm kernel (ii) Soak in water, mix with palm oil and fresh vegetables
2. Cassava flours a. Unfermented flours (*obusye, obutu, uhu, kokonte, ipep, unga*, etc.)	1. Dry 2. Mill/pound	1. (i) Dry in sun (ii) Dry over fire 2. (i) Mechanized (ii) Manual	1. _ 2. (i) Flour stirred into hot water to form a paste (ii) Flour mixed with other ingredients and deep-fried, cakes and snacks
b. Fermented Flours (*lafun, alebo, elubo*, etc.)	1. Ferment 2. Dry 3. Mill/pound	1. (i) Soak in water (ii) Ferment in bags/basket (iii) Sundry more than 2 days 2. (i) Dry in sun 3. (i) Mechanized (ii) Manual	3. (i) Flour stirred in hot water (*ugali, kokonte*) (ii) Mixed with other ingredients and deep-fried (snacks)
3. Roasted cassava granules (*gari, atoukpou*, etc.)	1. Peel and wash 2. Grate/pound/mill 3. Dewater/ferment 4. Granulate 5. Fry/roast	1. _ 2. _ 3. (i) Press during fermentation (ii) Press after fermentation 4. (i) Sieve (ii) Roll on wood 5. _	1. _ 2. _ 3. _ 4. _ 5. (i) Stir into boiling water (*eba, gari*) (ii) Mix with cold water and sugar (iii) Soak in water and steam (iv) Fried with coconut
4. Cooked cassava granules	1. Peel and wash 2. Grate/pound/mill 3. Dewater/ferment 4. Granulate 5. Cook	1. _ 2. _ 3. (i) Press during fermentation (ii) Press after fermentation 4. (i) Sieve (ii) Roll on wood 5. (i) Steam (ii) Deepfry	1. _ 2. _ 3. _ 4. _ 5. (i) Steamed granules are ready to eat, (*attieke*) (ii) Mixed with onion and spices and deepfried (*kwosai*)

Appendix 1. continued

Products types and subgroups	Essential processing steps (sequential)	Variations in essential steps	Manner in which prepared food is eaten
5. Fermented pastes (*placali, agbelima, fufu, akpu, myondo, bobolo, chikwangue*)	1. Ferment 2. Pound/grind 3. Boil	1. (i) Soak in water (ii) Ferment in bags/baskets 2. _ 3. (i) Wrap in leaves, boil and steam (ii) Wrap, boil, repound/grind, wrap, reboil	1. _ 2. _ 3. (i) Ready food, (*fufu, myondo, bobolo,* etc.) (ii) Ready food (*akpu, chikwangue, mentoumba*)
6. Sedimented starches (starch, tapioca, etc.)	1. Grating 2. Sedimenting 3. Drying	1. _ 2. _ 3. (i) Dry in sun (ii) Semi-dry in sun/cook (iii) Semi-dry in sun/granulated (iv) Roast	1. _ 2. _ 3. (i) Stir into boiling water (ii) Boiled starch; roasted and boiled as porridge; roasted and eaten (iii) Steamed granules (iv) Eat as a snack
7. Drinks a. Fermented drinks (*togwa, kawogo, kwete, chimbuku, malwa, ajono*)	1. Mix cassava product with cereals 2. Ferments liquid	1. _ 2. (i) No starter culture (ii) Starter culture	1. _ 2. (i) Refreshment (*togwa*) (ii) Beers
b. Distilled fermented drinks (*gongo, kawogo, (w)aragi, enguli, araga, kpanga, busera*)	1. Mix cassava product with cereals or starter culture 2. Ferment liquid 3. Distill	1. Several cassava products and/or wastes are used 2. _ 3. _	1. _ 2. _ 3. Alcoholic beverages
8. Leaves (*pondu, kisamwu*)	1. Cook	1. Boil; boil/pound; boil, squeeze, boil in coconut milk	1. Vegetable
9. Medicine	1. Scrape peeled (sweet) cassava 2. Mix with other ingredients		1. _ 2. Stomach medicine

Appendix 2. List of cassava products in African countries.

Name of product	Country	Characteristics	Used or form eaten	Product type	Other names & places used
Abacha (wet)	Nigeria (Ibo)	boiled cassava cuttings	part of main meal or dish eaten with stews or vegetables	cooked fresh cassava	
Abacha (dry)	Nigeria (Ibo)	boiled sliced cassava	snack: eaten soaked with coconut; main dish: prepared with palm oil, vegetables, meat or fish	dried cooked cassava	
Agbelima	Ghana (mainly Ewe)	fermented paste	part of main meal or dish, boiled paste eaten with stews, sauces	fermented paste	
Agbelikaklo	Ghana	deep fried seasoned semi-dry starch	snack, sold in markets	sedimented starch	
Ajono	Uganda	beer from cassava and cereals	drink	fermented drink	
Akaaro	Uganda	flour mixed from cassava and millet	stirred into boiling water, eaten with stew	flour	
Akpu	Nigeria	fermented reboiled paste	part of main meal, eaten with stew	fermented paste	
Aluki	Cameroon	flour		flour	
Amala	Nigeria	paste from fermented flour	stirred into boiling water to form a thick paste and eaten with soup/stew	fermented flour	*lafun*: Nigeria, Yoruba *ugali*: Tanzania *tuo*: Ghana
Ampesi	Ghana	boiled cassava	part of meal, or dish	cooked fresh cassava	
Arki	Cameroon	distilled cassava or cassava and maize	distilled beverage made from fermented cassava with starter culture from maize	distilled drink	
Arege	Uganda	distilled cassava or cassava and cereals drink	drink distilled after fermentation with starter culture from cereals or cassava mixed with cereals	distilled drink	
Attieke	Côte d'Ivoire	Steamed cassava	Part of main dish or meal ready food eaten with stews and sauces	granules	*yakayake*: Ghana

Appendix 2. continued

Name of product	Country	Characteristics	Used or form eaten	Product type	Other names & places used
Atoukpou	Côte d'Ivoire	roasted cassava granules	part of main dish or meal, soaked in water steamed, eaten with stews, sauces (*attieke*) or stirred in hot water and eaten as paste with stews	roasted granules	*gari*: all areas
Bobolo	Cameroon	boiled wrapped fermented paste	part of main dish or meal, eaten with stews, sauces vegetables	fermented pastes	
Sourles de manioc	Côte d'Ivoire	deep-fried seasoned pounded cassava	snack from boiled pounded cassava mixed with onions and tomatoes, spices and deep fried	(deep-fried) cooked fresh cassava	
Buita	Uganda	cassava flour	part of main dish or meal, stirred in hot water, paste eaten with stews, sauces	flours: fermented (bitter cassava); unfermented (sweet cassava)	*obuita*: Uganda
Busera	Uganda	distilled cassava or cassava and cereals drink	drink distilled after fermentation with starter culture from cereals or mix with cereals	distilled drink	
Cassada	Nigeria Rep. of Benin	fried *gari*-coconut pancake	snack from *gari* mixed with coconut pieces/gratings fried in pan	(fried) roasted cassava granules	
Chikwangue	Zaïre	reboiled wrapped fermented paste	part of main dish or meal, eaten with stews, sauces vegetables	fermented pastes	
Chinanya	Zaïre	dried sliced small cassava chips (sun dry)	intermediate cassava product, stored and marketed before milled into flour	flours: unfermented	
Chips	All areas	dried chipped roots	intermediate cassava product, stored and marketed before it is milled or pounded, and sieved	flours: fermented or unfermented	

Appendix 2. continued

Name of product	Country	Characteristics	Used or form eaten	Product type	Other names & places used
Cossettes	Zaïre	dried cassava cuttings or chips (sundry or smoked)	intermediate cassava product, stored and marketed before milled into flour	flours: fermented or unfermented	*Miteke* (Zaïre = Z.) *manioko* (Z.) *songo* (Z.) *tshiomba tshia pan* (Z.) *tshiomba tshia mayi* (Z.)
Dimwehe	Zaïre	whole small dried cassava roots (sundry or smoked)	intermediate cassava and marketed before milled into flour	flours: unfermented	
Enguli	Uganda	distilled cassava or cassava and cereals drink	drink distilled after fermentation with starter culture from cereals or mix with cereals	distilled drink	
Friandes	Zaïre	deep-fried cassava pieces	snack or part of main meal or dish, dried cassava pieces are soaked and deep-fried	deep-fried dried cassava	
Fufu	Ghana	boiled and pounded fresh cassava	part of main dish or meal, unfermented paste eaten with stews, sauces	cooked fresh cassava	
Fufu	Nigeria	boiled fermented paste	part of main dish or meal, white cassava paste eaten with stews	fermented paste	
Foutou	Côte d'Ivoire	boiled and pounded fresh cassava	part of main dish or meal, paste eaten with stews, sauces	cooked fresh cassava	
Futari	Uganda	boiled and pounded fresh cassava	part of main dish or meal, paste eaten with stews, sauces	cooked fresh cassava	
Gari	All areas	roasted cassava granules	part of main dish or meal, stirred in hot water eaten with stews, sauces; snack: soaked in cold water with sugar	roasted granules	*atoukpou*: Côte d'Ivoire
Gongo	Tanzania	distilled cassava or cassava and cereals drink	drink distilled after fermentation with starter culture from cereals or mix with cereals	distilled drink	

Appendix 2. continued

Name of product	Country	Characteristics	Used or form eaten	Product type	Other names & places used
Haragi	Uganda	distilled cassava or cassava cereals drink	distilled drink		
Iyan ege	Nigeria Yoruba	pounded cassava	part main meal or dish; boiled sweet cassava roots/root pieces that are pounded to a smooth paste	cooked fresh cassava	*utara akpu*: Nigeria, *Ibo* *fufu*: Ghana *foutou*: Côte d'Ivoire *futari*: Uganda
Kabalagala	Uganda	deep-fried cassava banana cakes	snack prepared from cassava flour dough mixed with mashed sweet banana, deep-fried	(deep-fried) fermented or unfermented flour	pancake: Uganda
Katogo	Uganda	fresh cassava boiled with beans, onions, and spices	full meal of cut fresh cassava roots boiled with onions, beans, spices	cooked fresh cassava	
Kawogo	Uganda	distilled cassava or cassava and cereals drink	drink distilled after fermentation with starter culture from cereals or mix with cereals	distilled drink	
Kipanga	Uganda	distilled cassava or cassava and cereals drink	drink distilled after fermentation with starter culture from cereals or mix with cereals	distilled drink	
Kisamwu		cooked leaves	vegetable		
Kokonte	Ghana	paste from flour	part of main meal or dish, stirred in hot water, paste (*tuo*) eaten with stews...	fermented or unfermented flours	Côte d'Ivoire
Kokonte	Ghana	dried cassava chips/cuttings/whole roots	intermediate cassava products that are milled into flour for paste (*tuo*) preparation	fermented or unfermented flours	Côte d'Ivoire
Kokoro	Nigeria Yoruba	deep-fried *gari* sweets	sweet snacks, soaked *gari* mixed with sugar and deep-fried	(deep-fried) roasted granules/*gari*	

Appendix 2. continued

Name of product	Country	Characteristics	Used or form eaten	Product type	Other names & places used
Kwadu	Nigeria (Hausa)	cassava-groundnut cake paste	full meal, boiled cassava, stirred or pounded with groundnut cake	cooked fresh cassava	
Lira lira	Uganda	distilled cassava or cassava and cereals drink	drink, fermentation with starter culture from cereals or mix with cereals	distilled drink	
Makopa	Zaïre	dried, fermentated or unfermented cassava (sun dry or smoked)	intermediate product, stored/marketed before milled into flour	flours; unfermented or fermented	
Malafu	Zaïre	distilled cassava maize drink	drink, fermentation with starter culture from maize or mix with maize	distilled drink	
Manioc braise	Côte d'Ivoire	roasted cassava	full meal roasted over charcoal or fire ashes	cooked fresh cassava	
Manioco	Zaïre	dried cassava cuttings or chips (sundry or smoked)	intermediate cassava product	flours: fermented or unfermented	*cossettes* (Zaïre = Z.) *miteke* (Z.) *songo* (Z.) *tshiomba*
Manieba	Tanzania	fermented pounded cassava paste	part of meal, boiled and pounded cassava fermented with starter culture	(fermented) cooked fresh cassava	
Manoumba	Cameroon	boiled wrapped fermented paste with vegetables and spices	snack or main dish	fermented paste	
Miteke	Zaïre	dried cassava cuttings or chips (sundry or smoked)	intermediate cassava product	flours: fermented or unfermented	*cossettes* (Zaïre = Z.) *manioko* (Z.) *songo* (Z.)
Mayondo	Cameroon	boiled wrapped fermented paste	part of main dish or meal, eaten with stews, sauces vegetables	fermented paste	
Ngunula	Zaïre	crushed dried cassava pieces (sundry)	intermediate cassava product, stored and marketed before milled into flour	flours: unfermented	

Appendix 2. continued

Name of product	Country	Characteristics	Used or form eaten	Product type	Other names & places used
Nnii akpu	Nigeria (Ibo)	boiled fresh cassava	part of main dish or meal, eaten with stews and sauces	cooked fresh cassava	
Ntilimbe	Zaïre	crushed fermented dried cassava pieces (sundry)	intermediate cassava product, stored and marketed before milled into flour	flours: fermented	
Obuita	Uganda	cassava flour	part of main dish or meal, stirred in hot water, paste eaten with stews, sauces	fermented (bitter cassava) unfermented (sweet cassava)	*buita*: Uganda
Obutaga	Tanzania	fermented crushed dry cassava	intermediate cassava product	fermented flour	*udaga*: Tanzania *lafun*: Nigeria
Oka	Nigeria Yoruba	paste from fermented flour	main meal, cassava flour (*lafun*) stirred in hot water, eaten with stews	fermented flour	*amala*: Nigeria *tuo*: Ghana *ugali*: Tanzania
Omudiyenge	Tanzania	fermented dried cassava cuttings	intermediate cassava product	fermented flour	
Pan or Pancake	Uganda	deep-fried cassava-banana cakes	snack from cassava flour mixed with mashed banana, deep-fried	(deep-fried) fermented or unfermented flour	*kabalakala*: Uganda
Placali	Côte d'Ivoire	boiled fermented paste	main dish or meal, boiled paste eaten with stew	fermented paste	
Pondu	Tanzania	cooked leaves	main dish or meal		
Ragout	Côte d'Ivoire	boiled roots spiced and mixed with vegetables	snack or full meal, boiled sweet cassava mixed with vegetables and spices	cooked fresh cassava	
Starch	All areas	sedimented starch	part of main meal or dish: boiled as paste semi-dry steamed; roasted snack; roasted granules laundry starch	sedimented starch	
Tapioca	Nigeria Ghana	roasted, sedimented starch	snack; granulated and roasted part of main dish or meal; roasted and boiled	sedimented starch	

Appendix 2. continued

Name of product	Country	Characteristics	Used or form eaten	Product type	Other names & places used
Tshiomba	tshia mayi Zaïre	dried cassava cuttings or chips (smoked)	intermediate cassava product stored and marketed before milled into flour	flours: fermented or unfermented	*cossettes* (Zaïre = Z.) *miteke* (Z.) *songo* (Z.) *manioco* (Z.) *tshiomba tshia mpandu* (Z.)
Tshiomba	tshia mpandu Zaïre	dried cassava cuttings or chips flour (sun dry)	intermediate cassava product, stored and marketed before milled into...	flours: fermented or unfermented	*cossettes* (Zaïre = Z.) *miteke* (Z.) *songo* (Z.) *manioco* (Z.)
Tuo	Ghana	paste from fermented flour	part of main meal or dish, cassava flour (*lafun*) stirred in hot water, eaten with stews	fermented flour	*amala*: Nigeria, Yoruba *oka*: Nigeria, Yoruba *ugali*: Tanzania *tuo*: Ghana
Udaga	Tanzania	fermented crushed dry cassava	intermediate cassava product, stored and marketed before milled/pounded-sieved for flour	fermented flour	*obutaga*: Tanzania *lafun*: Nigeria
Ugali	Tanzania	paste from fermented flour	part of main meal or dish, cassava flour (*lafun*) stirred in hot water, eaten with stews	fermented flour	*amala*: Nigeria, Yoruba *tuo*: Ghana *oka*: Nigeria, Yoruba
Ugimbi wa muhogo	Tanzania	beer from cassava and cereals	drink by fermenting cassava-cereals mixture	fermented drink	
Utara akpu	Nigeria (Ibo)	boiled cassava	part of main meal or dish, boiled sweet cassava roots	cooked fresh cassava	
Water *fufu*	Cameroon	boiled fermented cassava mash	part of main meal or dish, fermented cassava is mashed and boiled in water; eaten with stew	fermented paste	
Yakayaka	Ghana	steamed cassava granules	part of main dish or meal, steamed semi-dry granules, eaten with stews	steamed granules	*attieke*: Côte d'Ivoire

Technological Change and the Economics of Product Development in Cassava and Cocoyam in Nigeria

N. O. A. Ezeh, O. B. Arene, S. O. Odurukwe, and L. S. O. Ene[1]

Abstract

Average farm size for cassava and cocoyam in Nigeria is 0.025 ha and 0.008 ha respectively. Thus, production is dominated by numerous small-scale operators, a highly competitive group. Productivity studies show there is potential for positive commodity balance as against the current deficit situation. Results from farm size studies show smallness has a positive impact on rates of technological innovation and diffusion to operators.

Commercializability of technologies in processing were studied with respect to their use of cassava root meal as an energy substitute for corn in broiler production and cocoyam soup thickener. Results show that production of cassava root meal and its use is cost-effective with a gross margin of ₦ 1,224.6 and a benefit-cost ratio of 1.41. For cocoyam soup thickener, the gross margin per ton was ₦ 1,002.06 or equivalent of 128.2%, a good return that could easily help offset fixed costs in the short term.

Key words: cassava, cocoyam.

Introduction

The average farm size in Nigeria for cassava is 0.025 ha and 0.008 ha for cocoyam (Olayide et al. 1980). These small farm sizes are indeed atomistic, which mean that cassava and cocoyam production is highly competitive and dominated by small-scale producers. It is from these farmers that, between 1985 and 1986, 2.2 million tons of cassava were produced in a total growing area of 13 million ha and 0.22 million tons of cocoyam in 2 million ha (Ezeh and Arene 1989) (see Table 1). Production efficiency, however, is only 19.7% for cassava and 30% for cocoyam (Ezeh and Arene 1989).

Table 1. Production, area, and productivity of Nigerian root and tuber crops, 1985.

Crop	Production (million t)	Area (million ha)	Productivity (t/ha)		Production efficiency (%)
			actual	potential	
Cassava	2.2	13.0	5.9	30.0	19.7
Yam	1.4	15.6	11.1	40.0	27.8
Cocoyam	0.2	2.0	9.0	30.0	30.0
Sweetpotato	0.3	1.8	7.2	58.5	12.3

Source: Ezeh and Arene 1989.

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Studies at Umudike (Ezeh and Arene 1989) have shown that small-scale production does not impede either technological invention or technology diffusion to farmers. Rather, small farm size has a positive impact on the rate of technological invention.

The National Root Crops Research Institute (NRCRI) at Umudike has distributed available technologies in the processing, storage, and utilization of root and tuber crops. These activities are summarized in Table 2. Although the products have not been commercialized, cassava root meal and cocoyam soup thickener have been selected for studies of their market potential.

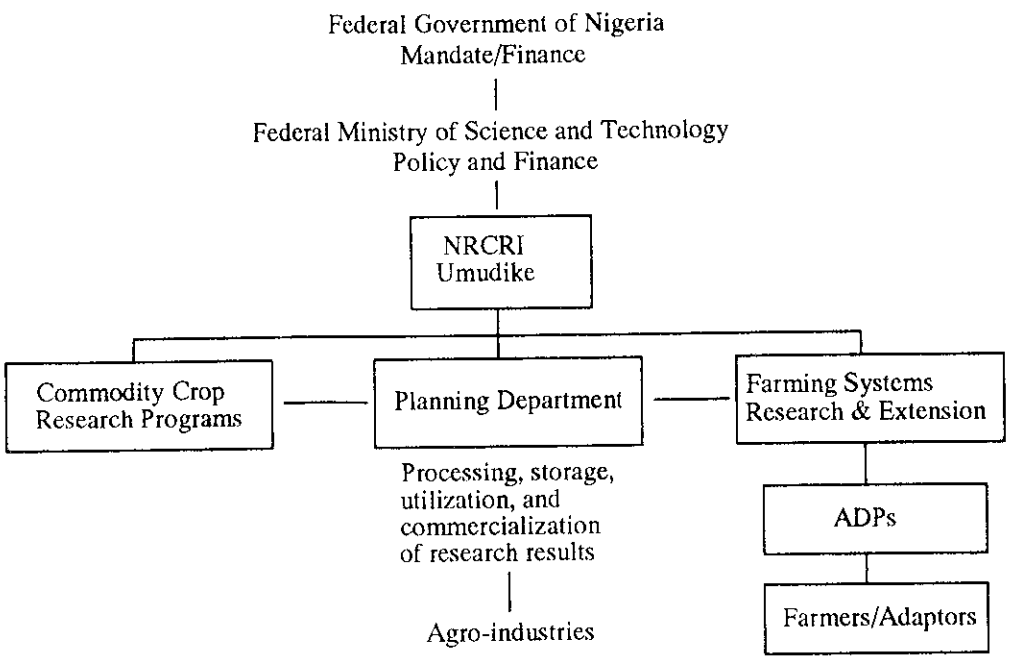
In Nigeria, research and development in root and tuber crops falls within the mandate of the NRCRI. Six major crops are under study: cassava, yam, cocoyam, sweetpotato, potato, and ginger. Research is being conducted into production, storage, preservation, processing, and utilization of these crops (Ezeh and Arene 1989). Intensive breeding activities are also going on to produce improved planting materials. In collaboration with the National Extension Research Liaison Services at the Amahdu Bello University, Zaria, the Farming Systems Research and Extension Department of the Institute is concentrating its efforts to transfer these research results to farmers, consumers, and agro-industrialists. The country-wide organization of research and development of crops is shown in Figure 1.

Table 2. Root crop products developed at NRCRI, Umudike, and their use, 1991.[a]

Products	For rural use	State of commercialization
Cassava root meal (peeled and unpeeled)	1	0
Cocoyam soup thickener	1	0
Odorless *foufou* flour	1	0
Starch	1	1
Gari	1	1
Cocoyam	1	0
Ginger powder	1	0
Yam flour	1	1
Sweetpotato flour	1	0
Cassava pellets	0	0
D. alata chips	0	0
Total	9	3

[a] 1 = occurrence of event; 0 = non-occurrence.

Figure 1. Organizational structure of NRCRI, Umudike, in relation to other agencies.



Cocoyam and Cassava

Aspects of Production

Production figures for cocoyam and casava are among those shown for important root and tuber crops in Table 1. Table 3 shows the demand and supply gaps of these crops. The inherent potential for substantial improvement in the aggregate output from existing land holdings could be exploited if currently available production technologies were implemented. For example, the improved high yielding and disease- and pest-resistant varieties of cassava available, NR 8083, NR 8082, NR 8208, TMS 30572, U/41044, and TMS 4(2)1425, have high dry matter content of 27-30%, high starch content of 19-25%, good *gari* yield of 21-25%, and *foufou* flour yield of 5-31%. Six cocoyam varieties also have been selected (Arene et al. 1987).

The Research Project

In-country Research

A national research project was begun on cassava and cocoyam. Objectives of the project are:

- to evaluate the available technologies in shortage, processing, and utilization of cassava and cocoyam;
- to examine the impact of farm size on the rates and diffusion of technological innovations; and,
- to show the market potentiality of cassava root meal and cocoyam soup thickener.

Processing/Commercialization

Cassava Root Meal

Feed alone accounts for 80% of production costs in poultry raising ventures in Nigeria. With the present ban on corn and wheat importation, demand by flour millers and breweries has generated a scarcity of these grains, consequently increasing their cost. Many feed mills and poultry projects have closed down and the survivors are running at excess capacity. Therefore, the need to identify and employ alternative sources of energy for poultry feed formulations is urgent.

Figure 2 shows the production process for cassava root meal. At NRCRI, Umudike, Ngoka et al. (1984) started addressing this problem. They used levels of 0, 50, 75, and 100% of cassava root meal to substitute for corn in layer, breeder, and broiler rations. While feeding the experimental ration, they monitored the effects on three aspects of poultry production: layer performance and egg quality; chicken egg hatchability; and broiler performance and meat yield. The results of the study showed that cassava root meal can be substituted for corn in layer, breeder, and broiler diets up to 75%. Higher substitution levels are possible provided animal protein, methionine, and Vitamin B12 are supplemented at appropriate amounts.

The estimated costs and returns of cassava root meal production are shown in Table 4, while the benefit-cost analysis of cassava root meal used as an energy substitute (50% substitution) for corn in broiler production is presented in Table 5. It can be seen from these tables that both processing of raw cassava roots into cassava root meal and use in poultry (broiler) diets are cost-effective, considering the realized gross margin of ₦ 1,225 (Table 4) and the benefit-cost ratio of 1.41 (Table 5).

Cocoyam Soup Thickener

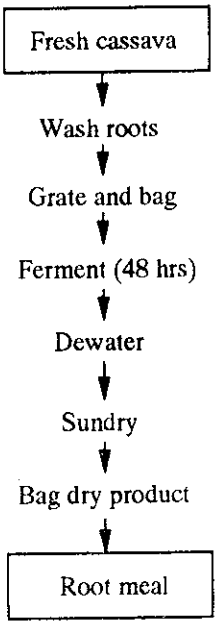
There is a declining trend in cocoyam production as well as a shortage of its supply in domestic markets due to declining yields and low storability. This trend has, however, been halted by introduction of the minisett technique and an improved agronomic package (Arene et al. 1987). With the prospects of an improved supply,

Table 3. Demand and supply (million t) of Nigerian root and tuber crops, 1984-90.

Crop	1984-85			1985-90		
	Demand	Supply	Deficit	Demand	Supply	Deficit
Cassava	5.429	4.652	0.777	6.643	5.272	4.371
Yam	11.353	9.730	1.623	13.893	11.025	2.868
Cocoyam	0.545	0.467	0.078	0.667	0.529	0.138
Potato	0.241	0.206	0.035	0.295	0.235	0.061

Source: Adapted from Okoli et al. 1986.

Figure 2. Flow chart of cassava root meal production.



the potential production of cocoyam soup thickener becomes a strong possibility.

The production process of the cocoyam soup thickener is shown in Figure 3, and the estimated costs and returns of the venture are presented in Table 6. The gross margin from processing 1 t of cocoyam is ₦ 1,002. This is quite a reasonable return, and could easily help in the short-run toward offsetting the fixed cost of investments in a new product.

Table 4. Estimated costs and returns of cassava root production, 1991.

Parameter	Quantity	Value(₦)[a]
Output (t)	1	
Revenue		1,500.00
Variable costs		
Raw material (t)	1	240.00
Labor (manday)	3	15.00
Fuel (litre)	11	0.39
Total variable costs		255.39
Gross margin		1255.39

[a] 1 Naira = US$ 0.089.

Constraints and Limitations

A major financial constraint of the project is that it was not funded as an approved project within the 1990-92 National Rolling Plan. However, activities related to the project are being undertaken in each of the commodity crop research programs.

In the program of work for 1991, a space was carved out for project activities. Still, the Processing and Storage Program as presently constituted suffers from limitations in terms of production of research results so as to be in line with the Honorable Minister's directive for 1992 that research institutes commercialize their results under the Research and Production (RAP) policy.

Table 5. Benefit-cost analysis of cassava root meal used as an energy substitute (50%) for corn in poultry (broiler) production, 1991.

	Corn-based diet		Cassava-based diet	
Parameter	quantity	value[a]	quantity	value[a]
Broiler output (kg)/revenue	984.1	14,652	862.5	12,841
Variable costs				
Corn (kg)	1,040	3,120	1,513	303
Other ingredients	—	5,968	—	5,968
Day-old chicks	—	4,000	—	4,000
Drugs	—	1,368	—	1,368
Total variable costs		14,456		13,173
Benefit-cost ratio	1.41			

[a] 1 Naira = US$ 0.089.

Figure 3. Cocoyam soup thickener production process.

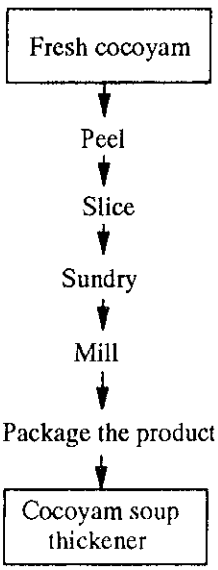


Table 6. Estimated costs and returns of production of cocoyam soup thickener, 1987.

Parameter	Quantity	Value[a]
Output (t)	0.233	
Revenue (Naira)		1,784.00
Variable costs		
Raw material (t)	1	400.00
Labor (mandays)	74.72	373.60
Polythene bags (#)	139	8.34
Total variable costs		781.94
Gross margin		1,002.06

Source: Adapted from Ezeh and Mbanaso (1987).
[a]1 Naira = US$ 0.231.

Future Projects

It is hoped that this project will launch technological changes using roots and tubers to benefit end-users. The complete realization of end-user benefit would encompass invention, entrepreneurship, investment, and development on the part of small-scale farmers.

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Sweetpotato - A Versatile and Nutritious Food For All

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Abstract

Sweetpotato has considerable untapped potential as a nutritious food crop particularly for the poor and more vulnerable groups of society in developing countries. This paper analyzes the nutritional content of sweetpotato roots and leaves in both cooked (fresh) and processed forms. It highlights the high content of carotene and Vitamin A of sweetpotato roots and leaves. Processed products are then discussed as well as extension/promotion efforts as means to broaden the crop's appeal and thereby encourage its greater use.

Key words: calorie, protein, vitamins, minerals, consumption.

Introduction

The sweetpotato (*Ipomoea batatas*) has been a life saver for centuries in many tropical, sub-tropical, and warmer temperate areas of the world, warding off famine in times of both climatic disaster and war. It was domesticated in the New World, somewhere in the Central or South American lowlands, remains of thousands of years old dessicated roots having been found in the pre-Columbian sites in Peru. Columbus became aquainted with it on his first voyage to the New World in 1492. Since then, it has spread widely throughout the world.

Although entering to only a very limited extent into international trade, due to its bulky and highly perishable nature, the sweetpotato is one of the world's most important and valuable food crops. It lies seventh in the crop league table in terms of total production and is the fifth most valuable developing world food crop. Approximately 90% of the world's sweetpotatoes are grown in Asia (more than 80%—nearly 100 million t in China alone), just under 5% (6 million t) in Africa and only about 5% in the rest of the world. Only about 2% of the total are grown in industrialized countries, mainly the United States and Japan.

Status

In spite of the many agricultural advantages sweetpotato possesses, its use has declined in many parts of the world. This has been attributed to various causes. Among these are: the total dependence of some populations on sweetpotato during times of hardship and suffering, for example in wartime; the supposed low status of the sweetpotato as a "poor man's food" (not helped by its use as a pig feed or dog food in some countries); and its sweet taste which, for some people, quickly palls if eaten too frequently and which makes it difficult to combine with other savoury foods in a variety of dishes. Moreover, once harvested, it is highly perishable and difficult to store and transport especially in tropical areas, a fact which often leads subsistence producers to leave roots in the ground and harvest them as and when needed for food. However, associations of sweetpotato with hardship are now a distant memory for most people, or are unknown by younger generations. The status of sweetpotato is not invariably that of a poor relation to other food crops, and varies considerably in different parts of the world. In the United States, it is a festive food served traditionally at Thanksgiving and has even been included in a program of research aiming to grow crops *in situ* for consumption by space station

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Table 1. Average consumption (kg/year) per adult equivalent of sweetpotato and other selected foods in rural households of five Rwandese regions, 1986.

Food	North West	South West	Center-north	Center-south	East
Sweetpotato	*137 (17%)*	*211 (34%)*	*309 (40%)*	*213 (37%)*	*131 (17%)*
Cassava	174	40	43	19	8
Bananas	51	81	112	41	244
Banana beer	59	42	43	32	68
Legumes	102	66	131	88	138
Sorghum beer	79	48	31	61	24
Cereals	56	26	7	6	8
Animal products	8	5	4	6	26
Other	97	42	31	24	32
Total	787	615	756	580	774

Source: Ewell 1988.

dwellers (Bonsi et al. 1991). In Nepal, it is prepared as an offering to the God. Elsewhere, it features as an important item in traditional feasts and religious ceremonies. Most of the varied forms of processed sweetpotato that are hand-crafted or made on a small scale in Japan are luxury items, given as gifts to friends and relatives or bought as tourist souvenirs. Sweetpotato lines vary greately in sweetness (see below) and a variety of cultivars with a range of tastes are potentially available for cooking or processing into multiple forms.

The sweetpotato is eaten in large quantities on a regular basis as a basic staple food in only a few countries of the world nowadays. Among these are several African countries, namely Rwanda, Uganda, and Burundi, all with a production of well over 100 kg per capita per year. The importance of the sweetpotato in Rwandan diets is illustrated in Tables 1 and 2. Other countries where sweetpotato has a similar importance are the highlands of Papua New Guinea, the Solomon Islands, Tonga, and isolated and mountainous parts of China, and elsewhere in Southeast Asia. In some parts of Africa, for example northern Ethiopia, sweetpotato has been introduced in response to climatic challenges such as drought, and is now an important food crop where before it was not grown (Belehu 1988). However, as it is not held in any great esteem by most people, the sweetpotato is now used as an essential part of the meal only in a fall back capacity, on a seasonal basis, when other, preferred staples are expensive or in short supply. In Mozambique, sweetpotato is a security crop used as a dietary energy source from when supplies of the first maize crop finish until the second maize crop is harvested (Jimenex et al. 1988). In many countries, it is most frequently found as a vegetable accompaniment to a meal, or baked or roasted as a street snack food. This role is by no means unimportant; daily consumption of baked sweetpotato on the streets of Jinan, China, is estimated as 4 tons (Wiersema et al. 1989).

Table 2. Contribution (%) of sweetpotato and other selected foods to energy and protein intakes of Rwandese rural households, 1986.

Food	Energy	Protein
Sweetpotato	*17.4*	*7.5*
Cassava	12.3	2.6
Potatoes	3.5	2.6
Bananas	8.2	2.5
Banana beer	4.7	0.0
Sub-total	46.1	15.2
Legumes	35.2	71.3
Cereal products	14.3	8.8
Animal products	1.4	2.5
Other	3.0	2.2
Total	100	100

Source: Ewell 1988.

The migration of large populations from the countryside to the city and the need to transport sweet-

potato long distances to urban markets has highlighted the need to explore solutions to problems of damage and disease which have led to poor quality, wastage, and relatively high prices. An alternative to the problem of storage and one which also addresses the declining interest in sweetpotato in its fresh form is to process it, particulary by dehydration, into a variety of forms which are easy to store and transport, provide tasty, nutritious, and convenient foods for consumers and lead to value added products for producers.

Potential

Until recent times sweetpotato, in common with other root and tuber crops grown by poor farmers in developing areas, was neglected in favor of international concentration on research into yield and disease resistance improvement in cereals, particulary wheat and rice. However, with the realization that root crops such as sweetpotato constitute local resources (foods and industrial raw materials) which can enhance self sufficiency and food security in countries where the world's poorest people live, they have begun to receive the attention they deserve from international scientists and policy makers. Sweetpotato combines a number of advantages which give it an exciting potential role in combating the food shortages and malnutrition which may increasingly occur as a result of population growth and pressure on land utilization. Grown from 40 °N to 32 °S of the equator from sea level to 3000 m, wherever there is a guaranteed frost-free period of 4-6 months and relatively high temperatures during this time, it is often the only crop surviving extremes of drought, flooding, or typhoons. Capable of yielding even in marginal conditions, the sweetpotato is one of the most efficient of crops in terms of the amount of food produced per unit area per unit time (Table 3). Yields still remain disappointingly low in many tropical developing countries. However, the potential increase in yield which could be achieved, given the example of some countries like China, where yields increased from about 8 t/ha in 1961 to 18 t/ha in 1985 (Horton 1988), and the experimental yields of 30-45 t/ha produced on research stations (Kay 1987) means that sweetpotato is a crop of the future.

Variability

Roots may weigh from 0.1 kg to several kilograms, vary in skin color from white, brown, or yellow to red or purple and in flesh color from white through various shades of yellow to deep orange and even dark purple. Cooked roots owe their sweetness to the presence of amylases, enzymes which convert part of the starch present in root dry matter to sugars, mainly maltose. Clones vary greatly in sweetness, however, and some do not develop sweetness even on cooking, due to the absence, in freshly harvested roots, of ß-amylase (Kumagai et al. 1990). Such lines hold out a promise of popularizing the sweetpotato as a bland tasting staple or snack food rivaling the potato (*solanum tuberosum*) in humid tropical areas where it is well adapted but where the potato does not thrive.

Table 3. Yields of sweetpotato and other major crops.

Crop	Average tropical yield (t/ha)	Days to harvest	Average yield (kg/ha/day)
Roots/tubers			
Sweetpotato	6.5	140	46.4
Cassava	8.7	330	26.4
Yam	7.0	280	25.0
Legumes			
Beans	0.6	120	5.0
Soybeans	1.3	100	13.0
Cereals			
Rice	2.0	140	14.3
Maize	1.2	130	9.2
Sorghum	0.8	110	7.3
Experimetal yields			
Sweetpotato roots	30.0	140	214.3
Sweetpotato leaves	13.0	120	108.3

Source: Woolfe 1989.

Some people, especially in certain countries of Asia (e.g., Philippines, Taiwan) and Africa (e.g., Liberia, Mozambique, Sierra Leone, and Zaïre), eat the green tops as well as the root. The tops (part of the above ground prostrate vine), usually the tender leaf tips, younger leaves, or leaf petioles, are eaten as a vegetable or salad green. Thus, sweetpotato yields two useful forms of food from the same plant, and can be eaten as a staple or vegetable food, a spinach or salad green, a sweet dessert, a variety of convenience processed

products, a fast food (french fries), a snack (chips), a multi-purpose flour, an alcoholic or non-alcoholic drink, a starch, and can be used as an animal feed or a basic industrial raw material. It therefore has tremendous potential as a local resource which can be used in preference to imported crops and products thus enhancing self-sufficiency and savings on foreign exchange. Per unit area, it can provide a larger number of people with energy and certain nutrients than many other major crops (Table 4).

Both roots and vines form an indirect food for humans by utilization as an animal feedstuff, especially for pigs, in China and elsewhere. In the Cañete Valley of Peru, for example, an efficient production and marketing system has provided not only roots for human consumption, but has also enabled the establishment of dairy farming, which thrives in an area devoid of natural pasture land, by use of the vines for feeding purposes.

In some countries, for example China, the sweetpotato is also an industrial material forming the basis of starch and alcohol industries (for both food and pharmaceutical purposes) which relies on hundreds of individual small farmers who slice the roots up into chips which are spread out to dry in the sun before being conveyed to a large factory for processing. Many Chinese sweetpotato farmers also process the roots into starch and starch noodles on a home or village scale (Table 5). This provides a storable source of food energy for use throughout the year. Systems that are successfully utilizing sweetpotato as a local food resource with potential beyond that of fresh root consumption could be studied by African countries and adapted to their own cultural patterns.

Nutritional Value

Apart from the advantages mentioned above in relation to its efficiency as a food crop, the sweetpotato has nutritional qualities which more than justify the increasing research efforts being devoted to its improvement and promotion as a food. Its sensory versatility and the variety of forms into which it can be processed mean that its composition should be compared not only with other starchy foods such as roots, tubers, and plantains, but also with a wide variety of vegetables and even with fruits. Malnutrition, in its various forms is widespread in the world today. Dietary deficiencies in terms of both quality and quantity of food are still among the most pressing problems in many African countries. The sweetpotato is well fitted to form part of any campaign to promote thorough food self-sufficiency.

In Tables 6-10 inclusive, the energy and major nutritient contents of sweetpotato roots are compared with those of other basic staples, vegetables, and fruits, respectively. The values given in the tables should be taken as guides only; nutrient contents vary considerably with such factors as cultivar, climate, soil, and postharvest treatments, as in the case of other crops. The variation in nutrient content in sweetpotato has been described in considerable detail elsewhere (Woolfe 1992). Sweetpotato is a moderately good energy source either cooked or as flour (Table 6). In contrast to what is usually thought of as the rather poor energy value of

Table 4. Estimated number of people which one hectare can support per day in terms of major nutrients.

Crop	Energy	Protein	Vitamin A	Vitamin C	Iron
Sweetpotato roots					
(6 t/ha)	20	20	0 - 1,856	387	30
(30 t/ha)	92	92	0 - 8,565	1,786	138
Leaves (13 t/ha)	23	93	542	1,444	325
Roots and leaves (14 t/ha + 13 t/ha)	63	63	542 - 4,532	2,276	390
Cassava	13	7	0	264	29
Beans	6	27	0	0	38
Rice	14	31	0	0	14

Source: Woolfe 1989.

Table 5. Sweetpotato processing units in Sichuan, China 1989.

Number of plants	Processing capacity/ fresh roots per year per plant (000 t)	Final product	Total output per year (000 t)
17	0.3-15	Starch	93
> 200	0.1-0.3	Noodle & starch	67
> 2000	(village scale) Less than 0.1 (family scale)	Mainly noodle	> 100

Source: Wiersema et al. 1989.

roots and tubers, it has a similar energy value to foods such as rice and beans when these are cooked. It is a source of fiber (Table 7), containing both insoluble fiber which helps to prevent constipation, and soluble fiber which appears to play a favorable role in reducing blood cholesterol levels. Although the protein content is on average 1.5% of the fresh root weight, it varies widely. A range from 0.46 to 2.93% of fresh weight was found among South Pacific lines (Bradbury and Holloway 1988). Baked or as a flour, sweetpotato roots are a more concentrated source of protein than when boiled. Protein quality is good, and better than that of either maize or beans with which it is complementary. While capable of satisfying a significant part of the energy and protein needs of an adult if eaten in large quantities, sweetpotato requires supplementation with more energy dense and protein-richer food for small children whose appetites and capacities are limited. However, its satisfactory content of many essential vitamins and mineral (Tables 8-10 inclusive) makes it an attractive proposition as part of the diet for all age groups. Sweetpotato contains significant quantities of the antioxidant nutrients ß-carotene, vitamin C, and vitamin E which can quench singlet oxygen and inhibit the formation of free radicals which may be implicated in the development of coronary heart disease and cancer. These chronic diseases now increasingly affect affluent sections of society in developing as well as developed countries (WHO 1990). Research is continuing into the possible importance of the antioxidant nutrients in combating various nutritional diseases. If this is confirmed, foods such as sweetpotato may gain a higher nutritional profile as a result.

Sweetpotatoes are a valuable item to include in backyards or home gardens in developing countries as they are a source of nutrients that do not have to be purchased, and can significantly improve the nutritional value of family meals. As sweetpotato is adapted to the hot, humid tropics, it is easier to grow than many introduced western vegetables. Sweetpotato vines are more tolerant to extremes of climate than many other green leafy vegetables. The tops can be harvested continuously over a number of weeks in contrast to many

Table 6. Proximate composition of sweetpotato roots cooked or as flour (per 100 g).

	Energy (Kcal)	Protein (g)	Fat (g)	Carbohydrate (g)	Dietary fiber (g)
Boiled	114	1.7	0.4	26.3	2.4
Baked	141	2.1	0.5	32.5	3.3[a]
Flour	336	2.4	0.7	79.2	nd

Source: Woolfe 1992.
[a]Holland et al. 1991.
nd: not determined.

commercially grown vegetables. Table 11 shows the valuable quantities of protein and riboflavin (vitamin B_2) in sweetpotato leaf tips compared to other vegetables. Riboflavin is another vitamin which is often deficient in rice-based diets. A recent experimental introduction of pot- or plastic bag-grown sweetpotato greens to urban slum dwellers in the Philippines (Villamayor 1991) holds out the promise of increasing vegetable consumption even among the poorest sections of an urban society who have the minimum of conditions necessary to cultivate their own food. Where acceptable to the growers, the pots or bags can be fertilized with human urine. Approximately 50 g of leaves can be harvested per pot every 10-15 days. Therefore if a family has 10 pots they can harvest 50 g every few days or so. Such a quantity of leaves can contribute to the protein, vitamins A, B, C_2, iron, and calcium needs of the family.

Table 7. Energy and protein in cooked plant foods (per 100 g edible portion).

	Moisture (%)	Energy (Kcal)	Protein (g)
Sweetpotato			
Roots (boiled)	71	115	1.5
Roots (baked)	64	141	2.1
Cassava (boiled)[a]	69	130	0.5
Yam (boiled)[a]	67	114	1.5
Taro (boiled)[a]	73	91	1.2
Rice (boiled, white)	68	135	2.3
Maize (porridge)	81	76	1.8
Wheat (bread)	33	278	8.7
Beans (boiled)	69	118	7.8

Source: Woolfe 1992.
[a]Holland et al. 1991.

An outstanding characteristic of sweetpotato leaves and the flesh of deep yellow or orange clones is their content of ß-carotene which is converted to vitamin A in the body. Vitamin A deficiency, leading to eye problems of varying degrees of severity and resulting sometimes in complete blindness, is still a serious problem among children in about 40 countries. Lack of vitamin A decreases resistance to infections and increases mortality in the young. The WHO (1976 and 1982) have pointed out that vitamin A deficiency is still prevalent in parts of Africa and may be more serious in some regions than others within a particular country, or at certain seasons of the year than at others. In recognizing the continuation of this widespread problem, the International Vitamin A Consultative Group, meeting in 1989, stressed the need to improve diets and raise the level of vitamin A nutrition wherever in the world current intake is inadequate. Vitamin A as retinol occurs only in animal foods which are eaten infrequently, if at all, by many poor people. Green leafy vegetables and some fruits are rich sources of ß-carotene. However, some leafy vegetables may not survive unfavorable climatic conditions and fruits may be seasonal or expensive. In some countries, sweetpotato leaves are almost the only vegetable still on sale in the market after an event such as a typhoon or severe flood. Their other advantages were mentioned above. Sweetpotato roots are the only starchy staple which contains appreciable quantities of ß-carotene. Regular intakes of about 100 g per day of deep yellow- or orange-fleshed roots having moderate concentrations of ß-carotene (for example, 3 mg/100g fwb), or of green tops, or a mixture of the two in various proportions, would more than cover the daily needs of most small children as long as their diets also contain a modest amount of fat (which is needed for adequate absorption of the vitamin). Unfortunately it is a sad fact that vitamin A deficiency is common in some environments where sweetpotato leaves are readily available but not consumed. Yellow- or orange-fleshed roots are rejected by adults in many developing countries, including those of Africa, in favor of white- or cream-fleshed types. This may be because the orange roots are also those with the sweetest taste and most syrupy texture on cooking or because of the "carroty" flavor. The reason for local prejudices should be investigated as a means to seek ways of overcoming resistance to consumption. Meanwhile, it would seem unlikely that adult prejudices extend to young children who might actually prefer the sweet, soft orange roots if given the chance. Watson (1988) found that farmers she interviewed in one part of Indonesia certainly noted this preference in their children who ate more sweetpotato than they did. They therefore planted orange roots for their children to eat. Although this adoption of the idea of children's foods is difficult in many African countries, where a child is simply given part of the food from the family pot, carotene-rich cultivars could be promoted by extension workers for use as a childrens' snack or fillers.

The contributions of sweetpotato roots and leaves to the recommended daily intakes of selected nutrients for adults are shown in Table 12. As recommended daily intakes are set at levels which ensure that the needs of all but a very small proportion of a population are met

Table 8. Selected vitamins and iron in cooked sweetpotato roots and other staple foods (mg per 100 g).[a]

Staple	ß-Carotene	Thiamin	Vitamin C	Iron
Sweetpotato (boiled)[a]	3.96[b]	0.09	17	0.7
Cassava (boiled)	tr	0.04	17	0.5
Taro (boiled)	0.03	0.05	7	0.8
Yam (boiled)	tr	0.14	4	0.4
Plantain, green (boiled)	0.345	0.04	12	0.6
Bread, white	0	0.09	0	1.3
Rice, white (boiled)	0	0.02	0	0.3
Beans	0	0.11	0	2.4

Source: Data on bread, rice and beans (Holland et al. 1991); all other data (Woolfe 1992).
[a]Sweetpotato roots also contain significant amounts of riboflavin (B_2), niacin, pantothenic acid, pyridoxine (B_6), folic acid, calcium and phosphorus.
[b]Orange-fleshed lines. Values for lines of all flesh colors range from 0 to about 20 mg/100 g (Woolfe 1992).

Table 9. Selected vitamins and iron in sweetpotato roots and other vegetables (mg per 100 g raw).

Vegetable	ß-Carotene	Thiamin	Vitamin C	Vitamin E	Iron
Sweetpotato	1.8 - 16[a]	0.10	23	4.56	0.7
Carrots	4 - 11	0.06	6	0.56	0.6
Onions	0.0	0.03	10	0.31	0.3
Tomatoes	0.6	0.06	20	1.22	0.4
Okra	0.09	0.10	25	nd	1.0
Pepper (green)	0.27	0.01	120	0.80	0.4

Source: Data from Woolfe (1992) except information on pepper, ß-carotene for sweetpotato and carrots, and Vitamin E (Holland et al. 1991).
[a]Orange-fleshed lines.
nd: not determined.

Table 10. Composition of sweetpotato roots and selected fruits (mg per 100 g).

Fruit/Root	ß-carotene	Thiamin	Vitamin C	Vitamin E
Sweetpotato (fresh)[a]	1.8 - 16[a]	0.09	24	4.56
(sweet sour, dried)	7.8	nd	7	nd
Apricots (fresh)	1.0 - 2.4	0.04	7	nd
(semi-dried)	0.55	tr	1	nd
Mangos (fresh, ripe)	0.35 - 13.0	0.03	37	1.05
(canned)	1.47	0.02	10	0.64
Oranges (flesh only)	0.03	0.11	54	0.24
Pawpaw (fresh)	0.2 - 1.5	0.03	52	nd

Source: Data from Woolfe (1992) except ß-carotene and Vitamin E for sweetpotato; information in semi-dried apricots, canned mangos, oranges from Holland et al. (1991); and data on sweet sour, dried sweetpotato from Truong (1989).
[a]Orange-fleshed lines.
nd: not determined.

Table 11. Protein and selected vitamins and minerals in sweetpotato leaves and other leafy and non-leafy vegetables (mg per 100 g).

Vegetable	Protein	ß-Carotene	Riboflavin (Vitamin B_2)	Vitamin C	Iron	Calcium
Tropical leafy						
Sweetpotato	2.9	2.7 (2.3 - 7.0)	0.35 (0.29 - 0.41)	55 (32 -136)	1.8	150
Amaranth	2.8	6.5	0.22	23	2.8	176
Taro	3.3	5.5	0.34	63	0.95	96
Tropical non-leafy						
Okra	2.8	0.09	0.10	25	1.0	70
Cho cho	0.7	0.05	0.03	15	0.4	16
Temperate						
Cabbage	1.7	0.39	0.02	49	0.7	52
Carrot	0.7	4-11	0.01	6	0.6	48
Lettuce	1.0	0.36	0.08	15	0.9	23
Tomatoes	0.9	0.64	01.01	20	0.4	13

Source: Data from Woolfe (1992), except for cho cho, cabbage and ß-carotene and Riboflavin for carrot and tomatoes, taken from Holland et al. (1991).

they are above what many people actually need. Therefore sweetpotato may make greater contributions to individuals needs than shown, depending on the nutrient content of a particular sample.

The high nutritional value of sweetpotato could be used as a valuable tool for improving its popularity and encouraging renewed utilization. Promotion of sweetpotato should start with the young, for example by encouraging its cultivation in school gardens or farms, and featuring it in home economics classes, in order to encourage the preparation of a range of tasty and nutritious dishes.

Processing

At present a significant proportion of the sweetpotato crop is devoted to processing in only a few countries, most notably China and Japan. Processing holds a key role in the preservation of a very perishable commodity with (in some areas) a highly seasonal production lead-

Table 12. Percentage of adult recomended daily intakes of selected nutrients provided by 100 g of cooked sweetpotatos roots or 85 g of cooked sweetpotato leaves.

	Vitamin A	Thiamin	Riboflavin	Vitamin C	Iron	Calcium
Roots						
Male	0 - more than 100	4	8	60	2 - 7	4 - 5
Female	0 - more than 100	6	11	60	1 - 4	4 - 5
Tops						
Male	40	5	13	30	7 - 20	26 - 33
Female	50	7	18	30	0 - 10	26 - 33

Source: Woolfe 1992.

ing to gluts, dearths, and strong price fluctuations. However, it also promises to transform sweetpotato into forms which offer diversity, nutritional value and convenience, thus widening its appeal to consumers from different strata of society, especially in countries when the fresh items have a poor image. Moreover, "fruity" processed products made from deep yellow- or orange-fleshed roots may stand a better chance of success with consumers than the fresh form in regions where adults prefer white-fleshed roots or where there is a cultural resistance to eating the green tops.

Sweetpotato roots can be processed into an extremely wide variety of products ranging from starch and alcohol and multiple derivatives of these two items (for example, citric acid, sugar syrups, monosodium glutamate) to snack foods, candies, soy sauce, and even a food coloring agent (either ß-carotene from orange-fleshed roots or the anthocyanin pigments extracted from deep purple roots). Leaves could be canned or dried and petioles pickled. The many and varied forms of products potentially available from sweetpotato have been exhaustively reviewed elsewhere (Woolfe 1992) and only a few examples will be given here. The sweetpotato, by the nature of its myriad root characteristics, lends itself to processing into desserts as well as savory items. One very practical use is its direct incorporation into bread. The commercial production of bread in which grated raw sweetpotato roots replace about 30% of wheat flour began in Peru (see Woolfe 1992). This was followed by research into a similar type of production in Burundi in 1990, which resulted in the adoption of the process by a suburban bakery, and in Cameroon in 1991. Preliminary trials in Cameroon indicate that producing sweetpotato bread provides a better income for the bakery and a lower price for consumers (CIP 1992). The possibility of utilizing sweetpotato-wheat composite flours for making bread and other baked goods has also been investigated in Ghana (Bortey 1982; Osei-Opare 1987). This process, if adapted on a larger scale in these countries and elsewhere in Africa, could be a valuable means of conserving foreign exchange at present spent on importation of wheat from abroad. The nutritional value of the bread can be improved by using orange-fleshed sweetpotato as the partial wheat substitute. Such a bread can be eaten by school children or other vulnerable groups. Puréed or mashed sweetened roots can be used as an inexpensive stuffing for cakes and pastries. In the Philippines, researchers have focused on converting orange-fleshed roots into fruity products. These include a dried sweet and sour sweetpotato, which can be eaten in the same way as dried apricots, peaches, or mangos (and has a similar nutritional value - see Table 9). Catsup, jam, and a nutritious non-alcoholic beverage have also been prepared (Truong 1989; Truong and Fementira 1990). In Taiwan, spaghetti-type noodles have been made by replacing a percentage of the wheat flour with white or orange fleshed cultivars or by incorporating sweetpotato leaves in the same way that spinach is added to pasta in Europe (Woolfe 1992). Orange or purple-fleshed sweetpotato has been added to ice cream in Japan (Woolfe 1992) and to yogurt in the USA (Johnson et al. 1991). At an international conference on sweetpotato held at Tuskegee University, USA in 1991, an entire lunch for all the delegates was prepared from sweetpotato dishes and an attractive display of processed products (chiefly from small enterprises) from around the world was arranged. Researchers in the USA have recently devised a snack chip from yellow-orange sweetpotatoes which contains 4.8% protein, 4.6% fiber, 70% carbohydrate, and 80% of the adult daily requirement for vitamin A (Anon. 1993).

Processing does not have to be sophisticated. The example of the hundreds of small farmers in China who process sweetpotato into starch and starch products on a home or village level has already been mentioned. Such processing could well be adopted elsewhere. Experimental production of flour and starch using technologies which could be adapted for small-scale industries and farmers has been carried out in Nigeria (Ukpabi and Ene 1991). A series of tools and equipment, for producing and drying root chips or cubes, that is suitable for use by small-scale rural industries has been developed in the Philippines (Truong and Guarte 1985). Pedal-operated peeling and slicing of roots is followed by blanching and then drying in equipment heated by burning wastes such as coconut husks.

However, if processed products are to contribute to the nutritional well-being of consumers, care has to be taken to limit the destruction of nutrients during processing. Drying of sweetpotato leaves could provide a dry season stock of vegetables, but is of little value if essential vitamins are lost. Solar drying by exposing sweetpotato leaves to direct sunlight destroys most of the ascorbic acid and ß-carotene. Research carried out in Africa showed that the retention of carotene, but not ascorbic acid, was improved by enclosing the solar drier and providing shade (Maeda and Salunkhe 1981 and see Table 13). More investigations of this kind are needed to overcome the problems of food preservation on a small scale. (The estimated contributions which some processed products make to daily nutrient needs are shown in Table 14).

Table 13. Carotene and Vitamin C in fresh and dried sweetpotato leaves.

Treatment	Carotene (mg/100g)	Retention (%)	Vitamin C (mg/100g)	Retention (%)
Fresh leaves	49.6	100.0	1,374.0	100.0
Dried leaves[a]				
Enclosed solar drier (with shade)	16.9	34.1	22.5	1.6
Enclosed solar drier (without shade)	5.2	10.5	19.0	1.4
Open sunlight	2.1	4.2	30.7	2.2

Source: Maeda and Salunkhe (1981).
[a]Blanched before drying.

Table 14. Contribution (%) of 100 g of processed sweetpotato to the adult (male) recommended daily amounts of various nutrients.

	Protein	Vitamin A	Thiamin	Ribo-flavin	Niacin	Vitamin C	Iron
RDA	37g	600 mg	1.2 mg	1.8 mg	19.8 mg	30 mg	5-15 mg
Flour	10	0 - >100	20	10	8	17	20 - 40
Flakes dry	10	0 - >100	5	10	8	150	25 - 50
prepared	3	0 - >100	2	2	2	40	7 - 12
Steamed, sliced, dried	10	0 - >100	20	5	9	30	25 - 50
Candied	2	0 - >100	2	2	2	20	13 - 22
Dried "fruit-like" product	3	>100	nd	nd	nd	25	nd

Source: Calculated from data in Woolfe 1992.

The very special food attributes of sweetpotato should prove an incentive to researchers in many countries to overcome agronomic, culinary and socio-economic problems so that sweetpotato can achieve its potential to contribute variety and nutrition to diets world-wide.

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Product Development for Sweetpotato in Rwanda

David G. Tardif-Douglin[1]

Abstract

Detailed analysis of current production, consumption, and marketing practices in Rwanda indicate that considerable potential for expanded utilization of the crop currently exists. Furthermore, given population growth and the shrinking agricultural frontier, Rwandese farm households need improved methods for reducing postharvest losses and generating value added from the crop that they harvest. This paper examines various alternatives for storage and processing for sweetpotatoes. The results indicate that innovations in these two fields are both technically feasible and economically attractive.

Key words: storage, processing, marketing, economics.

Introduction

Research into storage and processing techniques is probably the single most important contribution that can be made to the expansion of sweetpotato utilization in Rwanda because it can address the twin constraints of bulkiness (low unit value) and perishability that underlie many of the other postharvest problems. Research into storage could extend the advantages offered by storage to the marketing chain, and could provide farmers with alternatives to the in-ground storage they already practice. Processing has the greatest potential for developing the market, by virtue of its likely effects on bulkiness and perishability.

Storage

There is no long—or even intermediary—term postharvest storage of sweetpotatoes in Rwanda. Some very-short-term storage, generally overnight warehousing, is done by retailers, and was the only kind we encountered during our field work. Otherwise, what storage there is occurs in the field as part of attempts by farmers to ensure continuous food supplies.

In-Ground Storage

The only kind of storage regularly practiced in Rwanda is in-ground storage, by which farmers keep unharvested, mature sweetpotatoes in the field until they are needed for consumption or sale. By planting the first hillside crop between September and January, the second crop between March and May, and the bottomland crop between April and July, and engaging in in-ground storage, they can be sure of year-round availability.

Sweetpotatoes mature after four to six months, depending on the varieties and climatic conditions. After that, they can be left in the ground unharvested for as long as 12 months if conditions are ideal, e.g., well-drained soil and lack of pests and disease vectors (Ndamage 1988). The normal duration of in-ground storage is three to four months after maturity (Preissler 1986).

In-ground storage is appealing primarily for its ability to provide farm households a constant supply of food. It also provides a continuous supply of planting material. In-ground storage is, to some extent, a by-product of the strategy of continuous planting and piecemeal harvesting. Piecemeal harvesting supplies the necessary cuttings for continuous planting, which in

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turn provides the necessary outlet for cuttings. If harvesting were done all at once, a large field would be needed to accommodate the cuttings.

In spite of its benefits, in-ground storage has costs and limitations. After maturation a number of problems begin to appear in tubers that are left in the ground. The most important are (De Lannoy 1988):

- Diseases, which are especially problematic in wet and poorly drained soils;
- Pest infestations (weevils, termites, nematodes, and rodents), which can become very heavy and cause large losses;
- Germination, which destroys their commercial value; and
- Cracking and increasing amounts of inedible fiber, which leads to spoilage and loss of eating quality.

Unfortunately, it is not clear when these problems become serious under Rwandan conditions, nor when they render in-ground storage impracticable. No estimates have been made of their magnitude, so no cost estimates can be made.

The costs of in-ground storage are the costs of not being able to use the land for the next best alternative and the costs associated with the deterioration in quality, described above.[2] At the very least, one alternative would be fallow, or a short resting of the land for improved productivity later. This is an alternative that is always possible but not always most profitable; it represents the minimum opportunity cost of in-ground storage.

The opportunity cost depends on the alternative uses of the land, which depend on the type of field (bottomland or hillside), the season, and the available technology. Rwandan agriculture is primarily rainfed; hillside fields exclusively so. Bottomland fields have drainage and limited irrigation that enable them to be used in the dry seasons as well as during parts of the wet season.

Land freed up from storage in hillside fields is most likely to be used only for new crops of sweetpotatoes because farmers relegate the least fertile of their farmland to sweetpotatoes. Furthermore, because hillside agriculture is purely rainfed, planting and harvesting periods for more demanding alternative crops, such as sorghum and beans, are sharply defined. In the absence of irrigation, it is difficult for farmers to successfully plant beans or sorghum on hillsides outside of a fairly limited period at the beginning of the rainy season. Consequently, the most likely alternative to in-ground storage of sweetpotatoes is the establishment of a new crop of sweetpotatoes.

Bottomland fields are more versatile in types of crop as well as timing of planting. Their greatest limitation is flooding, which is most problematic at the height of the long rains. Other than sweetpotatoes, the crops most often planted on bottomland fields are beans and sorghum, which are generally considered preferred crops. Beans are planted in the bottomland at the onset of the dry season at about the same time sweetpotatoes are planted. When sorghum is cultivated in the bottomlands, it is planted in the same months (September through October) that the bottomland crop of sweetpotatoes is being harvested and, in some cases, stored in the ground. Early harvesting of sweetpotatoes could free up land for a larger sorghum crop and for earlier planting; it could also enable another crop of sweetpotatoes to be planted.

Opportunity costs will differ, depending on which crop could be planted. Computations presented in Table 1 suggest the opportunity cost is greater when sweetpotato cultivation is an alternative to in-ground storage. The opportunity cost of using 2.5 ares of land for in-ground storage for two months when sweetpotato cultivation is an alternative is a little over twice as much as it would be when sorghum is the sole alternative. This is because two months represents a larger proportion of time to maturity for sweetpotato, and consequently the expected value at maturity is multiplied by a larger fraction, and because sweetpotato has higher yields.

The costs of losses from diseases and pests is harder to quantify, no enquiries having been made about the magnitude of such losses in Rwanda. What is known is that they become greater the longer tubers are kept in the ground. Not including losses, the opportunity cost of leaving a 2.5 are field of sweetpotatoes unharvested

[2] There are also the costs of losses associated with insect infestation and the other problems listed above, which become progressively worse the longer tubers are left in the ground.

Table 1. Components of opportunity cost of using 2.5 ares for two months of in-ground storage of sweetpotatoes under two crop alternatives in Rwanda.

Alternative Crops	Field	Yield[a] (kg)	Price (franc/kg)	Value at harvest (francs)	Months to mature	Percent maturity[b]	Two month share of expected value[c] (francs)
Sweetpotato	Hillside & bottomland	200	9	1,800	5	40	720
Sorghum	Bottomland	30	27	810	6	33	270

Source: Tardif-Douglin 1991.

[a]Based on per hectare yields of 8,000 kg and 1,200 kg for sweetpotato and sorghum, respectively.

[b]Number of months required for crop maturation, divided by two months of in-ground storage.

[c]Expected harvest value, kilogram yield multiplied by price/kg, multiplied by percent maturity (two months in-ground storage divided by months to mature) gives the expected two month share of harvested value.

for two months after maturity is probably 270-700 francs in the expected value of alternative crops.

Alternative Methods of Storage

There are two broad categories of alternative methods of storage that might be considered and provided as options for farmers and other intermediaries. One is the storage of tubers that are essentially fresh and unprocessed aside from a procedure called curing. The other entails processing tubers into forms that are less perishable (dehydration, canning, and so forth). Systems of fresh tuber storage are considered in this section, processing in the subsequent section.

Curing in preparation for storage. Curing is an essential first step in any but the shortest-term fresh tuber storage systems, and a limited amount occurs naturally immediately at harvest. Under controlled temperature and humidity conditions, the naturally occurring latex in the sweetpotato is secreted to form a protective covering over any wounds to the tuber, hardening the skin in the process and making it more resistant to damage (Winaro 1982).

Although curing is done in developed countries as a matter of course, it usually involves relatively capital intensive procedures impracticable in Rwanda.[3] It can be done simply. An *Institute des Sciences Agronomiques du Rwanda* (ISAR) study suggests this approach: as soon as sweetpotatoes have been harvested, cleaned, and sorted, they should be placed in crates or baskets, covered with plastic sheeting, and placed over containers of water. By doing so the temperature (27 to 30°C) and relative humidity (85-90%) necessary for curing can be achieved (Ibid.). For optimal storage results, curing should be done for four to five days. The study also reviews alternative methods of storage. The two that seem most promising for Rwanda are underground silos and aerated mound silos (De Lannoy 1988).

Underground storage. Underground storage, not to be confused with the in-ground storage strategies currently employed by producers, has the potential of conserving tubers for up to four months if conditions are ideal (undamaged tubers and proper temperature and relative humidity). Under normal conditions, tubers can be preserved for one to two months (Ibid.). To store 200 kilograms of sweetpotatoes, or the yield of 2.5 ares, a pit one meter deep by 80 centimeters in diameter is dug and lined with a layer of straw. The pit is filled with tubers, alternating layers of tubers with layers of straw, and covered with a layer of dry leaves, 25 cm of earth, and more straw to ensure that the pit stays dry.

[3] Sweetpotatoes intended for the fresh tuber market are harvested, cleaned, and immediately placed in climate controlled (temperature and humidity) rooms for curing. After curing they are generally removed to storage rooms where they remain at cool temperatures until they are to be placed on the market.

In Cameroon, selected undamaged (but, apparently uncured) tubers are first dried in the shade while a pit lined with a layer of ash is prepared into which the tubers are to be placed. After filling the pit with alternating layers of tubers and ash, it is sealed with a layer of straw and earth. Average losses from respiration, insect infestation, and rotting have been found to be 30% after four months (Kwatia 1988). They would be less if tubers were first cured. Elsewhere, cured tubers have been found to lose about one-third the weight lost by uncured tubers during storage (Booth 1974). Similar systems are reported in Zimbabwe and Malawi (Ibid.).

Mound storage (clamps). To create a mound silo for the storage of the same amount of sweetpotatoes, a 60 cm high mound of tubers is formed on a bed of straw 1.2 m in diameter, and covered by a 20 cm layer of straw and a 15 cm layer of earth. A straw chimney is placed vertically in the middle of the mound to eliminate excessive buildup of heat. The chimney is covered with screening and an overturned earthen pot to keep rodents and rain out. For proper drainage a trench 30 cm deep is dug around the mound. Storage in mound silos substantially improves aeration over underground storage, and is considered well suited to the highlands of tropical Africa, where the climate is cool. Mound silos can conserve tubers for 30-50 days (De Lannoy 1988).

Both underground and mound storage technologies appear technically feasible for Rwandan producers. The placement of underground silos would be more restricted than that for mound silos. It would be imperative that soil conditions not be excessively wet, and that soils drain well, which would probably preclude placing silos near bottomland fields. As long as a good drainage ditch is provided, mound silos could be placed anywhere. For security, however, silos of either type would probably be placed most frequently on the hillsides or hilltops where farmers have their compounds.

It is also extremely important that tubers be handled carefully and as little as possible. Any bruises or cuts from harvesting or through insect infestation will accelerate the rate at which tubers deteriorate. Furthermore, the optimum temperatures (between 13°C and 16°C) at which sweetpotatoes should be stored tend to be lower than normal temperatures found in much of Rwanda's sweetpotato growing region.[4] It is not clear whether the necessary temperatures could easily and cheaply be achieved by either method.

Cost Comparison

The costs of in-ground storage and alternative methods are roughly equivalent. No previous attempts have been made to determine what the costs of fresh tuber storage would be. The author has estimated investment or start-up costs for storage systems capable of handling 200 kilograms of sweetpotatoes to be 2,600 francs:

2 large wooden crates @ 800 francs	1,600 f
2 plastic basins @ 300 francs	600 f
Plastic sheeting	200 f
Straw	50 f
Screening	100 f
1 Earthen pot @ 50 francs	50 f
Total	2,600 f

This is a large cash outlay for the average farm household whose net annual cash income is 22,000 francs (Rwanda 1988), and would be one of the first hurdles to be cleared, possibly through government assistance.

The equipment cost associated with each time 200 kg of sweetpotatoes are stored is 400 francs. This is based on the assumption that crates, basins, and screening could be used 10 times before replacement, that plastic sheeting could be used twice, and that the other equipment would have to be purchased every time a silo was prepared. Labor costs are harder to quantify. We have estimated the labor requirements for curing and storing 200 kg to be five man-days. Calculated at a daily rural wage rate of between 30 francs and 60 francs, labor costs would be in the range of 150 to 300 francs. Together, labor and equipment costs would be between 550 and 700 francs. The costs in francs of in-ground and alternative methods of storage are roughly equivalent:

In-Ground		Alternative methods	
Value of forgone production (sweetpotato)	700	Equipment	400
		Labor	150-300
			550-700

This also assumes, in the absence of data to the contrary, that storage losses are equivalent. It is most likely, however, that losses from alternative methods

[4] Temperatures in the Central Plateau average between 18°C at the higher elevations and 22°C at lower elevations.

would be larger, especially during a learning period. Alternative methods also carry relatively large start-up costs.

Risk of losses is the most likely impediment to adoption of alternative methods of storage, or to the replacement of in-ground storage by them.[5] It is up to research and extension services to develop simple, low-loss methods and to establish the probability of losses. It appears, nonetheless, that sweetpotato storage at the farm level is at a threshold. Rapid population growth is creating pressures for greater intensification. As farming intensifies, and with it changes occur in agricultural technology such as irrigation and adoption of early maturing varieties, the opportunity cost of in-ground storage is likely to increase and before long exceed the cost of alternative methods. In preparation for that time, research should be ready with well-tested alternatives well-suited to Rwandan conditions.

Processing

Fresh tuber storage addresses only the perishability problem, and even that in only a limited way; it is unlikely that tubers could be stored longer than three or four months. Storage would have little effect on the cost of transportation. An answer to both bulkiness and perishability problems is processing—making new, higher-value products that are less bulky and easier to handle and transport. The kinds of processing we emphasize are those that also have a relatively simple storage component to them like chipping and milling as well as those that are likely to produce foods that will be accepted in the urban and possibly the rural diet.

Acceptability and uses

The success cassava flour has had in the urban areas of Rwanda, particularly Kigali, suggests sweetpotato flour or meal might have similar acceptability, because it can be used in similar ways. Using flour to make a *foufou* or *ugali* is accepted in the urban diet. Cassava flour is a relatively new product in Rwanda. Cassava was introduced, or at least promoted and widely expanded, as a famine crop by the Belgian administration, but has begun to gain importance as a food, especially recently in the cities. Production and consumption have grown faster than that for any other crop in large part because of the advantages cassava flour affords to the marketing chain and ultimately the urban consumer.

Nine out of 10 urban households eat cassava flour, nearly all of which is purchased (Rwanda 1985). The average annual value of household consumption of cassava is 5,500 francs, of which flour represents two-thirds. Unfortunately, the study does not yet have figures on actual household consumption, nor on prices used in the estimate. Rural households consume roughly 200 kg of cassava flour annually. Having smaller households, but higher propensities to consume cassava flour, urban households probably consume as much if not more than their rural counterparts.

Dried sweetpotato chips could be reconstituted, boiled, and eaten that way, or they could be pounded or milled into a kind of *foufou*, to be eaten with beans and sauce, much as is done with cassava flour. There are other uses to which sweetpotato flour could economically and acceptably be put. It could find use, mixed with other flours, as an ingredient in the simple market pastries, doughnuts, and muffins that are becoming more and more important in urban and rural markets.[6]

Sweetpotato flour might also have commercial potential as a low-cost extender in bread making, much as manioc flour has been used periodically elsewhere in Africa. When sweetpotato is used, the optimal mix for bread making is 20% sweetpotato flour to 80% wheat flour. For bakery products for which gluten is less important, an even greater amount of sweetpotato flour could probably be used. Even with a 50% marketing margin, sweetpotato flour could undersell wheat flour, which is priced at 100 francs/kg at retail.

Type and Organization of Processing

There is no tradition of sweetpotato processing in Rwanda. Elsewhere where sweetpotato has some importance in the diet, numerous methods of processing are reported. In Papua New Guinea, for example, a relatively capital

[5] If, for example, 30% of a 200 kg silo is lost, it will cost the farmer more than 500 francs in lost value.

[6] In most markets there is a section where doughnuts and other simple bakery products are made and sold. Wheat flour is rarely the only, or even the primary, flour in these products. Flours from sources as different as peanut, pea, and sorghum are often used. A doughnut maker to whom we gave some sweetpotato flour claimed not to have had any problem selling doughnuts made with some sweetpotato flour.

intensive technique is employed to make a *gari*-like product, called *kaukau* rice, out of sweetpotatoes, which is stored, cooked, and eaten much like rice (Moy and Chi 1982). In India, sweetpotato flour is reportedly often used in bakery products, and can be 25% of a wheat- sweetpotato flour mix in bread making (Hrishi and Balagopal 1979). In Cameroon, sweetpotato flour is made for the preparation of cakes and other bakery products. Tubers are washed, grated, and dried, then pounded into a flour for use in a variety of cake-like products (Kwatia 1988). The ancient Maori of New Zealand developed *kao*, a product from cooked roots, as a storable product, and in South China farmers make a similar product, as well as storable forms of flour, *sago*-like granules (a *gari*-like product), and dried flakes (Yen 1982). In Nyanza in Kenya and in Western Tanzania tubers are peeled, sliced, dried, and then ground into a flour with sorghum or maize for making *ugali* or *uji* (Jana 1982). In Tanzania, tubers are boiled, sliced, dried, and stored as dried chips (Kwatia 1988).

Cassava's example. The evolution of cassava processing in West Africa is instructive. Fresh cassava is highly perishable, and begins to show distinct signs of spoilage within two days of harvest. Consequently, when producers have desired to market or store surplus production they have had to resort to some form of processing. There are two basic types of processing in Africa, the production of *gari* or *farinha de mandioca*, which is a cassava meal made from grated, extruded roots, and the production of *kokonte*, flour made from dried roots. It is only in West Africa that both systems are used, and it is of interest to sweetpotato processing that where both products are made, flour, which is cheaper to produce and lower in market value, was the first to gain acceptance (Jones 1959). In East and Central Africa the predominant form of processing remains the production of flour by soaking, peeling, drying, and then pounding the dried roots into a fine flour.

The two procedures are distinct in the final product and in the ways they are consumed, *gari* being eaten like rice, cassava flour being made into a variety of dough-like products like *foufou* or *ugali*, to be dipped in a sauce and eaten that way. The two procedures also have different implications for the organization of production and marketing.

Making cassava flour requires little equipment and relatively little time, but results, nonetheless, in a product that is highly storable and marketable. Farmers can easily peel, soak, and dry the roots with a minimum of equipment. There are probably no economies of size to make centralization of processing attractive. Marketability is enhanced when farmers restrict themselves to producing and selling dried roots, flour being made at the point closest to the consumer. By so doing, costs of transportation and handling are substantially reduced.

Gari, a rice-like product, requires much more labor and equipment. It is a high-cost product with relatively high market value (Kreamer 1986). Because it is more capitalized, there are likely to be economies of size that warrant centralized processing. Kreamer shows that *gari*-making is evolving towards a highly centralized system as modern, commercial *gari* processors contract with farmers to buy entire fields of cassava and ship the roots to their processing plants (Ibid.).

In Central Africa, including Rwanda, cassava processing remains at the first and simplest stage, simple sun drying of peeled, split, sometimes soaked roots, destined exclusively for flour with which a *foufou* or *ugali* is prepared. There is reason for this. Farmers remain predominantly subsistence oriented, and this is the least cost way to render the roots storable. There is the additional influence, in Rwanda, of a dispersed settlement pattern that favors decentralization. These factors are likely to exert similar influences on the development of sweetpotato processing in Rwanda.

Technical Feasibility

The simplest, least cost approaches will be adopted first, with farmers peeling, slicing, and sun-drying sweetpotatoes, and flour being made by the retailer or the consumer. Like cassava processing, sweetpotato processing would initially be decentralized. Farmers would prepare dried sweetpotatoes—chipped or shredded, which would be marketed in that form and made into flour just before use. Making dried chips is feasible at the household level, which is where it would need to be done if the full advantages of low weight and ease of transport were to be realized.

During our field work, we experimented with a rudimentary approach to chipping and sun drying hand peeling tubers, slicing them, drying them on mats in the sun for two days, then storing them in plastic bags or metal containers for several weeks.[7] The largest quan-

[7] For faster and more complete drying, chips could be placed above ground, on racks.

tity we dealt with at one time was the dried equivalent of 30 kilograms of fresh tubers. Drying the chips adequately and keeping them dry was easy during dry weather, but proved more difficult in the wet season. When chips were insufficiently dried, they rapidly developed mold spores and spoiled.[8]

Inadequate periods of sunshine during wet seasons might constitute a limitation to the most rudimentary drying techniques. It does so for cassava, which is scarcest and lowest in quality when the weather is wettest (October, November, March, and April). Farmers should avoid drying their sweetpotatoes during these months; sweetpotato products being unlikely, for the foreseeable future, to have a high enough value to warrant more sophisticated methods and equipment that could moderate the problem of lack of sunshine. Once dried, however, if the chips can be kept in a dry space, storage should pose no problems regardless of the season. In Tanzania, dried chips are reportedly stored for as long as two years with no apparent deterioration (Kwatia 1988).

Cost of Production

Chips or sweetpotatoes dried in one of the other ways described above can be milled in mills designed to make flour from maize, sorghum, or cassava. For direct consumption in *foufou*, a rougher, less expensive flour could readily be made by pounding the chips in a mortar.

In our experiment it took 30 kg of fresh tubers to make 11 kg of flour, a conversion rate of 3 to 1.1, which is similar to findings communicated to us by Joseph Mulindagabo, the principal technician responsible for extension work in root crops at ISAR. Elsewhere a conversion ratio of five to one was found (Taylor 1982). The amount of flour that could be made from fresh tubers would vary by variety as well as technique employed. We have assumed that the manual chipping and sun-drying used in our experimentation is technically inefficient, and that at higher volumes unit costs would decline; nevertheless, the per kilograms cost of producing 11 kg of flour, including purchase of the raw product, was 50 francs:

Cost component	Cost (kg) (francs/kg)
Sweetpotato	23[9]
Labor (2 man-hours)	25
Milling (2f fee)	2
Total per kilogram cost	50

This included purchasing tubers in the market; paying hired labor to clean, peel, and slice the tubers; and paying a milling fee. Farmers would probably only peel, slice, and dry the tubers, leaving milling to intermediaries or the consumer. Their costs would be roughly half of ours:

Cost component	Cost (kg) (francs/kg)
Sweetpotato	20
Labor (2 man-hours)	8
Total per kilogram cost	28

The cost of tubers would be one franc lower per kilogram, since farmers would not have to carry the sweetpotatoes to market. Labor costs would be lower in part because own household labor would be used rather than hired labor, but also because farm wage rates are lower than urban rates (30-60 versus 100 francs), and finally, milling would be done elsewhere in the system unless producers sold directly to consumers.

Conclusions

A principal advantage to the marketing chain of processing fresh sweetpotato into dried chips or flour would be the reduced importance of transport costs as a percentage of the marketing margin. Bag-denominated transport fees would be smaller because more flour or dried chips than fresh tubers could be fit into one bag. The relative cost of transport would be less because the value of one bag would be greater. Similarly, the tax burden would decline.

For the following estimates we have assumed dried chips, the form most likely to be transported from the farm gate to the consumer or to the retail market, would

[8] For best storage results, chips should be dried to below 15% moisture. Above that they readily take up and retain water and spoil easily.

[9] The market price of the quantity of fresh tubers required to make one kilogram of flour. This is very likely a high-cost scenario, since part of the market price of fresh tubers reflects producers' imputed cost of headload transportation to market. It would be more expensive to transport the fresh tuber equivalent of dried chips or flour than to transport the dried chips or flour themselves. Furthermore, it is expected that part of the processing, at least chipping and drying of chips, would be done on the farm.

cost 30 francs/kg at the supply market and 40 francs at the terminal market.[10]

	Fresh tubers	Chipped dried tubers
Sales price (francs/kg)	14	40
Purchase price (francs/kg)	9	30
Margin	5	10

The 10-franc marketing margin is the same percentage margin as that in the cassava market. The expected sales value of one 110 kg bag would be 4,400 francs of which the per bag transport fee and the shipping tax would represent 3% and 2%, respectively. Drying before shipping would reduce shipping's share of the marketing margin. This does not even take into account the additional potential savings that would come from filling each bag more fully with chips than is possible with fresh tubers.

Fresh tubers sell for approximately 14 francs per kilogram in Kigali and can be bought for 9 francs in Gitarama supply markets. The 5-franc/kg margin must cover transport fees, taxes, labor costs, and profits of merchants engaged in the long-distance trade. If one considers the transport margin as a residual, the amount available to pay for transport services after all other costs, and gross profit of 2 francs/kg are subtracted, one finds on average 1.3 francs/kg available for transport. According to data we collected from six markets, the transport fee is approximately 23 francs/t/km, which amounts to a per kilogram fee of 0.02 francs for each kilometer.[11] The relatively low margin in the fresh tuber trade suggests bulk-shippers can travel 50-100 km to supply markets depending on the quality of the road. This contrasts with a potential market supply radius for cassava bulker-shippers (also assuming a 2 franc/kg gross profit margin) of more than 100 km.

Were merchants to trade in dried sweetpotato chips costing approximately 30 francs/kg in supply markets and perhaps 40 francs in urban Kigali, the residual margin available for transport fees would be larger, as much as 4 francs/kg. As a consequence, the market supply radius could increase to 200 km, more than double that for fresh tubers. Assuming similar rural prices for wholesale sweetpotatoes, the hypothetical market supply radius increases by 50 km as the part of the margin available to pay shipping fee increases by one franc:[12]

Amount available for shipping (francs/kg)	Market supply radius (km)
1	50
2	100
3	150
4	200
5	250
10	500

With processing and improved storage options at all levels of the market, the sweetpotato could achieve a degree of marketability similar to that achieved remarkably quickly by cassava. The advantage would be that the production base for sweetpotatoes is larger and more evenly spread around the country; the income effect of increased demand would be spread more widely. Also, there is capacity for greater production through intensification. Were the market to develop, producers could meet product needs, thereby improving their incomes. It is conceivable that 20 years hence storage and processing will be regular features of the sweetpotato market.

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[10]The difference between the 50-franc cost of producing one kilogram of flour and the 30-franc wholesale market price of dried chips is a function of two factors. In the first case, fresh tubers were bought in the market, which meant that producers had to headload them in at relatively high cost. In the second case it is assumed that lighter, easier-to-transport chips are brought to market. Secondly, an additional 2-franc-per-kilogram milling fee was paid in the first case.

[11]The World Bank estimates transport costs at between 20 francs per ton kilometer on paved roads, to 60 francs per ton kilometer on poorly maintained, unpaved communal roads (World Bank 1986).

[12]This holds for truck transportation only. For head load transportation, by contrast, the market radius increases by only 1.5 km for every franc available in the margin to cover transport costs.

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Consumer Demand for Sweetpotatoes in Dar es Salaam, Tanzania

Gabriel T. Ndunguru[1]

Abstract

The demand for sweetpotatoes in Dar es Salaam is modest, but sustained. The availability of the crop in the region is seasonal covering only 6 months of the year. The type of sweetpotatoes consumers prefer are those from Bagamoyo and Gairo which are floury, moderately sweet with pale/yellow flesh. Retail prices of sweetpotatoes are quite high especially during Ramadan month. In Dar es Salaam, sweetpotatoes are neither stored nor processed. The crop is more often consumed in boiled form or as *futari*. Leaves of sweetpotatoes are consumed by some people in the same way other vegetables are consumed. Similar studies should continue in order to position the product in various urban markets of the country.

Key words: market segment, availability, preferences, prices, volumes.

Introduction

Sweetpotatoes (*Ipomoea batatas* (L) Lam) traditionally have been produced in the subsistence sector in Tanzania, but they are moving into the monetized sector. This crop has always been regarded as a poor man's food in Dar es Salaam and other urban centers. In Dar es Salaam, sweetpotatoes and other root crops such as cassava appear in large quantities in the markets during the months of Ramadan for *"futari"* (breaking the fast). While sweetpotato production in the region of Dar es Salaam declined from 45,600 t in 1988 to 13,771 t in 1990, the consumption of the crop has risen with the increasing number (over 2,548) of street vendors (City Council 1991). This makes it an important market crop with a high potential for expansion. A rough estimate indicates that about 5% of the vendors deal in sweetpotatoes. This is encouraging as sweetpotato consumption is promoted and potentially, food security improved.

However, knowledge on the consumption patterns of different ethnic groups is limited. A better understanding of demand would facilitate the formulation of strategies for the production and marketing of preferred cultivars; postharvest handling; and the possibility of promoting processed products in the city and other urban areas. This information would also guide breeders to produce cultivars that would satisfy both producers' and consumers' needs.

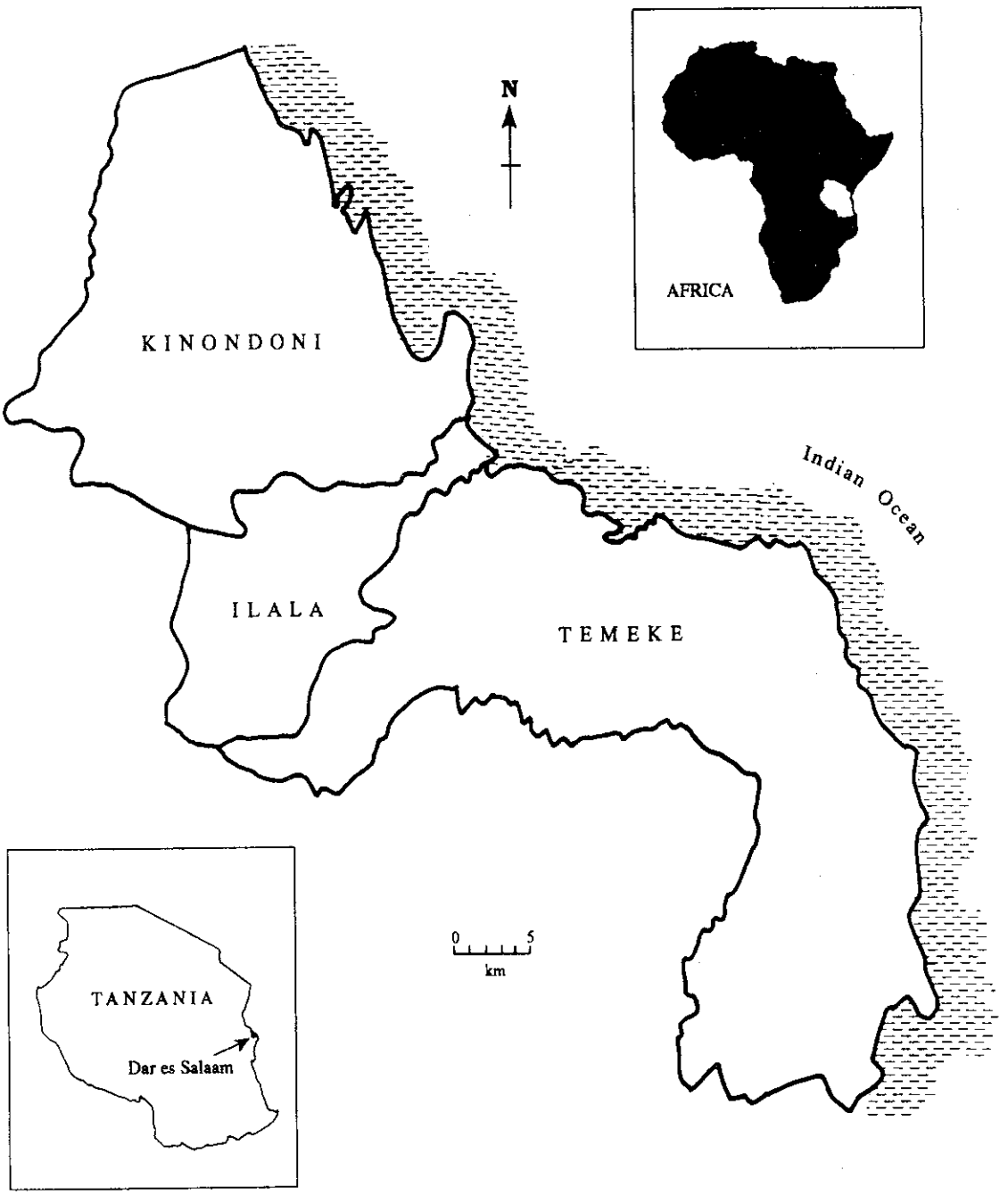
This study aims to establish the level of consumer awareness of the crop in the market; to find out who consumes the crop and with what frequency; to determine how traders and consumers characterize it; and, to analyze price fluctuations in relation to quantities of the crop being marketed.

Regional profile

Location. The Region of Dar es Salaam lies in the Eastern part of Tanzania along latitude 7 °S and longitude 38 °E, bounded by Coast region on the North, West, and South, and the Indian Ocean to the East (Map 1). It is the smallest region in the country covering an area of 1,129 km^2, 448 of these are classified as urban and 673 as rural. The region is subdivided into 3 administrative districts: Ilala, Kinondoni, and Temeke.

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Map 1. Dar es Salaam region.



Climate. The climate is tropical, hot and humid with temperatures ranging from 28°C in August to 33°C in February. Annual rainfall averages 1,315 mm.

Demography. The population of Dar es Salaam was estimated in 1988 to be 1,369,850 with a growth rate of 4.8%, significantly higher than the national rate of 2.8% (Bureau of Statistics 1988). This growth rate is borne out in the 1992 population estimated at 1.6 million. The region has the highest population density in the country, 1,997 people per km^2, compared to the national average of 26. The population is highly mobile, with migration both within and from outside the region.

Socio-economic structure. The socio-economic status of the inhabitants of Dar es Salaam is highly variable. However, income levels in real terms have declined for the past 10 years, and many people employed in the formal sector (80% male) cannot maintain families with their wages.

Food production. The Dar es Salaam Region produces only 6% of its own food supply (TFNC 1991). Food crops cultivated in the region include cassava, paddy, legumes, maize, sorghum, sweetpotato, banana, coconut, fruit, and vegetables. Production is rapidly decreasing as the city grows, stimulating production for the market in regions such as Morogoro and Coast. Table 1 gives an overview of the changing levels of production comparing sweetpotato and cassava.

Table 1. Production (t) of sweetpotato and cassava in Dar es Salaam, 1987-90.

Crop	1987-1988	1988-1989	1989-1990
Sweetpotato	45,600	23,500	13,771
Cassava	69,223	35,900	7,210

Source: TFNC 1991.

Methodology

303 households, 2 prisons, 4 hospitals, 7 schools, 11 hotels, and 8 public markets were included in the survey. The Marketing Corporation of Dar es Salaam was also contacted about the annual supply sources and prices of sweetpotato in the city.

A stratified random sampling method was used to choose the households to be interviewed, while a purposive method was used to sample the rest of the target groups. Formal questionnaires were used to interview both users and traders.

Open-ended questions were used to obtain information from schools, hotels, prisons, hospitals, sidewalk vendors, and traders. This method gave the respondents a forum in which to talk about their views on the crop and its role in their lives.

Three supervisors and twelve trained enumerators carried out the survey. Desk research was also undertaken, especially on the supply and demand of sweetpotato public markets. The survey took 12 days. Data analysis was done using the EPI INFO 5.0 computer program.

Household Survey

This household survey was conducted in order to characterize different groups or segments in the sweetpotato market in the city. It was hypothesized that sweetpotato consumption varied according to income (purchasing power), ethnicity, religion, age, household size, and whether or not the crop is produced by the family. The survey mainly focused on women, with about 98% of the respondents female. This decision was based on the assumption that women were responsible for purchasing and preparing the meals in most families. Males surveyed were street vendors and hoteliers.

Respondents' ages ranged from 12 to 65 years. About 69% had primary school education, 7% secondary education, 1% university education, and another 8% had reached various stages in adult education programs. Fifteen percent were illiterate. The respondents were of all religious denominations: 71% were Moslems, 17% Catholics, and 12% Protestants. Most of them were housewives (68%) and others were farmers or self employed. A few grow sweetpotatoes in backyard plots, but quite a large proportion have farms outside the city. The largest numbers originated from Dar es Salaam (21%) and up-country regions such as Coast (19%), Morogoro (12%), Tanga (8%), Lindi (6%), and Kilimanjaro (5%). The average family size was 6-8 people.

Although the survey revealed a larger proportion to be housewives and farmers, it found that on the basis of property ownership about 14% were in the upper middle class, those owning videos and cars; 80% in the lower middle class, those owning radios and bicycles; and, 4%

in the lower class, those who did not own the four mentioned items and rented houses built of wood and mud.[2]

The socio-economic status of the market sample was very heterogeneous. This signifies a higher degree of interaction within the market. The effects of specific socio-economic attributes of the market segment of the total demand for sweetpotatoes was not investigated. Table 2 gives a general description of the socio-economic status of the target group.

Table 2. Socio-economic profile of the consumers surveyed.

Items	Status	Percentage
Target group	Households	99
	Sidewalk vendors	1
	Institutions	insignificant
Age	12-65 years	100
Household status	Rich	14
	Average	80
	Poor	4
Gender	Male	2
	Female	98
Education	Primary	69
	Secondary	7
	University	1
	Adult education	8
	Illiterate	15
Religion	Muslims	71
	Catholics	17
	Protestants	12
	Others	insignificant
Involvement in purchasing food	Involved	91
	Not involved	9
Employment	Housewives	68
	Self-employed	14
	Unemployed	9
Place of birth (Region)	Dar es Salaam	21
	Coast	19
	Morogoro	12
	Tanga	8
	Lindi	6
	Kilimanjaro	5
	Others	29

[2] Unfortunately, the figures on the socio-economic status of the respondents could not be compared to figures from other surveys so to evaluate their representativeness.

Marketing of Sweetpotato in Dar-es-Salaam

Data on the supply of sweetpotato marketed in Dar es Salaam from 1989-1991 were obtained from the Kariakoo Market Corporation and information on wholesale prices was obtained at Kariakoo market corporation and Tandale Food Product Cooperative Society Ltd. Retail prices were obtained from the vendors and households. Figures 1 and 2 indicate the amount of sweetpotato received in the various public markets of Dar-es-Salaam and the average yearly wholesale prices per kg. The average 1991 price in the wholesale market was TSh. 35 shillings/kg. However, the retail price remained at TSh. 100 shillings, similar to 1989 and 1990 prices. While prices at wholesale markets indicated some degree of elasticity, retail prices for the crop tended to be inelastic.

According to the law of supply and demand, one could expect prices of sweetpotatoes to vary significantly with the variation in availability. Instead, prices went up with the increase in the supply of the crop and remained stable during some periods of serious scarcity. This unusual market behavior probably results from two factors. Sweetpotato is a secondary crop. Hence, relatively small volumes are traded.

Another reason could be related to the seasonal variation in the way consumers perceive the crop. Strong demand for sweetpotato is tied to Ramadan. Outside the Ramadan period, consumers may not consider the commodity as an essential part of their diet, so demand may remain flat contributing to stable retail prices.

The annual demand for sweetpotato in Dar es Salaam, calculated from weekly purchases by the sample households during the peak period, is estimated to be 67,859 t. The average amount of the crop available for consumption is estimated at 26,782 t with all but 124 t produced in the Dar es Salaam Region. This amounts to only 39% of total demand.

Sweetpotatoes are sold at 23 public markets in Dar es Salaam. During the period studied, the average price of sweetpotato was 29% higher than that of cassava. While cassava prices varied, the prices of potatoes, pumpkin, cocoyams, and plantains remained very high during the sweetpotato cropping season.

Sweetpotato was found to be available in Dar es Salaam markets for only 6 months of the year. Why the crop is unavailable year round is not clearly understood, since production is always possible in accessible areas having the necessary ecological conditions.

March and April are the peak months for sweetpotato availability. This correlates with higher wholesale prices during these same months (Fig. 2). March and April are characterized by high supply and prices, presumably because demand is high during Ramadan. The supply from May-August/September is much lower, but prices remain high which one would expect from the law of supply and demand. The high price could also be a response to salary increases after the annual budget announcement in June.

From September-February, there are almost no sweetpotatoes on the market. One could hypothesize that there is a significant unmet demand, and therefore an opportunity to develop a combination of production systems in nearby areas to extend the harvest period, and transportation/marketing systems to bring sweetpotatoes in from more distant parts of Tanzania.

Sweetpotatoes marketed in the city were mainly from Gairo (Morogoro Region), Bagamoyo (Coast Region), Kigamboni (Dar es Salaam Region), Songea (Ruvuma Region), and Kondoa (Dodoma Region).

Marketing channels

The marketing channels for sweetpotato documented during the survey are simple and do not involve stages such as grading and storage. Figure 3 shows the two marketing channels. One channel is for roots sold for fresh cooking at home. The other channel is for roots marketed by street vendors who sell a cooked product. Middlemen normally bring the product to the city for marketing. It should be noted here that the retailers in channel two are mainly market and sidewalk vendors who sell the crop directly to consumers, with or without simple processing. The consumers in this case are mainly householders, school children, and pedestrians.

The marketing channels of sweetpotato are relatively simple and invariably cheap. However, this advantage was out-stripped by high losses resulting from the lack of grading and proper storage. Surveys were conducted in three markets (Kariakoo, Tandale, and Buguruni) of Dar es Salaam to identify storage systems of sweetpotatoes. Results revealed that no storage mechanism exists for the crop. Tandale Food Product Cooperative Society Ltd. indicated substantial sweetpotato losses during marketing. The crop is not preserved at the household level either.

Figure 1. Volume of sweetpotatoes received in Dar es Salaam markets in 1989, 1990, and 1991.

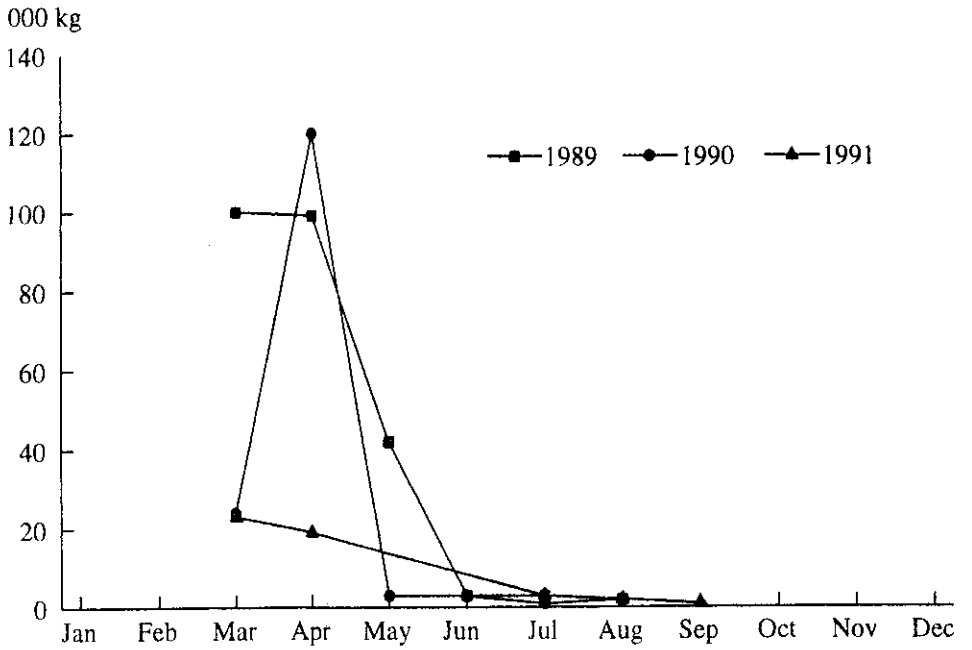


Figure 2. Average wholesale prices (per kg) for sweetpotato in the Dar es Salaam market for 1989, 1990, and 1991.

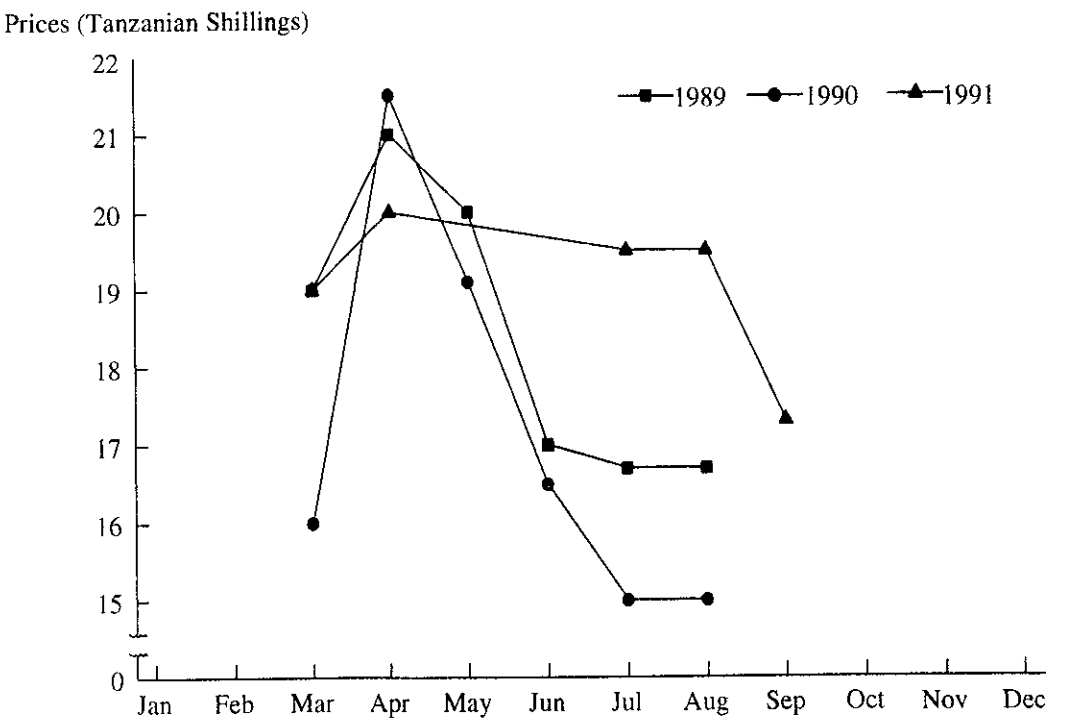
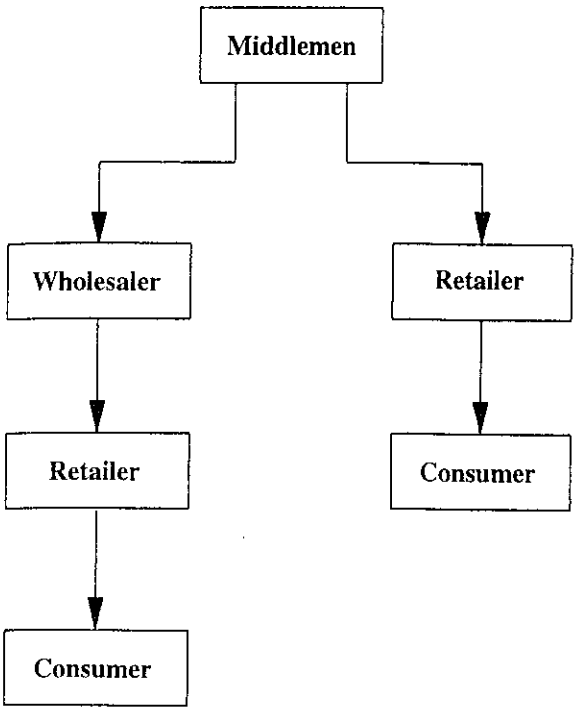


Figure 3. Sweetpotato marketing channels in Dar es Salaam.



Respondents were asked to indicate the markets where they normally buy sweetpotatoes. Twenty-three public markets were identified which market sweetpotato in the city. Seventy-nine percent of the respondents buy from these markets, whereas only 10% procure sweetpotatoes from their own farms.

Weekly Consumption

Consumers and traders are key decision-makers in sweetpotato marketing. Their tastes and preferences determine the type and quality attributes of the crop in terms of color, size, shape, and texture. Householders, vendors, traders, and school children were asked to describe the type of sweetpotato they preferred. Respondents differed in their size preferences. Households preferred medium sized (240-450 g), vendors large (450 g), and traders either large or medium.

All the respondents preferred sweet, pale yellow, fleshy, and starchy/floury roots. Vendors responsible for making chips wanted large roots. They can sell them easily and cut them into many pieces. All the vendors also preferred sweetpotato from Gairo (Morogoro Region) and Bagamoyo (Coast Region). Roots from these places best met the qualities which vendors wanted. Sweetpotatoes from other places mentioned here were not considered good because they are often white, moist, and sometimes fibrous.

Local Names of Sweetpotatoes

While it is easy for farmers to mention local names of sweetpotatoes available in the country, it was not possible for some of the respondents in Dar es Salaam to identify by name all of the sweetpotatoes in the markets. Table 4 lists the local names of sweetpotatoes known by the respondents. About 75% of the respondents were able to distinguish all cultivars in the market. Often the same cultivar is known by several names by different people in different locations. This confusion would be avoided if the cultivars were characterized and given standard names.

Another goal of the survey was to assess the average amount of sweetpotatoes consumed in the households per week. The assessments on Table 5 covered both high and low peaks of the availability of sweetpotato in the city markets.

Table 4. Sweetpotato names.

Name	Respondents identifying
Karoti	20
Hali Mtumwa	15
Canada	11
Vibogwe	6
Moyo wa Simba	6
Kandolo	6
Mayai	5
Kangeo	1
Majeshe	1
Mpoke	1
Mtangetange	1
Shangazi	1
Shizowiya	1
Mkambe	1
Unknown varieties	25

Table 5. Average amount of sweetpotato consumed per week in Dar es Salaam.

	Lowest period	Peak period
Less than 1 kg	38	0
1-5 kg	59	77
7 kg	2	17
14 kg	1	6

That 38% eat less than 1 kg/week in the lowest period is presumably due to the high prices of the crop and lack of special demand such as during Ramadan. Nevertheless, not all markets are supplied in the lowest period contributing to low accessibility to the crop. Of the respondents who eat sweetpotato, 62% consume one or more kg/week in both seasons. If sweetpotatoes were available throughout the year in these markets, this 62% could create a permanent demand.

Table 6 shows a very strong seasonal pattern; 72% of the households reported eating sweetpotato twice a week or more in the peak period; 75% once a week or less in the lowest period. However, 25% of all consumers eat sweetpotato twice a week or more even in the lowest period when prices are high. This 25% represents a group who will normally buy sweetpotato regardless of the changes in prices or season, and who would eat sweetpotato throughout the year if the crop were available.

About 97% of the households interviewed consume sweetpotato. This is equivalent to 304,875 households. The annual demand for sweetpotato for these households calculated from the weekly purchases of the sample population during the peak season is estimated at 67,859 t. This is equivalent to 62 g (297 KJ) of sweetpotato per day/household. 297 KJ/day is only 2.7% of the minimum energy requirement (11,000 KJ). The annual availability of sweetpotatoes in the markets (26,782 t) is only 39% of the total demand for the crop in Dar es Salaam. Therefore, there is still a lot of room for additional supplies of sweetpotato for marketing in Dar es Salaam.

Uses of Sweetpotato

Some city vendors reported that they cook sweetpotato chips, which are sold to consumers. Others cook cassava chips because compared to cassava the price of sweetpotato was very high. The use of large quantities of oil

Table 6. Frequency of consumption per week during lowest and peak period in Dar es Salaam.

Frequency per week	Lowest period (May-August)	Peak period (March-April)
Less than once	45	8
Once	30	20
Twice	15	22
More than twice	10	50

also raises prices, because sweetpotatoes absorb more oil during frying than cassava. To relieve this situation, researchers could breed cultivars with starch levels similar to that of cassava in terms of oil absorption capacity/properties. To prepare chips, the roots are normally peeled and chopped into pieces of about 8 cm long x 4 cm wide x 2 cm thick. These pieces are then dip-fried in oil until cooked. Salted and spiced chips are displayed on a small table for sale. A typical vendor sells 40 kg in three days.

Roots in Household and Institutional Diets

Representatives of hospitals, prisons, and hotels were interviewed to learn how sweetpotatoes are used in these institutions. Hospitals and prisons do not use sweetpotatoes during the months of Ramadan. Some hotels prepared a few sweetpotato for fasting Moslems. In the households, however, 85% of the respondents ate sweetpotato for breakfast. The rest ate the crop at lunch and/or dinner whenever the crop was available in the market. Normally, sweetpotatoes were reported to be eaten with beans (44%), cassava (46%), meat (14.3%), fish (12.2%), and cowpeas, while some households consumed the product without mixing it with other foods. Results also indicated that sweetpotato could be fed to any household group without problem: from children aged between 3-24 months to adults, the aged, and convalescent people.

When eaten for breakfast, sweetpotatoes are normally peeled, sliced into pieces of about 2.54 cm thick, washed, salted, and boiled in water. Some households cook the roots before peeling. Peeling is done at the table by individual consumers. The dishes prepared from the crop were limited to *futari*, boiled, mashed, and fried sweetpotato. In the preparation of *futari*, sweet-

potatoes are first peeled, sliced, and washed. Then the lean slices are put into a cooking pot with salt, sugar, and cardamom, and boiled until cooked. Coconut milk is added and the mixture simmered for another 10 minutes. The *futari* is then served with tea or soft drink.

Diversification of consumption patterns through new and unusual recipes for the crop could probably help to create higher demand and hence better prices.

Leaves in the Diet

Sweetpotato leaves were eaten by 84.3% of the householders interviewed. The type of leaves eaten are those which are long and thin, and mounted on the long stalk of non-tuber forming varieties. It was not clear why the consumers chose to eat only these type of leaves. It would be advisable to investigate the reasons for not eating the broad leaves of tuber forming cultivars. The leaves are cooked by frying them in oil, boiling them, or mixing them with fish or meat.

Neither roots nor leaves of sweetpotato are commonly fed to animals in the city of Dar es Salaam. The low production of the crop in the city could be the reason why sweetpotatoes were not fed to animals.

Dietary Limitations

Approximately 7.7% of the surveyed respondents disliked sweetpotatoes. They said sweetpotatoes caused them constipation, ulcers, flatulence, heartburn, or stomach pain. Areas for future research and study in this context are: looking into the substances responsible for causing the problems inherently present in the roots; advising breeders to produce highly nutritional cultivars free of the anti-nutritional factors; developing cooking methods that would render the products free from these factors; assessing the nutritional value of sweetpotatoes marketed in the city; and making a chemical analysis of the crop.

Conclusion

Sweetpotato (*Ipomoea batatas* (L) Lam) is a staple food in some regions of Tanzania, but is subject to many marketing problems.

In this study a survey was conducted in all districts of Dar es Salaam (Temeke, Ilala, and Kinondoni) in order to establish the consumer demand for sweetpotatoes. Interviews were conducted among household members, street vendors, hospitals, hotels and prisons. Wholesalers, retailers, and consumers were also surveyed.

Sweetpotatoes are eaten by people of every socio-economic status. While hospitals and prisons do not use sweetpotato in their meals, 97% of households interviewed ate the product either during breakfast, lunch, or dinner mixed with cassava, beans, cowpeas, meat, or fish. Consumption is at its highest during the season of Ramadan. Sweetpotato leaves are eaten by 84% of the households. Only 8% of the respondents said that they did not like sweetpotatoes. Reasons given were that they reportedly caused constipation, flatulence, ulcers, heartburn, or stomach pain.

Market availability of sweetpotatoes was shown to be concentrated in the months of March, April, May, June, July, August, and September. Almost none were available in Dar es Salaam markets during the other months.

The two marketing channels for sweetpotato are simple and do not involve grading or storage. Channel one involves wholesalers buying the crop from middlemen for sale to retailers who in turn sell it to consumers. In channel two, retailers buy the crop directly from the middlemen. Some vendors in the city fry sweetpotatoes into chips for sale to pedestrians.

Consumers prefer sweetpotatoes which are firm, starchy, floury, non-fibrous, moderately sweet with pale yellow flesh. The frequency in which sweetpotatoes are consumed varies according to the availability of the crop in the market. During the peak season, people eat the crop more than twice per week, while during the period of low supply the crop is eaten less than once per week. Householders appeared to consume the same amount per meal regardless of the availability of the crop in the market. Most households consume about 2.5 kg per meal while the rest consume either over 7 kg or under 1 kg regardless of the change in supply. While sweetpotato prices in wholesale markets indicate some degree of elasticity, retail prices for the crop tend to be inelastic. The wholesale price of sweetpotatoes rose by 2% from 1989 to 1991; but the retail price remained at TSh. 100/kg regardless of the fluctuation in supply.

Based on the survey findings, the following recommendations merit mention for further development of the crop.

- Carry out a special study in Dar es Salaam in order to support or nullify the hypothesis that consumption of sweetpotatoes varies according to income, ethnicity, religion, age, and size of the family.

- Encourage all markets handling sweetpotato to develop a system for keeping records on the amount of the crop received.
- Begin the practice of making weekly broadcasts of sweetpotato prices, as in the case of other crops, to create awareness on the part of producers and consumers of the supply and price of the crop.
- Explore processing techniques to increase the variety of products available, to stimulate product demand and hence production.
- Develop storage systems at receiving centers to ensure continuous availability of the crop for consumers.
- Carry out regular assessments of the culinary and nutritional properties of sweetpotatoes by various national research institutes in order to recommend suitable cultivars which are preferred by consumers.
- Carry out an analysis of the chemical composition of sweetpotatoes consumed in Dar es Salaam to determine the exact role of the crop in the diet.
- Conduct research on how to overcome the negative physical factors reported by consumers.

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A Rapid Appraisal of Sweetpotato Marketing in Uganda

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Abstract

Uganda is the largest sweetpotato producing country in Africa and the fourth largest in the world. Yet, relatively little is known about the production, utilization and, in particular, marketing of this crop under Ugandan conditions. This paper presents the results of a rapid appraisal of the marketing system for sweetpotatoes in Uganda. It also provides useful information about recent production and utilization patterns. The conclusions highlight the importance of developing new markets for fresh and processed sweetpotatoes as well as measures to extend the storability of the crop both in the ground and after harvest.

Key words: production, utilization, storage, processing, prices, constraints.

Introduction

A rapid appraisal of sweetpotato marketing was carried out in Uganda in order to identify possible support by the Natural Resources Institute (NRI) for postharvest research on this important food crop. The objective was to characterize the marketing system and identify constraints, in order to make recommendations for future research.

Methodology

A number of different methodologies exist for carrying out marketing studies (see Magrath 1992 for a review), each with its particular limitations, and the choice of methodology largely depends on the objectives and resources available to undertake the study. In this case a rapid appraisal was carried out to provide "relevant, timely, accurate and usable data" (Chambers 1980 quoted in Magrath 1992), about the structure and performance of the sweetpotato marketing system in Uganda.

This approach entailed identifying "key informants" at all levels of the marketing chain and carrying out semi-structured interviews developed for each type of participant. In some cases where interviews commenced with individual producers or traders these developed into group interviews because of the interest the discussion generated from other participants. The study focussed on the urban consumer markets of Kampala and Jinja, and the important supplying Districts of Soroti and Kumi in eastern Uganda and Mpigi and Masaka in the Central Region (Map 1). The following types and numbers of participants were interviewed as key informants:

- Urban market traders (12 individual and 2 group making a total of 32 wholesalers and retailers in Kampala and Jinja)
- Rural traders (13 wholesalers, producer/traders, and retailers)
- Producers (21 individuals and 2 groups, making a total of 69 in Soroti, Kumi, Mpigi, and Masaka Districts)
- Urban consumers (16 in Kampala and Jinja).

Other key informants included District staff from the Ministry of Agriculture, Animal Industries and Fisheries (MAAIF) and the Ministry of Commerce, Cooperatives and Marketing, market administrators,

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Map 1. Uganda Administrative Districts.



and an exporter of the crop. Secondary data and information on sweetpotato production and marketing from a number of other reports, papers and studies have also been used (see References). This paper is largely descriptive because of the nature of the methodology and objectives.

Production

Uganda has been estimated to be the most important producer of sweetpotatoes in Africa and the fourth most important producer in the world (Table 1).

Table 1. Principal producers of sweetpotato world-wide, 1991.

Country	Production (000 t)
China	107,190
Vietnam	2,105
Indonesia	1,976
Uganda	1,800
Japan	1,460

Source: FAO Production Yearbook 1991.

Two sources of production data are available from MAAIF: annual estimates are made by district extension staff and an agricultural census was carried out in 1990/91. However, a comparison of the two sources shows marked differences (Fowler and Stabrawa 1993). This is further complicated by the fact that the agricultural census was incomplete, with data collected in only 26 of the 33 Districts due to security problems.

The agricultural census records production from the enumerated Districts as being 1.37 million tons. Since the Districts not enumerated by the census contribute an average of approximately 20% of national production each year (according to the MAAIF annual estimates), the total national production in the 1990/91 season would have been approximately 1.7 million tons. This compares closely with the normally-quoted national production figure of 1.8 million tons (Table 1 and Appendix 1).

The census data show that sweetpotato is the fifth most important food crop in terms of area, after bananas, beans, maize, and finger millet; and, the third most important in terms of fresh weight produced (Table 2). The three non-grain starchy staples, bananas, cassava, and sweetpotatoes, contribute 85% of food production, by weight, in Uganda.

Table 2. Agricultural census: Area and production of the major food crops, 1990/91.

Crop	Area (000 ha)	Production (000 t)
Bananas	642	4,717
Beans	312	507
Maize	267	433
Finger millet	240	342
Cassava	184	5,007
Sweetpotatoes	170	1,371
Groundnuts	142	162
Sorghum	134	259
Potatoes	20	174

Source: Ministry of Agriculture, Animal Industries and Fisheries 1992a.

Sweetpotato has been widely grown throughout Uganda for many years, it is a crop of minor importance only in Apac District and in the relatively dry areas of Karamoja. It is also grown over a wide range of altitudes, including the highland areas in the south of Kabale District. The main sweetpotato-producing districts according to the agricultural census are shown in Table 3.

Average per capita production was approximately 105 kg per head of rural population in 1990/91. Above average production figures are, for the most part, confined to the southern Districts, in particular those immediately adjacent to the principal urban centers of Kampala, Jinja, and Entebbe. High per capita figures are also recorded in the highland part in the southwest part of the country, which is also an area of relatively high population density. However, the exclusion of certain Districts from the census coverage, in particular Kumi and Soroti, means that the national picture is incomplete.

During the census, the average sweetpotato plot size during the first growing season (March/April planting) was measured as being 0.12 ha, and 0.08 ha in the second season. The average area under the crop

throughout the year was one-tenth of a hectare, illustrating that it is a crop grown principally by smallholders.

Table 3. Principal sweetpotato growing districts, 1990/91.[a]

District	Production (000 t)
Mpigi	126
Kamuli	112
Mubende	118
Bushenyi	112
Iganga	112
Kabale	99
Kabarole	96
Mukono	95
Tororo	59

Source: Ministry of Agriculture, Animal Industries and Fisheries 1992a.

[a]There are inconsistencies between the census data and those published annually by MAAIF. The latter indicates that nine major producing districts (excluding those not included in the census) over the 1990/91 period were Mbale, Iganga, Tororo, Hoima, Apac, Kumi, Kamuli, Masindi, and Gulu. Only one third of the districts are common to both lists.

Census data also show that the proportion of the area under sweetpotatoes planted as pure stands during the first season of the year was 44%, and 56% in the second season. By contrast, the 1963/64 census revealed that 86% of the sweetpotato area was planted as pure stands. Maize and beans are the principal crops interplanted with sweetpotatoes. Sixty-two percent of the area recorded as being under sweetpotatoes during the census year was planted in the first growing season (March/April).

A survey of various aspects of sweetpotato production was carried out by the Sweetpotato Research Programme team at Namulonge Research Station, funded by the International Potato Center (CIP) and the German Agency for Technical Co-operation (GTZ). Between 1989 and 1992 a total of 635 smallholders were interviewed in nine Districts of the country (Apac, Arua, Gulu, Iganga, Kabale, Kabarole, Luwero, Mbale, and Mpigi). The principal production-related findings of the survey (Bashaasha et al. 1993; Ocitti p'Obwoya n.d.) are that:

- the main planting season is March/April, although planting takes place throughout the year;
- sweetpotato tends to be grown first or last in the crop rotation;
- sweetpotato is mainly grown on mounds except in high altitude areas where ridges predominate; 3-4 vines per mound are common;
- weeding is done once or twice depending on weather conditions;
- sweetpotato is usually "hilled-up" during the season to encourage growth and to protect the tubers;
- little use is made of fertilizer, manure, or pesticides;
- multiple varieties are grown by individual smallholders;
- farmers usually provide their own planting material or obtain them from neighbors. They are often in short supply at the beginning of the season;
- women play a major role in the cultivation of the crop; and,
- piecemeal harvesting is prevalent, from about 2.5 months after harvest for some varieties.

Like cassava, sweetpotato is an important source of food for those living in the rural areas, as well as performing an important role as a food security/famine reserve crop. For example, it shows some resistance to drought (although not as tolerant as cassava); can be stored in the soil for a significant period thus offering flexibility with regard to harvesting (Uganda, GTZ and CIP 1992); do well in marginal soils; are more tolerant than most other crops to late planting; and can be grown throughout the year in much of the country. Furthermore, it can yield some return with no purchased inputs and very little labor since the vines quickly cover the ground, therefore weeding requirements are minimal, and they protect the soil against erosion. Finally, sweetpotato is a significant source of cash income for many smallholders.

Sweetpotato is well-integrated into the farming system, being widely grown as a supplementary crop primarily for home consumption, with occasional sales being made. In addition, farmers are familiar with the crop. It is perhaps the basic staple food in much of the northeastern and northern part of the country given the recent decline in cassava production as a result of cas-

sava mosaic virus. In the east and central areas it is one of the major staples after bananas and millet, respectively (Ocitti p'Obwoya 1991).

Women play an important role in the cultivation and postharvest operations of the crop. However, recent changes have been reported with the greater involvement of men in the production and marketing of sweetpotatoes as the commercial importance of the crop has increased (Odogola, pers. comm.). This topic merits further research.

Production trends

The widely reported recent changes in the dynamics of the production of major food staples were confirmed during the study and from a review of local production figures. These changes were clearly illustrated in Kumi and Soroti Districts where there has been a marked decline in cassava production since 1991 due to the cassava mosaic virus, and a corresponding expansion of sweetpotato production following advice from local MAAIF staff.

The rapid increase in planting of sweetpotatoes in Kumi District is portrayed in Table 4. The area under the crop tripled between 1989 and 1992, when the largest area of sweetpotato was cultivated in the District since records began in 1981. As can be seen from the corresponding figures for cassava, much of this increase can be explained by the rapid reduction in the area planted to cassava arising from the spread of cassava mosaic virus.

A more dramatic change in the relative importance of the two crops has been recorded in Soroti District (see Table 5). A significant fall was also recorded in the area planted to millet during 1992, the reasons for this are not yet clear.

In addition to the reduction in the area planted to cassava, a number of other factors have combined simultaneously to boost sweetpotato cultivation in these districts in recent years. Since 1986 cattle raiding has decimated the herds in this area, where traditionally draught power had been extensively used, particularly in opening up new areas. The lack of cattle has meant that land opening is now done by hoe. Sweetpotato does not need a well-prepared seed-bed and have therefore

Table 4. Kumi District: Area planted (ha) to sweetpotato and cassava.

	Year				
Crop	1983-88[a]	1989	1990	1991	1992
Sweetpotatoes	19,743	6,862	9,909	13,073	28,313
Cassava	31,452	26,200	23,638	12,138	3,519

Source: District Agricultural Officer, Kumi.
[a] Annual average.

Table 5. Soroti District: Area planted (ha) to sweetpotato, cassava, and millet.

	Year				
Crop	1983-88[a]	1989	1990	1991	1992
Sweetpotatoes	8,097	9,226	6,613	15,424	19,020
Cassava	9,505	15,565	16,734	15,899	3,797
Millet	25,539	31,647	34,812	31,132	15,346

been planted in areas which have been only partially cleared. The speed with which the crop establishes itself and covers the ground prevents subsequent weed infestation.

Without cattle, an important source of income for the inhabitants of the region was no longer available. Sweetpotato has been able to fill this gap, at least partially. It has also been able to replace some of the income previously earned by smallholders in this region from the sale of their cotton crop. The marketing of cotton has been plagued by inefficiencies in recent years and producer prices in real terms are significantly lower than those prevailing in the 1970s. This has consequently resulted in a dramatic fall in area planted.

At the same time, the general security situation in the region improved, and the main road to Kampala together with some of the rural roads, were upgraded. This considerably reduced the cost and time of transport, a critical factor in the marketing of a high weight/low value crop such as sweetpotato. The demand for sweetpotato was also greater than usual in 1992 because low rainfall during the previous growing season adversely affected the production of *matooke* in those districts normally supplying the Kampala market, which are located immediately surrounding and to the west of the capital. At the same time, the 1992 rainy season in Kumi and Soroti Districts was unusually extended which meant that near continuous cropping was possible between April and October.

Finally, since much of the land had not been used since 1986 due to the insecurity which prevailed in the region until recently, its soils were well-rested and yield levels during the first few seasons have consequently been high. However, the long-term sustainability of intensive sweetpotato production on land which is not fertilized, is questionable.

Most farmers who replaced cassava with sweetpotato said they would grow smaller areas of both crops in the future if a solution was found to the problem of cassava mosaic virus. It was also reported that in Kumi District, sweetpotato was replacing recently-introduced rice in swamp areas because it is considerably less labour intensive.

Similar changes have been reported in Masaka District which is a major producer of *matooke*. Here sweetpotato is said to be replacing *matooke* because of banana weevils and nematodes.

Harvesting

In light of the relatively short shelf life of the sweetpotato tubers (Bashaasha et al. 1993), and since most of the crop is produced for home consumption, farmers normally harvest the crop piecemeal to meet the needs of their families over several months. For example, 64% of the farmers in Tororo district and 86% in Mukono District never sold the crop (Prevention of Post-Harvest Losses Project report). The farmers are thus effectively "storing" the crop in the ground. However, some limited storage of tubers does take place inside the farmhouses for an average of four days (Bashaasha et al. 1993).

Only if significant quantities of the crop are to be sold are entire fields harvested at once (Uganda, GTZ and CIP 1992), otherwise mature tubers from small areas are harvested piecemeal for sale to meet smallholders' cash requirements.

Yields

Yields estimated by the census varied from 5.1 t/ha in Apac district, to 11.3 t/ha in Mubende, with a national average of 8.1 t/ha. Vanegas and Bashaasha (1991) note that yields are highest in the northern part of the country, although this is not supported by the results of the census.

Although the crop can be harvested over a period of months, optimum yields are realized approximately ten months after planting. However, the incidence of weevil damage and tuber rot diseases becomes significant approximately 8 months after planting, although this varies between varieties (Uganda, GTZ, and CIP 1992a).

Returns

Bashaasha and Mwanga (1992) reported that, at current input levels, the gross margin per hectare for sweetpotato was significantly higher than that of cassava —USh 40,730 compared with USh 23,696.

An analysis of the domestic resource costs (DRC) of the principal food crops grown showed that there was a comparative advantage of growing cassava —the DRC was 2.1, compared with 4.7 for bananas and 1.7 for sweetpotatoes.

Utilization

Storage and processing

Sweetpotato tubers are highly perishable once harvested and are therefore rarely stored for more than three or four days, and even less when they are bruised or damaged. For this reason, they are usually "stored" in the ground until required.

They are mainly consumed fresh, either boiled or steamed. In the drier north and east parts of the country the tubers are often dried and subsequently stored, reportedly for up to six months or longer. This latter process consists of peeling the tubers, which are then either sliced or crushed into small pieces. They are subsequently sun-dried, particularly during the dry period between December and January. The survey by the Sweetpotato Programme (Bashaasha et al. 1993) found the storage of dried sweetpotatoes practiced in only 4 of 9 Districts covered. Forty per cent of farmers in both Kabale and Apac said they used this method, 29% in Iganga and 10% in Gulu. However, the importance of drying is still unclear because no assessment has been made of quantities produced or percentage of the total harvest dried, and because of the limited coverage of the survey (9 Districts out of 39).

The only cases of storage encountered during this rapid appraisal were of the dried form in Kumi and Soroti Districts, where the sliced and dried form is known as *amukeke*, and the mashed and dried form is known as *inginyo*. Demand for these dried products exists in local urban centers and traders transport them further north to Moroto District, but not to the south. Dried sweetpotatoes that have become mouldy can be fermented into the local spirit (*waragi*). Some traders buy the cruder form of *waragi* and distill it further to make a purer spirit.

It was not possible to assess the importance of drying which would require a more detailed study. However, it was clear from discussions that dried sweetpotatoes are very important as a famine reserve crop in the Districts where this is practiced. It ensures food security not only for the stock-holding household, but for the whole community. In times of famine those without food reserves work for those who have in exchange for dried sweetpotatoes. It is likely that the practice of drying was traditionally carried out in areas where agro-ecological conditions resulted in periodic droughts, production short-falls, and famines. The importance of dried sweetpotatoes is another area suitable for further investigation. It may well be changing due to the increasing use of monetary payments, and the greater availability of alternative ood staples such as maize meal.

Limited storage of sweetpotato tubers has been reported in underground pits covered with either earth or leaves. However, the period of storage by this method is rarely more than one week (Mwanga and Wanyera 1988); it is not clear how widespread this practice is and problems of sprouting and rotting have been reported (Bashaasha et al. 1993).

Demand

As incomes rise, the future demand for food could witness a significant shift out of root crops into livestock products, since the income elasticity of demand for sweetpotato and other root crops which comprise the dietary staples, is estimated by some observers to be well below one (World Bank 1992).[2]

However analysis of time-series data by Vanegas and Bashaasha (1991) has shown that the income elasticity of demand for sweetpotatoes is positive, although low at 0.14. Sweetpotato is therefore not an "inferior" good (Bashaasha and Mwanga 1992), and thus demand for the crop is set to increase as the economy expands.

The National Household Budget Survey, which was carried out between April 1989 and March 1990, gives details of the purchases of a number of basic staple foods made by different categories of households.[3] Data on sweetpotato purchases are summarised in Table 6.

As might be expected, purchases of sweetpotatoes comprise a smaller part of total expenditures in the Central (urban) and Eastern (urban and rural) region where production tends to be highest. These two regions also allocate less of their total household expenditure to food in general than the Western and Northern regions.

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[2] The Household Budget Survey shows that approximately one-third of the diet of the rural areas is made up of *matooke*, sweetpotatoes, potatoes, and other starchy staples, compared with less than one-quarter of the urban diet (World Bank/UNDP Project 1991). Therefore, as the polutation becomes increasingly urbanized, fundamental changes can be expected to take place in the national diet.

[3] A number of districts were not covered by the Household Budget Survey, two in the Eastern region and five in the Northern region.

Table 6. Proportion (%) of monthly household consumption expenditure on sweetpotato, by geographical region.

Region	Urban	Rural	Total
Central	2.09	4.54	3.75
Eastern	1.95	4.15	3.80
Western	2.52	4.68	4.51
Northern	4.22	4.27	4.26
Uganda average:	2.20	4.50	4.04

Source: World Bank/UNDP Project 1991.

Table 7. Average monthly expenditure (USh) on sweetpotato by region.

	Location		
Region	Urban	Rural	Total
Central	1,205	1,656	1,552
Eastern	966	984	982
Western	1,255	1,677	1,652
Northern	1,196	942	965
Uganda average	1,175	1,424	1,393

Source: World Bank/UNDP Project 1991.

In value terms, the average monthly expenditure on sweetpotatoes was USh 1,393 (Table 7). Surprisingly, perhaps, expenditure was slightly higher in the rural than in the urban areas. The average retail price of sweetpotato during the year of the survey was USh 72.7 per kg. It is appreciated that this is the retail price in Kampala and is likely to be significantly higher than the prices prevailing in many of the rural areas in which purchases took place. Nevertheless, it can be hypothesised that an average of at least 16 kg per month was purchased by households in the urban areas and approximately 20 kg per month by households in rural areas.[4]

Recently, a more limited study was undertaken of food expenditures made by a family in the suburbs of Kampala. It revealed that an average of 20 kg of sweetpotatoes were consumed each week and that purchases of the crop accounted for approximately the same proportion (9%) of total expenditure on food and sundry items in 1990 as they had done in 1971 (Bigsten and Kayizzi-Mugwera 1992).[5]

Compared with the other staple food crops, average expenditure on sweetpotato throughout Uganda ranks behind *matooke*, maize, and cassava (Table 8), although it is relatively more important in the Central and Western regions and much less so in Eastern region, where production is relatively less significant.

Tastes and preferences

The preferred sweetpotato tuber is large (but not too large or the sugar content is lower), with a high starch content and not "stringy". Small tubers are not liked due to the difficulties involved in peeling them and because they quickly become over-cooked when boiled. The tubers have to be eaten within 3 to 5 days of harvest, as their quality declines rapidly.[6] They are normally peeled, boiled until soft, and then eaten while still hot with a sauce. Weevil infestation is reported to give the tubers an unpleasant "bitter" taste.

In parts of the country where the tubers are dried, these are either rehydrated in boiling water or ground to make a flour which may be added to millet or sorghum flour. Roasted sweetpotatoes are an increasingly popular food item, cooked and sold in the urban markets at the height of the sweetpotato season (December-January).

[4] The average household size as recorded by the Household Budget Survey (HBS) was 4.5 in the urban areas and 5.6 in the rural areas, giving a national average of 5.5 people per household. The consumption figures presented here indicate that the average annual quantity of sweetpotato purchased per head amounts to approximately 42 kg in both urban and rural areas. With average production per capita estimated to be approximately 104 kg, the HBS data would suggest that a relatively high proportion of the crop (40%) is marketed, double the estimate made by the Planning Division quoted earlier (Uganda National Food Nutrition Council Sub-Committee 1992).

[5] Compared with 25% on *matooke* in 1990 (a slight increase from 1971), 10% on maize (little change), and 5% on cassava (a slight decrease).

[6] This compares with cassava which should be eaten within one day of harvest.

Table 8. Proportion (%) of average monthly total household consumption expenditure on major starchy staples.

	Location		
	Urban	Rural	Total
Matooke	7.02	11.38	10.50
Maize	3.26	4.67	4.38
Cassava	1.99	4.85	4.28
Sweetpotato	2.20	4.50	4.04
Millet & sorghum	0.74	3.68	3.09
Rice	1.97	0.85	1.07
Total food	51.08	63.25	60.82

Source: World Bank/UNDP Project 1991.

Nutrition

The 1984 Uganda Food Strategy Study (quoted in Odogola and Kaliisa 1989) estimates that the average proportion of staples in the Ugandan daily diet is: cereals 39%, plantain 33%, cassava 20%, and sweetpotato 8%. It states that sweetpotato is an important component of the diet in all agro-ecological regions except Karamoja District in the northeast (see Map 1).

Macdonald (1970) reported that in that year the total calories supplied by sweetpotato ranked behind those supplied by cassava and bananas. A recent sector review (World Bank 1992, Volume II) notes that sweetpotato is ranked fourth, accounting for 10% of the calories available per head of population compared with 28% provided from cereals, 26% from bananas, and 19% from cassava. Sweetpotato accounts for 13% of the average gross volume of food available.

No instances were recorded during the production survey (Bashaasha et al. 1993) of sweetpotato leaves (vines) being used for food, although Mwanga and Wanyera (1988) note that in some cases they are "used as spinach", and also as animal feed and food for *Tilapia spp.* in fishponds (Ibid.).

Marketing

Marketing flows

It is estimated that 20% of the sweetpotato harvest (amounting to 393,000 t in 1990) is marketed each year, approximately the same as the proportion of the cassava harvest (MAAIF Planning Division, quoted in Uganda National Food Nutrition Council Sub-Committee 1992).

As might be expected, the direction of marketing flows is from the producing areas towards Kampala and other urban centres. In Soroti, it was reported that at peak harvest time lorries also come from Kenya and Somalia (Makai, O. pers. comm.).

Observers have noted that the marketing of the crop is constrained by the high bulk/low value nature of the crop, by its high perishability, by transport and marketing constraints, and by the absence of any processing infrastructure (Bashaasha and Mwanga 1992). It has also been noted that difficulties of transporting the crop meant that there was, until recently, no national market for sweetpotato, but rather a series of geographically discrete and relatively independent marketing systems (Vanegas and Bashaasha 1991).

The situation has now improved considerably following an extensive (and ongoing) programme to rehabilitate both trunk and feeder roads; similar efforts are being made to improve the railway infrastructure. The national lorry fleet has also been augmented in recent years. One commentator has noted that, "Improvement of the transport services, via (*sic*) repairs of roads and other infrastructure, has been the single most important outcome of the adjustment efforts" (Kayizzi-Mugerwa and Bigsten 1992). However, the costs of transportation are considered to be high, which is one justification for maintaining or increasing the levels of investment in rural feeder roads.

The study team was able to obtain a limited amount of data from the Kumi District Treasurer's office on the total amount of revenue collected in recent months from a tax levied on each sack of sweetpotato which is transported out of the District, usually to Kampala

(Table 9). The tax of USh 200 per sack levied is used for the District Development Fund (DDF). The monthly data gives an idea of the quantities of produce being marketed outside the district and the timing of sales.[7]

Table 9. Tax collected from sweetpotato marketing, Kumi District.

Months	Revenue collected (USh)	Bags
September 1992	160,600	803
October 1992	867,850	4,339
November 1992	2,954,655	14,773
December 1992	1,438,600	7,190
January 1993	897,940	4,490
February 1993	1,208,880	6,044

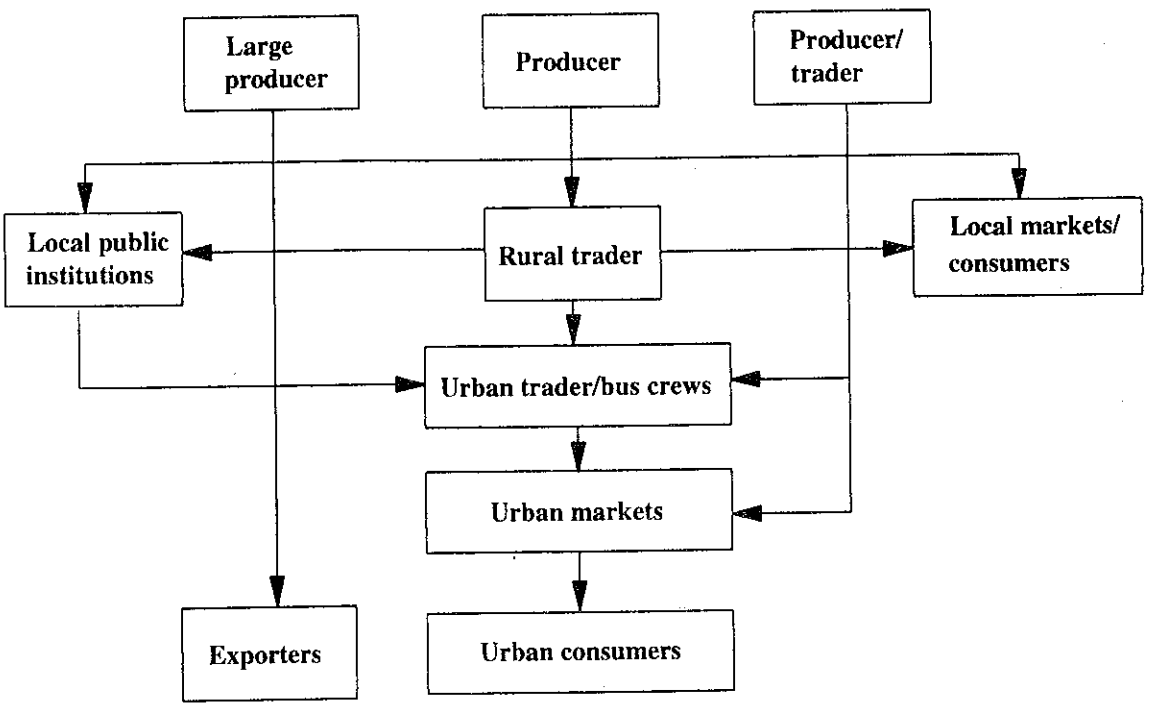
Since each sack contains approximately 100 kg of sweetpotatoes, we can calculate that in the peak month of November almost 1,500 t of sweetpotato were being transported to market outside Kumi District. Over the six month period for which data were obtained, the total quantity of produce taxed on leaving the District was 3,764 t.

Market structure

The structure and main participants involved in the sweetpotato marketing system (Fig. 1) have been compiled from the information provided during interviews and each component is described in the sections below. Although a distinction has been made between producers and rural and urban traders, in practice these functions may overlap. For example, there are producers who also trade.

During the study some variation was found in the characteristics of the sweetpotato farming system and mechanisms of marketing, depending on the District

Figure 1. Structure of the sweetpotato marketing system in Uganda.



[7] It is felt by some officials that the DDF tax may not have been levied on all the sweetpotatoes transported out of the District.

and proximity to the main urban markets of Kampala. Twenty-one individual and two groups of large and small producers were interviewed, including some large-scale, commercial growers in Mpigi and Kumi Districts. Most of the producers depended entirely on agriculture, including sweetpotato, for their incomes.

It is crucial that the tubers are sold immediately after harvest because of their perishable nature. Where production is greatest such as in Kumi, traders come to the farm with hired transport and labor, sort and bag the sweetpotatoes and transport them away. Some large producers organize their own transport to major urban markets in Mbale and Kampala but this can be difficult without contacts, and they may have to sell through a middleman or broker. Without contacts the traders are able to exploit the crop's perishability and offer low prices. One producer who tried to sell in Kampala in December 1992, a period when prices typically fall (Bashaasha n.d.), found the price did not cover the additional costs incurred.

Where producers are smaller and more likely to harvest and sell piecemeal, rather than all at once, they almost always transport the produce to the roadside or nearby market center. Transport is most often by head-load, bicycle, or hired wooden wheelbarrow, and there is said to be no difference between the selling price at the farmgate or the roadside to take account of transportation. Producers either wait at the roadside for traders to come to them, or in some areas traders wait at strategic points on the road and buy from passing producers on their way to town. In town, producers sell sweetpotatoes to consumers, market retailers, traders who come from Kampala by train or road, and long-distance bus crews en route to Kampala.

In districts closer to Kampala such as Mpigi and Masaka (see Fig. 1), marketing channels are more established. Often traders come to the farms, again with transport and labor, where they sort, bag, and transport the produce. There were reports that fewer traders were visiting the farms, requiring the producer to transport to the roadside or local markets, probably because of greater quantities coming from other areas. Some farmers have links or informal contracts with local schools or institutions which provide them with a regular guaranteed outlet for their produce.

Rural traders

There are three main types of traders in the rural areas who typically buy directly from the farmers:

- Small market retailers buying mainly from farmers who bring produce to the market, and sell to consumers;
- Farmers and/or traders who buy from producers and supply nearby markets or transport to the main urban wholesale markets; and,
- Other intermediaries such as long-distance bus crews.

All of these traders tend to deal in a range of different produce depending on the season, and during the peak season can market up to several hundred bags of sweetpotatoes per week. In Kumi, the number of traders buying sweetpotatoes was said to have increased as supply and demand increased. Few barriers to entry appear to exist at this level with the main requirement being the ability to pay the market dues or local taxes. However, good contacts with individuals in urban markets are essential.

There are no sources of formal credit available. Traders take produce on credit from farmers, borrow money from relatives and friends, or accumulate capital from other activities. One trader who had borrowed USh 1.2 million said he was paying USh 100,000 per month in interest.

Prices are said to be set according to forces of supply and demand, strongly influenced by the prices prevailing in the Kampala markets and marketing costs. When buying directly from farmers, the traders negotiate the price just before sorting and bagging. Urban traders in Kampala markets can exert considerable influence over rural traders, who may not get paid until these intermediaries have sold the produce and taken a commission.

Urban traders

Urban traders are wholesalers and retailers based in urban areas, particularly Kampala and Jinja, who buy directly from farmers or from other intermediaries such as rural traders or bus crews bringing sweetpotatoes from the producing areas.

Kampala is the largest urban center with a population of 773,463 in 1991, followed by Jinja (population 60,979) (1991 census, quoted in Ministry of Finance and Economic Planning 1992). There are numerous formal markets in central Kampala operated by Kampala City Council (KCC); the largest and most important is Owino which acts as both a wholesale and retail market. Nakaseru is the main retail market and the

oldest market in Kampala, established in 1927. It is reported to have the best quality and range of produce, and also the highest prices. There are 14 markets in Jinja, operated by the City Council, managed in a similar way to those in Kampala, the main market being the Central market.

The urban markets are managed by a Market Administrator, appointed by the City Council, who is responsible for the daily operations and collecting market dues. Each market also has a Market Management Committee comprised of traders and the Administrator. The markets are divided into sections by commodity, and traders apply to the Administrator for a stall or "pitch" in a particular section. Once this is allocated, a trader of sweetpotato, for example, cannot easily change to selling *matooke*, which requires the allocation of a stall or pitch in a different section of the market. The exception to this is in the retail markets such as Nakaseru where sweetpotato is sold with a range of other vegetable crops.

Exporters

There are a small number of exporters of sweetpotato based in the Kampala area who have contracts with certain large growers in areas such as Buganga, to the west of Kampala. These are firms which specialize in the export of "Asian" vegetables including sweetpotato, mainly to Europe. At harvest, they send their staff who select produce of the required shape and color, which is then boxed in the field (usually in 7 kg cartons) before being transported to the international airport at Entebbe. White-fleshed, red-skinned varieties which have oblong rather than a rounded shape, are demanded by the European market. Interestingly, in marked contrast to the Ugandan market, yellow-skinned varieties are not acceptable.

Table 10. Sweetpotato exports (kg) by air from Entebbe, 1992.[a]

Month	Quantity
July	1,029
August	1,528
September	1,410
October	1,134
November	1,770
December	1,919

Source: Nakazi, J. Plant Protection Unit, MAAIF (pers. comm.)

[a]According to both government officers and horticultural exporters, this data, which has been obtained from customs declaration certificates, are thought to be unreliable.

The principal market for Ugandan sweetpotatoes is the United Kingdom (UK), with smaller quantities also being sent to Switzerland, Italy, Denmark, and Sweden. Details of exports of sweetpotatoes in recent months are given in Table 10. The main supplier of sweetpotatoes to the UK market is said to be South Africa which transports them by sea. European wholesalers usually request supplies from Uganda when there are shortfalls from the normal supplying countries.

Urban consumers

Urban consumers were interviewed in Kampala and Jinja to obtain some idea of the main food staples consumed, their preferences for staples and varieties of sweetpotatoes, and constraints to increased consumption. As has already been mentioned, other studies have shown that the income elasticity of demand for sweetpotatoes is positive, although low (World Bank 1992; Vanegas and Bashaasha, 1991). However, the 1989/1990 National Household Budget Survey showed that in urban areas, high-income families consume more *matooke* and potatoes than cassava and sweetpotatoes, while the reverse is true for low-income families.

A number of commentators have noted that the habits of urban consumers are changing, with a gradual shift from *matooke* to more expensive but easily-prepared maize meal (*posho*). This supports Vanegas and Bashaasha's (1991) finding that in many urban areas of the country, root crops are regarded as "poor people's food". Unfortunately, no time series data are available which would confirm these changing food habits. These trends may also have been affected in recent years by the changes in cassava and *matooke* production and their possible substitution by sweetpotatoes.

Prices

Given the high rates of inflation experienced in Uganda, Table 11 shows the retail prices of the main staple food crops in constant (1987) prices. From the data presented there is little evidence of any significant trend in the

Table 11. Real price (USh/kg) of starchy staples and beans deflated by CPI (1987=100).

Year	*Matooke*	Maize meal	Sweetpotato	Dry cassava	Rice	Beans	Consumer price index (CPI)
1986	5.3	7.5	3.8	3.8	31.7	6.6	70.7[a]
1987	9.1	25.4	10.2	14.6	54.0	36.7	100[a]
1988	8.6	25.2	12.3	15.2	61.8	30.3	296[a]
1989	11.6	55.8	13.8	18.2	65.7	35.2	478[a]
1990	9.9	40.3	10.2	18.6	65.4	32.1	636[b]
1991	9.8	35.8	12.7	15.5	54.4	29.0	815[b]
1992	12.5	42.2	15.2	27.8	59.7	35.5	1242[b]
1993[c]	11.1	25.7	9.0	22.0	51.3	22.4	1635[b]

Source: Calculated using data from the Statistics Department 1993 and Ministry of Finance and Economic Planning 1992.

[a] Composite CPI.

[b] Kampala CPI.

[c] January 1993 figures are included for indicative purposes only.

retail prices of the six locally-produced food crops since 1987, apart from a slight upward trend in the price of dried cassava.[8] The real price of most of the crops rose steeply in 1989 and again in 1992, most probably as the result of the relatively low rainfall which adversely affected output, particularly in the south and west of the country during 1992.

While the prices of food crops have generally been maintained in real terms, cash crop prices have tended to fall. This has provided an incentive for farmers to shift into food crop cultivation. Thus the growth in the agricultural economy between 1981 and 1990 was the result of the strong growth in food production, at an annual rate of 3.3%, whereas the value of cash crop output increased by only 0.9%.

In marked contrast to the experience since 1986, future prospects are for an increased "softening" in the prices of food crops in general, with domestic market demand forecast to expand only gradually over the next decade, influenced by changes in the growth of the domestic market. Given the growing shortage of land, future increases in rural incomes from food crop production will therefore depend increasingly upon technological change and gains in labor productivity (World Bank 1992a). The need for an expanded programme of food crop research is therefore clear.

Retail prices of the different starchy staples relative to those of sweetpotatoes have remained remarkably constant since 1987 (Table 12). The relative price of rice has possibly declined slightly, although it would be necessary to include observations from a few additional years before any trend could be confirmed.

An analysis of sweetpotato monthly retail prices in Kampala over the 1989-1992 period showed that there is a definite seasonal price trend (Bashaasha n.d.). The lowest prices are recorded in June, the main harvest period nationally. Prices peak towards the end of the year due to the drying up of supplies and the increased demand which is registered in the run up to Christmas.

[8] 1987 was chosen as the begining of the period of analysis because food markets throughout Uganda were severely disrupted by the war during 1985-86 (World Bank 1992).

Table 12. Price of starchy staples and beans relative to sweetpotatoes (%).[a]

Year	*Matooke*	Maize meal	Sweetpotato	Dry cassava	Rice	Beans
1986	1.39	1.98	1.00	1.01	8.37	1.74
1987	.89	2.49	1.00	1.43	5.31	3.61
1988	.69	2.04	1.00	1.23	5.00	2.45
1989	.84	4.04	1.00	1.31	4.76	2.55
1990	.97	3.95	1.00	1.82	6.40	3.14
1991	.77	2.83	1.00	1.22	4.30	2.29
1992	.82	2.78	1.00	1.83	3.92	2.33

Source: Statistics Department 1993.

[a] Price data is only collected in Kampala.

Constraints to Sweetpotato Marketing

Producer level

During the study, 21 individual producers and two large group discussions, with a total of 69 farmers were held, at which they were asked to list and then rank the problems they faced in marketing sweetpotatoes. This ranking is given in Appendix 2 and summarized in Table 13 as the proportion of respondents mentioning each constraint.

Lack of or unpredictable markets is by far the most serious constraint producers face in marketing their produce, particularly reflected in low prices at times of peak supply which have a significant impact on profitability. The lack of markets reflects the recent increases in the production of sweetpotatoes described earlier, leading to a glut at peak harvest times. Producers are therefore forced to sell at a loss, suffer physical losses, or both.

Transport involves several issues including lack of transport from the farm to markets, the costs of hiring transport either locally or to larger urban markets such as Kampala, and transport unreliability resulting in losses either at the farm or during transportation because of mechanical breakdown. Poor roads were occasionally mentioned but, as a similar study found (Kristjanson et al. 1992), not as often as might be expected. This problem may, however, have been underreported due to the limited geographical coverage and urban bias of the study.

Perishability was noted as a problem by 22% of the key informants, although none ranked it as the most important. However, it is central to the constraints outlined above. The perishable nature of sweetpotato makes it a highly inflexible crop in terms of responding to unpredictable markets and oversupply, with substantial losses if it is not transported and marketed immediately after harvest. This increases the risks to producers from incurring additional marketing costs in order to benefit from higher prices further along the marketing chain. Traders take advantage of the product's limited "shelf" life which puts them in a strong position vis-à-vis producers.

High market dues and taxes incurred in selling the crop away from the farm, combined with the greater risk involved in trading further along the marketing chain because of perishability, act as a barrier to small producers becoming more involved in off-farm sweetpotato commerce. The main costs are the market dues paid at organized market centers, which in some cases have to be paid whether or not the produce is sold, and a local municipal tax charged on produce leaving the district.

Dishonest practices were reported in a number of cases. Traders took advantage of producers, particularly during times of glut, by procuring their sweetpotatoes on credit and never paying for them.

Rural trader level

For rural traders there are two major constraints to sweetpotato marketing, transport and perishability (Table 13).

Once again the key issues are availability, high costs and unreliability of transport, and they apply to wholesalers rather than retailers. To transport sweetpotatoes over long distances such as from Kumi to Kampala, traders usually hire "Tata" lorries from Kampala at a cost of USh 400,000-450,000 for one journey. These lorries carry up to 10 t or approximately 100 bags, and are often overloaded. Traders usually have to pay either the whole cost of hire or at least 50% in advance which, combined with buying and other marketing costs, requires substantial outlays of working capital. During the peak season, sweetpotatoes are also transported at night because of the availability of transport and the lower temperatures, which mean that the produce reaches the market in better condition.

An alternative in areas such as Soroti and Kumi Districts is the recently-restored passenger train service which arrives from Kampala on Fridays and returns on Saturdays. This means of transport has cost advantages but also has a number of drawbacks including:

- The train does not arrive in Kampala at a time when the produce can be sold immediately, resulting in delays and losses. An alternative would be to organize a special goods train, particularly at peak harvest time, with a timetable tailored to the needs of traders;
- The journey usually takes around 36 hours but it can take much longer with numerous delays;
- The metal wagons generate considerable heat which accelerates the deterioration of sweetpotatoes and other produce. This could be minimized by organising goods trains traveling at night, scheduled to arrive in Kampala in the early morning ready for the wholesale markets; and,
- The off-loading point in Kampala is frequently changed, leading to confusion amongst buyers. A permanent point with storage facilities would resolve this problem.

Perishability was also widely perceived as a constraint. Given the perishable nature of sweetpotatoes any delays in transportation result in physical and consequently financial losses.

Lack of available credit means rural traders must rely on borrowing from family, friends, or the informal sector and are therefore open to possible exploitation.

High market dues and taxes occur because rural traders have to pay dues of USh 300 - USh 500 per sack when selling, and a local tax if transporting the roots out of the District. This latter tax is set by the District Council and varies by District, but ranges from USh 200 to USh 300 per sack.

Dishonest practices refers mainly to farmers misrepresenting or mixing preferred varieties with less desirable ones.

Table 13. Marketing constraints identified by producers and traders (%).

Constraint	Producer	Rural traders	Urban traders
Lack of or unpredictable markets	91	15	85
Transport	61	85	31
Perishability	22	69	77
High market dues and taxes	17	23	
Dishonest practices	13	15	
Lack of credit		23	
Competition		15	15
Quality			31
Poor storage and market facilities			31

Competition involving an increased number of traders engaged in sweetpotato marketing and consequently increased competition was reported, probably because of recent changes in production.

Lack of or unpredictable markets is less of a constraint than at other levels in the marketing chain because rural traders tend to deal in a range of produce and are therefore more flexible.

Urban trader level

Urban traders were interviewed in Owino (16 traders), Kalerwe (2), Nakaseru (3), and Nateete (3) markets in Kampala and in the Central market in Jinja (8). The main constraints which they reported are set out in Table 13.

Lack of or unpredictable markets relates to the seasonality and variability of sweetpotato production and prices throughout the country, as well as the apparent abundance of produce in 1992 and its low income elasticity of demand.

Perishability is most serious at the urban level due to the deterioration which takes place as a result of the time involved in transporting the produce to market, as well as the damage during harvesting, bagging, transportation, and handling.

Transport is a much less significant constraint because most long-distance capacity originates in the urban areas, therefore urban traders are able to organize it relatively easily.

Quality constraints, particularly as they relate to damage during harvest as well as insect damage, arise because of the higher price of produce further along the marketing chain, and the greater influence which is exerted by consumers. In retail markets, where traders are more dependent on regular customers, they often have to replace the sweetpotato tubers which their customers find to be diseased or damaged internally.

Poor storage and market facilities is more of a constraint in urban areas where demand for such facilities is greater and their availability is limited, and often in a poor state of repair. In many cases, markets have expanded substantially both in size and number as the urban population has increased. In several markets, there are "old or inner" and "new or outer" areas.

Competition, as with rural traders, the number of urban traders was said to have increased, with new entrants being attracted by the opportunity to make a profit. It was not clear during the study whether traders in Kampala were dominated by a particular ethnic group, which might act as a barrier to entry.

Exporter level

Some constraints facing exporters of non-traditional horticultural products identified by Kristjanson et al. (1992) are equally applicable to sweetpotatoes. These include the following:

Buyer identification and market information/intelligence is the greatest constraint to exporting fresh produce because identifying a buyer usually involves visiting potential markets in Europe or the Middle East which involves considerable expense. Even traders wishing to export to nearby countries such as Kenya reported significant problems with formalities such as obtaining a passport. This reportedly can involve the need to make unofficial payments for a passport which officially costs USh 5,000. Most exporters of "Asian" vegetables identify buyers through personal contacts, but are unable to verify their integrity. This often results in problems between the exporter and the consignee.

Air-freight constraints involve airport delays and the number of carriers of airfreight to Europe. Delivery requirements for cargo have gradually been relaxed, so that produce can be delivered to the airport twelve hours in advance, rather than the 48 previously required. Therefore constraints on the movement of horticultural produce to overseas markets have and will continue to diminish as the number of scheduled flights to desirable markets increases.

Banking and credit policies are a constraint because the export of agricultural produce is considered to be a high risk by financial institutions, which normally lend to individuals with substantial security, usually in the form of property. Land is not considered to be good security because land titles are not always clearly defined and lengthy legal procedures are required to obtain possession. Furthermore, some banks are said to require letters of credit before approving working capital loans, which are inappropriate methods of payment for the horticultural trade and are not used elsewhere.

Consumer level

Urban consumers in Kampala and Jinja were asked to rank the staple foods, with the first ranking being given to those which they had consumed in the largest quantities during the past year, and those which they would prefer to consume assuming no constraints such as price

differences. This ranking is set out in Appendix 3 and those which were ranked first by the respondents are given as percentages in Table 14 below. This information indicates a strong bias towards *matooke* both in terms of quantity consumed and as the preferred staple. This confirms previous reports on dietary preferences and information collected by the Household Budget Survey, as well as agricultural production data (Appendix 1).

Table 14. Consumption (%) of and preference for staple foods.

Food	Most consumed	Most preferred
Matooke	31	56
Maize meal	31	0
Rice	19	19
Sweetpotatoes	12	19
Potatoes	6	0
Millet	0	0

Although a positive but low income elasticity of demand suggests that there is some scope for increased consumption of sweetpotato, consumers gave a number of reasons for not doing so. These included already eating enough; them not being a preferred food; or, only eaten to provide variety in the diet. Only once was it said that they were more expensive than other foods, and two consumers reported that if eaten too frequently they cause digestive problems and diarrhoea. Similar problems were reported by Bashaasha et al. (1993) and could act as an additional constraint to increased consumption.

Losses

The perishable nature of sweetpotatoes means that losses are experienced at all levels of the marketing chain, but little work has been done to quantify them. An attempt was made to establish the magnitude and causes of losses along the marketing chain by asking producers and traders to estimate the percentage of sweetpotatoes spoilt and identify causes. Consumers were not asked since it was assumed that produce is bought to be consumed quickly, but a more detailed study should investigate losses at all levels.

Because of perishability, the magnitude of losses will be directly related to time. Therefore, the more links in the marketing chain the more delays are likely between harvest and consumption and the greater losses are likely to be. Although the figures in Table 15 are only rough estimates they do suggest that as much as 37% of production might be lost. If unexpected delays occur, for example from mechanical breakdown during transport, the levels of losses are much higher, and sometimes total. High levels of losses may help to explain inconsistencies between per capita production and consumption, as well as the percentage of production marketed, that were highlighted earlier.

Amongst producers, spoilt tubers are commonly fed to livestock, primarily pigs and sometimes cattle, although this can reportedly cause sickness, or used as a mulch on the fields. One farmer in Masaka claimed never to suffer physical losses because he would rather sell at a financial loss, for as little as USh 1,000 per 100 kg sack, than let the produce rot. One means of minimizing losses amongst producers in the drier north-east is drying. Although most traders said they threw spoilt produce away, some took it home to consume, or sold it for a lower price.

Table 15. Estimates of losses (%) along the marketing chain.

Marketing level	Range	Average
Producer level	0-4	11.5
Rural trader level	0-30	10.3
Urban trader level	0.1-30	37.3
Total		37.3

Table 16 shows the percentage of key informants giving principal causes of losses, and how these vary along the marketing chain. At all levels, delay in selling was given as the most frequent cause, due to unavailability of transport or lack of markets. Losses caused by exposure to sunshine or heat and damage at harvest become more frequent at the urban level, and those from delay during transport at the rural trader level, as might be expected.

Table 16. Principal causes of losses (%).

	Producers	Rural traders	Urban traders
Delay in selling	73	46	85
Pests and diseases	45	38	38
Sunshine/heat	23	15	62
Delays during transport	14	46	8
Poor handling	–	–	8

Conclusions

The rapid appraisal carried out cannot substitute for more detailed, in-depth studies, but it does provide a quick overview of the marketing system for sweetpotato and the constraints within that system. It enables a number of conclusions to be drawn about the performance of the system and recommendations to be made as to the direction of future research.

It has been widely reported that sweetpotato production increased substantially during the 1992 season for a number of reasons, the most important being substitution for other crops such as cassava which was attacked by the cassava mosaic virus. This led to a glut and consequently low prices at peak harvest times.

Marketing channels seem to be organized and responsive to variations in supply but face a number of constraints, the importance of which differ at each stage of the marketing chain.

Lack of or unpredictable markets—this is the result of the recent increase in production and limited market amongst urban consumers because of preferences for other foods, namely *matooke*, and saturated demand. Future research should be channeled into:

- A longer-term study to verify this reported increase in production, its extent, and sustainibility.
- Examining the technical and economic feasibility of processing sweetpotatoes into new, less perishable products and by-products for human and animal consumption, and possibly for industrial uses.
- Examining new markets for fresh sweetpotato and its products, particularly export markets in Europe, the Middle East and neighboring countries in Africa.

Transport—the issues are related to availability, reliability and high costs, which should be left to market forces and the private sector to resolve. The need to upgrade and maintain both rural feeder roads and main trunk routes is another aspect that requires constant attention. Greater use of alternative means of transport such as railroads is an issue that should be considered, most likely as part of a larger transportation or marketing project.

Perishability—this characteristic of sweetpotatoes is central to many of the constraints identified. If the crop were not perishable its timely harvest and transportation would not be such important issues. Research should focus on:

- Accurately assessing levels of losses at all stages of the marketing chain.
- Identifying varieties that are less perishable after harvest.
- Identifying varieties that can be "stored" in the ground for longer as with cassava, thus extending the harvest period and evening out the fluctuations in supply.
- Developing postharvest storage technologies and techniques such as "curing" which is done with *Solanum* potatoes. Some promising results using polythene bags were said to have been achieved at Kawanda Research station (S. Nandi, pers. comm.).
- Investigating the technical and economic feasibility of using cultural practices such as staggered planting and harvesting to reduce and even out production gluts.

The lack of marketing information is an issue that is not confined to sweetpotato but is common throughout the marketing chain, from producers to exporters. Although lack of information was never given as a constraint, many traders requested information from the study team, particularly concerning new markets. The availability of accurate and timely marketing information concerning price, supply and demand data would enable resources to be allocated more effectively by the different participants. A number of institutions exist whose functions theoretically include collecting market information. However, they lack the financial resources to function effectively. These include:

- The Marketing Section of the Production Division of MAAIF

- The Planning Department of the Ministry of Commerce, Cooperatives and Marketing
- The Ugandan Export Promotion Council
- The Export Policy Analysis and Development Unit (EPADU) of the Ministry of Finance and Economic Planning
- The Association of Horticultural Exporters
- The Horticultural Farmers Association

There is a need for the information collected by each of these bodies to be coordinated, standardized, and possibly centralized to avoid duplication. It should also be analysed and the results disseminated in a timely fashion since the value of market information depends on it being up-to-date and available.

Although some of the constraints are particular to sweetpotato others such as the need for improved transport and infrastructure, greater availability of credit, and improved marketing information are common to many agricultural crops, and would require considerable resources if they are to be addressed in a sustainable manner.

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Apendix 1. Production of staple food crops in Uganda, 1970-90.

Year	Sweetpotato	Matooke	Cassava	Maize	Finger millet	Sorghum	Beans
1970	1,570	7,657	2,578	389	783	462	388
1971	1,425	7,575	2,417	421	650	348	222
1972	1,224	7,634	2,650	500	594	419	237
1973	1,232	8,126	2,132	419	643	380	170
1974	1,786	8,879	2,350	430	591	345	196
1975	1,953	9,106	2,992	570	682	467	326
1976	2,002	8,137	2,838	674	567	390	337
1977	1,659	8,531	2,993	566	578	344	253
1978	1,689	8,855	2,028	594	561	351	291
1979	1,272	6,090	2,100	453	481	316	182
1980	1,200	5,699	2,072	286	459	299	133
1981	1,300	5,900	3,034	342	480	320	240
1982	1,487	6,596	3,127	393	401	270	237
1983	1,843	6,487	3,239	413	545	407	314
1984	1,630	6,250	2,969	338	332	247	295
1985	1,664	6,468	2,700	354	480	310	267
1986	1,865	6,565	2,900	322	427	280	267
1987	1,674	7,039	3,101	357	518	315	299
1988	1,716	7,293	3,271	440	578	344	338
1989	1,658	7,469	3,568	624	610	347	389
1990	1,780	7,791	3,339	584	564	360	396

Source: World Bank 1992, Volume III.

Appendix 2. Ranking of marketing constrains at producer level.

Constraint	Producer or group number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Lack of or unpredictable markets	1	1	1	1	2	2	2	2	1		1		1	1	1
Transport	3		2	3	2	1	1	1	2	1	2				
Perishability	2		3							3					
High market dues and taxes					1										
Dishonest practices			4	2											

/cont..

Constraint	Producer or group number								% Ranked	% Ranked
	16	17	18	19	20	21	G1	G2	overall	first
Lack of or unpredictable markets	1	2	1	1	1	1	1	1	91	70
Transport			2			2	2	2	61	17
Perishability							3	3	22	0
High market dues and taxes		3	2	2					17	4
Dishonest practices		1							13	4

Ranking of marketing constraints at rural level

Constraint	Trade number													% Ranked	% Ranked
	1	2	3	4	5	6	7	8	9	10	11	12	13	overall	first
Transport	2	4		3		1	1	1	1	1	1	2	1	85	23
Perishability	1	1	1	1	1	2		2	2				4	69	38
Lack of credit							2		3		1			23	8
High market dues and taxes				4	2						2			23	0
Dishonest practices				4									3	15	0
Competition								3				3		15	0
Lack of or unpredictable markets		2		2										15	0

Ranking of marketing constraints at urban trader level

Constraint	Trader or group number													% Ranked	% Ranked
	1	2	3	4	5	6	7	8	9	10	11	G1	G2	overall	first
Lack of or unpredictable markets	4	3			2	1	1	1	2	2	2	2	5	85	23
Perishability	3	1	4	1	4	2	1	3				1	3	77	31
Transport		5	1		3								1	31	15
Poor storage and market facilities			3				2			1			2	31	8
Competition									1		1			15	15
High market dues and taxes	2		5											15	0
Dishonest practices		2												8	0

Appendix 3. Ranking of consumer consumption of staple foods and preferences.

Most consumed food	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	% Ranked overall	% Ranked first
Maize meal	1	2	1			5		2	3	3	1	5	4	2	1	1	81	31
Matooke		1		4	1	1	1	3		1		2	2	4	3	3	75	31
Rice	2	4	3	1		6			1	3	3	4		1			63	19
Sweetpotatoes	2	3	2	5	3	2	2	1	2	2	2	3	1	3	2	2	100	13
Potatoes				2	4	4	3		3			1			4	6	50	6
Cassava			4		2	3		4			4		3		4		44	0
Millet				3	5												13	0

Most preferred food	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	% Ranked overall	% Ranked first
Matooke		1	1		1	1	1	1		1		1	2	4	1	3	75	50
Sweetpotatoes					2	3			3	2	1	3	1	3	3	1	63	19
Rice	1		2			2	2	2	1			4		1			50	19
Maize meal	2			2		5		3		3	2		4	2	2	2	63	0
Cassava		2		3	3	5	4	4			3			3			50	0
Potatoes					4	4	3		2			2				4	38	0
Millet		3		1	5												19	0

IV. Products and Processing Research

Having analyzed the recent trends in production, marketing and utilization in the case of a particular commodity in a given country, the alternatives for new product and process development then could be assessed. Results of that assessment enable researchers to focus on particular products or processes that have the greatest probability of success. This section begins by outlining procedures to do this type of research. Experiences acquired with different products and processes made from sweetpotato and cassava are presented in the subsequent papers.

In order for a specific product or process to realize its full potential, a systems approach calling into consideration a number of interrelated factors provides a useful framework. In **Research in Support of Process and Product Development**, Rupert Best, Gregory J. Scott, and Christopher Wheatley describe procedures for analyzing consumers' tastes and preferences, market structure in terms of the number of buyers and sellers and the supply patterns for raw materials as well as for conducting technical product and processing research. Some specific methodological tools like creating an idealized system for converting the raw material into the desired product, and the use of project briefs are also explained. Examples based on potato processing in Peru and Colombia illustrate the application of these procedures.

Cassava has the potential to help bridge the food gap in a number of countries south of the Sahara. However, full realization of that potential depends on obtaining more detailed information about the crop. In **Commercialization of Cassava: Potentials for Production Growth in Africa**, Felix I. Nweke analyzes three important issues: the percentage of output marketed, the effect of commercialization on production growth and the constraints to the commercialization of cassava production based on results of the collaborative study of cassava in Africa (COSCA). The findings indicate that as much as 45% of production is sold. Furthermore, improvements in market accessibility lead to diversification in products marketed. High labor requirements for cassava harvesting and processing as well as poor market access infrastructure are among the major constraints to increased commercialization of the crop.

The impact of different additives and varieties on such things as loaf volume, taste, and texture is the focus of research by G. Eggleston and P. Omoaka in **Alternative Breads from Cassava Flour**. Raw or roasted soy flour, margarine with egg white, xanthan gum, and tuberous roots of the International Institute of Tropical Agriculture (IITA) improved cassava clones were the key ingredients studied. The resulting breads have acceptable organolyptic and keeping qualities as

determined by the trained taste panels of Nigerian consumers. Successful marketing of such breads will depend, among other things, on the supply of high quality cassava flour to bakers.

In **Solar Dehydration of Cassava for Production of Flour for Local Foods in Kenya**, Jasper K. Imungi examines the feasibility of producing cassava flour using rustic techniques. He subsequently explores the incorporation of cassava flour in composite flours as a partial substitute for maize or wheat flour. His findings indicate that solar dehydration is only feasible during the dry seasons. Cassava flour could be acceptably substituted in some products up to 50%, much less so in others. Future research needs to focus on the cost of production of composite flours and the market for such products.

Instant weaning foods with high nutritional value are manufactured in Nigeria, but their high price makes them unaffordable to those potential users who may need them most. I.A. Adeyemi and O.L. Oke therefore suggest **Cassava as an Alternative Raw Material for Weaning Food Manufacture in Nigeria** as a means of bringing down the price of the final product. They point out that cassava has considerable promise in this regard. But, cassava-based weaning foods must be characterized from organolyptic, biochemical, nutritional, and rheological parameters in order to determine their commercial prospects.

Peasant farmers in Burundi produce 650,000 t of cassava annually, but over 30% of output is lost due to the extreme perishability of the crop and the time-consuming nature of traditional, local processing techniques. In **Introduction of *Gari* Making in Burundi**, M. Beavogui describes efforts to introduce this product—consumed by millions in West Africa but unknown locally—which can be made in a relatively short period of time and stored for a year or more. After two years of work including equipment design and the establishment of demonstration plants, eight private units which produce *gari* from cassava have been launched. Many other private entrepreneurs in Burundi are interested in this type of small-scale agribusiness.

Rapidly rising population, an urbanization rate of nearly 8% per annum and overdependence on maize as a basic staple have prompted interest in more intensive use of sweetpotato in processed form to help meet Kenya's mushrooming urban food requirements. In **Processed Sweetpotato: Responding to Kenya's Urban Food Needs,** Njeri Gakonjo reports on the results of her survey to measure consumers' reactions to a variety of sweetpotato products including different color fresh roots, sweetpotato chips (crisps), a mash made from sweetpotato flakes, and inclusion of 15% sweetpotato flour in bread. She also analyzes the economics of sweetpotato flour production utilizing a number of different assumptions regarding raw material prices, marketing margins, and selling prices. The findings are useful to the extent that they identify the most promising products from the consumer's perspective and those factors that need to be improved upon to optimize their commercial prospects.

Food security in Africa is most often associated with satisfying quantitative or calorie dietary requirements. In **Biochemistry and Utilization of Sweetpotato for Animal Feed: Implications for Food Security in Africa**, Olumide O. 'Tewe argues that animal protein must be included in human food to provide the essential amino acids in order to guarantee qualitative food security. He then goes on to analyze the results of feeding trials conducted in Nigeria in which sweetpotato was used as a partial replacement for maize in rations for broilers, layers, pigs, and sheep. While the findings are promising, they point to the need for renewed efforts in specific areas, for example, dehydration and ensilage to reduce bulkiness and perishability, so as to fully realize the potential for sweetpotato as an animal feed.

Nutritional evaluation of sweetpotato cultivars that abound in Kenya has not been the subject of much research at the national agricultural research stations. Given the sweetpotato's current importance and future potential in local diets, this issue merits more systematic attention. In **Cooking Characteristics of Three Sweetpotato Cultivars Grown in Kenya**, N.K.O. Ojijo and E.G. Karuri compare these materials for their chemical composition and culinary traits. Their findings indicate a noteworthy difference in nutritional constituents between the cooked cultivars and therefore, perhaps, the need to carry out this type of analysis on a regular basis.

Burundi consumers utilized 14,000 t of wheat flour in 1990. Nearly all that flour was imported and 99% was used for making bread. At the same time, each year Burundi harvests 650,000 t of sweetpotato, postharvest losses are high, and the roots are sold at one tenth the price of wheat flour. For these reasons, D. Berrios and M. Beavogui began **Trials for the Introduction of Sweetpotato in Bread Making in Burundi**. This work involved laboratory experiments as well as pilot production and a large consumer test. As the pilot production proved highly successful, the authors indicate that established bakeries have now taken over making the bread commercially.

In **The Use of Sweetpotato in Bakery Products in Cameroon**, Adhiambo Odaga and Rose Wanzie document local efforts to substitute sweetpotato for imported wheat flour in a variety of forms. After numerous experiments and a series of trials in commercial bakeries both small and large, a dual-tracked strategy for sweetpotato substitution has emerged. Freshly grated sweetpotato roots are most appropriate for partial substitution for wheat flour in breadmaking. Sweetpotato flour shows greatest promise in the production of higher value baked goods such as cakes, doughnuts, and croissants. The combination of new uses suggests sweetpotato has considerable untapped potential in processed form in Cameroon.

Research in Support of Product and Process Development

Rupert Best, Gregory J. Scott, and Christopher Wheatley[1]

Abstract

Consumers' tastes and preferences, market structure in terms of the number and size of participating firms, supply patterns for raw materials, and the state of existing processing technology are all key areas for product development research. This paper describes procedures for realizing the potential for new products and processes based on a systematic review of these factors. Market and consumer-oriented research methods are discussed first given that demand-driven processing endeavors have demonstrated the greatest probability of success. Farmer-level investigations are considered next so as to not overlook potential supply-side obstacles to product development. Product and process research is then outlined in some detail. The paper includes two appendices that illustrate the use of the procedures presented.

Key words: markets, consumers, farmers, processes, methods.

Introduction

Having identified a product that appears to have commercial potential, and knowing where a processing project could be located—an assertion based on the present and potential production of the selected commodity in a particular region, four critical questions need to be answered:

- What is the demand for the product?
- What are the key characteristics of raw material supply?
- Is there a suitable processing technology available for producing the product to the desired quality standards?
- Will it be profitable to produce the product?

Some information may already be available to formulate partial answers to these questions. However, before continuing to the next product development step —pilot scale operation, it is often necessary to undertake research to generate additional information on which to base a sound decision as to whether or not to continue with the project idea as originally proposed.

Two types of research are required:

Market and consumer research to characterize the existing production, marketing, and consumption patterns of the selected commodity and of products that could compete with the contemplated product. The information provided by these studies will highlight many of the socioeconomic, cultural, and technical constraints that will have to be taken into account in order to achieve success.

Technical research to develop the product idea according to consumer tastes and preferences, and to design processing technology that is appropriate to the scale of operation envisaged.

A Systems Approach to Research Planning

The first step in research planning is to create an idealized system for converting the raw material into the desired product by breaking the system down into those different components that will have to be linked if the

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project is to be a commercial success. The system components will include:

- production of the raw material;
- processing to transform the raw material into an end product. Often more than one processing component will be involved, with the raw material being transformed into a primary product, such as flour or starch, which is then used as a raw material to manufacture the final product through a secondary processing stage;
- marketing to make the product available to the consumer or client. Marketing, is often carried out at different levels, involving, for example, wholesalers and retailers; and,
- consumption of the product by consumers and clients. For the purpose of this approach, "consumers" refers to the ordinary man or woman who buys food products for consumption; and "clients" refers to industries that purchase primary products derived from roots and tubers as raw materials for the manufacture of products for human and animal consumption or for industrial use. Consumers are a heterogeneous group who show markedly different food preferences and habits depending upon their socio-economic status. Clients are much more homogeneous in their requirements for a particular product.

Many of the components of this ideal system already exist. For example, the geographical region where the project will be carried out will almost certainly have farmers that are cultivating the chosen commodity. Also, the potential consumers or clients of the new product have tentatively been identified. What may be missing, according to the particular circumstances in the selected region or country, are the processing and distribution components. Even these components may be present if the project contemplates expanding the market of an already existing product through reduced production costs and improved quality or diversified end uses.

Once the ideal system has been created it is a fairly straightforward exercise to enumerate the socio-economic, market, and technical issues that will need to be confronted for the system as a whole to be viable. An example of this approach is shown in Figure 1 which refers to a research project in Colombia on the production and utilization of a wheat-cassava composite flour. In this case, the objective was to link small-scale cassava farmers to the urban bakery product market through rural processing of cassava into flour. To facilitate the production of the composite wheat-cassava flour, it was proposed that wheat mills do the mixing for subsequent sale to bakeries using the wheat mills' own distribution channels. The missing component in this system is the processing of cassava into flour. However, as can be appreciated from the description of the issues to be researched, they were not restricted to those directly related to the supply of cassava, its processing into flour, and the sale of the flour to the wheat mill. This holistic, systems approach is helpful in identifying possible constraints that may not be immediately removable but should be taken into account and investigated during the research phase.

Characterizing the System Components

Once the various components that make up the system for producing the desired product have been defined, an analysis of the socio-economic and technical conditions under which the individual components operate will help to quantify and qualify the restrictions to establishing the proposed processing industry.

Market and Consumer Research

Processing—particularly new processing initiatives—frequently raises many technical and economic questions concerned with the production of these products. Perhaps for that reason, a tendency often develops to focus on solving these types of problems first and to worry about the marketing and eventual use of processed products later. The danger of this approach is in forgetting that the commercial success of processing depends more on what people will buy and how it will be used than on whether it can be made. A clear understanding of market/consumer requirements at the earliest phase of product development is therefore essential. This involves two complementary tasks:

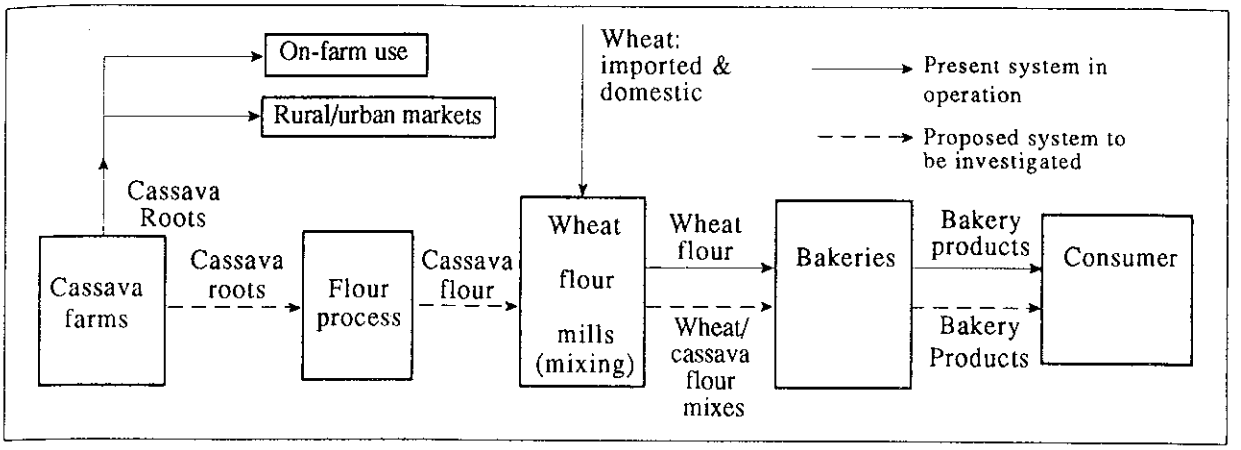
- an inventory of processed products already available in the market; and,
- an assessment of consumer attitudes towards these products.

Market research

The three essential components of market research are:

- identifying the types of processed products for sale and their characteristics, including where they are sold (e.g., marketplace, supermarket, shop, etc.);

Figure 1. Composite wheat-cassava flour (CF) system and the major issues for an integrated research program.



Socio-economic and market issues

Costs of production with & without new technology.

Output prices in traditional cassava markets.

Potential for production increase with new markets.

Changes required in system to meet requirements of processing plant.

Evaluations of increase in farmer incomes due to development of flour market.

Investment costs of alternative processing methods.

Evaluation of alternative organization and management schemes.

Calculation of per unit costs of flour processing.

Model of price determination for wheat & bread demand.

Evaluation of cost increase for CF production.

Determination of price differential between cassava & wheat flour to motivate CF production.

Evaluation of difference in social benefits due to government legislation vs market prices in CF production.

Price differential required to motivate use of CF.

Consumer preference for different bread types.

Evaluation of whether a price differential is necessary to motivate consumer acceptance.

Technical issues

Evaluation of varieties for flour quality at different planting and harvesting dates.

Evaluation of improved production technology.

Development & evaluation of selection, washing, peeling, drying, milling & storage methods for producing cassava flour.

Quality control of product.

Determination of additional equipment needed to produce CF.

Storage characteristics of CF.

Determination of local bread types & quality parameters.

Evaluation of different % mixtures on bread quality.

Effect of variety, harvesting age & processing on flour characteristics and bread quality.

Adjustment of bread-making techniques for CF.

- estimating the most important processed products by the volume and value of products sold; and,
- determining what factors impede expansion of sales.

This information is intended to answer certain basic questions about the proposed processing activity. For example, will the processing create a totally new product (because there are no others like it currently in the market place)? Will it be a modified, improved version of existing products (e.g., appearance, package, size of unit of sale)? Is there already a considerable volume of similar products being sold? Or, is there currently little interest in this type of product? According to wholesalers, retailers, and consumers what factors are most important in discouraging greater sale/use of this type of product (e.g., price, appearance, use)?

It is fairly easy to prepare a list of processed products produced from a particular food crop based on visits to representative markets in a given place. There are simply not that many products available for each of the major food crops. Still, one may be surprised to find more than one had imagined or was familiar with. This list of products should also include information about their respective characteristics, e.g., color, size, shape, type of package, size of unit of sale, price. "Representative markets" refers to the types of places people shop (e.g., store, streetmarket, covered market, supermarket), not to a particular location where people shop. It is also wise to visit intermediate users (e.g., bakeries, restaurants) as well as industrial concerns (e.g., flour mills, confectionary companies) to complete the identification of existing products.

Casual conversations with retailers, wholesalers, and industrial users can serve to clarify opinions about the marketability of different products. For example, could traders sell more if they could be supplied more? Is price the key factor influencing sales? Appearance? Packaging? Such questions should be posed in a manner that reflects empathy, rather than aggressive curiosity. The parties interviewed are also less likely to be put off by people who don't write down what they say in front of them. A possible solution is to record these conversations immediately after leaving the premises. In the course of this exercise, it can be extremely useful to compare the different opinions expressed to clarify apparent contradictions, to identify common points of view, and to isolate genuine discrepancies.

While there is no substitute for firsthand information of this type, it may also prove useful to consult specialized libraries or documentation centers to check for additional facts and figures. For example, an agro-industrial institute may have feasibility studies that focus on the type of processed products in question. The School of Food Technology at a local agricultural university may be another source. The relevant offices of the Ministry of Agriculture or the Agrarian Bank may also have useful data or be aware of similar attempts in the past that could be looked into.

A word of caution is in order here about who should collect this type of information. Many food technologists and agricultural engineers (even social scientists) have a certain phobia about information gathering in offices and markets. These locations often require the ritual procedures of appointments, written explanations of what is required and why, or, in the case of the market place, they represent a noisy, dusty, and congested contrast to the relative tranquillity of a farmer's field or a science lab. Nevertheless, people who work on processing-related, agricultural research have special qualifications for this type of information gathering. They bring with them their accumulated knowledge about farm commodities and processing techniques. Finding out, for example, how the market works (e.g., who buys what, at what price, in what quantities) may be mundane; but, why it works in such fashion can be positively enlightening. The specialized knowledge of these individuals puts them in a much better position to evaluate the reasons offered and perhaps probe areas less well-trained interviewers might never have asked about. Results of the market survey provide the basis for conducting interviews with consumers.

Consumer Research

Consumers are key decision makers in the development of simple processing. Their tastes and preferences influence the type and quality (color, shape, size) of the products most likely to find ready acceptance. Their purchasing power helps to determine the quantity of such products that can be sold. Hence any prospective processor would do well to take consumers' opinions into consideration prior to launching full-scale production. After a brief statement of the objectives and justification for consumer research, this section describes some simple procedures on how to go about this. Ideally, the same individual(s) who carried out the literature review and market survey would also undertake this research. Knowledge acquired in prior activities is then directly incorporated into this component of the study, sharpening the focus while extending the coverage.

The objective of consumer research is to establish the level of consumer awareness of processed products; whether they are consumed and if so, with what fre-

quency; how consumers characterize the products, positively and negatively; and what the consumer would like in a new product. Product description includes form, flavor, preparation time, storage characteristics, and price. It should be noted that the type of consumers interviewed will depend on the product. For example, processed products for restaurants or industrial use would require contacting restaurants and industrial buyers, not household consumers.

There are various reasons for consumer research. This process aims to distinguish those types of products that have the greatest—or least—potential because they are/are not desired on the basis of one or more attributes such as taste, appearance, or use. Similarly, it attempts to discover those that are the most/least affordable. Such research also seeks to identify those characteristics that are most desirable in existing products or that because of their presence, e.g., poor quality control or unattractive appearance, discourage greater consumption. For example, a prospective processor wants to produce industrial starch, but contacts with possible future clients point to the inexpensive price of currently available substitute products due to a cheap raw material price. Most people can readily think of an example of a new product that was supposed to be widely accepted, but then turned out to be a complete failure.

Consumer interviews may be carried out in an informal fashion, i.e., without a written questionnaire; with or without a list of topics to be covered; or utilizing a survey form. The latter facilitates collection of quantitative responses, e.g., by imposing standard units of measure, and more extensive amounts of information. The former is by definition more flexible. Whether one procedure is more appropriate than the other will depend, among other things, on the number of processed products that questions are to be asked about; the amount of information already available in the literature or through the market survey; and the experience of the researchers in conducting informal interviews.

Both procedures involve considerable advance preparation to specify the questions to be asked or topics to be addressed and the way they should be phrased to avoid confusing the persons interviewed. Table 1 presents a list of questions for consideration in this regard (see also Appendix A). Prior to launching the data collection process, it is particularly important to consider how the data will be processed and written up (e.g., are there too many questions to enable ready analysis?). Pre-testing of the questions both on members of the research team and on actual consumers can also be extremely useful in minimizing problems of misinterpretation or repetition.

One of the most important aspects of consumer interviews is to remember that it is a pilot survey. In other words, the results gathered are intended to be indicative, rather than definitive. This characteristic is particularly relevant when considering size and composition of the sample of consumers to be contacted.

Table 1. Questions for consumer research.[a]

Key questions for consumer research (by type of processed product under consideration) include the following:

- What is the current level of annual food crop, e.g., rice, wheat, potato, consumption per capita?
- Does it vary by income group?
- What is the level of consumption for processed products?
- Does consumption of processed products vary by income group?
- Does consumption of processed products vary by season?
- What are the principal types of processed products purchased by consumers?
- Where do they purchase processed products? In what form? and at what price (per weight)?
- Do consumers consider such products nutritious?
- Do they consider these products filling?
- Are processed products considered tasty?
- Do consumers feel that processed products are of attractive, hygienic quality?
- Are the available processed products of the desired size, color, weight (units of sale)?
- In the consumers opinion, do processed products keep well?
- Are processed products easy to utilize in cooking or preparation?
- Do available processed products have different uses, e.g., can they be utilized in various dishes?
- Are such products considered inexpensive? With reference to what substitutes?

[a]This list is by no means exhaustive. See also Austin (1992:205-222) for additional ideas.

Rough guidelines in this regard would be no more than 200 consumers and no less than 50. Any more than 200 raises a series of questions about the time available to do the interviews, analyze the data, and write up the results, as well as the infrastructure required for processing the data. A sample that is too small raises doubts about its representativeness and also preempts much meaningful comparison between the different types of consumers interviewed.

It is essential that the consumer interviews be done with a cross-section of individuals reflecting differences in incomes or a proxy for incomes such as place of residence. For example, obvious distinctions between low-, middle-, and high-income housing areas are easy to identify in most cities in developing countries. The literature should also provide some help in this regard. By interviewing different types of consumers, not only are the current consumption patterns of different groups identified but also some appreciation of the potential for change (e.g., should incomes rise) can be detected.

How does one actually select the consumers to be interviewed? One procedure that was used successfully in Lima, Peru, was to interview people who were in the act of buying processed products. In other words, those contacted probably consumed the articles in question and hence had some opinions to express about them. Furthermore, if questions are to be asked about several items, a simple display of the products to be discussed can both arouse curiosity (hence make consumers eager to be interviewed) and ensure that the names and products that they refer to are not confused. Once the interviews have been conducted, it becomes a question of reporting the results. The example in Appendix A illustrates the use of a market survey and consumer interviews to evaluate the market potential of processed products.

Farm-oriented Research

In addition to having to know who might buy the processed product, the processor has to be sure that the raw material can be obtained for processing and at a reasonable price. One objective of farm-oriented research is to establish what supply patterns exist and whether price movements are such that growers will be interested in selling to a processor or consider processing themselves as an alternative outlet for some/all of the crop. Another is to ascertain whether processors can easily procure sufficient quantities of raw material to justify establishing a processing facility. At this stage, such issues as the quality and uniformity of supply, as well as assembly and transportation costs, must be considered.

Agricultural supply is naturally cyclical while the demands of a processor are stable. Thus processors have to balance the seasonal availability of supply with the steady raw material requirements of their plant and facilities. In some cases, depending on operating costs and returns per production unit, processing can profitably be undertaken during only a few months a year; in others, year-round operation may be needed to earn a profit. Alternatively, growers may already have a ready outlet for their produce even in the peak harvesting period; or they may have only occasional difficulty selling their crop.

The purpose of farm-oriented research is to determine commodity-supply patterns by seasons, varieties planted, experience of producers, and postharvest practices such as grading for size and quality, and the typical uses for these grades. This research also establishes producer preferences for varieties and the reasons why, thereby acquiring information from farmers on varietal characteristics and performance. The potential processor also has interest in the type of varieties available (or potentially available) in order to obtain desired processing characteristics. Growers' marketing habits are also closely examined: marketing channels, their seasonal stability, typical buyers, and traditional arrangements for payment. Once present conditions are mapped out, then the research explores the potential for change to include/expand processing. Finally, constraints that the producers may have in producing or marketing a processed product may also be analyzed.

In carrying out farm-oriented research, it is particularly important to interview different types of representative growers. Small, subsistence growers may have minimal surpluses to sell and hence a limited interest in commercial processing. Just the opposite may apply to growers who seek to maximize profits. The research should aim to measure the interest of both types.

Methods for farm-oriented research include a synthesis of secondary data, a review of available literature, and primary data collection. Information on the annual volume of crop production in a particular region, department, or province can usually be obtained from the Ministry of Agriculture or the National Bureau of Statistics. Commodity programs usually have data on planting and harvesting dates. The size of different types of farmers and their importance as a group in accounting for total production can be estimated from the agricultural census or by synthesizing the results of previous

formal farm surveys. Producer prices for specific crops by calendar year (or month-to-month) are often available from the Ministry of Agriculture. Analyzing this information may be sufficient in itself to identify or eliminate certain crops or areas as the most likely current possibilities for processing. For example, perhaps Region "X" produces very few sweetpotatoes and prices for this commodity are always quite high. It is thus unlikely that there would be much immediate interest on the part of growers in sweetpotato processing.

In the event that this analysis suggests strong possibilities for particular foodstuffs in a given location, then it is advisable to check relevant research centers, e.g., university libraries, agro-industrial institutes, to review the available documentation on previous, farm-level attempts to introduce (or improve) processing activities. This search may well uncover ongoing experiments or pilot projects that have proven unsuccessful that merit closer examination to comprehend their operating rationale, track-record, and any major constraints encountered.

A third component of farmer-oriented processing research is contact with growers themselves. The purpose of this exercise is to sound out growers' opinions and listen to the reasons for their stated views. Methods for obtaining this type of information may be formal or informal. The larger the number of possible alternatives, the more precise the quantitative information required, then the more likely that a formal survey may be necessary. The extent to which the range of processing possibilities has been narrowed to one or two, e.g., through analysis of secondary data, may make formal interviews unnecessary.

If the informal approach appears most appropriate, given the time and resources available, several recommendations are in order. Consult the literature on how to carry out such appraisals (see e.g., Rhoades 1982; Khon Kaen University 1987) and to be aware of their strengths and weaknesses (see e.g., Holtzman 1986). For the relatively less-experienced researcher, it is probably advisable to memorize a list of specific topics (if not questions) to pose to growers in the course of these casual conversations. Carefully recording the results of these interviews and contrasting them with the opinions of technical specialists, owner-operators of existing processing facilities may serve as a check/point of comparison to the views expressed by growers.

A formal farm survey is another option. Horton (1982) suggests a framework for evaluating the appropriateness of this approach as well as some practical suggestions on how to implement it. A few words of caution are in order here. Sample size should be kept below 200. Half that number may be sufficient, depending on the number of locations to be visited and the type of farmers to be contacted. Minimize the amount of information requested, i.e., check through the proposed questionnaire to be sure what is being asked is what you need. Be sure to pre-test the questions so that you are certain that they are readily and correctly understood. Finally, think through the process of data analysis as well as data collection so that completed survey forms can be processed rapidly and the results written up in the minimum amount of time necessary. The example in Appendix B illustrates the use of a formal questionnaire to evaluate processing potential.

Developing the Product and the Process for Its Manufacture

This section looks into aspects related to technical research that will ensure that the product meets the expectations, in terms of price and quality, of the consumers or clients that are going to buy it. Two closely related activities are involved: research on the product itself and research on the process that will be used to make the product. At this point it is worthwhile differentiating between two types of product: first and second generation products.

The term "first generation product" refers to a product resulting from what may be described as primary transformation or from a process of selection, treatment, and packing. Examples of first generation products derived from roots and tubers would be flour and starch and also fresh roots that have been selected, treated, and packed in order to improve their presentation and prolong their shelf life.

In the case of flour and starch, these products are often used as raw materials in secondary transformation processes, which give rise to second generation products. These secondary processes may include the addition of other ingredients, as in the case of balanced animal feed rations or the production of composite flour for example, while maintaining the same physical characteristics of the ingredients or involve biochemical or physical modifications to the raw materials through cooking, extrusion, fermentation, etc.

The Project Brief

With the information that has been gathered thus far, it is now possible to draw up a detailed project brief,

giving a well-defined specification of the product and its physical attributes, the raw material, the processing and packaging requirements, and the intended marketing methods and consumers to be targeted. Examples of two project briefs are illustrated in Table 2. The project brief, as well as giving a short summary of the project in its entirely, helps to identify the areas that require in-depth research or experimentation. As can be observed, a number of technical options exist and these options will need investigating to decide which is the most appropriate.

Product and Process Research

Product and process research can be broken down into two stages.

- Developing a prototype product on a lab- or bench-scale.
- Producing the product with prototype equipment under experimental conditions.

Table 2. Project briefs for two cassava products.

	Dry cassava for animal feed	Fresh stored cassava for direct human consumption
The product	A carbohydrate source in the form of dried cassava chips for incorporation into balanced feed rations to compete with traditional carbohydrate feeds such as sorghum and maize.	A fresh cassava root product of high quality with a storage life of up to two weeks.
The raw material	Cassava roots with high dry matter and low/intermediate cyanide content.	Cassava roots, selected by size and eating quality.
The processing	The roots will be washed, chipped and dried by either natural or artificial means. The processing will be carried out by farmers' cooperatives or small- to medium-scale agro-entrepreneurs.	The roots will be treated to suppress physiological and microbial deterioration. Treatment and packing will be carried out by farmers' coops or assembly agents.
The packaging	The dry root chips will be packed in 50-kg sisal or polypropylene sacks. Closure of the sacks will be performed manually or by machine.	The roots will be packed according to type of market outlet. Polyethylene bags, plastic crates and wooden boxes are options.
The marketing	The dried chips will be sold directly to animal feed concentrate companies or to livestock producers. Promotion emphasizes high starch digestibility, availability and relative cost.	The stored cassava will be sold through supermarkets and local neighborhood shops. Promotion will emphasize freshness and storability.
The consumer	See marketing above.	Consumers will be families from all socio-economic groups, favoring those with poor market access.

Source: Adapted from Anderson and Earle 1985.

In the first stage, the focus is on trying to achieve an acceptable product in terms of its physicochemical properties and, in the case of foods, organoleptic characteristics. For foods, therefore, a taste panel is an essential element for checking the product's acceptability. In the second stage, the focus is more on selecting and developing suitable prototype equipment that will then be incorporated into the pilot plant. The following are some of the most important areas that need to be taken into account.

Characterizing the Small-scale Agro-industrialist

One other vital piece of information may still be lacking at this stage; that is who is ultimately going to invest in the process to manufacture the chosen product? In most situations there will be a number of options depending on the circumstances, and at this stage it may not be possible to select any one of them. In a situation where the purpose is to improve the marketability of an existing product through reduced production costs or improved quality, this does not pose a problem. However, where it is necessary to establish a new product, there are the following options:

- an existing agro- or food industry takes on the manufacture of the new product. This possibility would come to light during the market research. This option would be most appropriate for second generation products that will require a certain level of skill and experience to achieve the desired quality characteristics;
- an entrepreneur, not necessarily with previous agro-industrial experience, invests in the process for manufacturing the product. If entrepreneurial groups can be easily identified (associations of food manufacturers or growers' federations, for example), then through them it may be possible to identify interested parties. Also, their involvement from an early stage would be important; and,
- processing is undertaken by farmers' organizations such as associations or coops. If these organizations already exist and have many years of experience, they are an ideal alternative given that they will have direct control over the supply of raw material and will also have the required managerial and administrative capability for taking on a new venture. On the other hand, it may be necessary to form a farmer organization around the establishment of a processing activity. In this case first generation products are normally the most appropriate, at least in the initial stages.

A tentative idea about which of these alternatives will be the most appropriate is important because this may markedly influence the selection of technology for the manufacture of the product.

Raw Material Characteristics

The physical/mechanical characteristics and the chemical constituents of root and tuber crops were presented earlier (Scott 1991). The type of processing technology used will depend to a large extent on these characteristics, and the end product will be the result of this interaction between raw material and processes. To take a simple example, a root crop with a high dry matter content (40% +) can be successfully dried at low cost (natural drying, etc.); whereas a root with only 15% dry matter will obviously take longer, require more sophisticated drying conditions and equipment, and/or be of poorer final quality. In general, the economics of processing improves with increasing dry matter or starch content; that is, fewer tons of raw material make a ton of end product. The presence of toxic or anti-nutritional factors may necessitate extra processing steps or increased process time to eliminate/reduce them to acceptable levels.

The non-uniformity of size of some roots and tubers, especially cassava, poses problems for initial processing, especially peeling, which is very inefficient. Roots can be graded by size before peeling, but this represents an additional labor cost. Hand peeling is highly labor intensive and uneconomical in some areas, although it can be a useful source of employment in others.

The specifications for raw materials that must be available at the end of this stage will be those that, when combined with the processes as developed here, give a product of the required quality. If the specifications are such that only a small percentage of the harvested roots and tubers fall within them, then either a good market must exist for reject roots or a sufficiently attractive price must be paid to farmers to encourage sales to this, for them, difficult market.

Product Quality

A clear idea of the end product, its characteristics and quality will be available from previous consumer and market studies, summarized in the product brief. In addition, there may be legal standards (e.g., for foods) that must be met.

Both raw material and the process determine end product quality, and it is important to identify those

aspects of both that are crucial to meeting the quality requirements at an economic cost (Table 3).

During initial experimentation, it is important to monitor end product quality as well as process efficiency. Those quality characteristics to be evaluated will be those that will affect the product's appearance, organoleptic properties, hygiene, and performance in use; that is:

- chemical composition;
- functional properties; and,
- "use" characteristics (storage time, etc.).

In order to obtain satisfactory end product quality, it will be necessary to adjust process conditions and select appropriate raw material.

Determination of Technology and Equipment Selection

If the objective of the product development project is to benefit small farmers through market expansion and employment generation, the equipment chosen for root crop processing must be appropriate for use by such groups. In a research situation, it is tempting to opt for technologically sophisticated processes even though simpler options are frequently available. However, the latter have the advantages of local construction (generating more employment); few if any imported parts, which can cause bottlenecks later if spares are required; and, are straightforward for farmer groups to operate and perform basic repairs and maintenance on. The scale of technology is also important: small-scale equipment is most suitable to farmer groups. It is important to identify the capacity of each piece of equipment/operation in order to identify bottlenecks in the process. The plant should, however, be designed with future capacity expansion in mind; for example, the distribution of equipment, size of initial infrastructure, and capacity of certain key items of equipment.

For equipment design and testing, it is useful, initially, to consider similar equipment in use locally for other agricultural products. These will need adapting to the specific characteristics of root and tuber crops; but the local materials used, the sources of power employed, and the design of the equipment made locally can be helpful in defining some of the process options.

Equipment design is a specialized activity, and projects will need to include capable people in this field. Frequently, this specialization (mechanical engineering) is not found within the national agricultural or development institutions. It will be necessary to include in the project an institution that does have this capacity (e.g., university, industrial research center).

The design and prototype testing of small pieces of equipment (chippers, driers, mills, etc.) has proved to be an excellent subject for student theses.

Finally, a wide range of small-scale processing equipment has been designed in the recent past for root and tuber crops, by both international and national research and development (R&D) institutions. It is important to thoroughly review the available literature in order not to re-invent the wheel in each project.

Table 3. An example of assessing product quality requirements.

End product quality	Process	Raw material
Dry matter < 14%	Drying natural? Artificial?	High dry matter content needed
Low microbial counts	Hygienic conditions, water treatment, rapid drying	Absence of pre-harvest roots, etc.
Fiber content < 3%	Peeling, sifting	Age at harvest, variety, environmental conditions
Protein content > 5%	Fermentation	Variety
White color	Sulphiting, rapid drying, removal of impurities, water treatment, rapid postharvest processing	Variety

Taste Panels

Lab analysis of the experimentally produced end product can indicate if the product meets the quality specifications desired. However, only tests carried out with "real people" can tell if the more subjective aspects of quality are satisfactory. The perception of taste, aroma, feel in the mouth, texture, etc., are all crucially important in determining consumer acceptance of food products. It is essential to obtain some evaluation of these quality aspects during the research phase to ensure that an acceptable product is being developed.

Two types of situations can be used to evaluate organoleptic quality: taste panels in controlled conditions and consumer panels (at-home use tests).

In the lab situation, taste panels provide a "scientific," controlled environment in which the subjective nature of this testing is made as objective as possible. The panelists can be highly trained people with sensitive organoleptic capabilities, who meet on a regular basis to evaluate samples. A special environment with controlled lighting and samples presented in random order permits the reduction of human and other errors. However, it is not essential to construct a special facility. Any quiet, well-lit area will suffice. It is important to select the panelists carefully. This requires more than just gathering the lab workers for half an hour every week, but selecting a group of people who are both representative of the local or target population and who have a good sense of taste, smell, etc. (This can be tested with preliminary screening based on presentation of sweet, salt, bitter, and acid solutions of differing concentrations for identification and ranking.) Preliminary group discussions can help to reach a consensus on the quality characteristics to evaluate. The scales used for evaluation should be clear and simple to understand.

Many examples exist in the literature which can be followed (see e.g., Watts 1990). The statistical analysis of results is important; the method used will depend on the evaluation scale chosen and the experimental design.

Taste panels can be used to evaluate:

- intensity of different quality characteristics of a food; e.g., sweet taste—little ... very intense;
- intensity of quality characteristics relative to a standard; e.g., much sweeter than X;
- acceptability of a food; e.g., very acceptable ... not acceptable;
- preference of a food, relative to standard; e.g., prefer X to Y; and,
- hedonic evaluation; e.g., like ... dislike.

Consumer testing of products. Although food products can be evaluated in a lab setting, in the end they will be prepared and consumed by ordinary consumers at home. At later stages in the research process (and certainly during pilot scale operations), the product must be tested in these more varied environments. Consumers' methods of preparation (use of other ingredients, cooking times, etc.) will vary greatly, as will their perception of foods and their individual preferences. The results of this sort of evaluation will, therefore, be the summation of a series of factors, for example, giving an overall like/dislike acceptability rating, or a purchase intention.

Because variability is so high, it is important to include a relatively large number of consumers. The sample should be representative as regards income level, rural/urban areas, family size, etc., to ensure that the composition is similar to that of the overall target population. In urban areas, census data can be useful to guide this operation. Consumer tests that take place in an at-home environment can be very time consuming to organize and run. Repeated visits may be necessary, drop-out rates high, and instructions (e.g., dates for food preparation) may not be followed. In some countries, it can be difficult to obtain adequate participation by upper income households. The number of different samples that can be tested in this way is very limited, and it should only be contemplated at the end of the research phase.

Packaging and Shelf-life Studies

Again, once the product is nearing the end of the research process, packaging and shelf-life studies will be needed. Consumer and market research should provide information on the storage time necessary (i.e., shelf life in shops and homes for consumer goods; storage time before further processing for industrial goods). Other relevant information from consumer studies are:

- package size; and,
- storage conditions, at home and in store, etc.

Some initial storage trials in a range of package materials in typical storage conditions can then be evaluated for:

- changes in chemical composition, functional properties;

- changes in appearance, especially color;
- changes in organoleptic characteristics (use taste panels); and,
- signs of insect infiltration, microbial contamination.

These results can then be used to design the best package, considering stability of the product over time and the cost of the materials involved. Packaging costs should enter fully into the pre-feasibility study and should include those of printing logos, instructions, etc., on the package rather than using a plain box or sack, if this is envisaged.

Feasibility Studies

Reference is made here to two types of feasibility studies: the pre-feasibility study and the feasibility study. The objective of both types of study is to provide the technical, economic, and commercial information necessary to make an investment decision. These studies should define the production capacity of the proposed plant, the proposed technology or technologies to be used in processing, the raw material inputs and the total investment cost, the production costs, and sales revenues and returns on investment (Wilkinson 1985).

The essential elements of a feasibility study are:

- production specifications;
- raw material compositions, quantities, and costs;
- processing methods;
- project engineering development;
- development costs;
- plant capacity;
- plant equipment: specifications and costs;
- plant layout;
- building design and costs;
- total investments costs;
- processing operations including manpower;
- plant organization and overhead costs;
- operating costs and total product costs; and,
- financial evaluation.

The market and consumer studies and the research carried out on the product and the process should have provided sufficient information to be able to prepare a pre-feasibility study along the above guidelines and, depending on the results, take a decision on whether or not to set up a pilot-scale operation in the region where the selected commodity is grown.

Conclusion

Research in support of product and process development involves market and consumer research, and technical studies. Based on the authors' experience, sketching out an idealized system for converting raw material into the desired product(s) and its subsequent sale to a set of interested buyers can serve as a guiding framework for this research. It permits the researcher to breakdown this system into its various components for subsequent detailed analysis. A strategic consideration in this set of studies is to recognize from the outset the paramount importance of not only the technical feasibility but also the commercial viability of root and tuber processing.

Once the market for the proposed product has been assured, research can focus on technical product and process research on a prototype or pilot scale. Lab or engineering success then leads to taste panel evaluations as well as packaging and shelf-life studies. Promising results from this work sets the stage for a feasibility study of a specific pilot plant in terms of product, process, scale, location, costs, and returns. Once this study has been completed, the product development process can focus on the operation of the pilot plant itself—the subject of the following selection of papers.

Appendix A

Consumption of Processed Potato Products in Lima, Peru

The Problem. Research on various aspects of potato processing has gone on in Peru for years: simple processing technology (Keane, Booth, and Beltran 1986), traditional potato processing in the highlands (Werge 1979), prospects for increased consumption of traditional processed products in Lima (Benavides and Horton 1979), and the feasibility of introducing certain types of processed potato products into low-income diets in the capital (Benavides and Rhoades 1987). Nevertheless, basic information on the consumption of various processed potato products by different income groups in Lima simply was not available. Thus a team of social scientists at the Universidad del Pacífico addressed this topic during 1987 (Gomez and Wong 1988).

The Method. This study incorporated a variety of research procedures (Gomez and Wong 1988): a literature review; participant observation; informal interviews with potato processors and traders; and a pilot consumption survey utilizing a structured questionnaire. The sample (n = 199) consisted of high- (n = 19), medium- (n = 81), and low-income (n = 99) consumers interviewed in supermarkets, shops and stores, and markets. In addition, the preliminary findings were presented to a group of processors and traders as part of the information gathering.

The Results. The principal findings of this study follow.

1. A variety of different processed potato products are available including potato starch, dehydrated (traditional) potato (*papa seca*), instant potatoes (imported), potato bread, potato crisps, bleached and dehydrated (traditional) potato (*papa chuño*), and peeled and pre-cut potatoes for restaurants. The estimated total fresh potato requirement annually for the Lima market alone is 36,000 t.
2. Many consumers were unaware that one or more of these products exist; they professed considerable interest in knowing more about different uses for these products.
3. Particular attributes (and defects) of these products, as noted by the consumers, were identified (Appendix Table 1).
4. Products with practical use, e.g., crisps, instant potatoes, were found to be more responsive to simulated declines in price than those with specific uses, e.g., potato starch, dehydrated (traditional) potatoes.
5. Marked differences were detected in the knowledge of particular processed potato products by income group. High-income consumers had much less knowledge of traditional bleached and dehydrated potatoes than the middle- or low-income consumers interviewed.

Impact. Results of this survey were utilized by one processing group to improve the color (make more yellow-gold) of dehydrated potatoes and to exercise more quality control in packaging such as making sure the product has been properly washed, that the package contains no extraneous material (e.g., sand, small stones). These improvements led to successful contracts for the test marketing of the improved product in two major supermarket chains in Lima. The expanded volume of sales raised questions about the sources of supply for raw material, the subject of the next step (see Appendix B).

Appendix Table 1. Attributes and defects of potato products in Lima, Peru.

Product	Attribute	Defect
Potato starch	Good taste	Tends to go lumpy
Potato crisps	Practical, readily available	Greasy, salty, spoils
Instant potatoes	Easy to prepare	Acidic taste
Dehydrated potatoes	Filling	Bitter taste; uneven quality
Bleached & dehydrated potatoes	Nutritious	Small pieces

Source: Adapted from Gomez and Wong 1988.

Appendix B

Potential for Potato Processing in Northeast Colombia

The Problem. Colombian policy makers concerned with rural development as well as researchers in the National Potato Program are interested in developing alternative uses and markets for potatoes in an effort to stabilize prices and improve grower incomes. They considered simple potato processing as one potential means of bringing this about. The Pamplona region in northeast Colombia seemed an ideal location for establishing such facilities because it is an area where potatoes are the principal crop and is noted for its small-farm population and geographic isolation from the rest of the country. The first initiative was to set up a small pilot plant in order to demonstrate that processed potato products using simple technology could be produced utilizing local varieties, infrastructure, and technical personnel. Subsequently, a research project began to assess the socio-economic feasibility of such technology. A key component of this technology assessment was an attempt to determine the needs and interests of local potato producers with respect to simple potato processing.

The Method. Research methods for this project included a review of available studies and secondary data on potato production, prices, and marketing in the Pamplona region; a gathering of producers to show them the types of dishes that could be prepared with processed potato products (e.g., crisps, cakes, soups); and a formal survey of 81 growers, selected from five different farming localities in the region. Recent agricultural census data and farm production statistics were consulted to determine the location of potato production in the various localities and the number of potato producers in each. Furthermore, since the survey was conducted by personnel of the Colombian Institute for Agricultural Research (ICA), the exercise was intended to collect information not simply about potential interest in simple potato processing, but also about technical aspects of potato production of interest to the National Potato Program.

The Results. Highlights of the producer survey findings were (Mantilla 1988):

1. Of the farmers interviewed, 63% have produced potatoes for over 20 years; in 1986, average potato production per farmer was 52.7 t, 9% of which went for sale; and, 60% of the production is harvested during the second half of the year.

2. Most potato sales take place from September to January when supplies are abundant in the market; 40% or less is sold in April-May, when growers prefer to sell because supplies are lower and prices higher; sales occur at harvest time with little storage for delayed sale.

3. Of the growers interviewed, 52% reported selling potatoes at very low prices in 1984 and 9% in 1985 and 1986.

4. Family labor is employed all-year round by 73% of farmers; in fact, 68% have difficulty hiring labor at harvest time.

5. Many (72%) are familiar with potato crisps, but 28% were unfamiliar with any processed potato product.

6. Of the 81 growers interviewed, 80 are interested in processing part of their production in order to improve prices, diversify the family diet, and provide employment for household members.

7. Products the growers are interested in producing include potato chips, potato flour, and french fries.

Impact. Results of this survey were decidedly mixed. Nearly all growers expressed interest in processed products and a disposition to conduct such activity in cooperation with other farmers. However, they also reported no particular difficulty in selling their harvest at remunerative prices. In fact, the last time prices were disastrously low was several years ago. Thus the economic incentive to process was not as compelling as in the case of India (see Nave and Scott 1991), where severe seasonal fluctuations in potato prices occur every year. The labor shortage at harvest time also raises questions about the feasibility of introducing a labor-intensive technology to operate at a time of year when manpower is already scarce. While these findings have not prompted abandonment of processing, they have led to a reconsideration of the economic rationale for this activity.

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Commercialization of Cassava: Potentials for Production Growth in Africa[1]

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Abstract

Cassava is one of the dominant starchy staples in Sub-Saharan Africa but one whose possible contribution to local incomes, development, and food consumption has yet to be completely achieved. Full realization of the crop's potential depends, among other things, on obtaining more precise information about existing marketing patterns. This paper draws upon the results of detailed village-level surveys in six countries to answer questions regarding the proportion of total cassava production that is marketed, the influence of the type of market access on marketing activities, the effect of commercialization on the growth in production, and the principal constraints to expanded marketing of cassava production.

The results indicate that as much as 45% of total cassava production is sold; a greater percentage of cassava output is sold in poor than good market access areas; and the participation of midlemen in areas of good market access tends to encourage greater cassava marketing and increase the relative importance of cassava production.

Key words: market access, marketing channels, products, farmers, traders.

Introduction

Background

Since its introduction into Africa in the 16th century, cassava has spread throughout Sub-Saharan Africa to become one of the dominant starchy staples in the diet of the people. Although the crop is grown in every country of the subcontinent, cultivation is concentrated in the humid tropical regions. Africa produces 48 million tons of cassava annually from 7.4 million hectares; which translates into an estimated average of more than 200 calories per day for 200 million people (Dorosh 1988). It is the dominant staple particularly in Central Africa where it constitutes over 50% of the average staple food consumption in Zaïre, People's Republic of Congo, and in the Central African Republic. In the coastal regions of West Africa, from Côte d'Ivoire to Nigeria, cassava is as important as yam, and further along the West African coast cassava is the second most important staple after rice. In East Africa, although maize is the dominant staple in most countries, cassava is crucially important in Mozambique, Tanzania, Uganda, and Burundi.

The central role played by cassava in the African diet is particularly important because per capita food production in Africa is declining. During the succeeding two decades, after most African countries became independent, the continent has steadily deteriorated into food import dependence, where cereal imports are filling the gap created by unsatisfactory growth in the production of domestic staples. Financing these imports has become more difficult because the balance of trade in African countries has become increasingly negative and the external debt has risen. Falling per capita food production and declining internal financial liquidity are particularly serious in light of the fact that an estimated

[1] Collaborative Study of Cassava in Africa (COSCA), Working Paper N° 14 (first draft), re-printed here with permission of the author.

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150 out of 450 million Africans suffer from some form of malnutrition.

The African food problem is commonly traced to inadequate food supplies. Because of stagnant or even falling food production, area expansion which is usually into more marginal agricultural zones, has not been sufficient to keep pace with the rapidly expanding demand for food. Moreover, rising population densities in marginal rainfall areas have reduced the buffering capacity of subsistence production units against major varations in rainfall, often resulting in substantial shortfall in food needs in years when rainfall is especially inadequete. This African food problem is a matter for deep and urgent concern.

Food production in Africa is fundamentally based on rain-fed farming systems. This makes African farming inherently risky, with marked variations in seasonal and annual food supplies. This highly variable production situation is made even more unstable in areas where land is scarce because of rapid growth in rural populations, which either reduces the farm size or induces migration to more marginal agricultural areas.

Cassava's adaptability to relatively marginal soils and erratic rainfall conditions, its high productivity per unit of land and labor, the certainty of obtaining some yield even under the most adverse conditions, and the possibility of maintaining continuity of supply throughout the year makes this root crop a basic component of the farming system in many areas of Africa. Famine rarely occurs in areas where cassava is widely grown, since it provides a stable base to the food production system. This indicates that cassava has the potential for bridging the food gap. However, the full realization of this potential depends on obtaining more detailed information about cassava growing conditions, production systems, processing methods, marketing, and urban consumption patterns. Authoritative information on these issues is lacking and even the production statistics that are available are at best educated guesses. The COSCA project was therefore initiated to correct these information deficiencies.

The Collaborative Study of Cassava in Africa (COSCA)

The COSCA which is funded by the Rockefeller Foundation aims to collect authoritative information over a wide area on cassava production systems, processing methods, market prospects, and consumption patterns. This information is needed to improve the relevance of research on cassava by national and international agricultural research centers in order to realize the potentials of cassava for increasing food supply and incomes of the people of Africa. The range of information needed to accomplish this objective is wide and includes information on the importance of cassava, cassava varieties, production trends, processing methods, marketing prospects, and consumption patterns.

The COSCA study commenced in 1988 in six countries, namely Côte d'Ivoire, Ghana, Nigeria, Tanzania, Uganda, and Zaïre. Since then however, nine additional countries, namely Burundi, Cameroon, Congo, Kenya, Liberia, Malawi, Rwanda, Sierra Leone, and Zambia are collaborating with alternative funding. The COSCA study is executed by a multi-national, multi-institutional, and multi-disciplinary team. Each collaborating country has a multi-disciplinary team of four senior level scientists from different national agencies within the country consisting of a breeder, an agronomist, an entomologist, an economist and/or a statistician depending on availability. The collaborating international agencies are the International Institute of Tropical Agriculture (IITA), Centro Internacional de Agricultura Tropical (CIAT), Natural Resources Institute (NRI), and the Rockefeller Foundation.

COSCA is executed in four phases as follows:

Phase I involves a broad characterization of the following:

- Environment (physical, social, economic)
- Production
- Processing
- Marketing
- Consumption.

Phase II deals with cassava production details such as:

- Yield
- Land area
- Utilization (sale/home use, processing/fresh use)
- Input/output
- Production practices.

Phase III involves detailed studies of portharvest issues viz:

- Processing:
  Characterization of techniques,
  Product quality assessment (nutritional, toxicity, and quality assessment
- Marketing
- Consumption/demand.

A two-week planning meeting of all team members is the first activity of each of the phases of the COSCA study. In these meetings, researchable issues are identified, hypotheses are formulated, logistics are planned, methodologies are developed, the survey instruments are designed and tested. All team members, national and international, actively participate in all aspects of these meetings not as resource persons or students but as equal partners each of whom has valuable contributions to make. Data collection for Phase I was carried out in 1989, for Phase II in 1991 and Phase III in 1992. The survey instruments were administered directly by the national team members themselves with backstopping from the collaborating international scientists.

Objective of the Report

This report attempts to assess the level of commercialization of cassava production. The key questions addressed are:

- What proportion of total cassava production is marketed?
- What is the effect of commercialization on production growth?
- What are the constraints to commercialization of cassava production?

Method of the COSCA Study

Sampling Procedure[3]

Climate, demographic pressure and market infrastructure form the bases of stratification for sample selection. Climate is selected as the most convenient determinant of ecological conditions. Climatic differences strongly influence the growth of the cassava plant, production techniques, biological pressures, and processing methods. Density of human population strongly influences the intensity of land use, although it is not the primary controlling factor. Production and processing systems and the level of importance of cassava in the diet are all expected to be partly determined by population density. Market accessibility will be an important determinant of the degree of commercialization of cassava production as well as the degree of migration. The six original countries were selected because together they produce up to 70% of cassava in Africa and provide sufficient variability in climate, demography, and market access infrastructure.

A map of the distribution of cassava was produced by CIAT's Agroecological Studies Unit, using the most recent census statistics available and other data. The climatic classification devised at CIAT for cassava was used to subdivide the cassava producing areas of the selected countries (modified from that described in Carter 1987). It takes account of mean growing season temperatures, the length of the dry season, daily temperature ranges during the growing season and seasonality.

All-weather roads, railways, and navigable rivers were digitized from the 1987 Michelin travel maps of Africa to create a third computer image. Finally, secondary level administrative units for each of the six countries were digitized and their respective areas calculated.

Population data from the United States Census Bureau (unpublished data), projected forward to 1990, were used to calculate population densities for each of these administrative divisions. The population map was divided into high and low demographic pressure zones, the former comprising areas with 50 or more persons per square kilometer.

The three maps of climate, population density, and market access infrastructure were overlaid to create 12 zones with homogeneous climatic, demographic and market access infrastructure conditions of the cassava producing areas. Each climate/population density/market access infrastructure zone with less than 10,000 ha of cassava in each country was excluded as unrepresentative of cassava growing areas. The remaining areas which formed the potential survey regions were divided into grids of cells 12' latitude by 12' longitude to form the sample frame for site selection. A certain number of the grid cells distributed among the 12 climate/population density/market access infrastructure zones in proportion to the zone size were selected in each country, depending on the size of the country, by a random method; the total for the six original countries is approximately 300. One village was selected, by a random method, within each of the grid cells

[3] Up to the point of selection grids is based on Carter and Jones (1989).

(Map 1). In each selected village a list of farm households was compiled and grouped into "large", "medium", and "small" smallholder units with the assistance of key informants. Farms units which cultivated 10 ha or more of all crops were excluded. One farm unit was selected from each stratum by a random method. Information was taken from all the fields including cassava and non-cassava fields of such selected farmers.

Data Collection Procedure

For the Phase I survey, a rapid rural appraisal technique was employed in which farmer groups consisting of men and women with wide age range were constituted and interviewed in each village. Hence, in Phase I of the COSCA study the unit of analysis was the village site. The groups in each village were interviewed with structured instruments for qualitative information on the following aspects among many others: (1) various production practices including cassava varieties grown at present and the past; crops grown and their relative importance in the cropping system; (2) market access infrastructure including market type (rural or urban), distance to market, means to market, condition of access road to market, etc.; and (3) cassava marketing including cassava products marketed, points (field, rural or urban market places) of sale of fresh cassava roots, and buyers (consumers or middlemen) of cassava products from the farmers. The investigators who were leaders in cassava research in the national agricultural research system in each country administered the survey instruments. They are very knowledgeable regarding the cassava production system of the country and hence well qualified to collect this type of qualitative information.

For Phase II of the COSCA study information was collected at the field level as the unit of analysis. The information taken from each field included distribution of total production by proportion to be sold and proportion to be used at home, proportion to be processed and proportion to be used fresh, and field size among other information.

Market Access Infrastructure

The market access information which form part of the basis for the sampling in the COSCA study, namely road maps, vary widely in up-to-dateness. It was therefore considered essential to collect information, as part of the survey, that would permit objective definition of market access infrastructure for the purpose of analysis of commercialization of cassava production. Consequently, the farmer groups interviewed in the rapid rural appraisal phase of the COSCA study were asked to indicate the market they sell their cassava products most of the time, type of market (rural or urban), proximity of the market in km, condition of access road, and means of access to the market.

The categories of means of access as a type of market infrastructure are motor vehicle, foot, and others including bicycles, animals, and boats. Condition of access road includes motorable all season, motorable dry season only, barely motorable any season, and others which include foot paths and water ways as categories. Proximity to market is grouped into 10 km or less and above 10 km categories based on a subjective estimate of how much distance a farmer can cover in a day on foot with a head load a cassava products (Table 1).

The above information is however inadequete because it refers only to the farmers for the sale of their products. There are situations where the farmer sellers and the consumer or middlemen buyers have different market access conditions to the same market. This situation would distort the results of the following analysis.

Only about 50% of the villages reported that access roads to their primary markets are motorable in all seasons. This would imply good market access infrastructure because if a road is all season motorable it follows that motor vehicles would ply it and hence means of transport would be motor vehicle and relatively long distance may not be of major importance. In addition, regular plying of a road by motor vehicles would create highway side markets which are common features on most highways in Africa. However, motorable access road for the smallholder is not the only good market access infrastructure for the purpose of marketing of the cassava products. If the distance to the market is short enough, the smallholder may not need a motor vehicle and it is irrelevant to him whether or not his access road to the market is motorable provided that the same market is accessible by all season motorable road to the buyers. Close to 70% of the villages reported that their means of access to the market is on foot. As much as 25% or more of the villages reported that the markets are located above 10 km from the villages. Finally, as much as 77% of the villages reported that the market is located in the rural rather than in the urban areas. These situations do not, however, necessarily mean that a disproportionate number of the villages have poor market access infrastructure.

Foot as an access means to market may not imply poor market access infrastructure for smallholder farmers especially when proximity is considered. Out of the

Map 1. Location of survey sites for Collaborative Study of Cassava in Africa (COSCA).

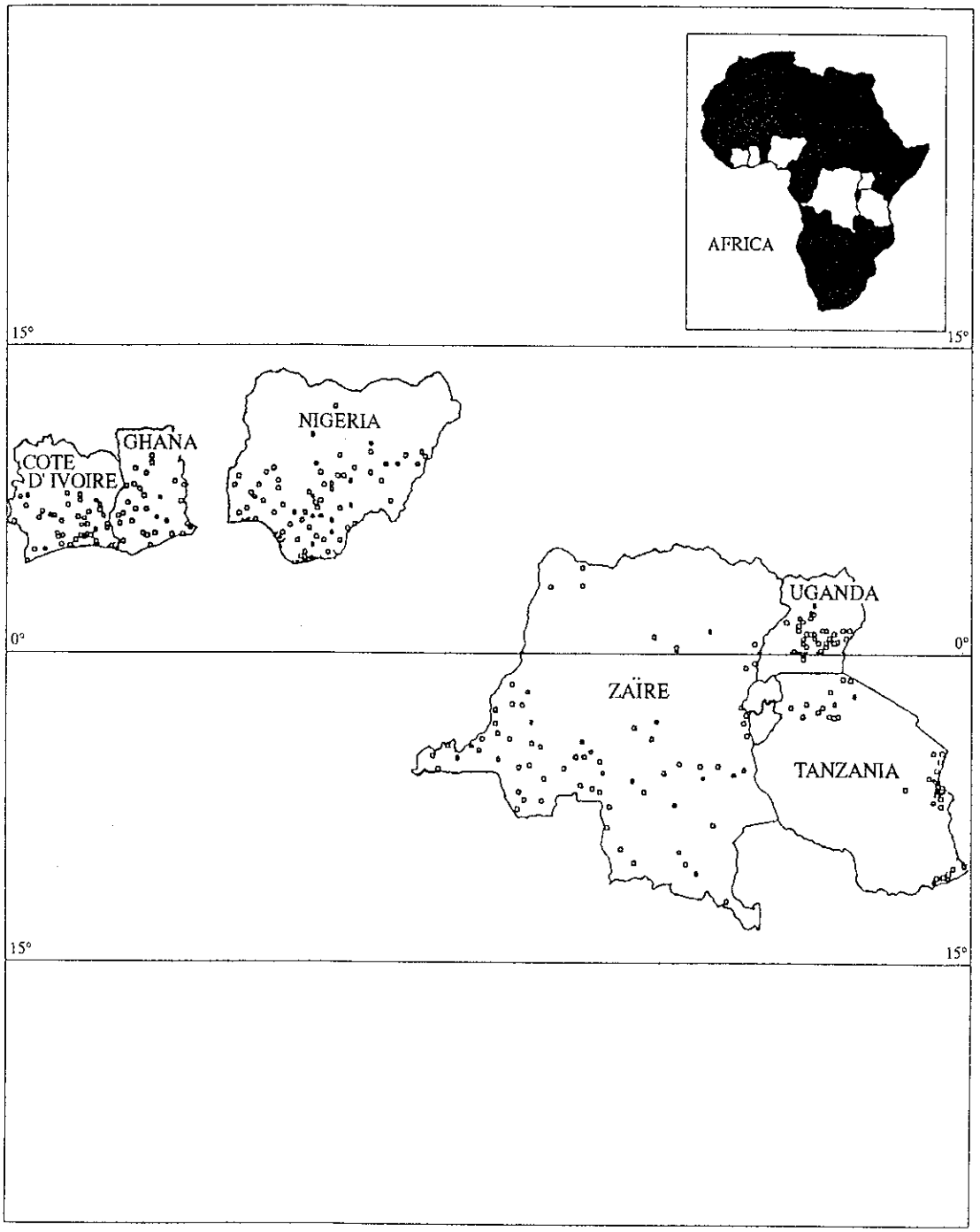


Table 1. Distribution (%) of villages by type/ category of market infrastructure.

Type: Category of market infrastructure	Percentage of villages
Road condition to market:	
Motorable all season	52
Motorable dry season	31
Barely motorable	9
Others[a]	8
Total	100
Means to market:	
Foot	68
Motor vehicle	24
Others[b]	8
Total	100
Distance to market:	
10 km or less	74
Above 10 km	26
Total	100
Market attended:	
Rural	77
Urban	23
Total	100
Distances and means:	
Motor veh. any distance	24
10 km or less on foot	53
More than 10 km on foot	15
Others	8
Total	100

[a] Water.
[b] Boats, animals.

close to 70% of the villages which go to their primary markets on foot, more than 50% reported that the markets are located within their villages or not more than 10 km away. Similary, market location at distances above 10 km from the village may not also imply poor market access infrastructure for all such cases as some of the villages have motor vehicle access to the markets. Out of the about 25% of the villages which have their markets located at more than 10 km away, about 10% have motor vehicle access to such markets.

In addition, it is not certain that access to urban markets imply better market infrastructure than access to rural markets for the smallholder farmers. The relative number of the villages which use such purchased inputs as hired labor, chemical fertilizers and mechanized methods of cassava processing respectively are higher among those villages which attend rural than those which attend urban markets (Table 2). This would suggest that level of agricultural commercialization is higher among the villages whose residents attend rural than those which attend urban markets. This conclusion would suggest that villages whose residents attend rural markets are likely to have better market infrastructure than those which attend urban markets. Farmers attend urban markets when rural markets are less accessible to them. The villages of such farmers are not necessarily located close to the urban centers and the farmers do not necessarily have motor vehicle access to the urban markets.

A combination of distance and means of access to the market would provide a reasonable basis for the assessment of the level of market access infrastructure. If the means of access is motor vehicle, it follows that the road condition is motorable at least in the dry season. If the distance is short, access on foot or any other means may not necessarily constitute poor infrastructure. However, a combination of long distance with access on foot would always constitute poor market access infrastructure. Consequently, the categories of the combination of distance and means as a type of market access infrastructure would be any distance by motor vehicle, 10 km or less on foot, more than 10 km on foot, and others including bicycle, animal, and boat means (Table 1).

In more than 50% of the villages residents attend their markets on foot over distances of not more than 10 km. Since the 10 km cut off point is more or less arbitrary, it is not certain how many of these villages face good or poor market access infrastructure. Similary, it is not easy to determine whether or not the about 10% of the villages which fall into the "others" category have good or poor market access infrastructure.

In only about 25% of the villages was it reported that people go to their primary markets by motor vehicle. Such villages would be said to clearly have good market access infrastructure. In as much as 15% of the villages, it was reported that the residents go to the markets on foot over distances of more than 10 km. Villages in this category clearly face poor market access infrastructure. The relative numbers of the villages which use the purchased inputs namely hired labor, chemical fertilizers, and mechanized methods of cassava processing, respectively, are substantially higher among the category of villages which go to their primary markets by motor vehicles than among the category which go on foot over relatively long distances (Table 2). This shows that the level of commercialization of agricultural production is higher among villages which have motor

Table 2. Distribution (%) of villages by use of purchased inputs by type/category of market infrastructure.

Purchased inputs	Type of market		Distance & means of getting to market	
	Rural	Urban	Any distance by motor vehicle	Above 10 km on foot
Hired labor:				
Used	70	64	8	37
Not used	30	36	16	63
Total	100	100	100	100
Chemical fertilizer:				
Used	33	18	39	11
Not used	67	82	61	89
Total	100	100	100	100
Mechanical processing:				
Mechanical (*gari*)	57	47	23	4
No mechanical	43	53	77	96
Total	100	100	100	100

vehicle access to their primary markets than those which access their markets on foot over long distances. This conclusion lends support to the conclusion that compared to foot access over long distances motor vehicle access would constitute a good market access infrastructure.

Cassava Fresh Root Marketing Channel

The farmers sell cassava in the field before harvest, they sell cassava roots after harvest in the rural markets, in the urban markets, and also at their homes. About 30% of the representative villages sold cassava in the field before harvest, 15% sold cassava roots after harvest at home, 40% in the rural markets, and another 15% sold in the urban market as their most frequent points of sale (Fig. 1). Tollens (1992) observed that in Bas-Zaïre, province of Zaïre, the traditional source of cassava for Kinshasa, most cassava sales (42%) are made at the farm, 20% of transactions occur in rural village markets, 14% of sales are made directly in urban markets, 17% is sold when the crop is still in the field and the remainder is sold along the road.

Sale of cassava fields before harvest is population driven, the frequency of it is higher in high than low population areas (Fig. 2). It is also higher in areas of limited commercialization of agricultural production such as areas of low use of purchased inputs including chemical fertilizer, mechanization, and hired labor (Table 3). In such areas, labor is not usually scarce so that people who buy cassava fields are able to afford harvesting labor. Cassava harvesting is labor intensive; it is estimated at up to 40% of total production labor (Knipscheer 1980).

The frequency of sale in the field before harvest as the main point of sale is higher among villages who use cassava mainly in the form of fresh roots than in any of the processed forms (Table 4). Cassava roots have a very short shelf life as fresh roots. Hence, users wishing to buy more than required for a day or two, must buy in the field before harvest where it can be stored.

The frequency of sale of cassava roots after harvest at home is higher in low population areas, in the areas of limited commercialization of agricultural production, and in areas of relatively poor market access infrastructure such as areas where farmers attend urban markets and areas where they go to the markets over long distances on foot (Table 5). In these areas even though population is low, labor may not be scarce relative to the need since the level of commercialization is low and use of hired labor is not important.

The frequencies of sale in rural and urban markets are highest in areas where market access infrastructure is well developed and where the commercial orientation of agricultural production is high, especially where the use of hired labor is important. In these areas, labor is likely to be scarce and hence farmers are not able to sell cassava in the field before harvest in spite of the high level of commercialization.

Figure 1. Distribution (%) of villages by market channel for cassava roots.

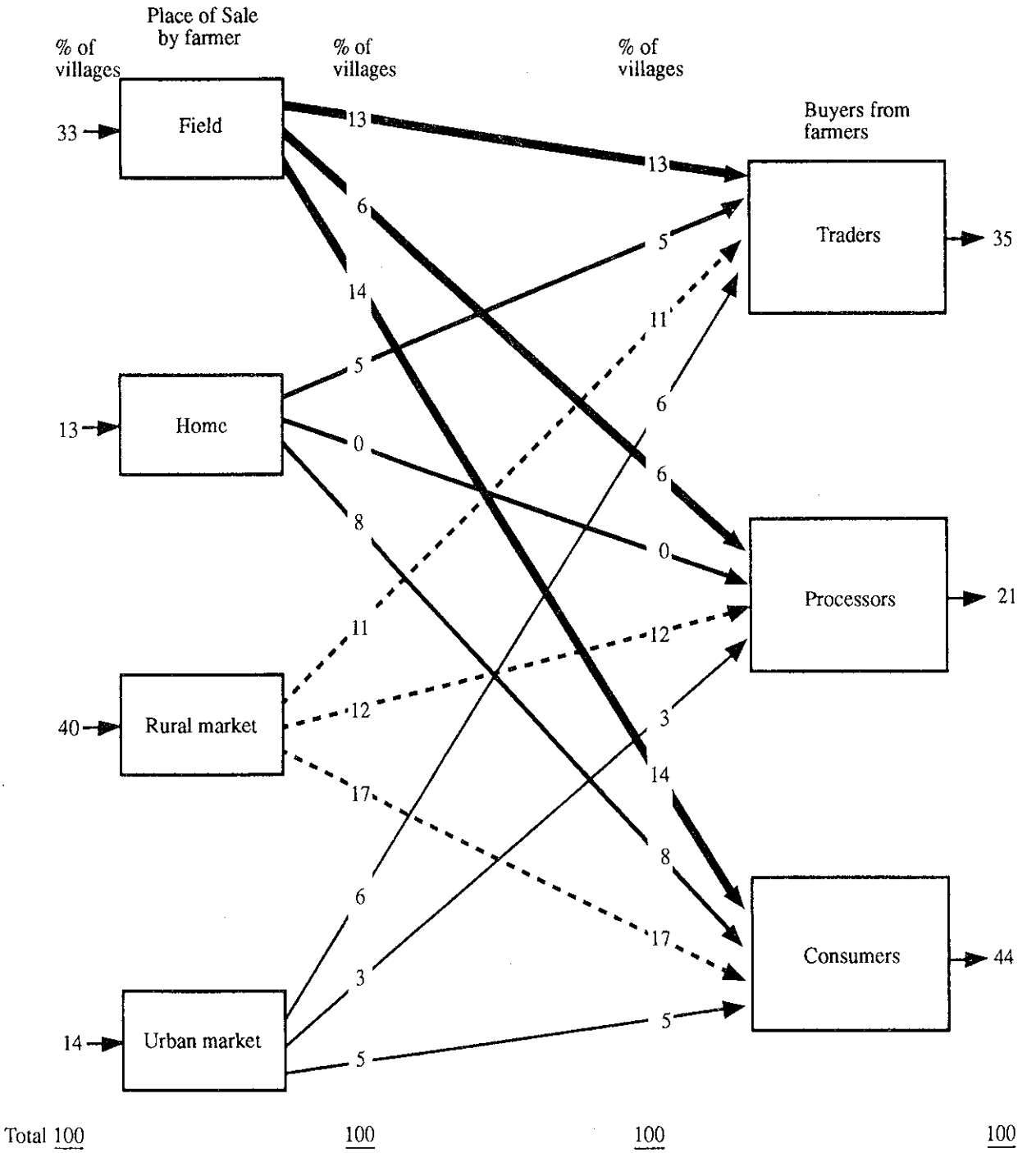


Table 3. Distribution (%) of villages by use of purchased inputs by location of sale of cassava roots.

Inputs purchased	Place of sale				
	Field	Home	Rural market	Urban market	Total
Hired labor:					
Used	30	12	44	14	100
Not used	42	18	30	10	100
Chemical fertilizer:					
Used	31	12	42	15	100
Not used	34	14	30	12	100

Table 4. Distribution (%) of villages by main cassava product used by location of sale of cassava roots.

Cassava product	Place of sale				
	Field	Home	Rural market	Urban market	Total
Fresh roots	47	13	2	8	100
Pastes	24	5	61	10	100
Chips/flours	33	17	35	15	100
Granules	18	5	64	13	100

Table 5. Distribution (%) of villages by types/category of market infrastructure by location of sale of cassava roots.

Type: Category of market infrastructure	Place of sale				
	Field	Home	Rural market	Urban market	Total
Type of market:					
Rural	31	11	49	9	100
Urban	33	17	20	30	100
Distance and means to market:					
Any distance by motor vehicle	26	5	33	36	100
Above 10 km on foot	29	29	32	10	100

Farmers sell to middlemen, namely traders and processors, and directly to consumers at each of these points of sale (Fig. 2). About 35% of the representative villages sold to traders, 20% to processors, and 45% sold directly to consumers as their most frequent buyers. Berry (1993) observes that commercial cassava production in Nigeria has entailed changes in contractual arrangements and market structures. People who plant cassava as a commercial investment often sell the crop in the ground after a few months to buyers who assume the risk and cost of managing the farm until harvest time as well as of harvesting and marketing the roots.

The relative number of villages which sell cassava mainly to the middlemen, processors, and traders is highest in areas of high population density (Fig. 3), in the areas of use of purchased inputs in agricultural production (Table 6), and where market access infrastructure is developed (Table 7). These are areas of commercial agricultural production where the relative number of villages which sell cassava mainly in the field before harvest is low. This correlation suggests that farmers do not sell cassava mainly in the field before harvest as much through the middlemen as they do directly to consumers. Tollens (1992) observes that traders buy at the farmer's door and regularly organized weekly or bi-monthly village markets. In Kwilu, which is the most commercialized subregion of Bandundu with a high density of agricultural production and a tarred road to Kinshasa, village markets are more important than door to door purchases in the cassava trade. Most sales are to specialized traders. In other subregions of Bandundu, exchange between farmers is more common.

Farmers are not able to take full advantage of the services of the middlemen when they sell cassava in the field before harvest because of the high labor requirements for cassava harvesting. In the areas of commercial agricultural production, farmers must harvest and transport to the market before they can sell through the middlemen or else, to sell in the field, they have to sell directly to consumers.

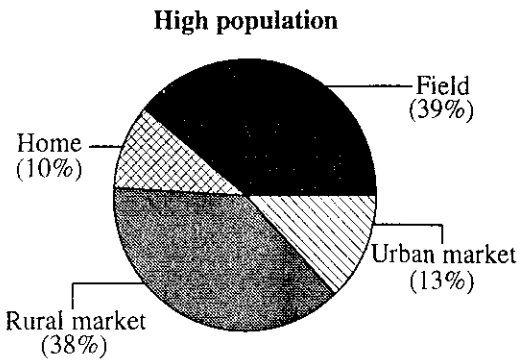
However, the relative number of villages where cassava production is increasing is significantly higher where farmers sell cassava mainly through middlemen than where they sell directly to consumers (Fig. 4). Following this, the relative importance of cassava increases from less than 25% in areas where farmers sell cassava mainly direct to consumers to up to 40% in areas where the farmers sell cassava mainly to processors (Table 8). This suggests that participation of middlemen in the marketing process provides an incentive for growth in cassava production. But, such participation is hampered not only by poor market access infrastructure, but also by the high labor requirements for cassava harvesting.

Diversification in Crop Production and in Cassava Products Marketing

The effect of the participation of the middlemen in cassava marketing therefore is to increase the relative importance of cassava in terms of percentage of arable land in commercial areas. In doing this, the level of diversification in crop production associated with commercialization is reduced in favor of cassava (Tollens 1992). The percentage distribution of arable land area by major crops under different market infrastructure (distance and means to market) conditions, shows that the level of diversification in crop production is almost the same between remote and easily accessible villages (Table 9). Under both these market access infrastructure conditions, cassava is the most important crop in terms of percentage of arable land; four other crops namely yam, maize, rice, and millet/guinea corn are also relatively important as they occupy at least 10% of arable land under each market access infrastructure conditions respectively. This lack of difference in the level of diversification in crop production among areas of different market access infrastructure conditions is due to the participation of middlemen in cassava marketing. The participation of the middlemen in cassava marketing has the effect of increasing the relative importance of cassava in easily accessible areas.

The difference made by middlemen in the level of diversification in crop production can be clarified where middlemen and consumers respectively are the main buyers of cassava in the easily accessible areas (Table 10). Where consumers are the main cassava buyers in the easily accessible areas, the level of diversification is high; cassava is only third in importance coming behind millet/guinea corn and maize while as many as four of the arable crops including rice take more than 15% of arable land each. On the other hand, where processors are the main buyers of cassava, the crop is more important than any other and only two other crops namely maize and yam each occupies 10% or more of arable land. These observations confirm the earlier conclusion that participation of middlemen in cassava marketing has the effect of encouraging growth in cassava production in areas of good market access infrastructure. As market access infrastructure improves, farmers will divert resources to production of other crops if middle-

Figure 2. Distribution (%) of villages by population density zone by location of sale of cassava roots.



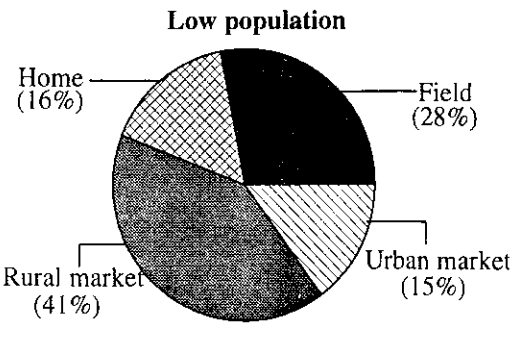
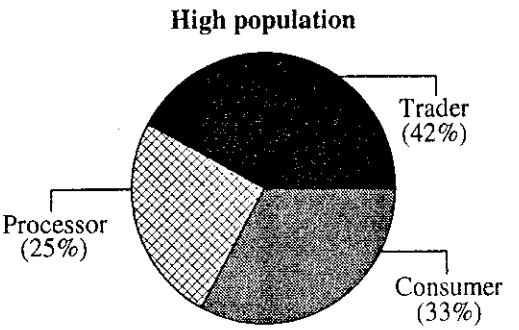


Figure 3. Distribution (%) of villages by population density zone by main buyers of cassava roots.



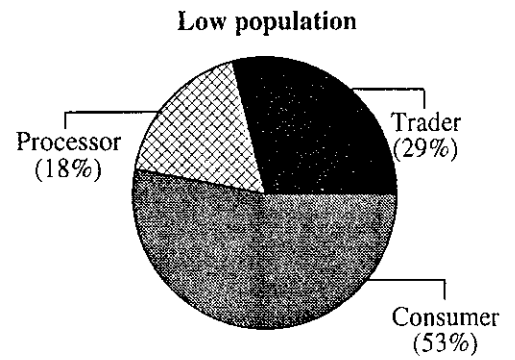


Table 6. Distribution (%) of villages by use of purchased inputs, by main buyers of cassava roots.

Purchased inputs	Buyers of cassava roots			
	Traders	Processors	Consumers	Total
Hired labor:				
Used	36	28	36	100
Not used	34	4	62	100
Chemical fertilizer:				
Used	37	34	29	100
Not used	34	16	50	100

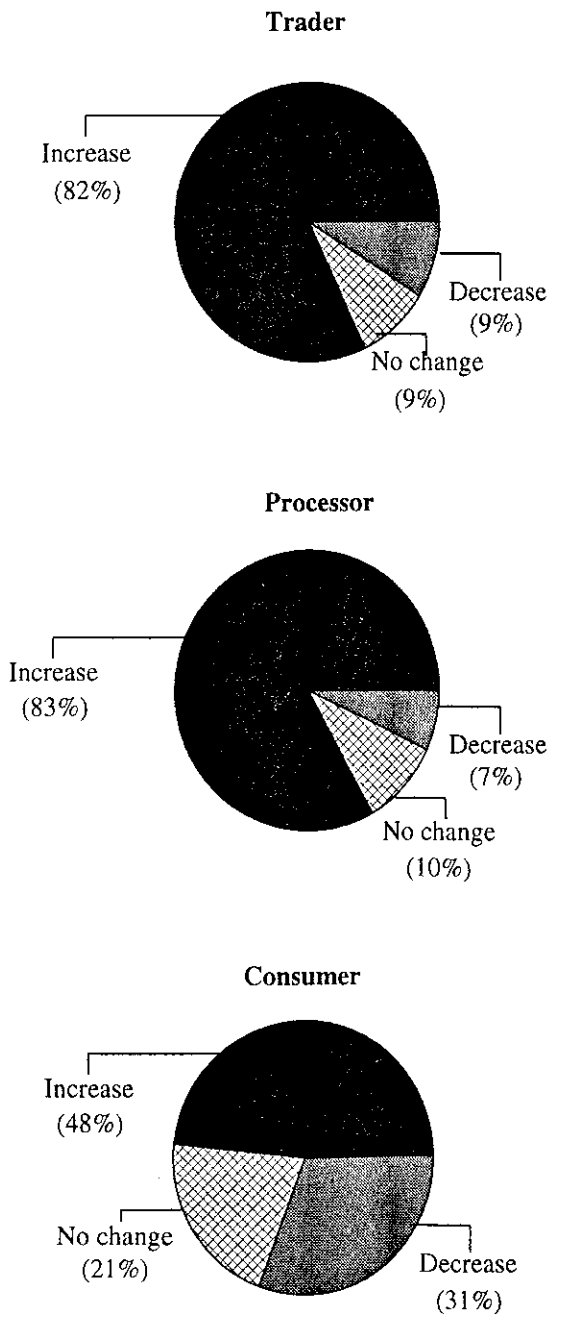
Table 7. Distribution (%) of villages by type/category of market infrastructure, by main buyers of cassava roots.

Type: Category of market infrastructure	Buyers of cassava roots			
	Trader	Processors	Consumers	Total
Type of market:				
Rural	34	25	41	100
Urban	43	15	42	100
Distance and means to market:				
Any distance by motor vehicle	38	31	31	100
Above 10 km on foot	47	19	33	100

Table 8. Arable land (%) allocated to major crops, by main buyers of cassava roots.

Crop	Buyers of cassava roots		
	Traders	Processors	Consumers
Cassava	33	40	24
Maize	26	14	18
Yam	14	16	7
Cocoyam	1	1	4
Sweetpotato	0	0	1
Banana	3	3	3
Rice	3	16	19
Millet	9	1	12
Peas	4	1	5
Others	7	8	7
Total	100	100	100

Figure 4. Distribution (%) of villages by cassava production trend by main buyers of roots.



men, traders and processors, do not come in to facilitate cassava marketing.

In Africa, most cassava is consumed in processed forms which are convenient to prepare and comparatively easy to store and transport (Cock 1985). Consumption of fresh cassava is limited by the extreme perishability of the roots which may begin to deteriorate within 24 hours after harvesting. With present facilities for storage and transport, it is difficult to market cassava at any distance from the place where it is grown. Processed cassava, on the other hand, is less bulky to transport and far less perishable than fresh roots. Perhaps for this reason, most cassava is eaten in processed form, especially in urban areas (Berry 1992). Forms of processed cassava include: cooked and uncooked pastes; fermented and unfermented chips/flours;

Table 9. Arable land (%) allocated to major crops, by distance and means to market.

Major crop	Any distance by motor vehicle	Above 10 km on foot
Cassava	32	35
Yam	11	10
Cocoyam	1	0
Sweetpotato	0	2
Banana	1	2
Maize	23	22
Rice	7	11
Millet/Guinea corn	15	3
Beans/Peas	4	7
Others	6	7
Total	100	100

Table 10. Arable land (%) allocated to major crops, by main buyers of cassava roots in areas where farmers go to market by motor vehicles.

Major product	Processors	Consumers
Cassava	40	18
Yam	15	3
Cocoyan	2	1
Sweetpotato	0	1
Banana	0	2
Maize	18	24
Rice	6	16
Millet/Guinea corn	3	27
Beans/peas	3	6
Others	13	2
Total	100	100

cooked and toasted granules; starch; alcoholic beverages, etc. In addition to fresh roots and leaves, cassava is also marketed in these various processed forms. In Central Africa, flour is often made at home by final consumers from dried chips or slabs of cassava root, known as cossettes. The cossettes are thus an important intermediate good, making up a major proportion of the marketed cassava in the region (Berry 1992).

Some 2% of the representative villages marketed seven or more different cassava products, nearly 20% marketed five or six, 45% marketed three or four, about 20% marketed one or two different cassava products, and less than 5% did not market any cassava product (Fig. 5). Thus the modal number of cassava products marketed is three or four. The number of products marketed is determined by the nature of market access infrastructure and by locally available processing resources such as sunlight, water, and fuelwood.

Virtually all of the few villages which did not market any product at all are in remote villages such as where farmers attend markets on foot over more than 10 km distances. Nearly 45% of the villages in that poor market access infrastructure zone marketed one or two products, nearly 50% marketed three or four products, and less than 5% of them marketed five or six products while none at all marketed more than six cassava products. Among villages in good market access infrastructure areas, however, such as villages which attend markets by motor vehicles, there was none that did not market any cassava product at all; only about 35% marketed only one or two products; 50% marketed three or four products; as much as 12% marketed five or six products; while 2% of them marketed seven or more products. These observations suggest that improvement in market accessibility leads to diversification in cassava products marketed.

Proportion of Cassava Production Marketed

For the representative villages, an average of 45% of total production is marketed. Proportion marketed is different from absolute quantity marketed as a high proportion may be low in absolute terms and vice versa depending on the size of total production. The proportion marketed varies from zero percent to above 90% (Fig. 6). The curve approximates normal with distribution skewed to the mean. Less than 10% of the villages were in the range of zero percent of total production marketed. These few villages are located in good market access infrastructure areas, have high level of diversification in crop production and produce mainly "sweet" cassava types. A small proportion, 2% of the villages, produce almost entirely for market as they market more than 90% of their total production. These few villages are mostly located in good market access infrastructure areas, adopt mechanized processing techniques, mostly produce "bitter" cassava types and are located in Tanzania, Nigeria, and Ghana.

In 1956 approximately one fifth of all manioc harvested in the Belgian Congo entered commercial channels. In the Kasai however, more then one third of the production was so marketed (Jones 1959).

Tollens (1992) shows that the averages of proportion of total cassava production marketed are 42% for the Bandundu and 55% for Bas-Zaïre regions of Zaïre. In Bas-Zaïre region, the proportion of total production marketed for cassava (55%) was similar to that for plantain (54%) but higher than for maize (45%), beans (45%), groundnuts (35%), and rice (20%). According to Berry, much has been made of cassava's advantages as a source of food security for "subsistence". However, cassava is also an important source of cash income for poor farmers as well as prosperous ones. Both rich and poor farmers often sell a higher proportion of cassava than of other crops and/or derive more cash income from cassava than from any other crop or income earning activity. In the more prosperous rural economy of southwestern Nigeria, sales ranged from two-thirds to 90% of women's cassava output. Even very poor farmers often sell a significant proportion of their crop (Berry 1992). Women farmers in southern Zaïre sold 20-40% of their cassava (Fresco 1982).

Marketing is a major constraint to the expanded use of cassava as a low cost food in urban areas partly because of infrastructure problems which in many parts of tropical Africa has deteriorated in recent years (Berry 1992). Most of the production areas in Bandundu regions are relatively close to navigable rivers. River transport is much cheaper than road transport. Bandundu only became a major supplier of cassava to Kinshasa after the completion of the Kinshasa-Kikwit tarmac road (525 km) in 1979 (Tollens 1992).

Yet, the proportion of total production marketed appears positively related to remoteness from market centers. For example, the proportion marketed increases from 40% among villages which are located no more than 10 km from rural or urban market places to more than 55% among villages located more than 10 km and whose main means of getting to such markets is on foot. There are hardly any differences among villages which

Figure 5. Distribution (%) of villages by number of cassava products marketed.

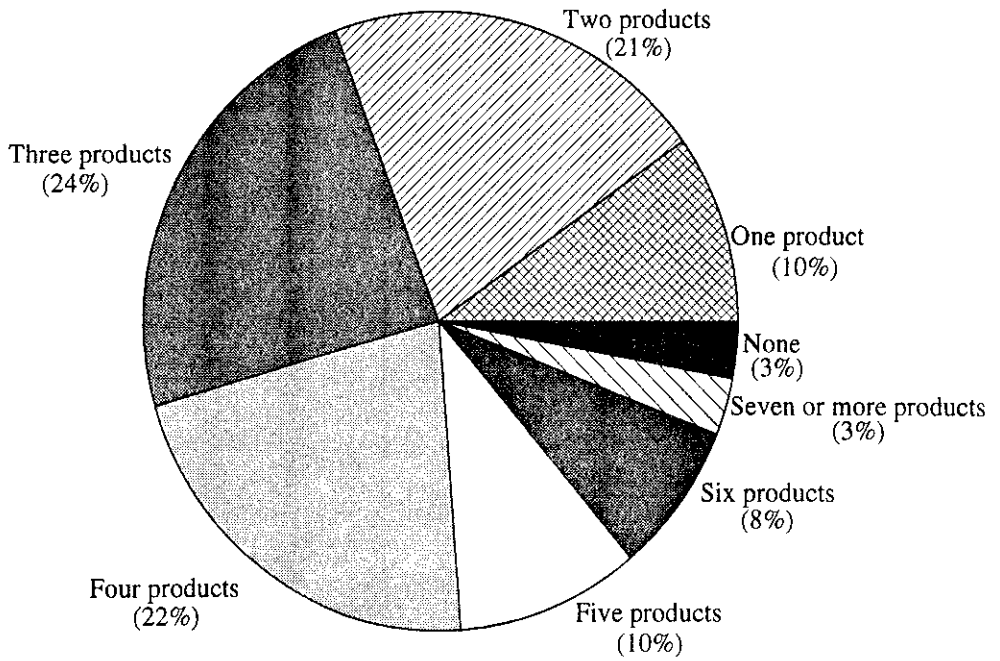


Figure 6. Distribution (%) of villages by percentage of cassava production marketed.

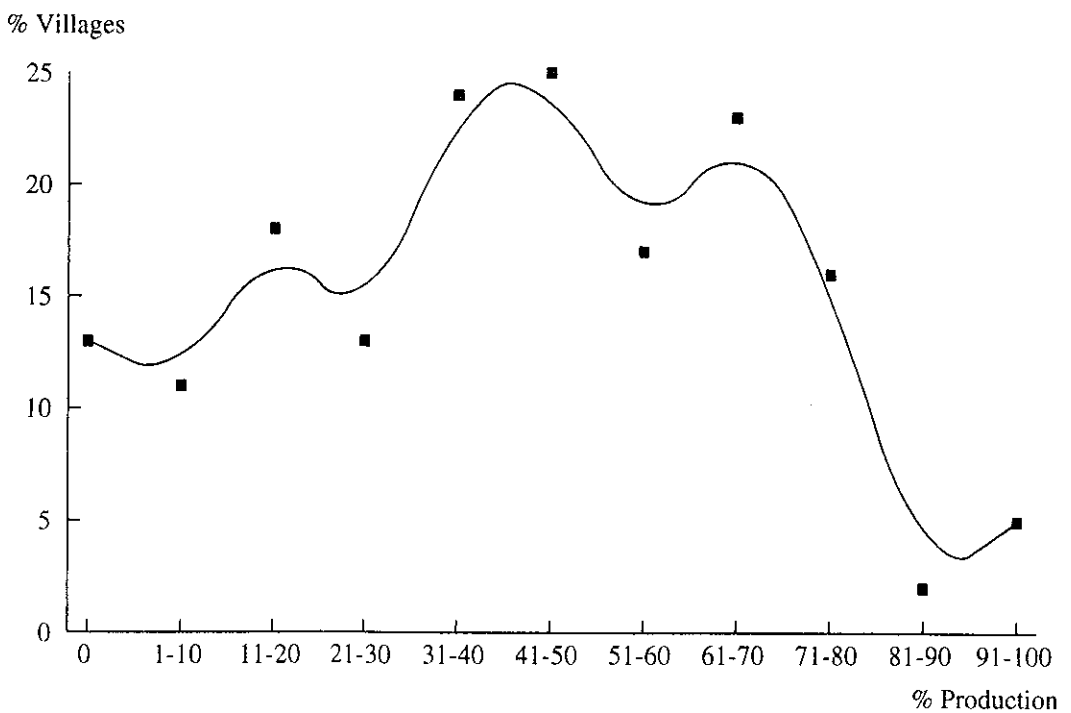
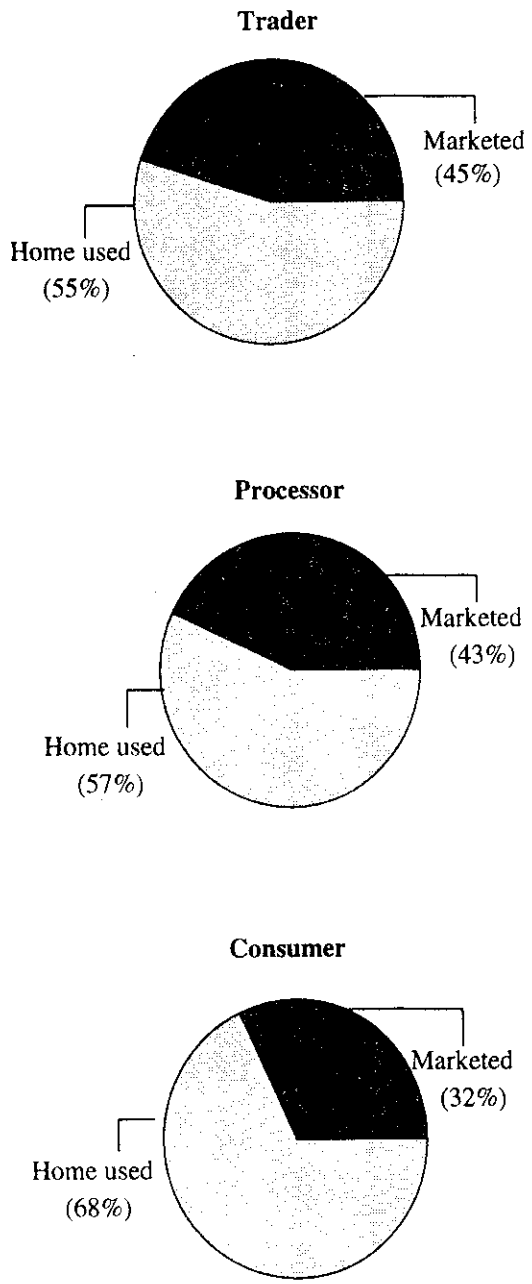


Figure 7. Cassava production (%) marketed by main buyers of fresh cassava roots.



use and those which do not use the various purchased inputs such as chemical fertilizers, hired labor, and mechanization in agricultural production.

The low level of diversification in crop production among remote villages helps to explain this situation. The proportion of total production marketed decreases from about 65% among villages where cassava occupies more than 60% for arable land area through about 50% where cassava occupies 20-60% of arable land area to about 40% among other villages where cassava occupies no more than 20% of arable land area. Thus, the less concentrated in cassava production, the lower the proportion of total production marketed. Tollens (1992) observed that as Kinshasa grew in population and Bandundu gained in importance for cassava, Bas-Zaïre diversified its agriculture and now supplies mainly cassava cossettes of higher quality (with a premiun price of +20%), cassava leaves (nearly all), firewood, charcoal, fruits, vegetables, plantains, bananas, beans, and rice.

The remote areas however sell mostly processed cassava; the proportion of total production processed is also positively related to remoteness from market centers. That proportion increases from about 65% among villages which are located no more than 10 km from rural or urban marketplaces to more than 80% among villages located more than 10 km and where main means of getting to such markets is by foot. This shows that processing is an important factor in cassava marketing. Unlike parts of Latin America where human consumption is mainly of fresh cassava, in Africa, increased sales do not necessarily depend on changes in processing technology or the development of alternative uses. In Colombia, for example, farmers located at any distance from market centers could not sell surplus cassava until the introduction of small scale processing plants, at the village level, to produce cassava chips for animal feed (Berry 1992).

The proportion of total cassava production marketed is higher among villages which sell mainly to the middlemen than among others which sell direct to the consumers (Fig. 7). In other words, the proportion marketed increases as participation of middlemen in the marketing process increases. This is in spite of the fact that the proportion marketed decreases while participation of middlemen increases as market access infrastructure gets better. The participation of middlemen discourages diversification away from cassava production as market access infrastructure gets better.

For example, in non-remote areas such as areas where farmers attend markets by motor vehicle, the proportion marketed is higher among villages where middlemen participate than among others where middlemen do not participate in the marketing process. Among villages which use purchased inputs such as chemical fertilizers, hired labor, and mechanization equipment, the proportions marketed are higher among

villages where middlemen participate that among others where the middlemen do not participate. These tendencies exist because in these areas of relatively high level of commercialization, the relative importance of cassava in terms of percentage of arable land is higher among villages where middlemen participate than among those where they do not participate in the marketing process.

Hence, while in remote areas far from market centers, the higher the relative importance of cassava in terms of percentage of arable land, the higher the proportion of total production marketed; in areas with developed commercial activities this trend is reversed; the higher the proportion marketed the higher the relative importance of cassava in terms of percentage of arable land.

Summary of Observations

As much as 45% of total cassava production is marketed. Sales occur in the field before harvest, or after harvest in rural markets, or at the farmers' homes. Sales are made through middlemen (i.e., traders and processors) as well as directly to consumers. Sales in the field before harvest are population-driven. Field sales tend to occur in villages of high population but where there is limited commercialization of production and where labor is relatively abundant. In such areas, people who buy cassava in the field are able to afford harvesting labor as cassava harvesting is labor-intensive. The relative number of villages where cassava is sold through middlemen is highest in areas of high population density and good market access infrastructure. These are areas of commercial production where the relative number of villages which sell cassava in the field is low. This means that farmers are not able to take advantage of the services of middlemen when they sell cassava in the field because of the high labor requirements in cassava harvesting.

The proportion of total production marketed is higher in poor than in good market access areas, because the higher the concentration in cassava production, the higher the proportion that is marketed. The level of concentration in cassava production is higher in poor than in good market access areas, except where cassava is sold through middlemen. Under the same market conditions, the proportion marketed is higher where farmers sell through middlemen than where they sell directly to consumers. The relative number of villages where cassava production is increasing is significantly higher where farmers sell through middlemen than where they sell directly to consumers. Following this, concentration in cassava production is higher where farmers sell cassava through middlemen than where they sell directly to consumers under the same market access conditions.

The effect of the participation of middlemen in cassava marketing is therefore to increase the proportion marketed and the relative importance of cassava in commercial areas, where farmers would otherwise diversify production away from cassava. In areas of poor market access, the higher the relative importance of cassava is, the higher is the proportion marketed. In areas of good market access, this trend is reversed—the higher the proportion marketed, because of the participation of middlemen, the higher the relative importance of cassava.

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Alternative Breads from Cassava Flour

G. Eggleston and P. Omoaka[1]

Abstract

New and alternative nutritious breads can be produced from cassava flour fortified with 20% raw or roasted soy flour using either locally available margarine with egg white, alone or with xanthan gum. Using margarine with egg white increased control loaf volumes by 29%; the subsequent addition of xanthan increased oven rise and volume by 35%. Margarine, and more significantly, egg white, reduced the extent of starch gelatinization and solubilization in the bread, making them less gummy. Loaf volume also depends on cassava variety: flours with relatively low diastatic activities and high maximum paste viscosities gave the best baking results. Flour diastatic activity depends on the moisture content of the harvested tuberous root. The breads produced in the project are acceptable to Nigerian consumers and have good keeping qualities.

Key words: cassava flour, bread.

Introduction

In recent years, the consumption of leavened wheat bread has risen enormously in many developing countries as a result of increasing populations, urbanization, and changing food habits. However, most developing countries, for climatic reasons, cannot grow wheat suitable for bread making and rely on expensive wheat imports paid for with scarce foreign currency. First attempts to effectively save foreign exchange were aimed at the partial substitution of wheat flour with flour from indigenous crops such as cassava and yam. This was spearheaded by the establishment of the Food and Agricultural Organization of the United Nations (FAO)'s Composite Flour Program in 1964. Although there is now a substantial body of composite bread technology available, such breads still usually require at least 70% wheat flour to be able to rise (De Ruiter 1978; Satin 1988; Dendy and Trotter 1988), and therefore implementation of the technology has been limited (Crabtree and James 1982).

Attempts have also been made to produce wheatless or gluten-free breads. Most of this work was carried out in the 1960s and early 1970s, but there has been a recent revival of interest in this area (Satin 1988). The ban on wheat imports into Nigeria by the Government in 1987 has also made the need for a marketable "alternative" wheatless bread more critical.

Much of the basic research was actually initiated in order to gain a better insight into baking or to produce gluten-free breads for celiac patients (a chronic nutritional disturbance of young children). The obvious problem is the replacement of the unique functional viscoelastic properties of the wheat protein gluten. Research workers have purported the use of various "gluten substitutes" (comprehensively reviewed by Eggleston et al. 1992), such as a special self-emulsifying GMS (glycerol monostearate); wheat/rye pentosans; gums such as methyl-cellulose and xanthan; and pregelatinized or extruded flours and starches. Unfortunately, there has been very limited or no implementation of the available wheatless bread technology in developing countries. This is probably mainly due to the fact that most gluten substitutes are rarely available locally or that the equipment necessary to produce some of them is relatively expensive and also has to be imported. Importation of products or equipment introduces another cost element

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which may outweigh the savings in imported wheat flour.

We therefore undertook a study to identify gluten substitutes which could be found locally in Nigeria and other developing countries or that might be produced locally at low cost, and which could improve cassava bread volume and structure. In preliminary studies we tested a variety of locally available gums, for example the gum from okra (*Hibiscus esculentis*) seed pods or imported gums which we knew could be found in developing countries (Eggleston 1991). Only xanthan, an anionic bacterial polysaccharide gum from *Xanthomonas campestris*, improved loaf characteristics. Other materials, products, and processing variations were also tested (Eggleston 1991). This included the addition of a pregelatinized portion (up to 20%) of the cassava flour, which did not improve cassava bread quality. The use of egg white (whole egg was not used because bread crumb structure became less fine and texture softer) with an ordinary table margarine gave the most beneficial results which, with those of xanthan, we reported previously (Eggleston et al. 1992). This paper reports further studies and a discussion of the effects of different cassava varieties on flour and breadmaking properties.

Materials and Methods

Cassava Tuberous Roots

Tuberous roots of the International Institute of Tropical Agriculture (IITA) improved cassava clone TMS 90042, grown without fertilizer 1 x 1 m apart, were harvested 13 months after planting.

Preparation of Cassava Flour

Flour was produced from peeled and washed unfermented tubers. The washed tubers were chipped in a manually operated chipper, sun-dried outside (30 ± 3°C) for 48 hr, then milled using a disc mill. The milled flour was sieved through a 250 µm mesh sieve and had an 11.2% moisture content.

Preparation of Roasted Soy Flour

Cassava flour was supplemented with soy flour to increase the nutritional status of the bread. Raw or roasted soy flour was preferred to defatted soyflour because the defatting procedure would considerably increase the cost, time, and energy required for production. Dehulled soybean seeds were washed and dried, then milled using a hammer mill. The milled flour was sieved through a 355 µm sieve and roasted in an oven at 150°C for 10 min. The resulting product had a 3.7% moisture content.

Ingredients

Food grade xanthan gum (Keltrol™) was obtained from Kelco Ltd., London, UK. The fat used was Blue Band™ margarine, produced by Lever Bros. of Nigeria, who reported the margarine contained 16% moisture and 80% vegetable oils (at least 80% palm oil), between 0.3% and 0.5% emulsifier (MGP = mono-glycerol palmitate), non-fat milk solids, preservatives, citric acid, Vitamins A, B1, B2, and D. Flavorings, and β-carotene were present in trace amounts. The melting, slip, and clear points of the margarine were 37.3°, 38.4°, and 41.1°C, respectively. Egg whites obtained from large-sized eggs, salt, granulated sugar, and Fermipan™ (Gist Biocades, Delft, Holland) instant dried yeast were all bought locally in Ibadan, Nigeria.

Baking Formula and Process

The baking formula (Table 1) and processing conditions (Fig. 1) were developed to take into account the tropical climatic (ambient temperature 28 ± 5°C; relative humidity (RH) 84 ± 14%), social, and economic conditions prevalent in southern Nigeria. The minimum sugar and fat concentrations were identified using trained taste panels. The whisked egg white was prepared by hand separation of the yolk from the egg white. The white was then whisked for 2 min at high speed (No. 2 setting) using a Philips mixer. All the dry ingredients, including the gum (if used), were mixed in a Kenwood high-speed mixer at low speed for 1 min using a flat "K" beater. The water and whisked egg white (if used) were added at this stage, and all the ingredients mixed at high speed for 10 min. The slightly cohesive and viscous batter produced (in triplicate) was then deposited into a Shogren-type baking pan and smoothed down with a plastic spatula. The batter was fermented at 30°C (85-90% RH) for 60 min in a fermentation chamber and then baked at 200°C for 30 min in a reel-type oven. Loaf weights and volumes were measured (by rapeseed displacement) after the baked loaves had attained room temperature (28 ± 2°C).

Bread Crumb Analyses

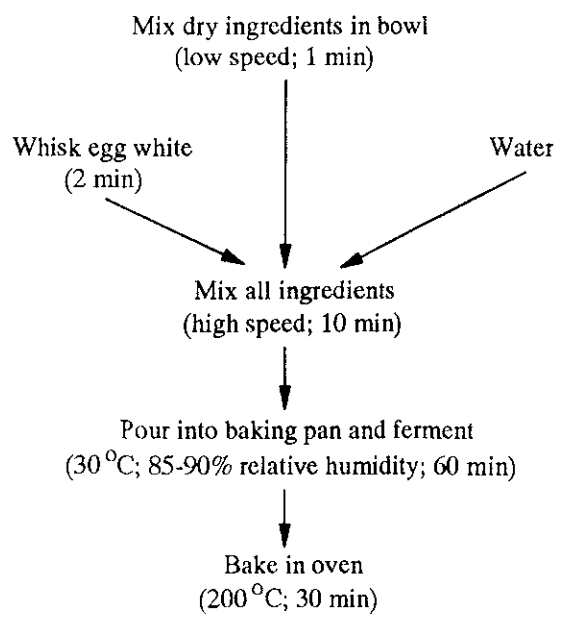
Crumb structure of the cassava breads was qualitatively evaluated for number of gas cells, cell wall thickness, uniformity, and texture. Crumb moisture content was

Table 1. Basic cassava bread formula.

Ingredient	Amount (g)
Cassava flour	80[a]
Raw or roasted soy flour	20[a]
Dried yeast	1.5
Salt	1.5
Sugar	6
Oil (margarine)	4-10
Water	110[b]
Whisked egg white	48[c]
or	
Xanthan gum	1

[a]Based on 14% moisture content.
[b]112 ml water was added for the xanthan formula.
[c]Based on 12% dry matter content. The water contained in the egg white is taken into account in the total water added.

Figure 1. Cassava bread processing flow chart.



measured using AACC method 44-15A (1981). Crumb hydration capacities and blue values were measured using the method of Yasanaga et al. (1968).

Analysis of Results

Results, where appropriate, were subjected to ANOVA, using a Super ANOVA (Abacus Concepts Inc., Berkeley) software package.

Cassava Bread Texture and Keeping Quality

Baked loaves were stored at ambient temperature (26 ± 2°C) in airtight plastic bags. Loaves were first cut 12 hr after baking. Bread texture was measured as the resistance to an applied shear force using a Standard Bread Shear-Compression Cell attached to the Model T1 Texturometer of Food Technology Corp., Maryland.

Cassava Bread Sensory Evaluation

A 15-member trained taste panel used was comprised of males and females from IITA and represented the low- and middle-income groups of Nigeria. The cassava bread quality attributes evaluated included texture, sweetness, taste, crumb color and structure, and overall general acceptability. The results were subjected to ANOVA, using an SAS (SAS Institute Inc., Cary, North Carolina) software package, with Duncan's Multiple Range Test used to determine the comparative degrees of significance.

Results and Discussion

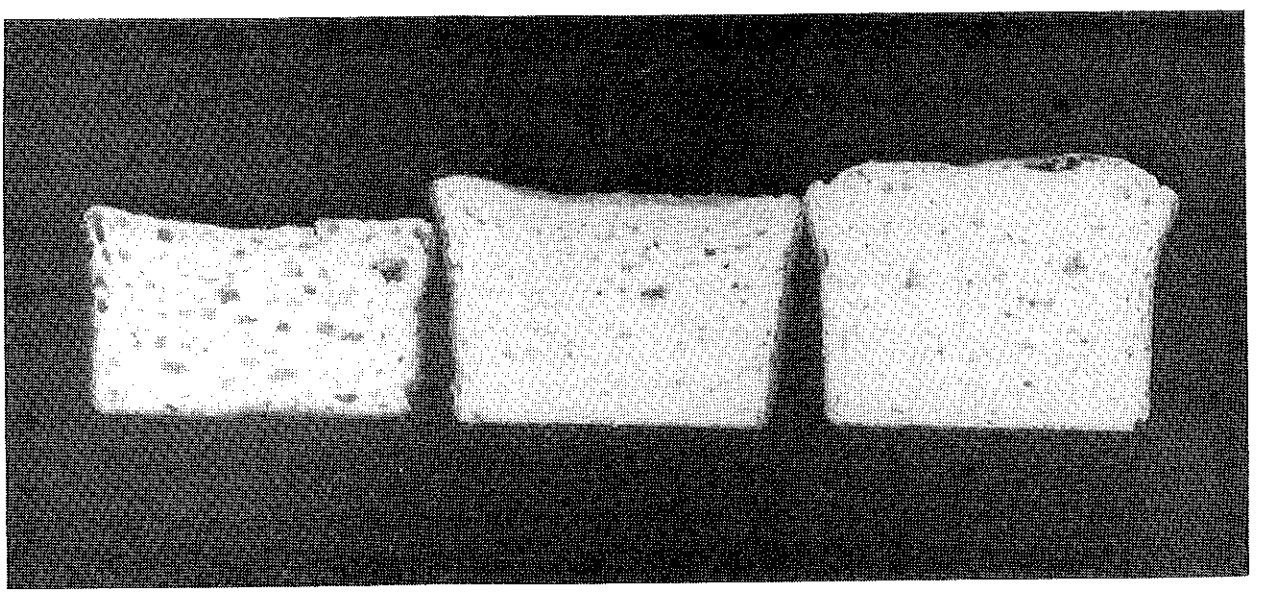
Influence of Different Additives

The cassava bread loaves baked with various combinations of fat, egg white, and xanthan are shown in Figure 2; the effect of the additives on loaf volumes, specific volumes, and crumb characteristics are presented in Table 2. Cassava bread baked without fat or any other additive (the control) collapsed in the oven and had a typically coarse and irregular crumb structure, and gummy texture. The subsequent addition of 4 g fat slightly improved loaf and crumb characteristics. It was previously shown (Eggleston et al. 1992) that margarine increases the amount of air entrapped in the bread batter at the mixing stage (as indicated by their lower batter densities), which subsequently increases the maximum gas retention attained.

Table 2. Loaf volume characteristics.

Additive	Loaf volume (ml)	Loaf specific volume (ml/g)	Crumb characteristics
Nil (control)	393	2.06	Large gas cells, uniform crumb; slightly gummy, slightly depression
4 g fat	418	2.21	Fine gas cells; uniform crumb; slightly gummy; slight depression; soft texture
4 g fat + xanthan	418	2.03	Fine gas cells; uniform crumb; slightly gummy; slight oven rise
10 g fat + xanthan	436	2.05	Fine gas cells; partially uniform crumb, slightly gummy; soft and spongy texture; good oven rise
10 g fat + xanthan + egg white	531	2.46	Fine gas cells; very uniform crumb; soft and spongy texture
10 g fat + egg white	508	2.45	Very fine gas cells; uniform crumb; not gummy; very soft and spongy texture

Figure 2. Alternative cassava breads baked with cassava flour with, left to right, basic formula (control), basic formula + egg white + 10g fat, and basic formula + egg white + 10 g fat + xanthan.



The addition of egg white and 10 g fat to the control formula significantly improved the bread, increasing the volume by 29%. Not only did the egg white prevent the loaf from collapsing; it produced a very uniform and fine crumb structure, enhanced the crumb color, removed the inherent gumminess of the cassava bread, and gave a very soft texture. The egg white acts primarily as a stabilizer (Eggleston et al. 1992) to the relatively unstable batter.

The addition of xanthan gum to the basic bread formula prevented the loaf from collapsing and improved oven rise and loaf volume. The preservation of structure and reduction in loss of entrapped gas can be attributed to the unusual ordered conformation of the polysaccharide, giving an inter-molecular network which—at the salt level present in the batter—would be stable to a very high temperature (Norton et al. 1984). However, the best loaf was produced (35% volume increase) when 10 g fat and egg white were present with xanthan; in appearance and softness this loaf most resembled a normal wheat loaf.

Bread Crumb Properties

The extent of starch gelatinization in bread is important because of its role in determining the distribution of moisture in the baked loaf and its effect on bread crumb quality and in the changes that occur after baking. Previous workers (Kim and De Ruiter 1968) acknowledged the need to retard gelatinization of cassava starch in cassava-soy breads "in order to avoid an excessively rubbery final product." Because the hydration capacity and blue values of bread crumbs have been used by earlier workers (Yasanaga et al. 1968), these properties were used to compare the extent of starch gelatinization (hydration capacity) and solubilized starch (blue value) in the cassava breads. These parameters, along with crumb moisture content, are presented in Table 3.

Generally, the percentage of different crumb moisture contents were only slightly lower than their respective baking absorptions; this could be attributed to evaporation during baking. However, the breads which contained egg white had significantly ($P<0.01$) lower moisture content and were less gummy/rubbery.

Among the cassava breads, the baking absorption was higher (by 2 ml) for the xanthan formulation than for the others. The hydration capacity was also higher, indicating that the xanthan gum was not fully hydrated in the bread, and could therefore still imbibe considerable amounts of water.

There was a notable difference in the relatively low hydration capacity and blue value of the bread which contained egg white. The presence of egg white, therefore, markedly reduces the extent of starch gelatinization, swelling, and solubilization. This could be attributable to the emulsification properties of the egg white proteins (Davies 1986) which may have been responsible for a delayed and therefore reduced gelatinization. However, as we reported previously (Eggleston et al. 1992), it is more likely that the protein network created by the coagulation of the whisked egg white proteins in the early stages of baking acted as a barrier to the limited water supply available in the bread reaching the starch, thus hindering starch gelatinization and swelling.

Table 3. Cassava bread crumb measurements.[a]

Additive	Crumb moisture (%)	Crumb hydration capacity (%)	Crumb blue value
Nil (control)	54.6 ± 0.5	557.6 ± 3.3	0.20 ± 0.02
4 g fat	55.2 ± 0.4	593.6 ± 1.1	0.18 ± 0.01
4 g fat + xanthan	57.1 ± 0.4	695.2 ± 4.9	0.29 ± 0.01
10 g fat + xanthan	56.5 ± 0.7	639.7 ± 4.8	0.26 ± 0.01
10 g fat + xanthan + egg white	53.8 ± 0.1	490.5 ± 2.6	0.18 ± 0.01
10 g fat + egg white	51.9 ± 0.6	395.0 ± 2.9	0.19 ± 0.01

[a]Values are means ± SD.

Sensory Evaluation

A multi-comparison scoring difference test was used to determine if there were any perceived differences among the cassava breads (Table 4) and a locally bought wheat bread (specific volume = 3.64 ml/g). The test showed that there were significant differences ($P<0.05$) in bread quality. The cassava bread control (no additives) and loaf with 10 g fat and xanthan had significantly ($P<0.05$) lower quality scores.

There was a substantial improvement over the cassava bread control for the general acceptability of the loaves with egg white and 10 g fat or egg white, 10 g fat, and xanthan; this is mainly attributable to the improved loaf textures and crumb structures (Table 4). Furthermore, even though the local wheat bread had a comparative "excellent to very good" acceptability score, cassava breads still had a "good" score. However, comparison to wheat bread is limited, because cassava products are produced using a baking technology very different from conventional wheat/dough procedures and their marketability would more likely succeed if they were viewed as new "alternative bread" products in their own right.

Keeping Qualities

Changes in crumb firmness, as measured by the resistance to shearing force, are shown in Figure 3. The loaves with egg white and 10 g fat, or egg white, 10 g fat, and xanthan kept for three days which is comparable to the locally bought wheat bread. On Day 4 the wheat bread was very stale and the cassava breads spoiled.

Effect of Varietal Differences

The results presented in this paper have been on the use of one cassava clone, TMS 90042. However, the variety (or clone) of cassava used to produce flour significantly affects bread quality. Those flours with a relatively high diastatic activity (i.e., below 150 mg maltose) and indirectly low maximum paste viscosity produce dense, pudding-like structures, and are therefore not suitable for bread making (Eggleston et al. 1993a, b). In a previous experiment (Eggleston et al. 1993a, b) where we screened seven IITA-improved cassava varieties and one local Nigerian variety "Antiota" for breadmaking ability, diastatic activities differed by almost a factor of two from 115-208 mg maltose. These values were substantially higher than the value (2.5) observed by Rasper et al. (1974) for a flour prepared from "Ankra", the most popularly cultivated cassava in Ghana at that time. This suggests that the diastatic hydrolytic enzymes α - and ß-amylases vary considerably with genotype, although preharvest age of the cassava was not reported by Rasper et al. Furthermore, the diastatic activity appears to be very dependent (Eggleston et al. 1993a, b) on the moisture content of the freshly harvested tuberous root ($r = 0.80$, $P<0.02$), which is probably because water activates the enzymes. Recently, we studied the effect of preharvest age and environment on flour properties. The diastatic activities of the cassava flours changed substantially over an 18-month cultivation period (August 1989-January 1991), and the pattern of change closely paralleled the moisture content of their respective tuberous roots (Fig. 4). Therefore, those times of the year when tuber moisture contents are high, for example in the rainy season, flour diastatic activities are

Table 4. Taste panel evaluation using a multiple comparison scoring difference test.[a]

Sample	Sweetness	Texture	Crumb color	Crust color	Crumb structure	Taste	Acceptability
Control	4.79^{c}	5.79^{c}	4.64^{e}	4.93^{d}	5.64^{d}	5.36^{c}	5.50^{c}
10 g fat + egg white	3.71^{b}	3.71^{b}	3.14^{bc}	3.00^{b}	3.21^{b}	3.64^{b}	3.86^{b}
10 g fat + xanthan	5.85^{d}	6.07^{c}	4.79^{e}	4.36^{cd}	5.14^{cd}	5.57^{c}	5.64^{c}
10 g fat + egg white + xanthan	3.81^{b}	3.86^{b}	2.71^{b}	3.28^{b}	3.36^{b}	3.93^{b}	3.71^{b}
Local bread	1.57^{a}	1.78^{a}	1.57^{a}	1.79^{a}	1.64^{a}	1.71^{a}	1.36^{a}

[a]Sample scores are based on a 7-point scale with 1 = excellent, 2 = very good, 3 = good, 4 = fair, 5 = poor, 6 = very poor, and 7 = unacceptable. Sample score means with different letters are significantly different ($P<0.05$).

Figure 3. The effect of storage time on alternative cassava bread texture.

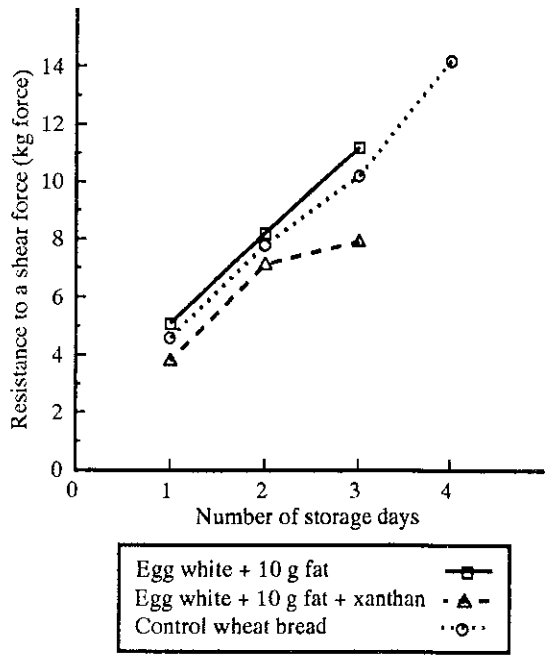
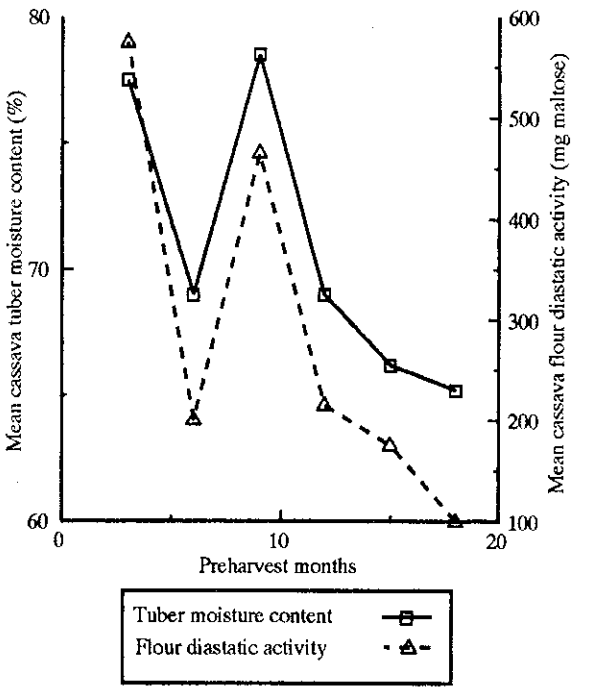


Figure 4. Effect of preharvest tuber age on tuber moisture and flour diastatic activity (%).



high and potential baking properties less. Moreover, the method of flour drying may be critical. We compared sundrying (32 ± 2°C) and oven drying methods (55°C): the sundried flour had a diastatic activity (46 mg of maltose) approximately one quarter of the corresponding oven dried flour (182 mg maltose). This suggests that sundrying is a much more effective method for reducing diastatic activity and that drying effects warrant further investigation.

Cassava flour diastatic activities and maximum paste viscosities can therefore be used as screening parameters by cassava breeders for cassava improvement. These results also suggest that cassava preferably should be harvested at those times of the year when the moisture content of the tuberous roots are relatively low, e.g., in the dry season, and that the flour should be sundried to maximize baking use.

Conclusion

Small amounts of locally available margarine and egg white, alone or with xanthan gum, can be used to produce alternative and nutritious cassava breads. These breads have acceptable organoleptic and keeping qualities. Unfortunately, at the present time, the unusual thermo-gelling xanthan gum has to be imported and, until it can be cheaply produced in developing countries, the xanthan-cassava bread will not be cost effective. However, egg white and margarine are invariably found in such countries and are therefore more economical to use. Successful production and marketing of these breads will ultimately depend on if there is a good and constant high-quality supply of cassava flour to the bakers, and if economic constraints can be overcome. Selling these products as a new convenience product,

which consumers can dip into their stews and soups (in the same manner as wheat bread is often eaten in Nigeria), and creating a new, alternative name would probably enhance implementation.

Acknowledgement

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Solar Dehydration of Cassava for Production of Flour for Local Foods in Kenya

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Abstract

Kenyans subsist for the most part on maize and wheat-based foods. The rapid population increase, however, has not been paralleled by a corresponding increase in maize production and has increased the need for wheat imports. This situation has led to the consideration, on a national basis, of the use of composite flours as potential alternatives to expanded maize production and increased wheat importation. This paper reports on the attempts to produce cassava flour for combining with maize meal in *ugali*, sorghum and millet flours in *uji*, and wheat flour in *mandazis*. Evaluations were also made on the shelf-stability of flour under the prevailing weather conditions in Kenya and in packages commonly used for milled cereal product storage.

Cassava slices 2-mm thick were dried within 5 hr during fine, sunny weather, and were milled to produce good quality flour. Up to 50% of the composite flour was acceptable in *uji* and *mandazi*, but only up to 20% was tolerable in *ugali*. The flour maintained good color and organoleptic properties for up to 6 months of storage. Results indicate that cassava flour has excellent potential for combining with milled cereal products in *ugali*, *uji*, and *mandazis*.

Key words: cassava flour, composite flours, Kenyan foods.

Introduction

The majority of Kenyans subsist on a traditional diet primarily consisting of maize. Among the main foods made from maize are *ugali* (paste prepared from maize meal) and *uji* (porridge prepared from maize flour). *Uji* is also prepared from other cereal flours such as sorghum and millet. Wheat is the second most important cereal food crop in Kenya. In addition to conventional oven-baked bread, wheat flour is also prepared into *mandazis* (doughnuts or buns) and *chapati* (unleavened flat bread).

Kenya's population growth rate is one of the highest in the world and far outstrips increases in food production. Occasionally there are maize shortages, especially in times following a drought. The country also is not self-sufficient in wheat and, therefore, has to rely heavily on imports to meet the large and growing domestic demand for wheat flour, both in the baking industry and for domestic use.

Recently, the Government has launched several initiatives to improve the availability of these foods. One means for doing this has been intensified production of drought-resistant crops, mainly sorghum, millet, cassava, and sweetpotato, and using them in composites with maize and wheat. Indeed, in 1988 to oversee this venture, the government created a new Ministry of Reclamation and Development of Arid, Semi-Arid and Wasteland.

Cassava is one of the marginalized crops in Kenya. It is, however, widely cultivated and consumed in various forms throughout the country. In western Kenya, within

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the Luhya and Luo communities, cassava is cut into small chunks and sun dried, then milled or pounded into flour. This flour is then mixed with maize meal to make *ugali*. The dried chunks and flour find their way to various urban markets including Nairobi. In addition to its use in making *ugali*, cassava flour is blended with maize, sorghum, and millet flours for porridge. Currently some composite flours for porridge blends are available on some supermarkets shelves in Nairobi. The price of cassava flour in the market place is not government-controlled and is much lower than the prices of the government-controlled maize and wheat flours. The cassava-cereal flour composites will sell at a price comparable to the price of pure flour from the corresponding cereal. The current prices are for wheat flour Ksh 12.15/kg (US$ 0.43), for maize meal Ksh 6.85/kg (US$ 0.23), and for cassava flour Ksh 5.00/kg (US$ 0.16).

Intensification of cassava production would boost farmers' incomes. Combining cassava flour with maize and wheat milled products would also increase availability of the commodities at potentially reduced prices.

The Research Project

From October 1988 to September 1989, the University of Nairobi (UON) Department of Food Technology and Nutrition (DFTN) conducted research on production of dehydrated cassava flour for incorporation into cereal-based Kenyan foods. The study's goal was to impact the whole country, but particularly Western Kenya (Nyanza and Western Provinces), and some parts of the Rift Valley and Coast Provinces, as well as all the urban and rural areas served by the millers who might adopt the composite flour production technology. The UON is a statutory institution which works very closely with other Government organizations to solve national problems. The DFTN is affiliated with the Ministry of Agriculture, which has a strong Extension Department for transmitting research results to users. The DFTN provided all the facilities for flour production and testing. Funding for the project was provided by the International Foundation for Science (IFS) and the Swiss Development Cooperation (SDC).

Objectives

The objectives of the study were to evaluate:

- solar drying of cassava slices for flour production;
- possibility of incorporation of the cassava flour into *mandazis*, *uji*, and *ugali*;
- acceptability of these foods to Kenyans; and,
- shelf-stability of the cassava flours.

Organizational aspects

The Dryland Research Station (DRS) of the Ministry of Agriculture is situated at Katumani, southeast of Nairobi, in Machakos District. The station provided cassava of different varieties for the study. Commercial cassava was purchased from the markets around Nairobi. This cassava normally comes from agricultural areas near Nairobi, but could come from as far away as Nyanza Province (500 km) and Coast Province (400 km). Cassava was dried in comparative trials to check for varietal differences in drying characteristics.

Aspects of production and processing

Cassava forms an important subsistence crop in Western, Nyanza, and Coast Provinces. Together, the three provinces produced over 94% of the approximate national production of 210,000 t in 1985. Nyanza Province alone produced about 59%.

Most of the cassava in Kenya is intercropped with maize, sorghum, beans, or bananas. It is mainly consumed in its production area, although some fresh roots and dried products find their way to distant markets within the country. Although over the last decade a few deaths have been associated with cassava consumption, most of the cassava grown in the country have been found to be of the sweet type (Imungi 1986).

Dehydration of cassava results in a highly stable product from a highly perishable commodity. Dehydration also reduces bulk, thereby reducing transportation and storage costs.

Roots for processing were obtained from either DRS or nearby markets and within 6 hours were washed, peeled, and split in half. The halves were left submerged in water overnight. The following morning, the root halves were sliced into 2 mm slices with a Lip's Kitchen Slicer, then the slices were washed with tap water to remove surface starch. After draining, the slices were spread on galvanized wire-bottomed wooden trays in a solar dryer with free air flow. They were dried until they achieved a moisture content of approximately 10%. The dried slices were milled into flour in the semi-commercial hammer mill which is conventionally used for milling maize at the village level.

Parameters used for evaluating the flour production process were the yield, color, blue value index, and the particle size distribution of the flour. There were no significant varietal differences between the flours from DRS-provided cassava and market cassava. Cassava roots from the market, therefore, were used for subsequent trials.

Flour yields averaged 40% from slices and 36% from unpeeled roots. The final flour color was good, while the blue value index indicated a very low percentage of damaged starch granules. The particle size distribution of the flour was more similar to that of maize meal than that of either wheat, millet, or sorghum flours.

The flour was incorporated into *ugali*, millet *uji*, sorghum *uji*, and *mandazis*, each at levels of 0, 10, 20, 30, 40, and 50%. All products were evaluated for color, appearance, taste, and mouth-feel on a seven-point hedonic rating scale using a 12-member laboratory sensory panel. Statistical analyses of the results showed that *mandazis* and *uji* of acceptable quality could be prepared from wheat, millet, and sorghum flours, supplemented with up to 50% cassava flour. Only 20% cassava flour could be tolerated in *ugali*. *Ugali* containing more than this level of cassava flour was considered undesirably sticky. A 1985 study by DFTN showed that cassava flour could substitute for wheat flour up to 15% in oven-baked bread without altering either loaf volume or sensory properties. It can be assumed that the same levels of cassava flour in wheat flour that were acceptable for *mandazis* would be appropriate for *chapatis*.

Cassava flour was stored at 22°, 28° and 33°C in both brown kraft paper bags and 150-gauge plastic bags. These storage temperatures represent conditions in the country's highlands (22°C), lowlands (28°C), and sea coast (33°C). The flours were found to store better in kraft paper bags than in the plastic bags. After six months of storage, however, the flour in both types of packaging did not change appreciably in moisture, color, and sensory properties.

Constraints and Limitations

During fine sunny weather (January-April and August-October), it was possible to dry the cassava slices to about 10% moisture within one day, from approximately 11 a.m. to 4 p.m. However, during the rainy seasons, it was not possible to effectively dry the slices in even two days. This resulted in mold growth on the slices and a darkening in their color. During bad weather, the slices could be dried in an air-oven or in a dryer with forced heated air.

The project was limited in scope because it had to be accomplished within the time frame (12 months) and budgetary allocation (Ksh 1,800 = US$ 600) for M.Sc. projects at UON. The supplementary funding from IFS helped only to finance the drying, not the subsequent operations.

Project Evaluation

Results from the project would be of direct benefit to cereal millers when they begin to implement the composite flour policy. Part of the results of the study already appears as a publication (Imungi and Onyango 1990), while another part of the results has been submitted for publication (Onyango et al. 1991). All the study results, however, have been published as a thesis (Onyango 1991).

The results of the study would also be useful to village-level cassava dryers in western Kenya who, instead of storing dried chunks, would mill and store the flour either in plastic or kraft paper bags. Finally, the Government of Kenya, through the extension service of the Ministry of Agriculture, will find it easier to implement the composite flour policy because the preliminary results of this study indicate that cassava certainly can be used for such purposes.

Future Prospects

To complete the project and therefore make it more meaningful and useful, the following activities will need to be accomplished.

- Conduct a market study to evaluate the acceptability of the composite flour and its products to the Kenyan community.
- Evaluate storage stability of the composite flour in conventional packages and under conditions prevailing in the country.
- Conduct a cost analysis of cassava and composite flours production for commercialization.
- Conduct on-farm drying trials of cassava slices for flour production.
- Educate extension staff on the technology of production of cassava and composite flours to facilitate their extension of the technology to farmers.

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Cassava as an Alternative Raw Material for Weaning Food Manufacture in Nigeria

I. A. Adeyemi and O. L. Oke[1]

Abstract

Weaning foods, commercial and traditional, are manufactured or prepared in Nigeria mainly from cereal grains and legumes, yet cassava is a potential constituent of infant foods. Factors limiting the use of roots and tubers in weaning foods are critically examined in this paper. Prospects for the adaptation of an intermediate process for weaning food manufacture are presented, and the relevance of the intermediate technology to weaning food manufacture from roots and tubers is discussed.

Key words: flour, processing, limiting factors.

Introduction

Cassava (*Manihot esculenta*), often referred to as "tropical staff of life," is the most popular of all root and tuber crops in most African countries (Onayemi 1982). Like other root and tuber food crops, cassava is processed into flours which are prepared into various food gels or consumed as boiled, fried, or as pounded food products (Oke and Adeyemi 1991).

Description of the Problem

Nursing mothers in Nigeria, as in other developing countries, depend on two sources for weaning foods. These are from either commercial or traditional sources with a large percentage relying on traditional weaning foods. Although instant weaning foods which are of high nutritional value are produced in Nigeria by drum drying, extrusion, or spray drying techniques, the cost of such manufactured foods exceeds the means of those who need them (Adeyemi 1988; Adeyemi et al. 1989). Consequently, infants are weaned on starch-based foods such as *ogi* porridge or mashed boiled yam or sweetpotato which is the usual pattern in most developing countries (Jansen 1982). Adult foods contain a higher proportion of fiber and water which also could precipitate malnutrition in infants (Malleshi et al. 1989).

Commercial weaning foods are formulated to meet the nutrient requirements of the infant in terms of energy, protein, vitamins, and minerals. Raw material selection is, therefore, considered from the nutritional point of view. In Nigeria, cereals, especially maize and sorghum, are employed in traditional weaning food preparation while commercial processors mainly use maize. Currently, there is a demand for cereal grains as food and as industrial raw materials. This trend has adversely affected the availability of weaning foods at affordable prices.

In attempting to reduce the incidence of undernutrition among infants, substitutes for cereals in weaning food manufacture need to be found. Such substitutes would include roots and tubers, especially yam, cassava, sweetpotato, and cocoyam. Although the use of root and tuber crops such as potato and cassava in weaning food manufacture has been reported (Kaur and Gupta 1982; Trèche and Massamba 1991; Idowu et al. 1991), their use in Nigeria is not common. Identification of an appropriate technology for weaning food manufacture would go a long way toward finding a

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lasting solution to the problem of infant malnutrition (Adeyemi 1988).

Weaning Food Manufacture from Cassava

Weaning food can be prepared in two forms, ungelatinized and pregelatinized.

Ungelatinized weaning foods. This group of weaning food needs further preparation (cooking) by the nursing mother. Flours from cassava can be used as weaning food depending on whether the cassava mash is fermented or not. Any of the steps or procedures given in Figure 1 could be employed for cassava flour preparation. However, the process of fermentation, which is accompanied by pressing out excess water, assists in the reduction of the level of cyanide in cassava.

Precooked weaning foods. These are classified as instant weaning foods since they do not need any further preparation by the mother except reconstitution, which involves adding warm or hot water. The manufacturing technology for precooked weaning foods includes drum-drying or extrusion cooking. However, steam blanching in a Barlett steamer has been suggested as an intermediate technology feasible in developing countries (Adeyemi et al. 1989).

The Barlett Steamer

The Barlett steamer is a device which generates steam from a built-in gas fired boiler. The steamer contains a chamber within which perforated trays are arranged for easy steam penetration. The trays are above the steam source. The chamber is constructed on a device within which gas paths and drainage are provided. The procedure for the preparation of pregelatinized cassava flour with the Barlett steamer is shown in Figure 2.

Preliminary investigation with cocoyam showed that steam blanching for 15 min significantly reduced the peak viscosity of the flour samples (Fig. 3). The amylograms of the unfortified and soy-fortified cocoyam products indicate that these could be classified as instant products which need addition of warm or hot water without further boiling. It is feasible, therefore, to adopt a similar procedure for the preparation of precooked cassava flour.

Product Fortification

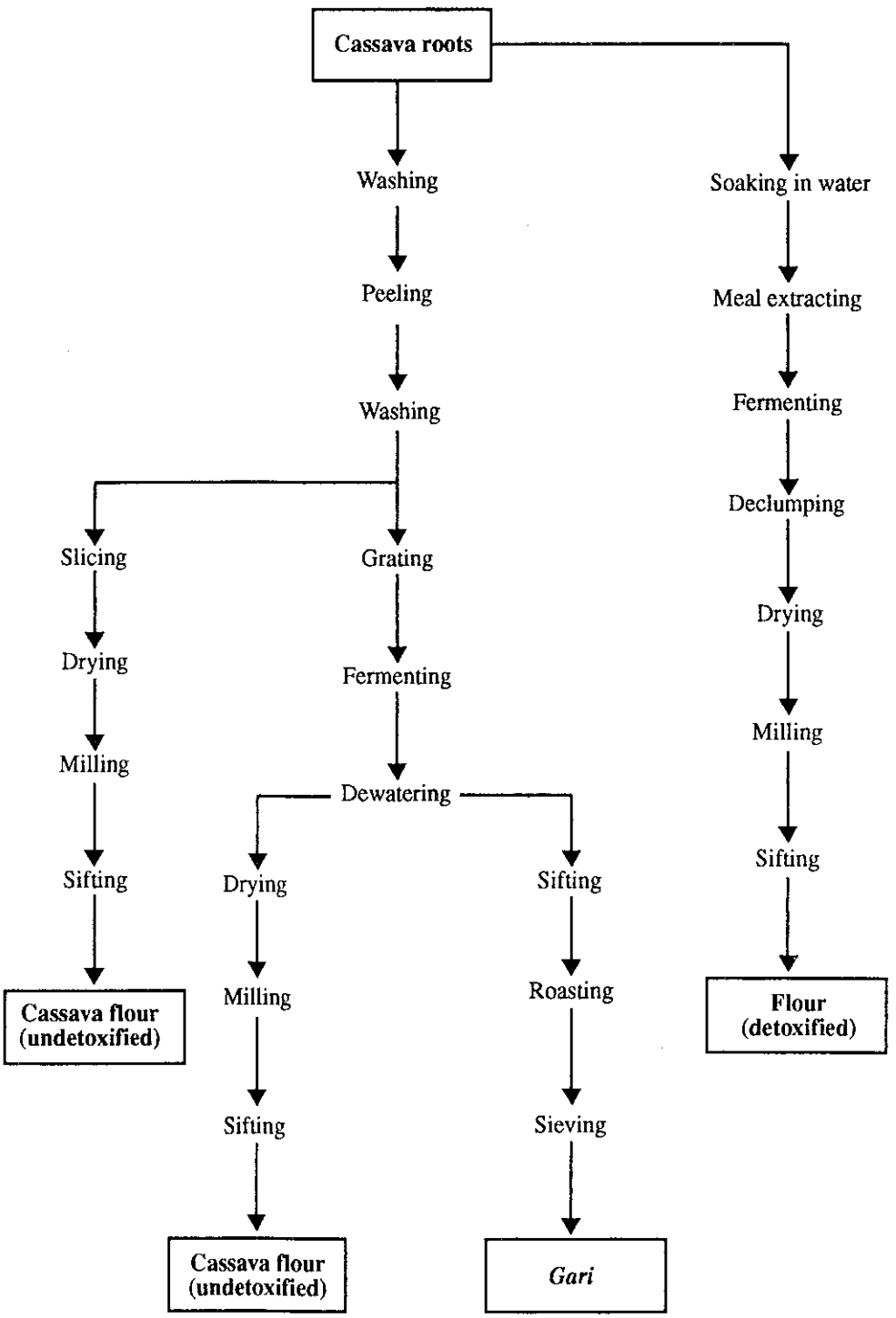
Both the uncooked and precooked products can be fortified with plant or animal protein sources. Furthermore, fruit-flavored products can be prepared not only as a means of improving the vitamin and mineral level, but also to improve the aesthetic value of the products (Adeyemi 1988). The proximate composition of some soy-fortified weaning foods is presented in Table 1.

Table 1. Proximate composition of flavored and soy-fortified cocoyan flour and some maize-based weaning foods.

Product	Moisture %	Protein %	Fat %	Ash %	(CHO %) by difference
Cocoyan-based[a]	11.86	13.64	7.51	3.68	63.31
Maize-soy mix[b]	10.97	14.50	13.10	1.68	70.72
Maize-banana-soy mix[c]	8.74	22.81	5.15	1.51	60.51
Maize-sweetpotato mix[d]	5.32	14.26	6.41	2.39	67.36
Nutrend[e]	4.62	15.98	3.06	2.95	73.59

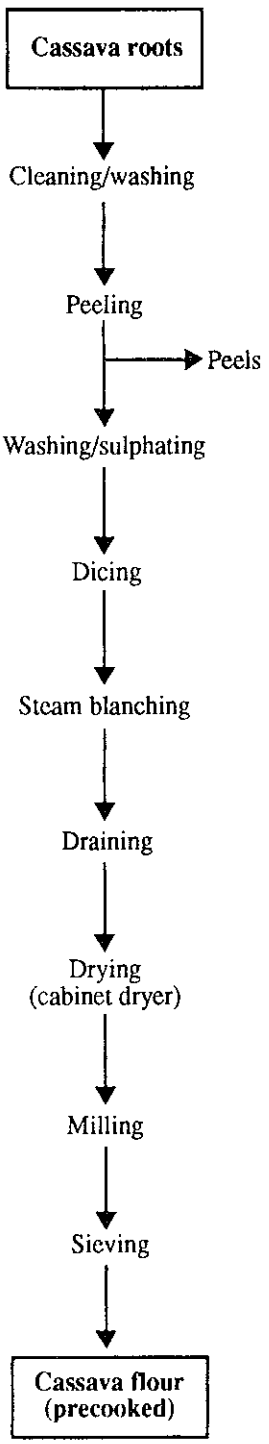
[a]A mix of pregelled cocoyam flour (55%) and whole soy flour (15%).
[b]Weaning foor prepared by blending steam blanched maize flour (70%) with whole soy flour at (30%) (Adeyemi et al. 1989).
[c]Drum-dried product of maize-banana-whole soy flour slurry blended at 7:1:2 (Adeyemi et al. 1991).
[d]Weaning food prepared by blending steam blanched maize and potato flours with soybean and groundnut flours at 4:10:5:1.
[e]A commercial weaning food in Nigeria prepared from a mixture of maize and soybeans.

Figure 1. Flow chart for cassava flour preparation.



Source: Chinsman 1982.

Figure 2. Flow chart for the preparation of precooked cassava flour.



Limiting Factors in Cassava

While cassava is a feasible alternative to cereals as an energy source in weaning foods, some of the factors limiting its use are the following:

High moisture content. Cassava is high in moisture (50-80%) with a dry matter content of between 7% and 40%. The high moisture content affects its keeping quality and material yield. However, if steam blanching is used to prepare an instant weaning food, high moisture content is desirable because this eliminates the steeping required for cereal grains.

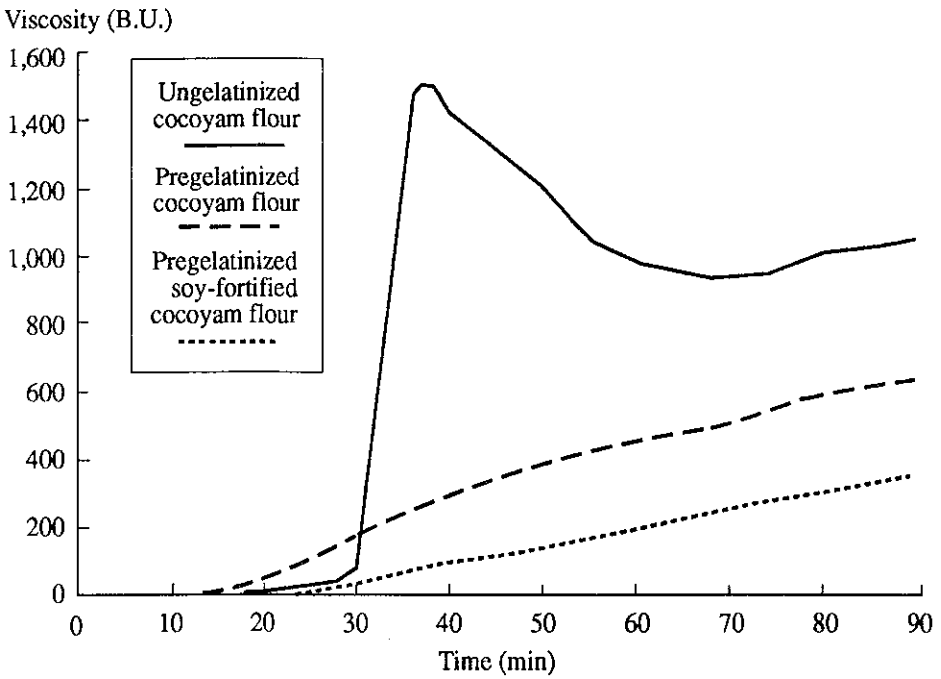
Toxic constituents. Cassava contains cyanogenic glycosides in the form of linamarin and to a lesser extent lotaustralin. The cyanogenic glycosides produce hydrocyanic acid (HCN) when the action of an endogenous enzyme, linamarase, is initiated by crushing or otherwise damaging the cellular structure of the plant (Tinay et al. 1984). Using cassava roots for both human and animal nutrition appears to be limited by the presence of these cyanogenic glucosides which could be eliminated during processing (Tinay et al. 1984; Arihantana and Buckle 1978). However, the extent of reduction or losses would depend on the processing technique. There is a need to carry out toxicological studies on weaning foods from cassava manufactured by different processes. Furthermore, studies should be conducted to evaluate the use of cyanide-free cassava as a constituent of weaning foods.

Drying characteristics. Cooked root or tuber dices have a very dense structure resulting from partial or complete gelatinization of the starch granules. As a consequence the material dries very slowly at an enormous energy cost (Ngoddy and Onuoha 1985).

Nutritional quality. Cassava is an excellent source of digestible carbohydrates and therefore energy, but a poor source of protein. In using cassava flour for weaning foods, fortification with a protein source, vitamins, and minerals would be desirable. This should be complemented with extensive nutritional studies on such weaning foods.

Choice of technology. One of the advantages of a steam blancher (i.e., Barlett steamer) is its feasibility for use in a rural setting (Adeyemi et al. 1989). However, it is necessary to carry out an analysis on the comparative cost advantage of using this process in producing pregelatinized cassava flour over other techniques such as drum drying.

Figure 3. Amylograph pasting viscosity of cocoyam flour samples.



Source: Banigo et al. 1974.

Conclusion

The major constraint in the manufacture of an instant weaning food, especially in developing countries, is the low rate of commercialization of conventional technologies such as drum drying or extrusion cooking, due to capitalization cost which eventually results in a cost of such manufactured foods exceeding the means of most nursing mothers (Milner 1969; Gupte 1972). Therefore, the use of intermediate technologies to develop instant and nutritious weaning foods has been suggested (Gupte 1972). It is feasible, therefore, to design an integrated intermediate process for weaning food manufacture using cassava as one of the basic raw materials to complement or reduce the demand on cereal grains.

Furthermore, there would be a need to characterize cassava-based weaning foods from organoleptic, biochemical, nutritional and rheological parameters. In addition, storage stability, based on packaging materials and storage conditions, should be evaluated to establish the performance of the product under market conditions.

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Introduction of *Gari* Making in Burundi

M. Beavogui[1]

Abstract

Burundi produces 650,000 t of cassava annually, with the postharvest loss rate estimated at over 30%. All cassava by-products (flour of *inyange, ikiynde, or muswage* cake) take a minimum of 15 days to process from fresh cassava. Moreover, these by-products can be preserved for only a month. To reduce losses, peasants leave cassava roots in the ground. Not only do losses still occur; but, in such an over-populated country (average of 400 persons per ha), every piece of soil is needed and farm lands are used extensively every year. It was therefore suggested to introduce *gari*-making into the country because it can be produced in only 3-5 days and can be preserved for a year or more. The project has used demonstration units built and supported locally as a method to promote specific products in surrounding rural areas. The equipment designed are a grater, a press, a roasting oven, and a mill. After two years, there are eight private *gari*-making units which each produce 500 kg of *gari* from 2 t of cassava weekly. Many other private concerns are in the process of installing new units.

Key words: processing, cassava, *gari*.

Introduction

In 1987, a United Nations Development Program (UNDP)/Food and Agriculture Organization (FAO) project, Promotion of Artisanal Food Processing Technologies, was begun in Burundi. The general long-term objective of the project was to contribute to the value-added of staple food production for the benefit of farmers. The main reason for establishing such a project was the understanding that one of the most important ways to increase agricultural production is to improve postharvest activities, i.e., processing, storage, and utilization. Moreover, the Government of Burundi considers improving food processing to be an activity with a direct impact on food self-sufficiency.

The short-term objectives to be reached were to:

- identify and adapt suitable food processing technologies for local agricultural products;
- identify and adapt corresponding equipment;
- assist associations or individual entrepreneurs to acquire the technologies and corresponding equipment; and,
- assist in the popularization of proven technologies.

The objective of this paper is to share the experience of project activities related to work on cassava processing. Of most interest is that the project introduced a cassava by-product, *gari*, which was entirely unknown in Burundi. Within one and a half years, *gari* was sold for consumption in rural areas and towns more or less under the conditions of a free market economy. How did it happen? This paper answers that question.

Why *Gari*?

Cassava is, after beans, the main staple food in Burundi. Total national production in 1988 was estimated at 600,000 t. The cassava grown is mainly the bitter variety which is mostly consumed in the form of flour or cake. These are obtained after a lengthy process of dry or humid fermentation. Unfortunately, various problems

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associated with processing and preservation lead to a postharvest loss of over 30%.

All cassava by-products in Burundi require 12-15 days for processing from harvest to finished product, and these cannot be preserved for more than 15 days. As a consequence, the cassava roots are left in the soil for preservation. This solution extends the occupation of land which could better be used to plant other much needed crops. Cassava left in the soil also leads to a high rate of pulp destruction.

To overcome the above-mentioned constraints, introduction of a cassava by-product, on an experimental basis, was suggested. The selected by-product was *gari*, a fermented pregelatinized and dehydrated product. It is consumed by millions of West Africans, but was unknown in Burundi. The production process takes only 3-5 days, and *gari* can be preserved for more than a year. Another advantage in the present case is that the taste of *gari* is not too different from *ignange*, a product made from local cassava flour.

Technology Selection

In order to proceed with the experimental production of *gari*, training of pilot farmers, and product promotion, the project installed two experimental centers. The equipment—a mechanical grinder, screw press, and roasting unit—were designed, adapted, and locally manufactured by the project. Two groups of pilot farmers were organized to run the two centers.

To produce *gari*, harvested cassava is peeled and ground on the same day. The ground cassava is then bagged and left to ferment. On the third day it is collected and pressed with a screw press. The cake resulting from the pressing process is disintegrated by hand and then roasted. The dry and pregelatinized semolina obtained from the process is called *gari*.

The six-month experiment conducted at the two centers enabled the project to obtain technical and economical data on *gari* production under prevailing local conditions.

Promotion

The introduction of any new product under the conditions of a country like Burundi requires—among other specific actions—the selection and promotion of entrepreneurs, training, marketing support, and follow-up.

Entrepreneur Selection

The project faced the problem of a lack of entrepreneurship in the farming sector. It was therefore necessary to promote *gari* production. In the prevailing conditions of Burundi, such entrepreneurs could either be associations or individuals. Farmers, artisans, pilot farmers, and active individuals were invited to visit the centers, to work there if they wished and to discuss all the aspects of the process with the project staff. Non-government Organizations (NGO) and development project staffs working in the area were also invited to visit the centers and participate in the experiment.

After the establishment of techno-economic data and having observed concrete results in the experimental centers, farmers and other individuals came to ask for assistance in order to acquire the same type of units. At that stage, the two experimental units were left on a loan basis to newly formed associations of pilot farmers.

Training

Training in processing, management, and maintenance was given in the experimental centers. The project started by training pilot groups who themselves became trainers. Such an approach enabled more effective communication and reduced the cost of the program. Sessions were organized in coordination with local NGO's and development projects to facilitate their future activities in project promotion. Booklets describing the technological process, management of the units, and equipment maintenance were produced in both French and Kirundi for easy reference.

Marketing

For *gari*, messages were developed to convince the producer of the relatively short processing time required and long preservation time; and consumers, particularly women, of the easy and numerous ways *gari* could be processed into ready food. The project created a series of eight recipes for popularization, produced posters, and assisted in the establishment of selling points. A radio advertisement was also launched.

Financing

One of the major problem faced by any entrepreneur in the sector is the lack of an adequate financing system. The majority of existing financial institutions prefer to

work through short-term credit, high-interest rates, and strong guarantees. The established conditions for gaining access to these resources are so drastic that a common individual can hardly get through them. At the government level, various investment laws do not favor small rural production units. It is therefore natural that the business of "import and sell" remains the easiest and most profitable.

For all these reasons and in order to help entrepreneurs in the food processing sector, the project launched a study which led to the establishment of an entirely new financing system. It was designed to work in close cooperation with the *Banque Nationale pour le Développement Economique*, and the *Coopérative d'Épargne et du Crédit*. Loans were given by the two financing institutions as usual, but with the advantage that the lacking portion of the required guaranty was supported by a fund called *Fond de Développement des Technologies Alimentaires* (FDTA). The system is being developed in such a way that it will become completely independent from the project and the government and will be self-sustaining in the future.

Conclusion

The experience described in this paper shows how difficult it is to promote entrepreneurs, particularly in the food processing sector. However, agriculture remains the area with the most potential in Africa. Also, the majority of the population lives in rural areas and devotes itself to agriculture. For any economic development program to be efficient, it must be harmonious with the rural sector. That is why the promotion of rural enterprises should be a priority.

This project reconfirmed that enterprise development needs an appropriate environment with adequate inputs, i.e., technology, equipment, financing, marketing, fiscal policy, etc. The experience has also shown that to achieve any result, it is necessary to create an institutional framework to promote activities in the sector. Rationally established on the basis of minimum needs, it will be most helpful for the promotion of rural food industries and therefore contribute to the economic development of the country.

Processed Sweetpotato: Responding to Kenya's Urban Food Needs[1]

Njeri Gakonyo[2]

Abstract

Sweetpotato is thought to have considerable unrealized potential as a food commodity capable of improving the diets of Kenya's rapidly growing urban poor. Key factors in realizing this potential concern the tastes and preferences of consumers for different types of processed sweetpotato products and the economic feasibility of rural processing. This paper examines these issues in closer detail by reviewing the results of a rural consumer survey to evaluate the acceptability of fresh roots, sweetpotato chips, a mash made from sweetpotato flakes, and sweetpotato flour in bread and *ugali* (a kind of stiff porridge widely consumed in Kenya). Sweetpotato flour was found promising from a gastronomic perspective. Furthermore, costs of production estimates indicate such a product is profitable to produce using currently available, rustic technology.

Key words: preferences, bread, flour, costs, returns.

Introduction

Kenya's Emerging Food/Population Dilemma

Kenya's legendary population growth rates which peaked at about 4.1% in the mid 1980s, threaten to erode the gains in food production achieved during the 1960s and 1970s. Population increased from about 9 million in 1963, when the country achieved independence, to 25.8 million in 1992 (FAO 1993). This phenomenon is a result of mortality rates which have fallen faster than fertility rates. Major improvements in health and sanitation helped to reduce crude death rates to the 1992 level of 9 per thousand from about 17.5 in the late 1960s. Yet attitudes towards family size remained largely unchanged even though more children were surviving to maturity.

Even were the country to immediately lower fertility rates to replacement level, the burden of feeding those already born is enormous. Most alarming are the United Nations' projections whose estimates for the year 2025 range from 62 to 84 million depending on the speed at which birth rates fall (United Nations 1991). The food production gains of the early period were primarily achieved through increased acreage under cultivation, adoption of high-yielding hybrid maize varieties, and greater use of fertilizers. During the 1980s, however, it appears that food production barely managed to keep up with the number of people to be fed. All

[1] This paper summarizes the findings of a thesis submitted to the Department of Agricultural Economics, Cornell University, in partial fulfillment of the requirements for the MSc degree, August 1993. The research on which it is based was carried out in Kenya during June-August 1992 and was made possible by generous grants from the Cornell International Institute for Food, Agriculture and Development, The First Presbyterian Church, The Institute for African Development, the International Potato Center (CIP), and the Mario Einaudi Center for International Studies. I wish to acknowledge the contributions of Dr. Peter Ewell, CIP, Nairobi; Dr. Jackson Kabira and Mary Anyango, National Potato Research Centre, and, Professor E. Karuri, Department of Food Science and Technology at the University of Nairobi. At Cornell, my work was guided by Professor Thomas Poleman and Professor Ralph Christy. Lillian Thomas' help with the manuscript was invaluable.

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indications are that the food situation is likely to worsen before it improves.

Limited Agricultural Resources

To compound matters, the country's meager agricultural resources preclude any great expansion of cultivation to bridge the gap between needs and availabilities. Only one fifth of the total area is suitable for cultivation, concentrated in the western and central regions where rainfall and elevation are greatest (Map 1). Population density patterns closely follow the geographical distribution of fertile and well-watered land (Map 2). As a result, per capita availability of arable land in these areas is extremely low at about 1/4 hectare per person, and will fall even further (Lele & Stone 1989). Problems associated with the intensive cultivation in the fertile regions include soil erosion and deforestation.

Overdependence on Maize

Kenya's precarious food supply situation is worsened by the country's heavy dependence on maize as a starchy staple. On average, the grain provides almost half the caloric intake for the population; the percentage may increase to 70% for some low-income groups. About 90% of all smallholders cultivate maize mainly for home consumption but also for the market (de Wilde 1984). With so much of the country's nutrition relying on this grain, a poor or failed crop means privation for many. Furthermore, maize is especially vulnerable to rainfall variations as evident in the wide production swings during the 1980s. For instance, the 1984 drought resulted in a 40% drop in maize production which necessitated imports amounting to 565,000 t (Lofchie 1989). Clearly, it is undesirable that the country remain vulnerable to food shortages in this manner.

The Plight of the Urban Poor

The rapidly growing numbers of the urban poor bear the brunt of the food supply problem because adequate nutrition depends on a marketed surplus from the rural areas. At 7.9% per annum, urban population growth is almost twice that of the overall population (World Bank 1992) (Fig. 1). Moreover, United Nations projections suggest that Kenya will continue to urbanize very rapidly: by 2025 it is expected that over 40 million Kenyans will reside in urban areas, representing more than half of the total population (United Nations 1991a). The bleak employment situation in the towns also means that most people living in the urban areas are poor. "Formal" sector jobs (for example in manufacturing) are few and, at about 3.4% per year, are increasing too slowly to absorb the growth in the labor force. Even at this seemingly strong rate of job creation, unemployment may well increase from about 13% in 1991 to above 20% by the year 2000 when the economically active population will number 14 million (EIU 1991).

Consequently, most of the urban population has to resort to low-wage or part-time employment. Opportunities in the informal sector, while significant, are nevertheless insufficient to provide adequate incomes for all who need them. Yet, wage and price trends for the five years ending in 1989 suggest that real incomes stagnated for salaried workers while lower income groups experienced a deterioration in their standard of living. In that same period, retail prices rose steadily by over 60% (Ibid.). As a result, food expenditures can command an appreciable proportion of the family's income. One household survey conducted in the latter half of the 1970s reported an average food bill of over 40% of income in the towns (Central Bureau of Statistics 1981). Although more recent figures are difficult to obtain, it is almost certain that the situation has not improved for the average person in the urban areas. In addition, government policies to reduce consumer subsidies on food items have meant rising food bills. Evidently, the demand for food resulting from rapid urban population growth is really demand for **cheap** food and is likely to increase all the more in the future.

Sweetpotato's Potential

Agronomic Appeal of Sweetpotato

Sweetpotato is an ideal candidate for cultivation under the conditions prevailing in the densely populated fertile areas of western Kenya. The root's yields in Kenya are higher than those of maize and potatoes when compared in terms of calories produced per acre (FAO 1993):

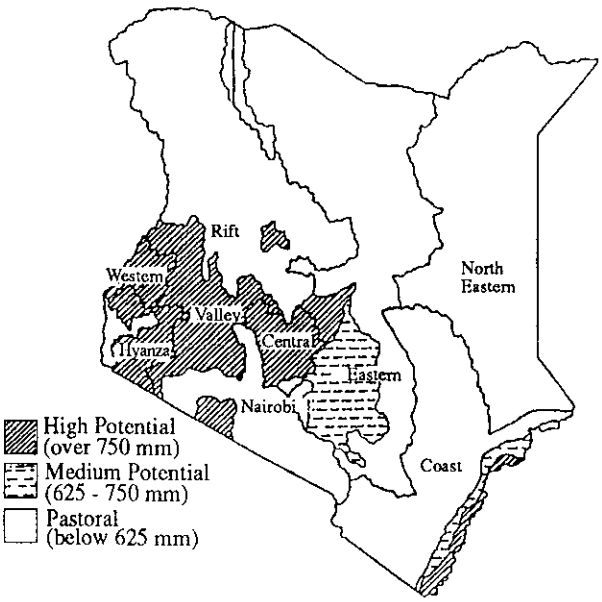
Table 1. Average yields (million calories/ha) in Kenya, 1981-91.

Sweetpotatoes	4.5
Maize	2.5
Potatoes	1.7

Source: FAO, Agrostal PC Database 1993.

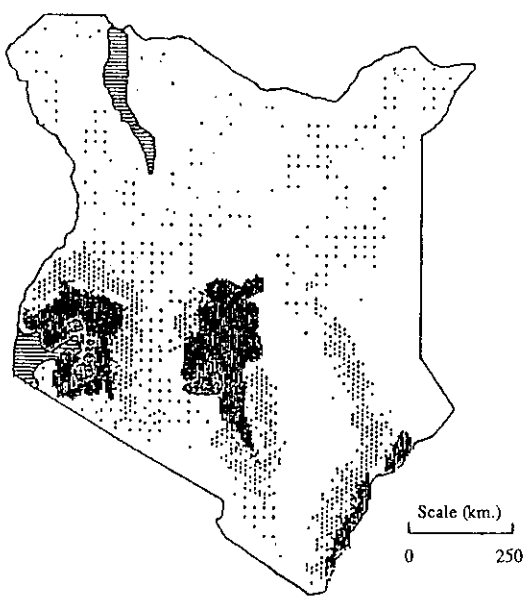
It is notable that these yields are achieved without the aid of fertilizers. Sweetpotato also exhibits drought-resistant qualities which enable cultivation when rainfall is less than ideal. Indeed, dry weather is desirable

Map 1. Kenya: Land potential by province.



Source: Jansen, Horelli and Quinn 1987.

Map 2. Kenya: Population distribution (1979 Census).[a]



Source: Kabogo 1986.
[a] Each dot represents 1,500 persons.

during root development because it promotes the storage of starch and thus helps to increase yields (Kays 1985). Accordingly, farmers in western Kenya always reserve space for sweetpotato in the event of inadequate rainfall and for the "hungry" periods when other foods are in short supply (Gor 1989). Planting is often calculated so that harvesting takes place during the periods when other crops are still immature or when granaries are empty (Fig. 2). This pattern also suggests that sweetpotato does not compete with maize for labor. Clearly, sweetpotato's role is that of a famine reserve food.

In warm and wet climates, sweetpotato can be grown all year round and piecemeal harvesting allows a constant supply of food. The crop is also an attractive choice for resource-poor farmers because propagation is vegetative. This means that seed storage or purchases are unnecessary. Planting material is obtained for free from the previous season's harvest or from neighbors and friends. In contrast, crops like hybrid maize require fresh purchased seed every year in order to maintain yield levels. Even when the farmer does not apply fertilizer and forgoes the use of pest control chemicals, sweetpotato produces respectable yields. Because the crop's roots penetrate deep into the soil, it can make use of residual fertilizer from previous crops. It also establishes a ground cover fast enough — within 4-6 weeks — to compete effectively with weeds. Usually, only one or two weedings are necessary. This same ground cover helps to prevent soil erosion (a common problem in the hilly fertile parts of the country). Problems with insect and fungal pests are few and do not result in significant yield losses (moles and weevils are notable exceptions) (Woolfe 1992). This eliminates two more major farming expenses.

For rural consumers sweetpotato is a cheap source of food energy. Given the low—perhaps even zero—**monetary** costs of growing the roots, consumers in local markets can obtain sweetpotato at much lower prices than other foods. In nutritional terms, sweetpotato is an excellent source of vitamin A, especially in the more orange varieties, while quantities of vitamin C are also substantial. However, as with other roots and tubers, it is not a satisfactory source of protein and must be supplemented with foods having higher amino acid content such as legumes. (Alternatively, the roots may be combined with the leaves of the plant which are a much better source of protein). Nevertheless, sweetpotato compares well with other foods in overall nutritional value.

Some Shortcomings

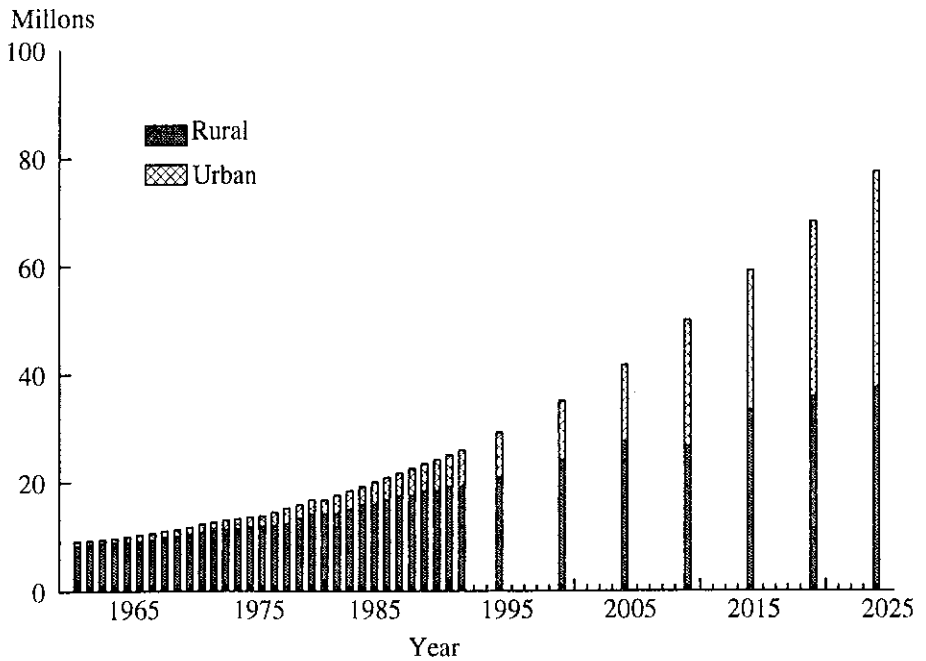
Despite the clear potential of sweetpotato in helping to meet Kenya's food needs, there are important constraints which prevent its full exploitation in urban areas. Because of its bulkiness and perishability, sweetpotato is an expensive and difficult commodity to transport. For the farmer, these features are also a disadvantage because the root is of low unit value. This may help to explain why, even in Nyanza and Western Provinces where production is highest, most farmers only plant sweetpotato on a very small portion of their plots. The greater part of the farm is reserved for more lucrative crops such as tea, coffee and maize. The latter are able to command a high price because they are much more amenable to movement over long distances and do not suffer from serious perishability problems.

At the other end of the marketing chain, sweetpotato faces problems of low consumer acceptability. Even though it compares favorably with other starchy staples in terms of nutritive value, it is still only used as a form of famine insurance and ranks low on the consumer's preference scale. Also, consumers perceive sweetpotato as a snack—not as a food which could constitute the main part of a family's diet. This perception is a substantial barrier to increased consumption. These low consumption patterns are partly responsible for sweetpotato's failure to become a more important food crop in Kenya.

Processing as the Solution

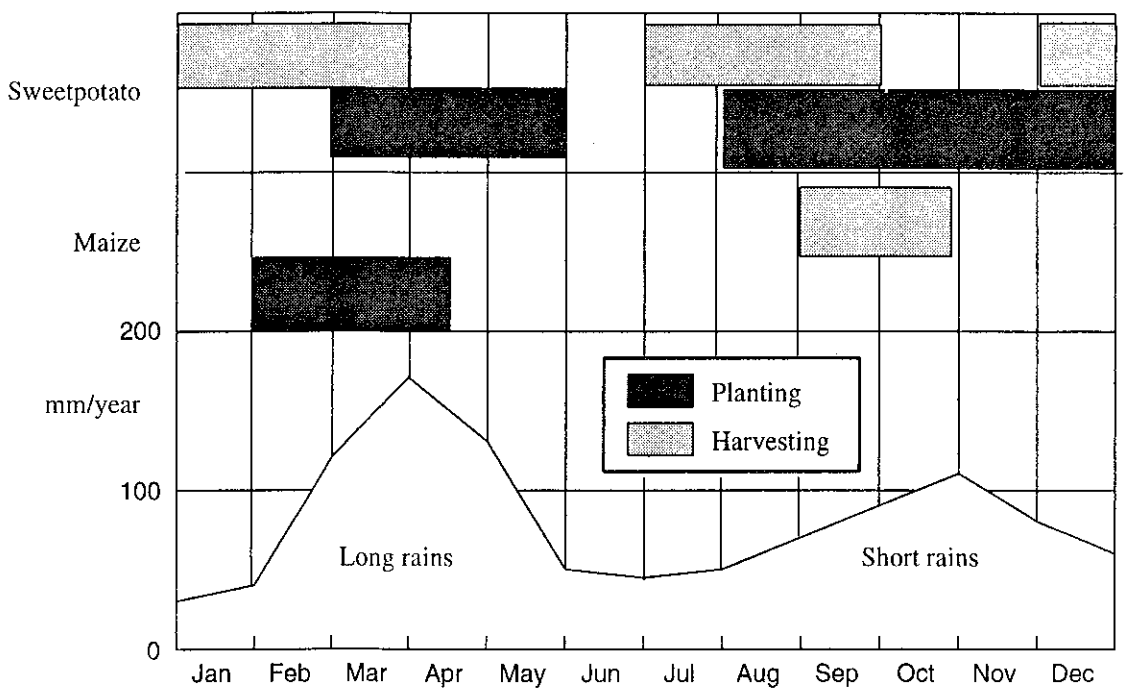
In order to overcome some of these marketing problems, sweetpotato could be modified to achieve greater storability, higher unit value, and increased consumer acceptance. As Bouwkamp (1985) notes, "... many staple crops are rarely consumed directly in the form in which they are produced. The importance of corn, wheat, and soybeans in the agricultural economies of temperate zone countries is related in part to the versatility in their utilization." Transforming sweetpotato could remove much of the moisture in order to extend its shelf life and to facilitate transportation. For the grower, processing could allow greater sales and profits due to the value added in the processed product. Moreover, the food energy cost of the processed product to consumers is likely to be lower than that of the root. In this manner, the crop can have greater appeal to producers, marketers and urban consumers in Kenya.

Figure 1. Population growth in Kenya. 1961-92, with projections to 2025.



Source: FAO 1993 & United Nations 1991a.

Figure 2. Agricultural calendar in Western Kenya.



Source: Adapted from Sands 1983.

Acceptability of Processed Sweetpotato

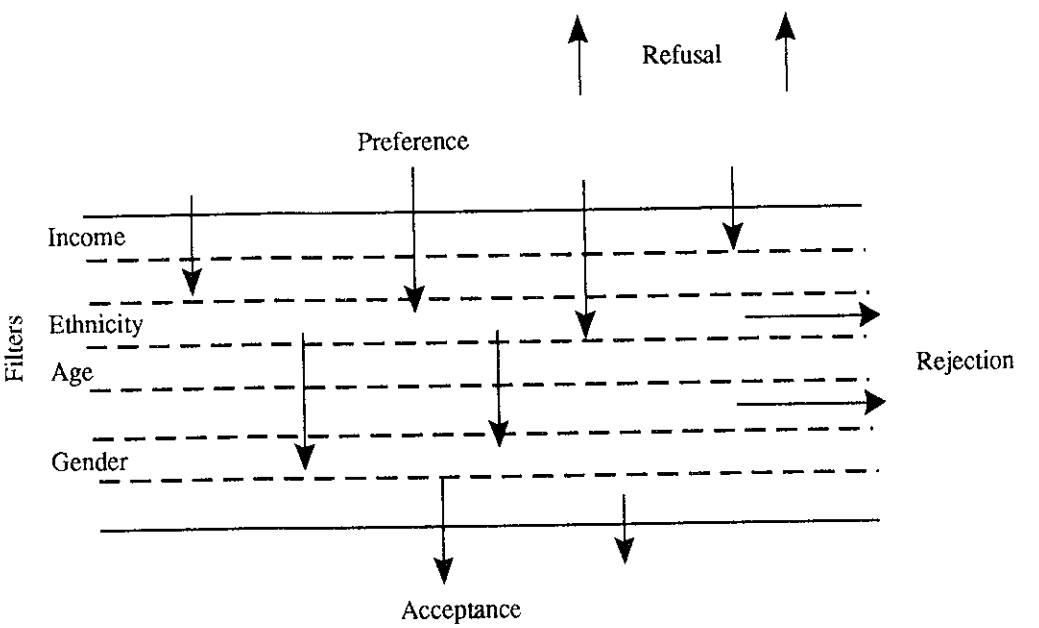
Survey Methodology

In order to estimate the potential of a new product, food marketers often elicit consumers' overall feeling or attitude towards the food. A key tool in determining this acceptability is the notion of food preference. Defined as the degree of like or dislike for a food, preferences play an instrumental role in the evolution of dietary patterns for the individual or the family. Obviously, unless extenuating circumstances exist, people will not purchase and consume a food which they do not like. For the food industry, then, preferences become a crucial indicator of potential markets and possible sales trends for products over time.

D. Elizabeth Randall's conceptualization of the individual's acceptability process is an appropriate tool for analyzing the preferences of Kenyan urban consumers towards processed sweetpotato products (Fig. 3). Randall envisions an initial purely sensory reaction which determines preference or refusal. According to the model, a refused food will not be consumed unless circumstances dictate otherwise. If preferred, the food is subjected to further evaluation according to the individual's socio-economic status, attributes of the food and environmental factors. These factors known as filters, may include income level, method of preparation for the food, and season of the year. If the food fails to permeate this filtering process, it is rejected. Otherwise the food goes on to become acceptable and will be consumed unless it is unavailable. Indeed, acceptability is considered a reliable predictor of consumption for measurement purposes. This model was deemed appropriate for the study because it allows us to separate out the important factors which determine whether or not a product receives a favorable response from consumers. The marketer can then target those populations with the greatest inclination to purchase and consume the product.

The hedonic category scaling technique allows detection of a person's instinctive response to a food. Panelists were also requested to make paired comparisons in order to determine preferences between samples. The study was conducted in Kisumu and Nakuru towns between May and August 1992. The rationale for choosing the two towns was to capture the effect of ethnicity: Luos are the predominant ethnic group in Kisumu, while Nakuru residents are largely Kikuyu. Panelist groups were drawn from neither the wealthiest nor the poorest sections of society. In each town, 30 each of children and adult men and 60 adult women were interviewed. There was no great emphasis on randomization—any cooperation received was accepted. The

Figure 3. Randall food acceptability model.



Source: D. Elizabeth Randall, personal communication.

filters chosen for the study were ethnicity, income, age, gender and education and the frequency of consumption of sweetpotatoes.

The food samples used were forms of processed sweetpotato believed to have substantial promise in terms of production and distribution. Previous studies by researchers at the National Potato Research Centre had identified these products for further evaluation (fieldnotes). Samples of sweetpotato chips (crisps), a mash made from sweetpotato flakes, 15% sweetpotato flour in both bread and ugali (a kind of stiff porridge widely consumed in Kenya) were tasted. For the latter two food samples, their conventional counterparts —all-wheat bread and all-maizemeal *ugali*—were used to compare acceptability. If the panelists were at least indifferent between the two pairs of foods, this was considered an indication that the processed forms could find markets among these consumers. White and yellow varieties of fresh sweetpotato roots were also included as controls. The panelists were asked to taste the food samples and give their preference rating on a 5-point category scale in the following manner: "Do you like the [name of the food sample]?"

1	2	3	4	5
No, not at all	Not very much	I cannot decide	Yes, a little	Yes very much

After tasting all the foods, panelists indicated the most and the least liked sample.

Survey Findings: The Preference Hierarchy

The results of the taste test surveys are encouraging in terms of the acceptability of processed sweetpotato in urban markets in western Kenya. The broad findings are presented in Figure 4. Each chart presents the cumulative proportion of responses that fell in each category. Thus, for the white sweetpotatoes, less than 10% of the panelists indicated categories 1, 2, and 3; about 20% chose number 4 and the rest awarded the roots the maximum score of 5. Clearly, the roots and the crisps were the most acceptable forms of sweetpotato as shown by the large shaded areas reaching the 4 and 5 level. The *ugali* made from composite flour made a significantly favorable impression, almost identical to that of the 100% maizemeal control. Some panelists could detect the sample's slightly sweet taste; it was mentioned that the *ugali* would probably be more acceptable if the sweetness was suppressed.

The picture is quite different for the sweetpotato bread which fared poorly compared to the all-wheat bread. However, these results must be viewed in light of the fact that the sample tended to lose freshness rather rapidly. Thus, it is probable that in more optimum conditions the average score would be higher.

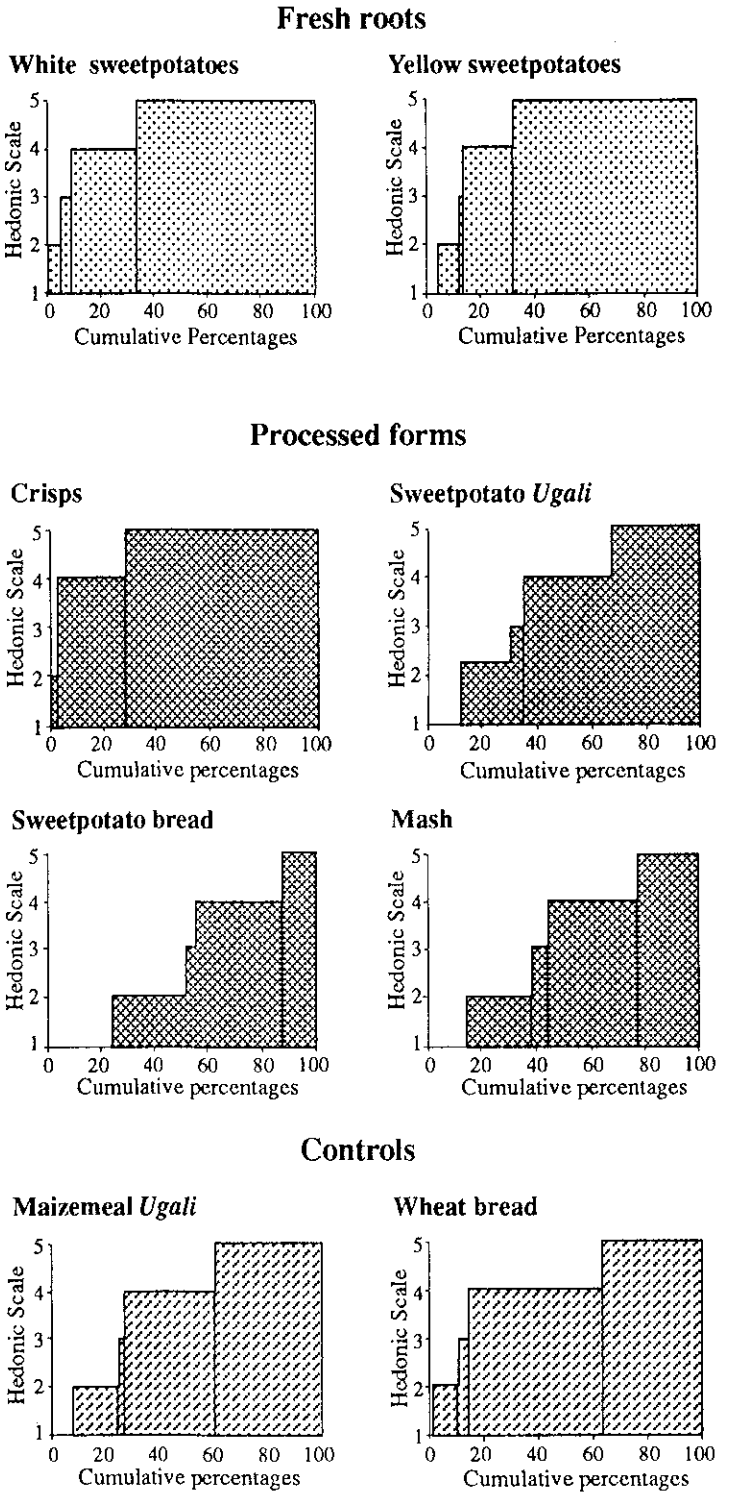
For the mash, acceptability was about evenly divided between the like and dislike categories. This food was most often mentioned as the least liked sample and had the lowest mean score for the whole survey. Given the almost complete lack of taste for this food, it was even surprising that some people responded positively towards it. Although the mash **smelled** of genuine sweetpotato, it had no corresponding flavor. This tended to create expectations about the taste of the mash which were not met. Somehow the flavor of the root is lost during processing.

Survey Findings: Operation of Socio-Economic Filters

Analysis of variance methods were used to draw out the effects of the filters thought to influence acceptance. This statistical tool (analogous to regression) uses the hedonic scores to determine the contribution of each filter to the final score and whether this result is statistically significant or not. Both single (main effect) and multiple filter (interaction) approaches were used. One important result of this analysis is that the filters were highly food-specific. For instance, some samples showed several significant filter effects while others had few or none at all. Moreover, a filter whose effect was statistically significant for one sample, may have made no perceptible difference for another. A word of caution: analytical results that indicate statistical significance do not necessarily also imply logical significance. Thus, it was difficult to find clear reasoning behind some of the patterns observed.

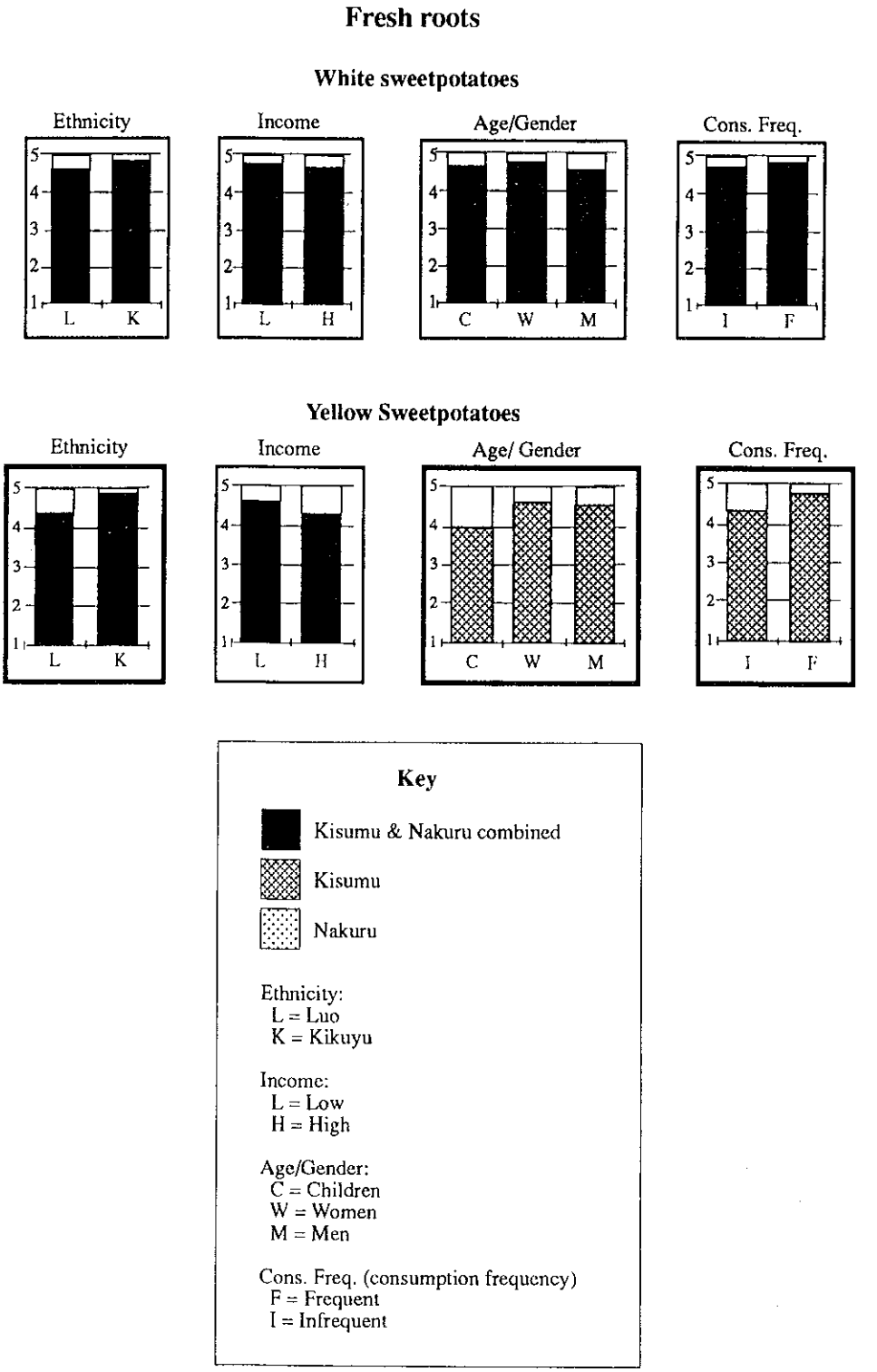
Figures 5-7 show the results of the analysis of variance by food sample. All the statistically significant results and some insignificant ones are presented (significance is indicated by the thickness of the box surrounding each chart). Thus, for the white sweetpotatoes there were no important filter effects as shown by the thin boxes (Fig. 5). Each bar in a box shows the mean hedonic score for the group named at the bottom of the bar. The bars are calibrated according to the category

Figure 4. Preference survey: Distribution of hedonic scores.



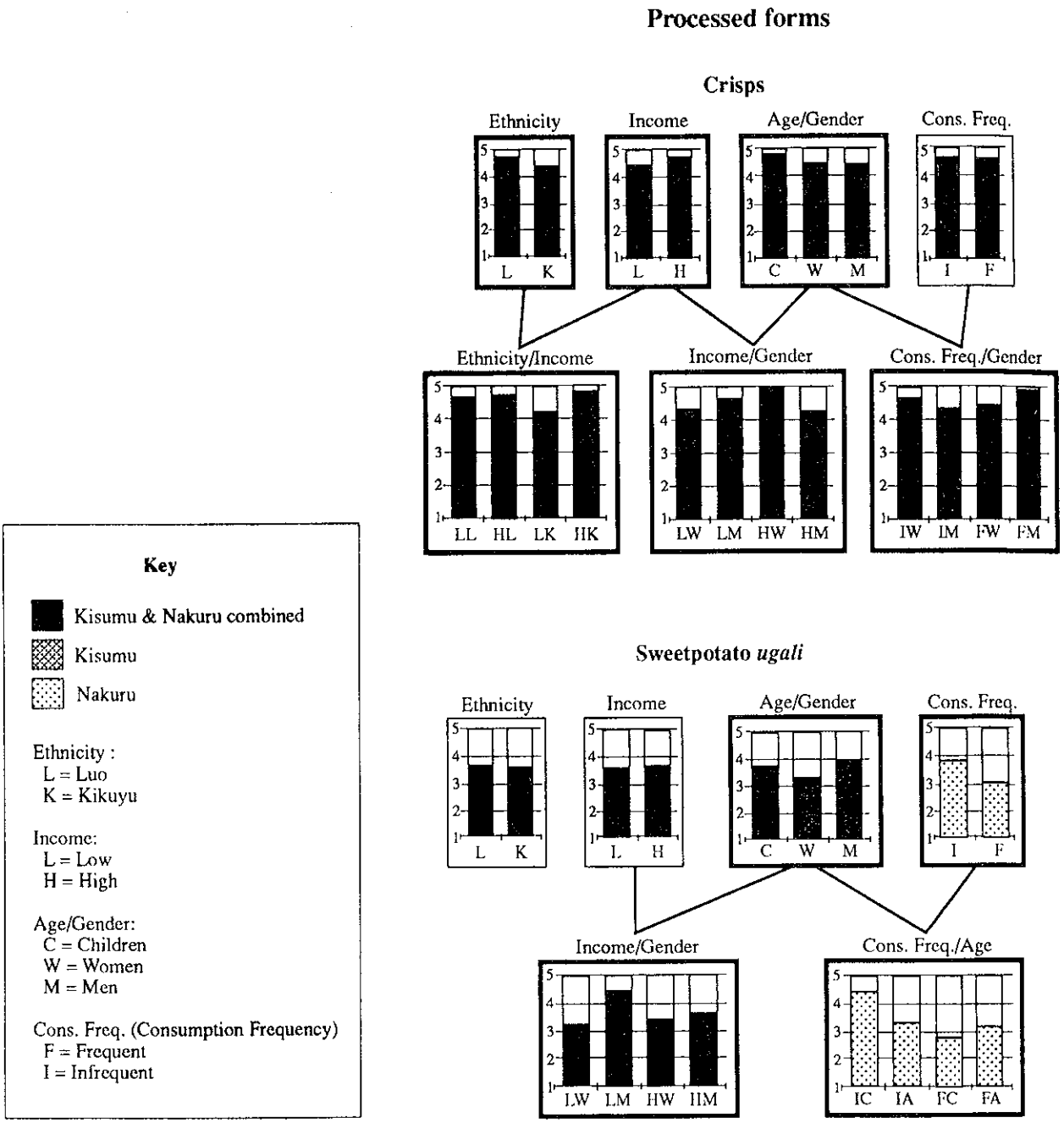
Source: Preference survey 1992.

Figure 5. Consumer preferences survey for fresh roots: Impact of socio-economic filters.



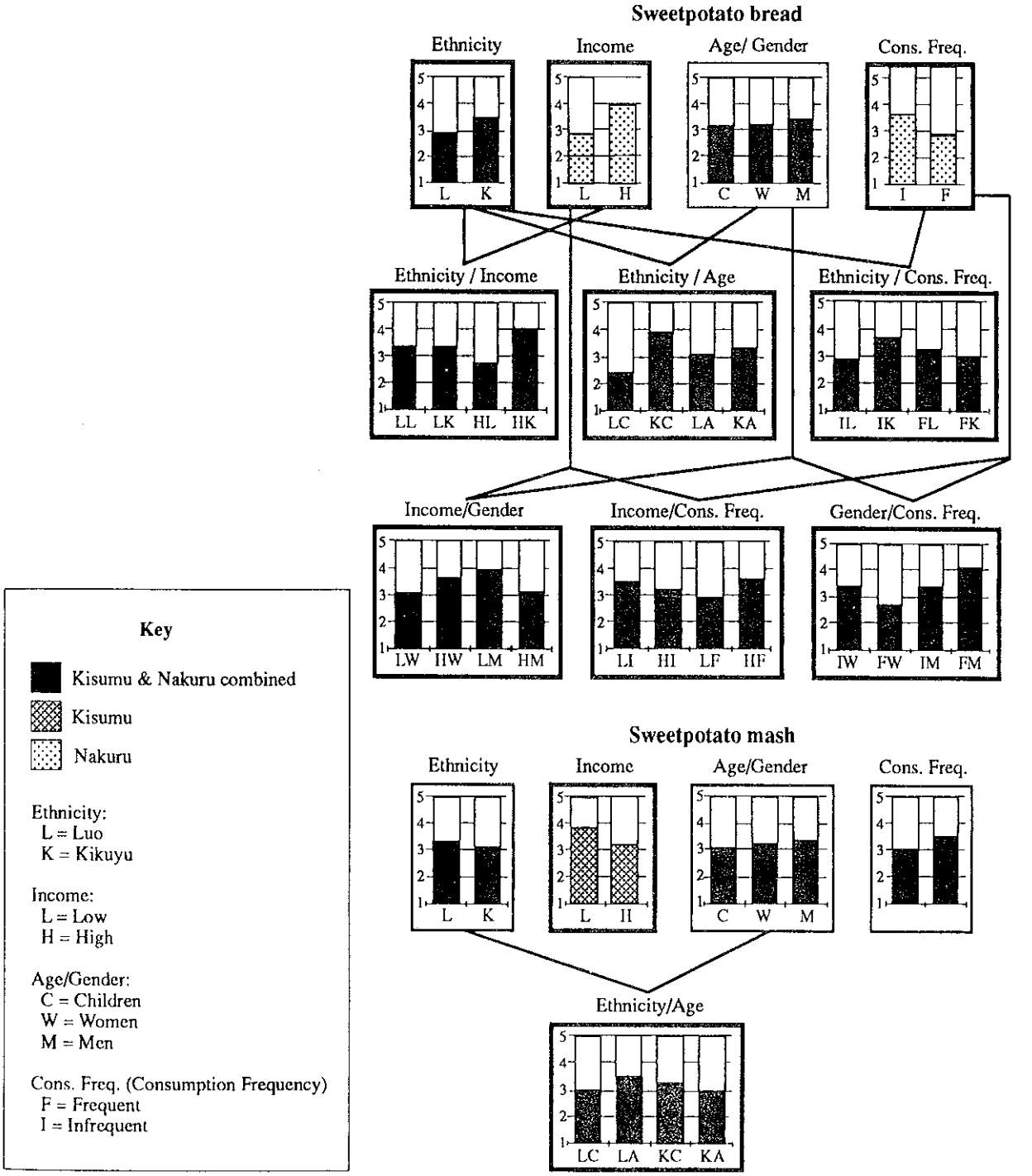
Source: Preference survey 1992.

Figure 6. Consumer preferences survey for chips and *ugali:* Impact of socio-economic filters.



Source: Preference survey 1992.

Figure 7. Consumer preferences for sweetpotato bread and mash: Impact of socio-economic filters.



Source: Preference survey 1992.

scale and different shadings denote the panelist group. The discussion highlights selected results of the analysis.[3]

Fresh Roots

Interestingly, none of the filters had a significant effect on the high acceptability of the fresh white roots (Fig. 5). This implies that the individual's socio-economic status has little discernible impact on preferences towards white sweetpotatoes. Ethnicity affected the acceptance of the yellow sweetpotatoes. Apparently, Kikuyus consider the yellow roots sweeter and better than the white roots—they are more prized among this ethnic group. This suggests the existence of an untapped market for the yellow sweetpotatoes. In Kisumu, children preferred this sample more than the adults. This may be due to the greater sweetness of the yellow roots. No logical reason is apparent for the result for consumption frequency among Kisumu respondents.

Processed Forms

Chips (Crisps). Whereas all groups indicated high positive preference for the chips, there were some significant variations between groups (Fig. 6). The results for ethnicity may have to do with a slight difference in the chip samples between the two towns: the Nakuru ones were somewhat thicker and thus less crispy. Hence the lower mean score for the Kikuyus. The greater familiarity of upper income groups with fast foods may help to explain the higher chip mean score for these panelists. However, it is puzzling that there is no positive **novelty** effect for the lower income panelists. For the age/gender filter, the high mean score for the children probably reflects their overall strong positive preference for snack foods.

The significant interaction effects for chips are between ethnicity, income, consumption frequency, and the adults. The relationship between ethnicity and income, in particular, is interesting because it shows the overpowering effect of tradition on preferences. In this case, ethnic background is more important than economic status. Thus, the pattern of preferences expressed by the Luos and Kikuyus remains even when the interaction with income is included. (The income relationship, on the other hand, is switched).

Sweetpotato *ugali*. No clear reasons behind the significant filter effects for this food sample are apparent (Fig. 6). For instance, it is not obvious why low income men would take a greater liking to the sweetpotato *ugali* than the wealthier men and both income categories for women. Also, some of the filter influences are only statistically significant for Nakuru. Without detailed information on specific differences between the Nakruru and Kisumu populations, one cannot posit a logical reason for these results.

Sweetpotato bread. The most outstanding feature of the results for this food sample is the great number of interaction effects between filters (Fig. 7). At the main effects level, the lower acceptability for the Luos compared to the Kikuyus is most likely a direct result of the fast deterioration of the bread in Kisumu. Thus, it was likely to be stale for most of the panelists in this town. Hence, this difference between the two sets of panelists may be discounted somewhat. In Nakuru, the frequent consumers of sweetpotato took more to the bread, as did the low income panelists.

The interaction results that include the consumption frequency filter suggest the overriding influence of this variable on preferences. However, since income and consumption frequency are inversely related, perhaps these results reflect a stronger overall influence of income status. The effect of income and consumption frequency together shows what happens for those panelists who fall outside of the conventional pattern for these two filters. In other words, high income, high frequency consumers are rare and their tastes are opposite to what we expect from high income respondents.

Mash. One unsurprising filter effect for the mash is that between low and high income groups in Kisumu: the latter group found the mash less acceptable (Fig. 7). Wealthier people are used to tasty foods since they can afford greater variety and spices. Since the mash was distinctly flavorless it is reasonable that it was less liked by this group. It is somewhat strange that this result is not repeated for the Nakuru panelists.

Implications for Production

Of all the food samples employed in the preference survey, two warrant further evaluation: the chips and the sweetpotato flour for use in preparing *ugali*. As the most acceptable processed sample, the chips could be evaluated further to determine their full market potential. However, production of the chips is unsuitable for an on-farm procedure. Specifically, chips are best when

[3] There was no significant effect of education on preferences.

produced as close to the consumer as possible since freshness is crucial. Moreover, chips may not be the most effective vehicle for increasing the role of sweetpotato in the diet. As merely a snack food, they would retain the same place in the diet that sweetpotato roots currently hold rather than helping the roots become more of a staple. For these reasons, production and cost analyses for the chips are not undertaken.

Sweetpotato flour appears to be a viable product given the favorable response for the composite flour *ugali*, even when compared with the all-maizemeal type. Marketers could emphasize that this flour can be used much in the same way as wheat flour—in the making of other common foods such as *chapati* (a type of flat bread), *mandazi* (a sort of doughnut), and cakes. In this respect, preparation ideas would help to extend the use of the flour.

Hopefully, the slight sweetness conferred by the flour would not be a great hindrance to sales. However, given the severe shortages of maizemeal in Kenyan markets in 1992, there is an obvious need for greater availability of alternatives such as sweetpotato flour. Since the *ugali* was especially popular with the children, the use of the flour as a supplement to maizemeal in educational institutions represents a substantial potential market. (During the survey period of May-August 1992, some schools had to close early due to lack of maizemeal). It is also encouraging that flours of sorghum and finger millet are becoming more widely used in the urban areas. These may pave the way for widespread acceptance of sweetpotato flour.

The Economics of Sweetpotato Flour Production

If processing is to be performed at the farm level, several important points must be taken into consideration. First and foremost, the technology used must be both cheap and easy to use. The rationale for this is clear: if female growers are to exploit this opportunity to the fullest, the investment and maintenance requirements have to be within their reach. Fortunately, fieldwork revealed that the two potentially most prohibitive stages of the processing—drying and grinding—can be simplified greatly. Drying merely requires a clean drying surface and favorable climatic conditions, while grinding into flour can be done at existing *posho* mills (used to grind maize into maizemeal). These facilities, located throughout the countryside, are designed to meet the needs of farmers who wish to process the home supply of cereal grains into a flour or meal. In this respect, they would be ideal for sweetpotato processors.

Moreover, the simpler the technology, the more likely that local *jua kali* (informal sector) artisans can provide the necessary equipment at a low price. Furthermore, it is preferable that the technology have multiple uses for the times that sweetpotato processing is not being performed (the procedure is assumed to be a seasonal activity). In Ghana, the simple equipment used to transform cassava into *gari* has enabled widespread exploitation by small-scale farmers and marketers who are mostly women. Kraemer (1986) reports that many small scale processors cited the ease of investment as one of the primary reasons for engaging in cassava processing.

Finally, the procedures must be flexible in their time demands because rural women's time is already crowded with activity. Flexibility implies that the women should be able to attend to pressing needs without endangering the processing operation and vice versa. Also, the more time it takes to process the roots, the less likely that women will decide to make the investment. This reflects the valuation of their own time in terms of opportunity cost.

Quality Considerations

The quality of the products in terms of color, taste, texture, cooking quality, and the like, should be acceptable to consumers. The processed foods should be comparable to that of the samples used in the taste tests. The sweetpotato flour used in the *ugali* was made without the use of sodium metabisulphite solution which whitens the finished product. Since panelists apparently found the slightly browner flour acceptable, color considerations could be eliminated. Consequently, the costs of processing fall considerably. In addition, one hurdle for the processor is removed because the chemical is not easily obtained in rural areas. The acceptability of a darker flour color also implies that leaving the peel on the root may still result in a marketable product (fieldnotes).

Perhaps the most important determinant of quality is the condition of the root itself. This is a problem as observed from the sweetpotatoes available in Kenyan markets. Many have large discolored or rotted areas resulting from diseases and pests which attack the roots in the field or during transportation. Because these parts of the roots are unusable, their widespread occurrence can greatly reduce the quantities of flour produced. In this way, they raise the costs of the operation for the

processor. The availability of good quality sweetpotatoes would also help to make the processing easier since finding and cutting out bad parts is a tedious job. In due course, quality differentiations for sweetpotato flour will emerge depending on the demands and discrimination of consumers.

The Processing Operation

If quality requirements are not too stringent, processing can be a simple exercise. The use of unsophisticated technology means that time and labor inputs are substantial. However, this is probably not much of a problem since the procedure would be carried out during times of low demand for labor on the farm. In the following discussion, costs of the various tools and materials required for processing reflect the retail prices for the items or were inferred from Kabira's (1987) work on potato flour. Kabira evaluated both the processing procedure and the economic feasibility of production for potato flour.

In estimating the daily load of roots for processing, it is important to recognize that time is as much a constraint for the women growers as money. Their days are already taken up with productive, child-rearing, and housekeeping duties. Yet, it is also true that the demands on their labor vary over the year depending on farm activities. Since sweetpotato processing would most probably take place during the slack times of the year, we can allocate one working day (about 8 hours) for harvesting through readiness for milling. During this time a quantity of 40 kilograms of roots could be processed (into about 15 kilograms of flour).

The average sweetpotato plot in western Kenya is 0.2 acres and its yield is 1,400 kg of roots.[4] The grower would need to harvest 1/35th of this land—a parcel measuring 4 x 6 meters—to obtain the 40 kg. Thus, if two crops are planted during the year, such a daily throughput suggests that 70 days each year would be given over to sweetpotato processing, not an unreasonable total.

The cost calculations assume a conversion ratio of 2.65:1 for unpeeled roots: flour.[5] In other words, 2.65 kg of roots yield one kilogram of flour. This rate of conversion is used to allocate the costs of equipment or materials whose role in the procedure applies to the fresh roots or wet slices.

Peeling. This step may not be necessary. It appears that leaving the peel on the root makes little difference in the final product, especially since color is not a major consideration (fieldnotes).[6] Compared to the cassava peel which is thick and fibrous, sweetpotato's outer covering is thin and would not pose problems if left on the root during processing. Moreover, peeling would reduce the yield of sweetpotato flour, thus increasing processing costs. For example, allowing for a wastage rate of 10% of root weight, 100 kg of peeled roots would yield 34 kg of flour while unpeeled roots would produce 38 kg.

Perhaps more importantly, the elimination of this step greatly cuts down on processing time since peeling is time-consuming (and tedious) work. However, if the roots are not peeled, they should be washed thoroughly before further processing to remove soil and other dirt. However, there may be a trade-off between peeling and washing. As peeling removes the dirt on the root, it may have to substitute for washing if clean water is not available.

Slicing. In slicing the roots into 2-3 millimeter chips the general principle is: the thinner the chip, the better, because this speeds up drying. This step is somewhat difficult (as experienced by the researcher) because roots contain some sap which makes smooth slicing a problem as compared to slicing potatoes or cassava. During slicing, the roots were resistant and would stick to the slicing tool. Some Kisumu cassava-chips producers interviewed even cited difficult slicing as the reason for avoiding production of sweetpotato chips alongside cassava and potato chips. Researchers at the International Potato Center (CIP) in Nairobi suggested that varieties may exist which contain less of the sap and are thus easier to slice (fieldnotes) (actually, the orange varieties found in the United States do not seem to contain this substance).

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[4] This acreage is based on the plot size devoted to sweetpotato which is most common among Kenyan small holders as reported by Mutuura (1990). Yields in the South Nyanza region average 7,000 kg per acre (Shakoor et al. 1988).

[5] The conversion factor is calculated from the known moisture content of sweetpotato (70% of weight) and the desired moisture content of the flour (12%) and assuming a 10% wastage rate during processing.

[6] Kabira's (1987) study on production of potato flour also concluded that unpeeled tubers could yield a good quality flour whose whiteness was little affected by the peel.

The slicer for sweetpotatoes could be the same as that used by Kisumu and Mombasa producers of cassava crisps. The tool is about 6 inches long and 4 inches wide and is made of heavy iron with a sharp blade positioned at about two-thirds of the length and held in by metal bolts. It can be held in the hand and allows the chips to fall in the space between the slicer and the palm. This tool produces remarkably good chips of even thickness with a minimum of fuss. It is a *jua kali* product which can last for at least two years under constant usage before the blade has to be replaced (the life of the tool is naturally greater if yearly use is reduced). In 1992 the cost of the slicer was estimated at Kshs 100 by the cassava chip makers interviewed (fieldnotes).

Blanching. This could take the form of incomplete cooking by boiling or dipping for 5 minutes into a 0.5% solution of sodium metabisulphite which whitens the finished product. Both methods confer greater resistance to bacterial infection or spoilage. However, as with the peeling, this step is not crucial to the quality of the finished product and may be ignored. Similarly, the Kabira et al. (1990) study on potato flour found that using raw chips gave higher yields of flour and did not reduce the overall quality of the flour. Leaving out this step also helps the grower to reduce processing costs.

Drying. Ideally, drying equipment would allow the maximum surface area for drying and would capture as much heat energy as possible to speed up the process. This would mean the use of a frame structure supporting several trays of a mesh material on which the sweetpotato chips could be placed. Favorable climatic conditions such as warm dry days and windy nights would help to ensure fast drying with minimum insect infestation or mildew losses. For our purposes, however, the ideal equipment is simply inappropriate for a grower-processor, given the costs of construction. Kabira's work on potatoes reported equipment costs in 1990 at roughly Kshs 4,900 and 11,200 for dryers that would handle 50 kg and 200 kg of tubers per day, respectively. For a country whose income per capita was Kshs 11,100 (US$370, Kshs @ 30 = US$1.00) per annum in that year (World Bank 1992), such outlays are largely out of reach for the rural population who may take on sweetpotato processing.

Yet drying does not necessarily have to involve such great expense. In its simplest form, the drying equipment could consist of plastic sheeting which would be spread out on the ground to expose the chips to sunlight and wind.[7] Drying would then take one 24 hour period consisting of a sunny day and a windy night or slightly more time if overcast or humid conditions prevail (fieldnotes). One drawback of this method is that the plastic exposes only one surface of the chips to the drying elements. However, the sheet's strong points are that it is cheap, portable and can lend itself to other purposes in the household or farm. Furthermore, if rain begins during the drying period it is easy to fold up the sheet and keep the chips waterproof until better conditions return. Replacement of the sheet would only be necessary about once every three years as long as it is not under constant exposure to sunlight (Kabira et al. 1990).

Based on the study on potato flour, drying would require 1 m^2 of the plastic sheet for every 4 kg of slices (Ibid.). At a unit area price of Kshs 35, the plastic is the most expensive item in the processing operation. In order to dry the 40 kg of sliced roots previously estimated, 10 square meters (1 X 10 meters) of the plastic is necessary at a total cost of Kshs 350. It is expected that this expense would be affordable for the growers without the need for heavy borrowing. This cost figure is used in the subsequent analysis.

Grinding. Fortunately, it is not necessary for the processor to buy a grinding machine. She only has to take the dried chips to the nearest hammer mill where maize and finger millet are also ground. Transporting 15 kg of chips to the mill is probably not an overbearing task since they are much lighter to carry than the original slices. Also, it is not necessary that all the chips be ground immediately since they are a highly storable form. Thus, the processor can transport the chips to the hammer mill on a need basis. The owner of the grinding machine will charge a fee: whereas in 1990 this was Kshs 0.30 per kilogram of flour produced, the cost in 1992 was estimated at Kshs 0.50 per kilogram for a total cost of Kshs 7.50 for the whole 15 kg.

Packaging. Gunny sacks or flour sacks made of synthetic material may be used. The price of a single bag was Kshs 20 in 1992. Both are widely available, cheap, and can hold up to 100 kg of the product. Thus, if the grower produces 15 kg of flour per day, it would take

[7] In fact, some Chinese dry their sweetpotato chips directly on the ground (Woolfe 1992).

about one week to fill up the sack. The most desirable packaging, however, would be airtight in order to avoid problems with moisturization of the flour which reduces its shelf-life. However, such packaging would also be much more expensive than the gunny sacks. The latter are widely used in Kenya for other flours and seem to provide adequate storage for the product.

Cost Analysis

To fully evaluate the processing operation, it is necessary to perform two kinds of cost analyses: one incorporating only cash costs and the other allowing for opportunity costs. The cash cost analysis is based on the belief that the women growers are unlikely to explicitly account for several cost components. Yet the opportunity cost of performing the operation must demonstrate whether or not processing is in the interests of the grower vis-à-vis the economic alternatives. Also, in making these different accounting assumptions, it is possible to determine which cost options provide reasonable price estimates for the consumer while maintaining comfortable profit margins for the producer. Table 2 details the costing procedure and compares the cash costs with opportunity costs.[8]

The cost of fresh roots used in the analysis—Kshs 3.71 per kilogram—is the average of sweetpotato prices observed in rural markets in a 1992 CIP study (fieldnotes). Since 2.65 kg of fresh roots are required to produce one kilogram of flour, the cost of one kilogram of the former is multiplied by 2.65 to arrive at Kshs 9.83 as the cost contribution of the raw material to each kilogram of flour.

This particular item is really an opportunity cost since the grower is using her own supply of sweetpo-

Table 2. Production costs for sweetpotato flour assuming a daily throughput of 40 kg of fresh roots and various opportunity cost alternatives for roots (in Kshs/kg of flour).[a]

		Opportunity cost assumptions for roots[b]				
Items	Cash costs	0%	25%	50%	75%	100%
Cost of roots (a)	0.00	0.00	2.46	4.92	7.37	9.83
Processing costs: (b)	0.96	4.33	4.33	4.33	4.33	4.33
Fixed costs:	0.26	0.26	0.26	0.26	0.26	0.26
Bucket	0.05	0.05	0.05	0.05	0.05	0.05
Slicer	0.09	0.09	0.09	0.09	0.09	0.09
Plastic sheet	0.12	0.12	0.12	0.12	0.12	0.12
Variable costs:	0.70	4.07	4.07	4.07	4.07	4.07
Labor	0.00	3.37	3.37	3.37	3.37	3.37
Milling	0.50	0.50	0.50	0.50	0.50	0.50
Gunny sacks	0.20	0.20	0.20	0.20	0.20	0.20
Total Cost (a+b)	0.96	4.33	6.79	9.25	11.71	14.16

[a] This analysis assumes that 1,000 kg of flour are produced per year, at the rate of 15 kg per day or 40 kg of roots per day (about 70 days' worth of processing activity).

[b] One kilogram of sweetpotatoes cost Kshs 3.71 in 1992. At an allocation rate of 2.65 kg of fresh roots per kg of flour, the total unit contribution to costs of the roots is Kshs 9.83 per kg. The different assumptions reflect the fact that growers may be willing to accept less than the full cost of the roots to the processing operation.

[8] The Kenya shilling is made up of 100 cents of wich the smallest denomination is 5 cents. However, the figures used in the analysis are not rounded up to the nearest 5 cents to avoid losses of accuracy.

tatoes. In effect, the cost of roots represents the amount of money she forfeits by processing the sweetpotatoes rather than selling them fresh. However, the grower may reduce the value of the roots to the processing operation because she knows that she could not sell all the sweetpotatoes fresh. In recognition that the cost contribution of the roots may be viewed in different ways, the table also shows how the total cost figures vary under different assumptions for the cost of roots. Thus, in the first two columns, the cost of roots is discounted completely; subsequent columns increase the cost of the roots by 25% each time until the full cost of roots is included.

Processing costs

Fixed costs. An estimated asset life of 3 years for each piece of equipment is assumed based on the apparent durability of the item as observed during fieldwork. Then, using the straight-line depreciation method and assuming a zero salvage value, the contribution of each item to the unit cost of the flour is calculated:

$$\frac{\text{Cost of item}}{\text{Life of the asset} \times \text{Quantity produced/year}} = \text{Cost/kg of flour}$$

(Edwardson and MacCormac 1984). The costs of all the equipment are then multiplied by the conversion factor (2.65) since their functions occur early on in the processing. Naturally, if daily processing load rises or costs of equipment fall, the unit contribution to the cost of flour declines. In reality, small-scale operators are not likely to use such accounting methods in arriving at a price for their products. However, these costs are included to show the total costs of processing were all costs fully included.

Variable costs. Costs of labor are estimated from agricultural wage rates from previous years to give a daily rate of Kshs 50.94 per day in 1992 (ILO 1992). Using the assumption that 15 kg of flour can be made per day (from 40 kg of roots), this wage rate gives a cost of labor of Kshs 3.37 per kg of sweetpotato flour (this cost would fall were the daily amount of roots processed rise). As with the roots, labor is an opportunity cost. It assumes that the processor could obtain employment at this wage rate but is giving up that opportunity to engage in processing. The cost of labor does not change across the table as does the cost of roots because the latter can vary substantially (between Kshs 0 and almost 10). Conversely, allowing for a range of labor costs affects the total costs only slightly. Milling and packaging costs are Kshs 0.50 and 0.20 per kilogram of flour respectively. These also remain constant for each assumption of the cost analysis.

Marketing costs. These include all costs incurred after the flour leaves the processing site (in this case, the grower's homestead) until it reaches the consumer. These costs will vary depending on the distance to the final market, transportation conditions, and the number of hands through which the flour must pass before the consumer purchases it. The actual costs cannot be anticipated. Therefore, in order to estimate the apparent profitability of processing, alternative assumptions are made about the percentage of the sales price which could be attributed to the post farmgate marketing process.

A range of marketing margins (10% - 50%) is posited, drawn from the case of maizemeal in Kenya and *gari* in Ghana. For the former, Jones (1972) estimated margins amounting to 42% for Nairobi in 1966. In Ghana, the difference between the costs of production and the producer price of *gari* was 23% of the sales price (Kraemer 1986). Marketing costs are calculated as the product of the margins and several sales prices. The resulting figures range from a low of Kshs 0.55/kg of flour to Kshs 6.50/kg.

The four sales price assumptions used to estimate post farmgate costs are based on various plausible scenarios for sweetpotato flour. The responses to the preference survey questionnaires indicate that consumers would only purchase sweetpotato products if their prices were equal to or less than, those of corresponding conventional foods. We can therefore estimate a maximum sales price of sweetpotato flour at Kshs 11 per kg: the price of maizemeal (of course this is the best case scenario for the producer the sweetpotato flour would probably be unable to command such a price unless extenuating circumstances obtained, such as a severe shortage of maizemeal). Two other selling prices—Kshs 8.25 and 5.50—assume that sweetpotato flour could be sold at 75% and 50% of the price of maizemeal, respectively.

Since the price of maizemeal is subsidized, we also use an estimate of the free market price in the analysis. In 1990, 18% of the maizemeal price was borne by the government rather than the consumer. This suggests that the market price in 1992 (assuming similar rates of subsidization) could have been Kshs 13 per kg instead of Kshs 11.

The Profitability of Processing

Figure 8 shows how returns on flour sales (on the vertical axis) change with total costs (on the horizontal axis; total costs are the sum of production and marketing costs), selling price, and marketing margins. The cost

assumptions from Table 1 are used to generate each line for a particular selling price. Thus, the point at the extreme left of each line represents the cash cost assumption. Costs increase along the line until the last point on the right which assumes that 100% of the cost of roots contributes to the production of the flour. The Kshs 3.71 horizontal line denotes the point below which returns from processing are lower than those from selling fresh roots. The processor would want to operate at points above this line. The shaded area in each chart represents the cost and price combinations (for a given marketing margin) for which the processing will always outperform the sale of fresh roots, regardless of production cost or consumer price.

As the marketing margin increases from 10% to 50% (from one chart to the next), the shaded area diminishes. Obviously, returns to the processing operation are inversely related to the proportion of unit revenues taken up by post farmgate costs. Processors gain when factors such as transportation costs which make up the margin, contribute little to the consumer price of the product. Since growers would have no control over the flour once it changes ownership, they could only aim to keep production costs low. By so doing, they are more likely to profit from the processing operation even if marketing costs are high for any given sales price.

The point at which each sales price line crosses the Kshs 3.71 return line, marks the maximum total costs allowed if processing is to remain more profitable than selling fresh roots. Indeed, an absolute maximum for total costs may be posited: the difference between Kshs 11 and 3.71 since the price of sweetpotato flour cannot rise above that of maizemeal. These conclusions can be extended for any cost, marketing margin, and price combinations.

We can focus on the 20% marketing margin case as the most likely outcome of sweetpotato processing. This percentage is chosen based on the experience with maize and *gari*: from the 42% margin for maizemeal in Kenya, we may subtract out the 24% that accrues to the Maize Marketing Board leaving a marketing margin of 18%; the corresponding figure for *gari* is 23%.[9] The 20% margin chart suggests that the processing enterprise would be worth the grower's attention only if the price of the flour is above 50% of the maizemeal price (or Kshs 5.50 per kg). However, if production costs are low, the price of the flour could fall to make it even more attractive from the consumer's point of view.

Moreover, even under the lowest marketing margin assumption, only the left-most part of the lines appear in the shaded area. In the situation where the price is Kshs 8.25 per kg and the marketing margin is 20%, the producer would have to lower the contribution of the roots by at least 80% in order to realize profits above those of selling the fresh roots. This implies that the processor must be willing to reduce the opportunity cost of the fresh roots to 20% or less of their retail price.

This simulated analysis can act as a guide for policymakers or others who may seek to promote sweetpotato processing into flour in Kenya. Actually, production costs would probably be much lower than envisioned since people can be extremely innovative when resources are scarce. For example, the grower may make use of her own buckets or similar receptacles instead of buying one solely for the purpose of processing. Also, marketing margins may be higher or lower than assumed, depending on the distance between the grower and the final consumer, the efficiency of the marketing system, and the length of the marketing chain. Thus, it is difficult to say, *a priori*, which margins are most likely.

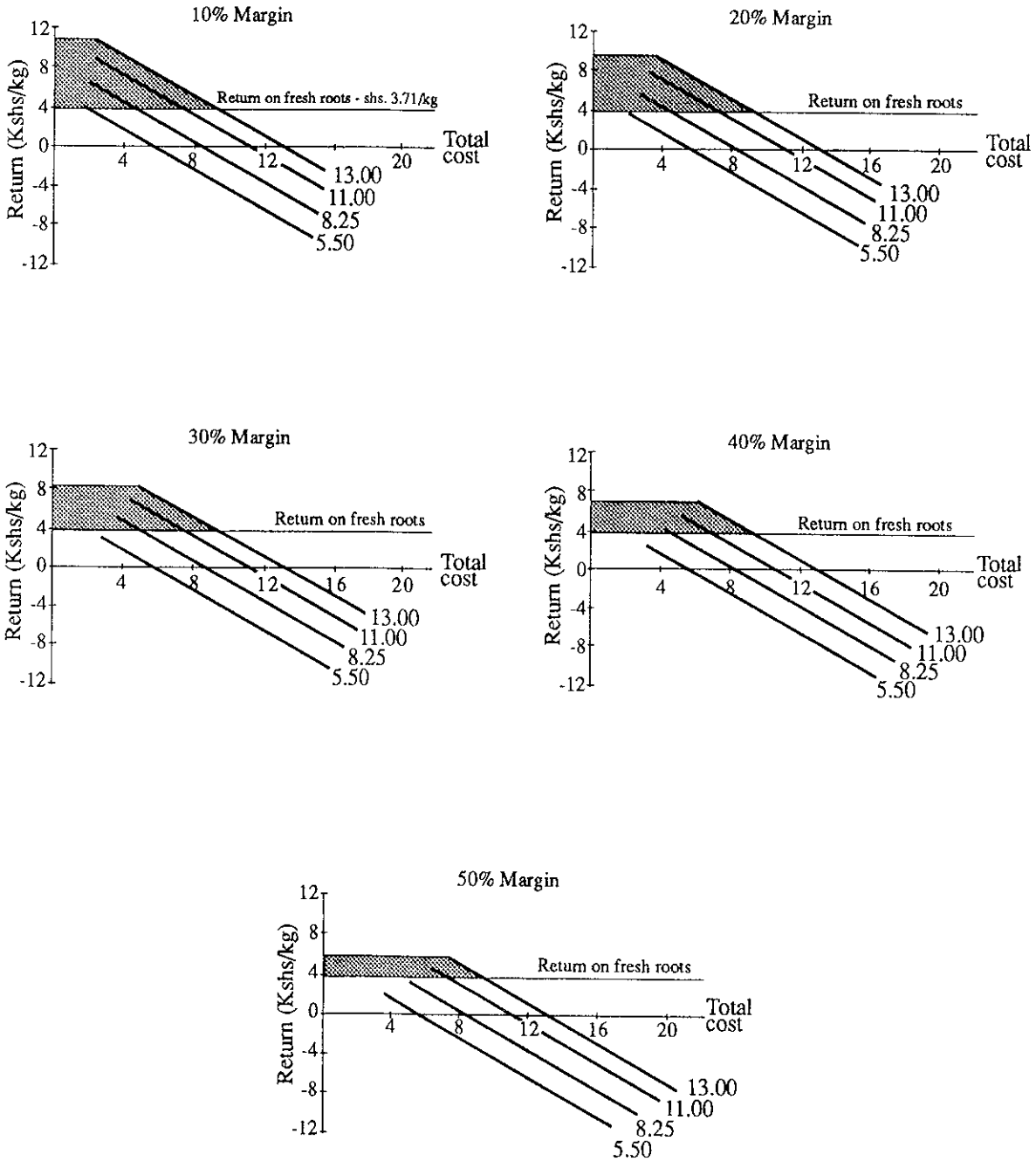
More importantly, the grower is unlikely to follow accounting procedures such as those used in the analysis. The way in which the grower values her supply of sweetpotatoes and her labor will have important implications for the overall costs and profitability of the enterprise. Nevertheless, the analysis has shown that, even under conservative assumptions, the processing of sweetpotatoes into flour can be an economically viable enterprise.

Conclusions

Since sweetpotato is considered merely a minor snack or breakfast food by urban consumers, perhaps the greatest task for marketers will be to change these perceptions to allow the root's importance to grow. Thus, whereas the positive response from panelists towards the processed forms was encouraging, actual long-term consumption cannot be guaranteed unless more work is put into making the foods attractive from the consumer's point of view. For instance, processed

[9] The Maize Marketing Board (now the National Cereals and Produce Board) is a government parastatal body with an official monopoly on maize marketing.

Figure 8. Returns on sales of sweetpotato flour (Kshs/kg) as total costs, sales, price and marketing margins change.



Source: Preference survey 1992

sweetpotato products will appeal to consumers if their versatility of usage is evident, as is the case with the more successful starchy staples.

In general, marketing could emphasize any nutritionally superior aspects of processed sweetpotato products. The importance of this can be seen from women's responses to questions on family dietary decisions. Over 60% stated that the nutritive value of the staple is the main concern. However, most crucial is the price of the product. Although almost all women stated that they would purchase sweetpotato processed products if marketed, a substantial number in Kisumu mentioned price as a deciding factor. At a time when inflation in the country is high and real incomes are declining, people will expect to obtain the greatest value from food expenditures. Thus, sweetpotato processors should endeavor to produce items which would be affordable for the majority.

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Biochemistry and Utilization of Sweetpotato (*Ipomoea Batatas*) for Animal Feed: Implications for Food Security in Africa

Olumide O. 'Tewe[1]

Abstract

Forty-nine varieties of sweetpotato tubers, vines, and leaves were obtained from the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. Chemical analysis revealed high levels of cabohydrates in roots. Leaves and vines contained appreciable levels of crude protein, fiber, and minerals. Some varieties contained crude protein of up to 8.6% in tubers. Total sugar varied between 3.7 and 10.4g/100g DM. Thus, selection can be made for low sugar varieties desired in animal feeds. Good growth performance was observed in broilers, layers, pigs, and sheep when sweetpotato partially replaced maize in their rations. In this paper, the potential of sweetpotato for food security in Africa is highlighted. Furthermore, strategies are recommended for overcoming constraints in the use of sweetpotato in livestock feeds.

Key words: broilers, layers, pigs, sheep, feeding trials, nutrient utilization.

Introduction

Strategies for ensuring food security in Africa should take cognizance of the diverse needs of such programs. These include the need to combat starvation and food-related diseases such as kwashiorkor and marasmus, which can lead to death particularly in children. To achieve this, the quantity and quality of food provided need to be considered. While root crops can contribute greatly to quantitative food security, animal protein must be included in human food to provide the essential amino acids in order to guarantee qualitative food security.

Food deficits constitute the major obstacle militating against satisfactory animal productivity in tropical Africa. Therefore, root crops can contribute significantly to food security, not only for man, but also for animals on this continent. This becomes imperative when it is considered that though Africa's agricultural system is heterogenous, the cultivation of roots and tuber has been shown to be the most economical and "convenient" for most of tropical Africa (Okigbo 1986). Livestock production must therefore be matched with appropriate crop farming systems in Africa for sustainable productivity and provision for adequate essential amino acids in human diets on this continent.

This papers reports on the biochemical characteristics of sweetpotato and its utilization for livestock feeding in Africa.

Biochemical Studies

Forty-nine (49) varieties of sweetpotato were obtained from the Tuber and Root Improvement Programme of the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. The leaves, vines, and tubers were analyzed for their proximate constituents and carbohydrate fractions (Oboh 1986). As shown in Table 1, tubers are high in carbohydrates, leaves are higher in proteins and crude fiber, and the vines are highest in

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crude fiber. The range of protein in the tubers (1.39-8.60%) shows that through selection, some varieties of sweetpotato can supply energy and protein equal to maize, thus serving as a complete replacement for this scarce cereal energy source. Table 2 also shows that levels of simple sugar and starch differ among varieties. This can be of significance in feeding man and animals, as the high total sugar of most sweetpotato varieties has been blamed for their non-acceptance as food and feed.

Animal Feeding Studies

Sweetpotato is a high moisture root crop. Processing to reduce the high water content is therefore highly desirable to enhance utilization, particularly for intensive livestock feeding. Solar drying has long remained an important economic means of converting harvested products to a dried state, particularly in the tropics. Its disadvantages are that the energy input and product quality can seldom be controlled (Moy and Chi 1982). These factors become particularly important in the rainy season when relative humidity is high, and the intensity of solar radiation is reduced and highly unpredictable. Such weather conditions predispose such food being dried to easy contamination by dust, insects, and microbial organisms that will thrive abundantly on the high soluble carbohydrate medium provided by wet sweetpotato roots. As a result, the quality of solar dried roots is often considered inferior to that of other dried foods. A drier to facilitate the dehydration of sweetpotato roots all the year round was fabricated locally. This oven (or smoke drier) (Fig. 1) utilizes saw dust or fire wood for fuel. Thinly sliced sweetpotato roots are dried on this to 10% moisture content within 12-24 hours. This drier can be used in the rural communities of tropical Africa.

Table 1. Dry matter, proximate composition (% DM) and gross energy value (Kcal/g) of forty-nine varieties of oven-dried sweetpotato leaves, vines, and roots.[a]

Part of crop	Dry matter	Crude protein	Crude fibre	Ether extract	Ash	N.F.E.	Gross energy
Leaves	27.94 ± 1.27 (26.43 - 36.36)	11.84 ± 0.44 (5.11 - 18.31)	20.15 ± 0.85 (5.91 - 31.00)	2.54 ± 0.11 (0.71 - 5.89)	9.72 ± 0.19 (6.30 - 11.80)	59.4 ± 0.83 (46.04 - 72.27)	3.5 ± 0.09 (1.53 - 4.59)
Vines	20.20 ± 0.44 (14.92 - 26.48)	4.94 ± 0.22 (1.80 - 7.96)	29.47 ± 0.50 (22.11 - 37.46)	1.61 ± 0.08 (0.18 - 2.61)	11.30 ± 0.13 (9.3 - 12.90)	52.53 ± 0.61 (41.92 - 62.08)	3.42 ± 0.09 (2.13 - 4.65)
Tubers	28.54 ± 0.57 (17.82 - 38.18)	4.51 ± 0.26 (1.39 - 8.60)	4.37 ± 0.10 (3.45 - 5.89)	0.88 ± 0.06 (0.33 - 1.90)	4.04 ± 0.17 (1.47 - 6.33)	86.56 ± 0.27 (80.99 + 91.55)	4.15 ± 0.07 (2.94 - 5.45)

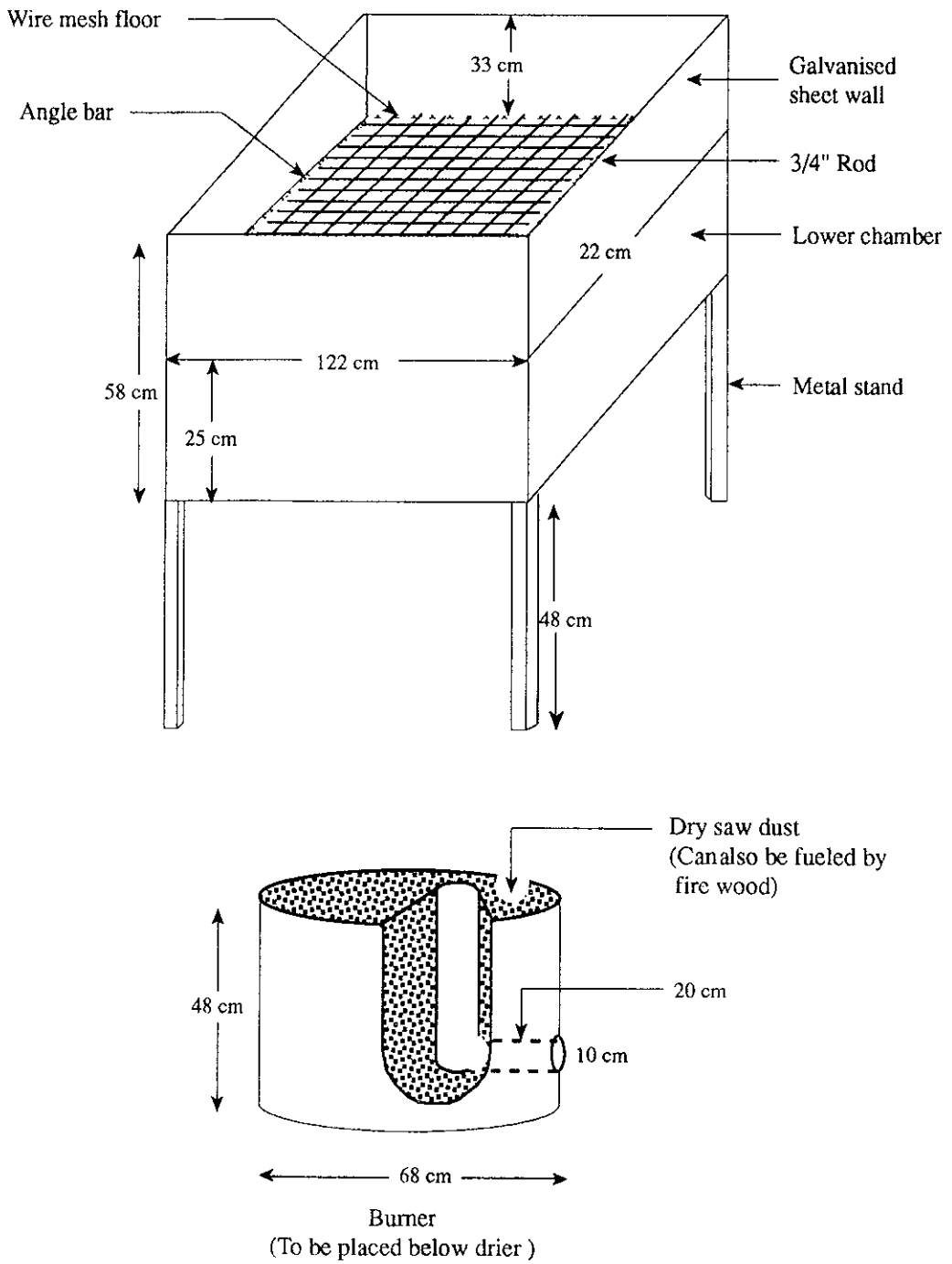
[a]Figures in parenthesis are the range of values for the 49 varieties.

Table 2. Total free sugars and starch content (g/100 g dry matter) of 49 varieties of oven-dried sweetpotato tubers.[a]

Total sugar	Hexoses	Fructose	Glucose	Maltose
6.24 ± 0.27 (3.68 - 10.40)[a]	1.56 ± 0.09 (0.86 - 3.36)	0.55 ± 0.02 (0.31 - 0.74)	0.37 ± 0.01 (0.28 - 0.51)	0.34 ± 0.02 (0.22 - 1.06)
Sucrose	**Reducing Sugar**	**Starch**	**Amylose as % of starch**	**Amylopectin as % of starch**
2.27 ± 0.02 (1.24 - 3.72)	1.22 ± 0.08 (0.46 - 2.04)	37.01 ± 0.40 (30.80 - 41.80)	27.72 ± 0.35 (21.0 - 38.4)	72.77 ± 0.35 (61.6 - 79.0)

[a]Figures in parenthesis are the range of values for the 49 varieties. Samples are being re-analyzed to confirm values obtained.

Figure 1. Diagramatic representation of the oven drier.



Two broiler feeding trials were conducted. In the first trial, sun-dried and oven-dried sweetpotato roots replaced maize at 0%, 50%, and 100% in broiler rations. As shown in Table 3, sweetpotato reduced performance as compared to the maize control diet. Performance was however better with the oven-dried, as compared to the sun-dried, sweetpotato-based rations. Microbial proliferation on the sun-dried sweetpotato can lead to the production of mycrotoxins (Clerk and Caurie 1968). In a second trial, oven-dried sweetpotato partially replaced maize at lower levels of 0%, 10%, 20%, 30%, 40%, and 50% in broiler ration. Performance was optimal at 30% replacement of maize (or 18% inclusion of sweetpotato) in the broiler rations as shown in Table 4.

In another 70-day feeding trial with layers, 30 week old Harco birds were fed a maize control diet or one in which 50% or 100% of maize was replaced with oven-dried sweetpotato at three metabolizable energy levels of 2.45, 2.65, and 2.83 kcal/g in a 3x3 factorial arrangement (Table 5). Performance was superior on the control maize ration as compared to others. Dustiness and high sugar content are factors possibly reducing performance at high level sweetpotato inclusion in dried poultry feeds ('Tewe 1986).

A 100-day feeding trial was also conducted with large white X landrace pigs at the weaner (7.7-25 kg) and grower (25-60 kg) phases. Sweetpotato replaced maize at 0%, 33%, 67%, and 100% levels. As shown in Table 6, performance was optimal at 0% and 33% replacement with sweetpotato at the weaner and grower phases respectively. This shows that as for poultry, sweetpotato can only replace maize partially for satisfactory productivity.

As small ruminants constitute a large proportion of stock particularly for the rural poor, a study on the use of sweetpotato for sheep feeding was conducted with West Africa Dwarf X Yankassa crosses. As shown in Table 7, while feed consumption was better on the sweetpotato diet as compared to maize and cassava diets, growth rate and feed conversion efficiency was slightly lower on the sweetpotato ration (<0.05). Diarrhoea was also apparent on the sweetpotato-based diet as was also observed for broilers and pigs.

As of now, we do not know if the problems of sweetpotato feeding for livestock can be explained by its high sugar content or microbial population of dried chips. Our studies have, however, served to identify some problems of usage of this root crop and we proffer solutions.

Identified Problems and Recommendations

Dehydration and ensiling of roots, vines, and leaves. Sweetpotato roots have a high moisture content which makes them quite bulky and difficult to transport in fresh form. There is a need to dehydrate the roots at production sites. Solar radiation is abundant in most parts of Africa and the vast potential of this energy source needs to be tapped for dehydrating this crop. The quality of such products needs to be checked for contamination with dust and microbes. Alternatively, driers can be fabricated locally as in this study for use where wood or saw dust is abundant.

In addditon to dehydration, this root crop can be ensiled along with its vines and leaves and the fresh product can be used for all classes of livestock including poultry, as is being practiced in Cuba. The ensiling process also generates lactic acid which makes the medium acidic and hence unfavorable for the growth of some micro-organisms. The heat of fermentation produced during ensiling can reduce toxic components like the trypsin inhibitors present in raw sweetpotato roots. Ensiled sweetpotato roots, leaves, and vines can therefore be suitable for feeding all livestock species. Sweetpotato is a suitable material for solar dehydration into a product that is acceptable as a livestock feed component.

Breeding and selection for desirable biochemical characteristics. As was reported for our poultry and pig studies, performance was generally reduced with high levels of sweetpotato. The nutritional factors that have been implicated include the high soluble sugar with the possibility of an adverse effect of the gastrointestinal tract physiology and the presence of trypsin inhibitors particularly in sun-dried (non-heated) materials ('Tewe 1986). From the range of values obtained on the chemistry of the forty-nine varieties from the IITA, it should be possible to select sweetpotato of low soluble sugar content, and possibly low trypsin inhibitor levels. It should be noted that the presence of amylase or other starch digesting enzymes in the roots can determine the level of sugar in the final product, particularly if the roots are heated before or during dehydration. Levels of such enzymes need to be monitored in selected varieties. Moreover, as shown in Table 1, some varieties of sweetpotato contain crude protein levels as high as maize. These can be selected to replace the scarce and expensive cereals in livestock feeds.

Table 3. Performance, nutrient utilization, carcass traits, and economics of production of broilers fed varying levels of sun-dried and oven-dried sweetpotato.[a]

Parameters	Sweetpotato level %				
	0	Sun-dried 50	Oven-dried 50	Sun-dried 100	Oven-dried 100
			Starter phase		
Weekly feed intake/bird (g)	331.45a	259.25b	271.63b	206.75c	214.13c
Weekly weight gain/bird (g)	135.75a	69.50c	82.00b	39.00c	55.00d
Feed intake/weight gain	2.442c	3.899b	3.811b	4.967a	4.139b
Mortality (%)	8	4	8	14	6
Feed cost/live weight gain (NGN/kg)	1.61	2.76	2.41	4.36	3.23
			Finisher phase		
Weekly feed intake/bird (g)	545.25a	519.88ab	496.00b	443.25c	488.25d
Weekly weight gain/bird (g)	146.88a	130.88c	124.25b	78.9d	88.00c
Feed intake/weight gain	3.712[2]	3.995c	4.040c	5.683a	4.982b
Mortality (%)	6.67	13.34	13.34	20.01	16.68
Feed cost/live weight gain (NGN/kg)	2.17	2.58	2.53	4.17	3.47

[a]Values in the same row followed by the same letters are not significantly different (P>0.05).

Table 4. Performance, nutrient utilization, carcass traits, and economics of production of broilers, on oven-dried sweetpotato as partial replacement for maize.[a]

Parameters	Sweetpotato level %					
	0	10	20	30	40	50
			Starter phase			
Weekly feed intake/bird (g)	331.45a	298.50bc	306.00b	270.95d	288.88c	271.63d
Weekly weight gain/bird (g)	135.75a	113.25c	115.13b	99.38bc	92.75c	82.75d
Feed intake/weight gain	2.442c	2.609c	2.380c	2.785c	3.269b	3.811a
Mortality (%)	8	12	6	10	12	8
Feed cost/live weight gain (NGN/kg)	1.61	1.76	1.85	1.91	2.24	2.41
			Finisher phase			
Weekly feed intake/bird (g)	545.25a	496.25b	499.38ab	494.38b	491.13b	496.00b
Weekly weight gain/bird (g)	146.88a	142.19a	136.13a	139.13c	121.63b	124.25b
Feed intake/weight gain	3.712c	3.759c	4.315bc	4.079bc	4.721a	4.040c
Mortality (%)	6.67	0	6.67	6.67	6.67	13.34
Feed cost/live weight gain (NGN/kg)	2.17	2.05	2.16	2.16	2.51	2.53

[a]Values in the same row followed by the same letters are not significantly different (P>0.05).

Table 5. Performance, nutrient utilization, and economics of production in layers fed varying levels of sweetpotato.[a]

Parameters	Metabolizable Energy level (Kcal/g)								
	2.85			2.65			2.45		
Sweetpotato level (%)	0	50	100	0	50	100	0	50	100
Cost of feed[b]									
NGN/t	775.3	656.6	560.3	728.8	634.5	545.3	640.5	595.0	349.5
NGN/100 eggs	12.29	22.4	38.13	17.86	19.68	22.21	21.01	13.28	18.05
NGN/kg eggs	16	22	29	18	20	22	21	16	18
Weekly feed consumption/bird (kg)	1.2b	1.09a	1.03a	1.18bc	1.14bc	1.13b	1.25cd	1.20c	1.24cd
Avg. initial body weight	1.545a	1.70b	1.74c	1.61ab	1.62c	1.52a	1.67b	1.64b	1.595a
Weekly body weight gain	.033a	.022a	.84a	.036a	.026a	.033a	.013a	.022a	.0252a
Weekly no. of eggs produced/bird	5.025a	3.195b	1.515a	4.351c	3.675c	2.929b	3.91b	3.905d	3.775cd
Average weight of eggs (g)	58.1a	58.02a	54.46a	68.88a	57.3a	56.67a	57.96a	59.74a	61.16a
Feed consumption (kg)/ egg produced	2.75a	2.68a	2.70a	2.76a	2.86a	2.76a	2.08b	2.86ab	2.89*ab*
Feed consumption (kg)/ egg produced	222.9a	314.2b	579.9d	245.1a	319.2a	320.1a	328.1b	286.8ab	328.56
Metabolizable energy (kcal/g)	2.92c	2.84c	2.73b	2.77b	2.71b	2.81ab	2.58a	2.54a	2.49a
Nitrogen retention (%)	55.9a	55.5a	64.8b	54.23b	67.58c	59.21b	81.99b	69.8c	71.64a

[a]Values in the same row followed by the same letters are not significantly different (P>0.05).
[b]Nigerian Nairas.

Improvement of physical limitations. Dried sweetpotato is dusty and this factor limits the level that can be incorporated into dry rations. The dustiness causes respiratory disturbance, particularly in poultry, and feed intake is reduced. Pelleting, addition of oil, gelatinizing, and possibly extrusion should be be investigated for the reduction of dustiness in sweetpotato-based rations.

Rural adaptation strategies for enhanced utilization. More than 90% of food produced in tropical Africa is from the rural areas. Root crops constitute the most economical and "convenient" crop that is cultivated in this region. Stimulation of production through greater demand by end-users will not only increase the availability of these root crops, but it will also improve rural population incomes. In this regard, it is imperative that end-users of root crops should be acquainted with practical postharvest technologies that can enhance the utilization of the root crops for man and animal. End-users constitute the major force that can create higher demand for these crops and thus, induce farmers to increase cultivation through the creation of a stable and favorable market. They are the group that can empower the rural population.

It is pertinent at this stage to reflect on the potentials of root crops for food security in Africa. I perceive a situation in which the mother of all crops (or the root of all crops or root crops as it is known) is calling on Mother Africa.

Africa, what more can I do for you?
"I provided you with yam and you complain that it is difficult to stake, nor can survive during wars.
"I gave you cassava and you complain that it is toxic, bitter, the stems too bulky for planting and long to mature.
"Now, I have provided you with sweetpotato. You can eat the leaves and tubers and still feed the vines to livestock and use them for planting. Even it matures

Table 6. Performance of weaner and grower pigs on graded levels of sweetpotato meal-based diets.[a]

	Replacement (%) with sweetpotato meal				
	0	33	67	100	SEx̄
			Weaner phase		
Average daily feed intake (kg)	0.81a	0.68ab	0.66ab	0.51c	0.04
Average daily wt gain (kg)	0.44a	0.34ab	0.28bc	0.19c	0.03
Feed efficiency	1.85	1.97	2.41	2.86	0.11
			Grower phase		
Average daily feed intake (kg)	1.69	1.49	1.44	1.30	0.04
Average daily wt gain (kg)	0.69	0.78	0.65	0.54	0.05
Feed efficiency	3.02	2.50	2.86	2.55	0.09

[a]Values with the same letters in horizontal rows are significantly different ($P<0.05$).

Table 7. Performance and nutrient utilization in growing sheep fed sweetpotato- and cassava-based diets.

	Experimental variable		
Parameter	Maize	Sweetpotato	Cassava
Daily DM gross intake (g)	257.4	255.9	203.0
Daily DM concentrate intake (g)	662.4	843.9	708.3
Total daily DM intake (g)	919.8	1,099.8	961.3
Daily weight gain (g)	121.1	119.9	122.2
DM intake/unit wt. gain	7.6	9.2	7.9
N-balance (g/day/W 0.734 kg)	1.5	2.06	1.67
Digestible energy (% of gross energy)	81.59	86.31	83.33

faster than all others. Still you complain that it is too sweet.

"Now, I am telling you, select sweetpotato for low sugar content and high protein. After all, I have given you thousands of varieties of sweetpotato. If you do this, you will never again complain of starvation nor the death of my dear children from food insufficiency and related diseases" (Nwakpa 1986).

As we march through the dusk of this century into the dawn of a new one, we certainly need to empower our rural populace who provide the bulk of food for our table. No crop can achieve this in Africa as readily as root crops. Certainly, sweetpotato must be accorded its rightful place for food security and sustainable development in tropical Africa.

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Cooking Characteristics of Three Sweetpotato Cultivars Grown in Kenya

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Abstract

Boiled sweetpotato root is a popular food in Kenya. In this study an objective method for determining the cooking times of sweetpotato roots was developed. Small sweetpotato pieces were cooked in boiling water and the degree of cookedness was assessed by both instrumental and sensory testing. The Instron Universal Food Testing Machine was used for puncture and back-extrusion testing. Results of these tests were analyzed against one another and also against the sensory assessment scores for the degree of cookedness. The puncture test yielded data that correlated highly with the sensory data in a typical power model relationship for all three test cultivars. Cooking times and the sensory acceptability of the cooked root could subsequently be predicted from the instrumental results.

Key words: back-extrusion, cookedness, objective measurement, puncture test, sensory assessment, subjective measurement.

Introduction

Sweetpotato (*Ipomoea batatas*) is cultivated in virtually all agro-ecological zones represented in Kenya, except the arid regions of the North-Eastern Province. Sweetpotato had a key role as a security crop in the diet of many communities especially during periods of unfavorable climatic conditions when staple grain harvests are insufficient. The cultivation of this crop is solely on a subsistence scale in small backyard gardens or along highways. The average annual per capita production in Kenya has been estimated at 14.5 kg/person/yr (Ewell and Mutuura 1990), with a total annual production of 380,000 t (FAO 1989).

The majority of Kenyan communities boil the roots, peeled or unpeeled, and eat it with tea for breakfast and fermented porridge or fermented milk for lunch or supper. In the coastal regions, the roots are boiled and consumed with coconut juice during the Muslim Holy Season of Ramadan. The vines may also be used as a vegetable when cooked in combination with other local green leafy vegetables and eaten along with *ugali* (thick porridge) for lunch or supper; but mainly vines are used as livestock fodder.

There is an immense varietal diversity of sweetpotato in various parts of Kenya which provide a favorable potential for selection and improvement of those varieties having desirable nutritional and culinary qualities.

Problem Statement

Traditionally, sweetpotato is consumed after cooking in boiling water. When the root is boiled it softens and if overcooked may disintegrate. Overcooking should be avoided to reduce nutrient loss. Undercooking during the boiling process may be hazardous for the canned product and, although the product is still palatable, it may contain high amounts of anti-nutrients. These anti-nutrients generally break down through proper cooking. It is, therefore, necessary to cook roots for the optimum time. The degree of cookedness can be assessed subjectively by sensory measurement. This is achieved by

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pressing the root between the fingers, by biting with the inscissors (followed by mastication), or by puncturing the root with a sharp object. These methods cannot be relied upon in a commercial operation.

Nutritional evaluation of sweetpotato cultivars that abound in Kenya has not been the subject for research at the National Agricultural Research stations. As a result, there is very little information available on local, as well as imported cultivars.

In this study, three sweetpotato varieties, e.g., Nyakura, Nyeri, and Katumani Sweetpotato 20 (KSP20), were compared for their chemical composition (including nutritional constituents) and cooking characteristics. It is our conviction that this study will augment concerted national efforts at improving sweetpotato for human food.

Materials and Methods

Materials

Sweetpotato Cultivars

The three sweetpotato cultivars were planted at the Field Station, Faculty of Agriculture, University of Nairobi (UON), between 15 and 23 November, 1989. All varieties were planted on manually prepared mounds spaced approximately 0.7 m apart, using vine cuttings procured from an experimental nursery plot at the station and also from the sweetpotato germplasm collection maintained at Katumani Dryland Research Station in Machakos District of Eastern Province. The soil type at the station can be described as Kikuyu friable loam with good fertility. Weeding was carried out about four weeks after planting and no fertilizer was applied. Harvesting of all three varieties was done approximately six months after planting. Rainfall was adequate over the growing season and the growing roots experienced no physiological stress.

Cooking Characteristics

Universal texture testing machine, Instron, Model 1122, which has a tension-compression load cell type 2511-312, Model No. A217-12, England, was used for gauging the cooking.

Methods

Total Solids

Pre-weighed samples were dried in a vacuum oven maintained at 65-70°C to constant weight. Total solids were obtained by difference (Ranganna 1977).

Crude Fat

Pre-dried sweetpotato samples were extracted with petroleum spirits (40-60°C) in a Soxhlet extractor under reflux for a minimum of 8 hr. The extract was evaporated in a vacuum in a rotary evaporator and the residue dried in an air oven at 105°C for 1 hr. After cooling, the dried residue was weighed and the difference in weight (crude fat content) was expressed on a dry matter basis. This procedure was adapted after Ranganna (1977).

Crude Fiber

Exactly a 2 g sample, pre-dried in a vacuum, was digested in boiling 2.04N H_2SO_4 (sulfuric acid) for 30 min and subsequently in boiling 1.78N KOH (Potassium hydroxide) for 30 min. The resulting residue was rinsed repeatedly with portions of ethanol, transferred qualitatively to a porcelain dish, and dried at 105°C for 1 hr in an air oven. Dish and contents were weighed and transferred into a muffle furnace. The sample was ignited at 550°C to constant weight, cooled, and weighed. Crude fiber was obtained by difference and expressed on a dry weight basis (Ranganna 1977).

Crude Protein

The Macro-Kjeldhal method outlined by Ranganna (1977) was followed with modifications in the analytical reagents.

A 1 g sample (pre-dried) was digested by controlled heating with 20 ml concentrated H_2SO_4 in a Kjeldhal flask containing Kjeldhal catalysts and anti-bumping pumice. After digesting to completion, an appropriate amount of distilled water and some drops of phenolphthalein indicator were added. The digest was distilled later adding a sufficient quantity of 40% NaOH (Sodium hydroxide) solution to make it alkaline. The released NH_3 (ammonia gas) was collected in 50 ml 0.1N HCL (hydrochloric acid) solution and residual HCL back-titrated against standard 0.1N NaOH (Sodium hyroxide) solution. A blank was run alongside the samples and crude protein calculated as N x 6.25, where N was obtained by a suitable stoichiometric factor.

Total Ash

A previously dried weighed sample was ignited at 500°C until a light grey or white ash of constant weight was obtained (Ranganna 1977). Total ash was obtained by difference in weights and expressed on a dry weight basis.

Total Carbohydrates

The total carbohydrates excluding crude fiber were obtained by difference.

Cooking Characteristics

Sample Preparation

Sweetpotato pieces (4 cm in diameter and 3 cm in height) were gored out of the tuber flesh. The cylindrical pieces were placed in wire baskets and cooked in boiling water for predetermined time intervals. The cooked pieces were then segregated for sensory and instrumental evaluations.

Instrumental Evaluation of Cookedness

Back-extrusion

Cooked sweetpotato pieces weighing 320 g were uniformly stacked in a back-extrusion test cell. The test cell had a diameter of 101.6 mm while the diameter of the piston was 93.5 mm giving an annular clearance of 1,241.2 mm^2. The stroke depth was 30 cm and the stroke rate or cross-head speed was 100 mm/min. Maximum force required to accomplish extrusion was recorded. Five replicate tests were performed at room temperature. This is a modification of the procedure for cooked potatoes applied by Kozempel (1988).

Puncture Test

A cylindrical loading indenter 7.5 mm in diameter was penetrated into sweetpotato pieces, at a constant cross-head speed of 100 mm/min, to a depth of 7 mm. Chart speed was also set at 100 mm/min. Twenty pieces were tested and yield point force recorded for each. Tests were performed at the geometric centers of pieces that had been cooled to room temperature (Adam et al. 1980).

Sensory Evaluation of Cookedness

Sensory responses were used to determine the optimal cooking times for the three sweetpotato cultivars. The method used was adapted after that employed by Harada et al. (1985) for texture determination in cooked potatoes.

A nine-point scale (Table 1) was used to assess the degree of cookedness of the sweetpotato pieces. The 15 panelists were regular consumers of sweetpotato. Each panelist recorded his numerical judgements for the same three sample pieces. Water was available for panelists to rinse particulate matter from the mouth between tests. The judgements for each given sample were averaged (for the three samples) and used for regression analysis. According to scaled categories, a numerical judgement of five corresponded to an optimally cooked sample. The time required to reach this value was taken to be the optimal cooking time as determined from the regression equations.

Table 1. Sensory scale for evaluation of cooked sweetpotato pieces.

1	Extremely raw
2	Very slightly cooked
3	Slightly cooked
4	Nearly cooked
5	Sufficiently cooked
6	Very slightly overcooked
7	Slightly overcooked
8	Overcooked
9	Extremely overcooked

Results and Discussion

Root Composition

Cultivar KSP20 had the highest crude fat content (1.35%) and total ash (3.66%). Dry matter content and specific gravity of roots seemed to exhibit a positive correlation. Nyeri had the highest total solids (34.98%) and the highest specific gravity (1.066). Nyakura was intermediate with total solids of 34.75% and a specific gravity of 1.056. KSP20 had the least total solids (24.32%) and specific gravity (1.041). Total carbohydrates were comparable in KSP20 and Nyeri, 88.39% and 88.95%, respectively. The crude protein content was also similar at 3.95% for KSP20 and 3.73% for Nyakura. Nyeri which had the least total carbohydrates (84.51%) was almost twice that of

KSP20 or Nyeri. Proximate composition of the three cultivars is summarized in Table 2.

Table 2. Proximate composition of KSP20, Nyeri, and Nyakura.

	KSP20	Nyeri	Nyakura
Total solids (%)	24.32	34.98	34.75
Specific gravity	1.04	1.07	1.06
Crude protein[a]	3.95	8.44	3.73
Crude fat[a]	1.35	1.15	1.20
Crude fiber[a]	2.65	2.40	3.05
Total ash[a]	3.66	3.50	3.40
Total carbohydrates[a]	88.39	84.51	88.95

[a]% of dry matter.

Cooking Characteristics

Tables 3 and 4 show the back-extrusion force and yield point force for pieces of cultivars KSP20, Nyeri, and Nyakura cooked for different time intervals. Table 5 shows the regression analysis of averages of panelist responses to pieces cooked for various time intervals in boiling water.

Table 3. Back-extrusion force at different cooking times.

Boiling time (min)	Force required to accomplish extrusion (kN)[a]		
	KSP20	Nyeri	Nyakura
8	2.8	5.0	4.15
10	1.7	3.25	1.25
12	0.6	—	—
14	0.53	1.20	1.25
16	0.43	0.90	1.23
18	0.56	0.70	0.83
20	0.48	0.53	0.58

[a]kN = kilo Newtons.

From the regression analysis in Table 5, three equations can be constructed for the respective cultivars as below:

$$R_1 = 1.029 + 0.257\,t \quad (1)$$
$$R_2 = 1.293 + 0.207\,t \quad (2)$$
$$R_3 = 1.330 + 0.196\,t \quad (3)$$

In these equations, R_1, R_2, and R_3 are the average sensory scores for KSP20, Nyakura, and Nyeri, respectively, and t is the cooking time in minutes. Since the sensory score of 5 corresponded to an optimally cooked sample according to the category scale in Table 1, substituting this value for R in equations 1, 2, and 3 will give 15.5 min as the optimal cooking time for KSP20, 18 min for Nyakura, and 18.7 min for Nyeri. It appears that the higher the dry matter content, the longer the optimal cooking time. Nyeri which had the highest dry matter (see Table 2) also had the longest cooking time; while KSP20 with the least dry matter content also had the shortest optimal cooking time.

Table 4. Bio-yield point force at different cooking times.

Boiling time (min)	Bio-yield point force (kN)		
	KSP20	Nyeri	Nyakura
0	0.130	0.160	0.213
2	0.095	0.122	0.149
4	0.068	0.070	0.109
6	0.038	0.035	0.036
8	0.022	0.014	0.036
10	0.012	0.014	0.028
12	0.014	0.009	0.011
14	0.011	0.007	0.016
16	0.012	0.009	0.005
18	0.006	0.009	0.009
20	—	0.006	0.009

From Table 3, it can be seen that the center of the cylindrical pieces (Nyeri and Nyakura) cooked sufficiently after about 18 min. Any further cooking was unnecessary because rigidity and strength do not change. This agrees with the optimal cooking time as gauged by sensory evaluation in the case of both Nyeri and Nyakura. For KSP20, the time at which there is no further decrease in back-extrusion force for any additional cooking is about 15 min. This also agrees with the optimal cooking time from sensory evaluation. In Table 3, yield point force for KSP20 ceases to decrease any further at about 13 min, and at about 17 min for both Nyeri and Nyakura. These are not in as close agreement with the sensory data as were the back-extrusion tests, indicating that the back-extrusion test technique may be a better, more objective test for changes in textural properties in cooked sweetpotatoes than the puncture technique.

The usefulness of the objective texture measurement technique can only be gauged by the degree to which collected data correlate with sensory data. The puncture data were better correlated with the sensory data than back-extrusion (Table 6). Also, the puncture

Table 5. Optimal cooking time of KSP20, Nyeri, and Nyakura by sensory evaluation.

	Regression constant	Std. error of Y	R^2	X coefficient	Std. error of coefficient
KSP20	1.02857	0.333	0.980	0.257	0.0210
Nyakura	1.29286	0.327	0.971	0.207	0.0210
Nyeri	1.33000	0.314	0.970	0.196	0.0198

Y = Average sensory score for degree of cookedness.
R^2= Regression coefficient.
X = Cooking time (min).

test was quicker. Back-extrusion exceeded the range of measurement during the earlier minutes of cooking. Data in Tables 3 and 4 were regressed to evolve the best mathematical models. Table 6 is the summary of the regression coefficients. A power model (log-log equation) fit the instrumental vs sensory data best. In this model, the puncture data showed better correlation for all three cultivars. The instrumental methods used did not correlate highly and a log function fit such data best.

Table 6. Regression coefficients for instrumental and sensory data.

	KSP20	Nyeri	Nyakura
Sensory vs. back-extrusion data: Equation $Y = AX^B$			
A	67.93	293.92	43.16
B	-3.02	-3.84	-2.48
r^a	0.81	0.98	0.78
Sensory vs. puncture data: Equation $Y = AX^B$			
A	0.18	0.37	0.51
B	-1.83	-2.61	-2.55
r^a	0.95	0.94	0.93
Back-extrusion vs. puncture data: Equation Y = A+BLog (X)			
A	1.37×10^{-2}	8.63×10^{-3}	1.38×10^{-2}
B	4.93×10^{-3}	3.92×10^{-3}	1.47×10^{-2}
r^a	0.51	0.78	0.63

[a]Correlation coefficient.

Conclusion

The instrumental methods used above are accurate and reproducible. However, the results are meaningless without the sensory responses. For field work or commercial operations, the Instron would have to be replaced by a simpler hand tool for more rapid results. A puncture probe would be most appropriate.

The sensory assessment of cookedness can be best predicted from the instrumental data using the power equation.

The force measured depends mainly on the dry matter content of the root. The methods described here will be useful for all tropical roots and tubers.

Finally, there is a big variation in composition between cultivars. More research work should be carried out to determine the nutrient composition of all available cultivars.

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Trials for the Introduction of Sweetpotato in Bread Making in Burundi

D. Berrios and M. Beavogui[1]

Abstract

Many African countries import large quantitites of wheat flour to satisfy the rapidly growing demand for bread among the expanding urban population. This represents a major drain on scarce foreign exchange as well as on food dependence. At the same time, many of these countries also produce sweetpotatoes. This paper describes efforts in Burundi to substitute locally produced sweetpotato in raw, grated form for wheat flour in the baking of composite bread. The techniques utilized are relatively simple. The necessary ingredients are all available locally. Pilot production and consumer testing have both proven quite satisfactory.

Key words: postharvest technology, wheat flour, pilot production, consumer testing.

Introduction

The people of Burundi consumed 14,000 t of wheat flour in 1990. Nearly all of that wheat was imported; and 99% of that flour was used for making bread. In 1990, it represented 1.759 million Burundese francs (FBU), or US$ 10.1 million. Considering the rapid growth of bread consumption in the country, this sum could increase drastically in the near future, taking away an important part of already small foreign exchange resources.

Even though the Government of Burundi is encouraging domestic wheat production along the Zaïre-Nile Divide, it is estimated that the local harvest will cover only 50% of the country's needs by the year 2000. There is, therefore, a need to find alternatives to simply importing more wheat flour. One possible approach is the promotion of composite bread made by including sweetpotato into the wheat flour mixture.

Each year, Burundi harvests 650,000 t of sweetpotato. The crop is produced throughout the country and consists of many different varieties. The roots are sold between 5 and 12 FBU, which is 10-15 times cheaper than wheat flour. Moreover, postharvest losses of sweetpotato nation-wide are estimated to be as high as 50%. For these reasons, and following a proposal of a CIP consultant, it was decided to try the introduction of composite bread in Burundi. The recipe used, of Peruvian origin (*pan de camote*), includes the incorporation of raw, grated sweetpotato in the wheat flour dough.

Materials and Methods

The project was carried out in two phases:

- laboratory experiments, including preliminary consumer testing; and,
- pilot production, complemented by a large consumer test which included some commercial promotion.

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Laboratory Experiment

Laboratory testing was necessary since it was not known how the locally produced sweetpotato varieties would perform during baking, nor what would be the best locally acceptable percentage of sweetpotato to wheat flour in the bread.

These laboratory experiments were conducted at the *Institut des Sciences Agronomiques du Burundi* (ISABU) at Gisosi Center.

Raw Materials

The wheat flour used was purchased at the local market from the usual importing company.

Analysis of the flour indicated the following results:

Zeleny test	= 21 ml
Chopin alvaeograph P	= 86.9
P/L	= 0.99
W	= 295.6
G	= 20.3
Dry matter	= 87%

The sweetpotato used was variety *Inzovu y'umaganba*. During analysis, only a dry matter content of 38% could be identified. Further testing could not be done because of equipment limitations. Other components (sugar, yeast, oil, and salt) were procured in the local market and were considered to be of good quality. The final ingredients, amylase and ascorbic acid, were obtained from ISABU.

Equipment

The equipment used for preparing the dough for baking included:

- Chopin alveograph
- Grinder/multirobot
- Mixing machine (Petrin)
- Electric oven
- Various containers and hand tools

Process

Several trials were made. These trials involved the baking of about 1,000 pieces of 70 g bread. The following process was used:

Preparation of raw materials. Wash sweetpotatoes using water and a brush; grind sweetpotatoes; weigh raw materials (flour, sweetpotatoes, additives); and mix with yeast in warm water (Fig. 1).

Mixing. Mix flour, sugar, amylase, and ascorbic acid in the mixing machine. Add yeast mixture; add water; add ground sweetpotato while still mixing; and add salt while mixing as the final step.

Fermentation. Let the mixture rise for 25 min; cut the mixture into pieces and let it rise again for 25 min; and form the pieces of bread and let them rise again for about 25 min.

Baking. The baking was done as for normal bread at a temperature of approximately 250°C.

Quality control. The main factors observed in quality control procedures were volume, color, smell, taste, and porosity.

Pilot Production

During the pilot production phase the sweetpotato bread was tested under real conditions. This was necessary to determine the best technological process to be used at a given production facility, fix the production cost, and obtain the opinion of the consumer. It was decided that the pilot production would be done in a neighborhood, cottage industry-type bakery in Bujumbura, since this is the way that inexpensive bread is baked in the rural areas of Burundi.

Raw Materials

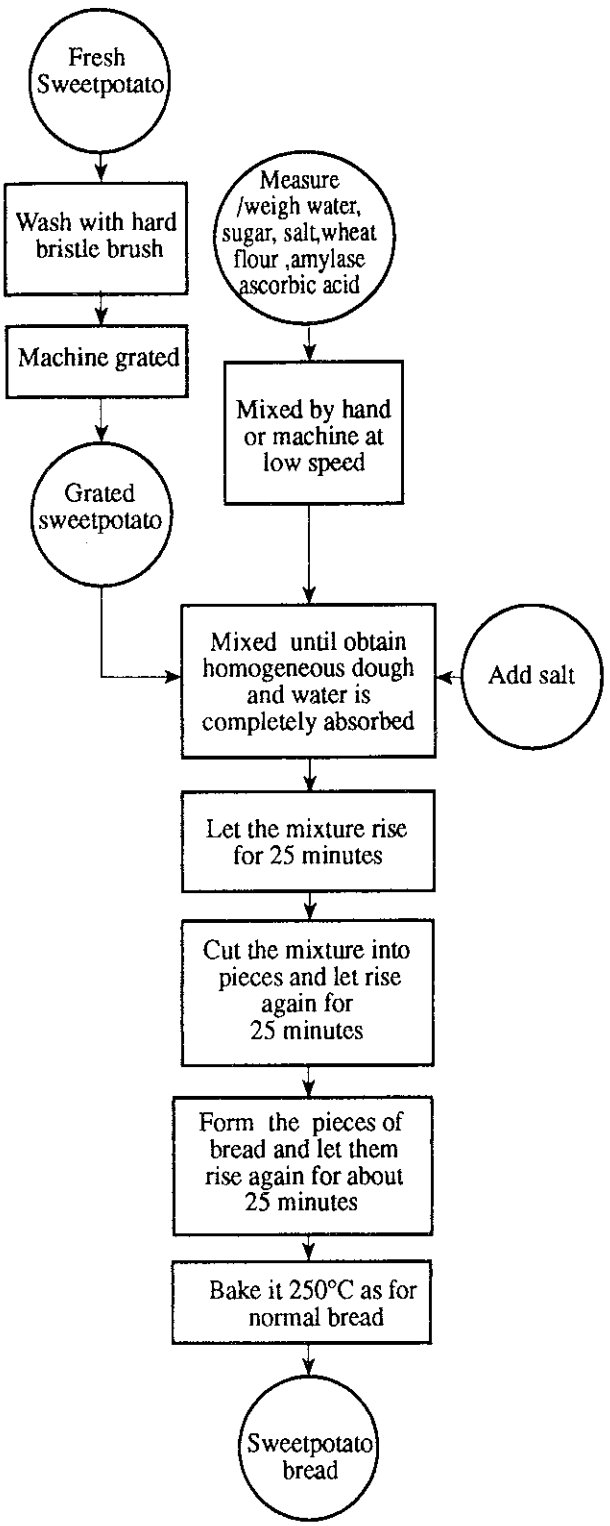
The raw materials used were the same as those in the laboratory test. Therefore, it was considered that their technological, biochemical, and microbiological qualities were good and no new analysis was needed.

Equipment

The sweetpotato grinder used was a machine manufactured locally by a project of the Food and Agriculture Organization of the United Nations (FAO). The grinder was built by modifying the design of a cassava grater, and driven with a 220V electric motor which has a capacity of 200 kg of sweetpotato per hour.

The rustic ovens in the neighborhood bakery are made from bricks with the baking chamber on the top of the combustion chamber. The two chambers are separated with a piece of sheet metal which serves as a heat exchanger. The oven is heated by a wood fire.

Figure 1. Process for making sweetpotato bread.



In addition to various containers and hand tools, the two major pieces of equipment used were the sweetpotato grinder and the rustic oven.

Process

The following process was used:

- After washing the sweetpotato roots with water and a brush to remove surface impurities, they were weighed. Twenty-five kg of wheat flour, 10.5 kg of ground sweetpotato, and other additives were set aside.
- First, the flour and water were mixed in a container, and the ground sweetpotato roots added progressively.
- Hand mixing was continued until the mixture became homogeneous. It was left to rise; after which pieces were formed. After rising again, the bread was baked for 15-20 min.

Results

The most appreciated bread obtained, using the *pan de camote* recipe, is the one in the shape locally called "sandwich." It is a 70 g piece made out of 70% wheat flour and 30% grated sweetpotato (fresh weight). In bread made with up to this percentage (30%), the sweetpotato taste was not perceived by consumers.

In terms of quantity, the number of bread pieces obtained with the mixture 70/30 is less (0.05%) than the one with 100% wheat if an equivalent amount of ingredients are used. Nevertheless, the overall production cost with the 70/30 bread is over 15% lower.

Large consumer tests have been very satisfactory as the bread was fully accepted. A commercial test was also done at the second stage. This test was advertised using posters and labels. Consumers bought the bread readily at the same price as bread made with 100% wheat flour.

Given this increase in profit, the female owner of the neighborhood bakery where the test was organized decided immediately to take over the production and to carry it out. The bakery, located in a suburb of Bujumbura, is now producing *pan de camote* on a regular basis. Since then, many other interested bakers have approached the project for assistance.

Conclusion

The *pan de camote* can be easily produced in the required qualities by local, cottage-industry-type bakeries.

It definitely can have an impact on the country's economy. In fact, the promotion of *pan de camote* will help:

- the country to save foreign exchange by importing less wheat flour;
- the farmer to have access to a new market for sweet-potatoes;
- the baker to increase profits by lowering the cost of producing bread; and,
- the consumer (maybe) to buy cheaper bread.

The Use of Sweetpotato in Bakery Products in Cameroon

Adhiambo Odaga and Rose Wanzie[1]

Abstract

Cameroon, like many African countries, uses scarce foreign exchange to import wheat flour. Cameroon also produces some 150,000 t of sweetpotatoes a year and there is considerable potential to expand output well beyond that total. However, prices for sweetpotato are low and demand for fresh roots limited. Thus, a key question emerges: if Cameroon's farmers harvest more sweetpotatoes, how will they be utilized? This paper documents the experience to date in substituting raw grated sweetpotato roots and sweetpotato flour in bread, cookies, doughnuts, and other bakery products. The results indicate that this is not only technically feasible but also economically attractive. Thus, considerable potential exists for generating additional uses for sweetpotato as well as reducing wheat flour imports.

Key words: bread, grating, women's groups, costs, revenues.

Introduction

The use of sweetpotato grated roots and flour in bakery products particularly in bread making has been attempted in several countries including the Phillipines, Trinidad and Tobago, Taiwan Province of China, Burundi, and Peru (Woolfe 1992). Sweetpotato is one of only two root crops for which improved varieties are available and widely cultivated in Cameroon. With an annual average production of 150,000 t, Cameroon is the leading producer of the crop in the West Africa region. Due to the success of a colloborative project between The International Institute for Tropical Agriculture (IITA), Cameroon's Institute of Agronomic Research (IRA), and Gatsby International, sweetpotatoes are widely grown in the country. Postharvest utilization of the crop, however, remains limited.

The Food and Agricultural Organization of the United Nations (FAO)/United Nations Development Program (UNDP) project has developed a technique for processing sweetpotato roots into dried chips that are then milled into flour. The process has been introduced to a women's group in Babungo who are now producing dried sweetpotato chips. Recipes that utilize both sweetpotato roots for bread making and sweetpotato flour for cakes, biscuits, pastries, and local snacks have been developed and introduced to local bakeries and bakers. Data on various costs are being collected.

This paper gives an account of an ongoing study on the viable use of sweetpotates in bakery products in Cameroon. The study developed composite sweetpotato/wheat flour recipes for bread, pastries, and local snacks and introduced them to local bakeries and bakers. An attempt is being made to analyse the economic benefits of such recipes and assess the viability of their long-term adoption and use. The paper describes what has been accomplished so far with regard to the two sweetpotato products in question: i) Sweetpotato flour; and, ii) bread made from freshly grated sweetpotato roots.

Some preliminary conclusions are also presented.

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Sweetpotato Flour

Bread

A local pastry chef was hired to develop recipes for popular local breads. Initially it was presumed that sweetpotato flour could easily be incorporated into bread making. Since bakers are used to flour, it was assumed that sweetpotato flour would be more acceptable and convenient to them than fresh sweetpotato roots. A recipe comprising 25% sweetpotato flour/75% wheat flour was introduced to a modern bakery in Bamenda. The first batch of bread baked turned out well but was rejected by consumers for several reasons. The sweetpotato flour bread looked like wheat bread which consumers are not familiar with in Cameroon. Since several of the distributors did not let their clients know that the bread contained sweetpotato, the products were rejected on sight. Those consumers who did taste the bread found it palatable though some complained that the bread was too crumbly and a little dry. The bakers also found the sweetpotato flour difficult to work with in bread making. They spent hours kneading in order to turn out reasonable dough. This exercise has laid to rest an ongoing debate amongst us on whether or not to endorse certain sweetpotato flour recipes. For now, we have decided not to recommend sweetpotato flour for bread making.

High Value Bakery Products

In the process of experimenting with the sweetpotato flour for bread making, it became evident that the flour was suitable for high-value baked products such as cakes, biscuits, and pastries. Consequently, a number of recipes using between 25-75% sweetpotato flour have been developed.

Three modern bakeries have had the recipes introduced to them. Staff of the bakery we are presently working with have been very impressed with the recipes for biscuits, doughnuts, and croissants containing between 25-50% sweetpotato flour. Although they advised us that high-value products such as those we have developed recipes for are not as popular in the Anglophone North West province as in the Francophone regions, they have been impressed at the quick rate at which all the products baked with sweetpotato flour have sold in their local retail outlet.

Each bakery has received 50 kg of sweetpotato flour. Data collection is well underway to enable us to calculate the economic benefits, if any, of using composite sweetpotato/wheat flour recipes.[2]

Local Snacks

In order to explore as wide a range of products as possible, the feasability of incorporating sweetpotato flour into recipes for local snacks was also explored. As mentioned above, several women both in the rural and urban areas fry, bake, and sell a variety of local snacks. A recipe utilizing 25% sweetpotato flour in making 'puff-puff'—a local deep-fried doughnut-like snack, has been tested and well received, so too, one for fish/meat pie utilizing 40-50% sweetpotato flour.

The 'puff-puff' recipe has been introduced by an extension worker to the group of women who are processing sweetpotato tubers into chips for milling into flour at Babungo and also to other women in Babungo who sell the snack locally. Eventually the recipe will be introduced to women in Bamenda and other parts of the province. Further experiments are being carried out to develop recipes for other local snacks. As news about sweetpotato flour have circulated, both projects are constantly receiving requests for the flour.

Processing Sweetpotato Flour

Any discussion about sweetpotato flour in Cameroon is incomplete without mention of the processing techniques used and production costs of the flour. Sweetpotatoes are amongst several other root and tuber crops produced in Cameroon. However, improved varieties are available for only two of these crops—cassava and sweetpotato. In the case of sweetpotato, the introduction and wide dissemenation of three IITA clones particularly TIB1 and 1112 has led to a tremendous increase in productivity. The improved varieties yield on average 20 t/ha versus 7-8 t/ha for the local varieties. Despite the success in promoting improved sweeetpotato varieties—the question of what to do with the increased yield is one that has been the focus of several discussions.

[2] Data collection has been slowed by a tense political situation in the last year which interrupted the normal running of all business enterprises.

In 1988 the Institute of Agronomic Research (IRA), Ngaoundere in the northern province of Adamawa, attempted to produce dried sweetpotato strips to be used in the production of composite wheat/sweetpotato flour. Due to several factors—financial and technical, the project was discontinued. In 1989/90 the FAO/UNDP Postharvest Food Losses (PFL) project installed a pilot plant for processing root and tuber crops at the Trials and Demonstration Center at Santa. Here they carried out trials involving practical processing techniques adapted to Cameroon conditions. They have been successful in achieving their objective for the production of dehydrated sweetpotato chips (Mbakwa 1992). The process has been introduced to a dynamic cooperative, the Bassibissi Women's Group, based in Babungo in the Ndop Plain. After identifying this group, which is also involved in the production of sweetpotatoes, the PFL project built a processing plant on a cost-sharing basis with the women. Installation of the equipment took place as part of a training session. The training covered introduction to the equipment, installation of the equipment, introduction to the processing technique, product hygiene, drying, packaging, and storage. All the flour used in the study has been produced by this group.

The group follows a simple technique to process fresh roots into chips. It involves the following steps: Washing→Peeling→Slicing→Blanching→Cooling→ Drying→Packing. Slicing is facilitated by the use of a pedal-driven slicer. Blanching prevents discoloration and preserves the natural flavour of the sweetpotatoes. The sliced sweetpotato chips are dipped in boiling water (90°C) for 10 minutes. The water contains 0.5% sodium bisulphite and 0.1% acetic acid. After blanching the potatoes are dipped into cold water for 5 minutes to cool down. The chips are solar dried on a raised platform. Since the chips are air-dried, processing is limited to the dry season, between November and February. Today the group can competently produce dehydrated chips.

We have been very concerned to collect data on the production costs of sweetpotato flour. Table 1 indicates production costs based on data from the pilot phase of product development. Drying was evidently a major constraint. Table 2 presents data based on dehydrated chip production at Babungo by the women's group. As the data clearly indicate, our major concern with regard to sweetpotato flour has been the viability of adoption given the relatively high-cost of the flour, 108-155 CFA per kilogram versus the low subsidized price of wheat flour (120-150 CFA/kg).[3]

This concern is mitigated by several factors. First, the recipes developed have been for high-value baked products which are the most expensive items in most bakeries. Second, there is a 40 to 70% reduction in sugar used in most of the recipes as a result of the high sugar content in sweetpotatoes. Third, the recent rise in the wholesale price of wheat flour and indications that they may be further increased very soon. And finally, the added nutritive value in using sweetpotato flour must not be overlooked. However, until enough data is collected for a cost-benefit analysis, we will be unable to fully assess the value of this product. Concerns about marketing and packaging must also be addressed.

Sweetpotato Grated Roots

At the time when the FAO/UNDP project was working on developing recipes for sweetpotato flour, they were given a video tape of an International Potato Center (CIP) recipe that utilizes grated sweetpotato roots in bread making. A woman baker, who was renting a small, local bakery, was approached to try out similar recipes. The results were quite encouraging. All the bread she baked was well appreciated by her customers and sold very well. After this informal exercise this 'wet-method' was put on the back-burner until early in 1992 when the FAO/UNDP project and CIP decided to collaborate on a research initiative to examine the potential economic benefits of introducing composite sweetpotato flour/wheat flour bakery products locally.

A decision was taken to introduce this method of bread making to a small "traditional" bakery in Bamenda. The bakery is located in Nkwen, one of the major quarters in the town. They bake only the square loaves, known locally as "English loaf" or "Kumba bread".[4] They hand mix their dough and bake their bread in a brick wood-fueled oven. The dough is kneaded in a diesel powered machine. The bakery is rented by the chief baker who hires 3 laborers and another baker on a daily basis. Each month the bakery consumes an average of sixty, 50 kg bags of wheat flour.

The hired baker had worked with the woman baker who first used the "wet-method" to produce bread and

[3] Central African Franc, US$ 1 = 273 CFA; French Franc 1 = 50 CFA.

[4] The french loaf or baguette is also a very popular type of bread but is not produced in this particular bakery.

Table 1. Pilot phase production costs of sweetpotato flour.

	A[a]			B[b]		
Item	Quantity	Unit price (CFA)	Cost (CFA)	Quantity	Unit price (CFA)	Cost (CFA)
Sweetpotato roots	450 kg	17	7,650	450 kg	17	7,650
Labor	14 persons	300	4,200	9 persons	300	2,700
Fuel	270 kg	10	2,700	270 kg	10	2,700
Water	390 litres	0.216	84	390 litres	0.216	84
Depreciation (bldg, slicer, etc.)			760			304
Running costs			343			137
Total costs			15,737			13,575
Output: dried chips	125 kg			125 kg		
Cost/kg			126			
Milling cost			29			
Flour cost/kg			155			137

[a] Considering labor works five hours a day and there is a drying platform constraint. Labor consists of 4 persons for the first two days, 1 person for the third day, 4 persons for the fourth day, 1 person on the fifth day (drying).

[b] Considering labor works for eight hours a day and there is no drying platform constraint. Labor consists of 4 persons for the first two days and 1 person for the third day.

was thus familiar with the grated sweetpotato/wheat flour recipe. We were therefore able to use the bread from the first exercise with the bakery in April to carry out palatability tests to establish the percentage of sweetpotato that would be acceptable to consumers. The data from the palatability tests has been analysed elsewhere. Suffice it to say that there was no significant difference in consumer preferences for bread containing 20% and 30% grated sweetpotato. Based on these results we recommend a composite mixture that contains between 25-30% grated sweetpotato to local bakeries.

The bakery has made and sold several batches of sweetpotato bread ranging from 25-35% of the dough. Most of the batches have been less than 50 kg in weight. Table 1 presents data comparing costs and revenues from a mixture of one bag wheat flour, the smallest amount the bakery mixes at any given time and one bag of wheat flour plus 17 kg of grated sweetpotato (i.e., 25% grated sweetpotato on a fresh weight basis). Ideally we would have preferred to make a comparison between two similar weights, that is 50 kg wheat flour versus 35 kg wheat flour and 15 kg grated sweetpotato (30% grated sweetpotato) for example. The baker however preferred to make his comparison in the manner presented here (Table 3). The data clearly indicate that it was cheaper to produce sweetpotato bread than to produce 100% wheat bread. This is due to the reduction in sugar, magarine, and water in the sweetpotato bread which is greater than the additional cost for sweetpotato roots, grating, and groundnut oil in this recipe. Since the sweetpotato bread dough was larger it gave more units of bread and thus earned 3,000 CFA more than the wheat bread.[5] The difference in revenue (4,461 CFA) that accrued from the 50 kg bag of wheat flour plus grated sweetpotato versus the 50 kg of wheat flour alone is very attractive. As we prepare to move the grater the bakery has been using to the next bakery, the manager is seriously considering investing in an electric grater and has approached us to arrange a meeting with a local manufacturer.[6]

[5] It is important to note that the bakery does not have a scale to weigh the dough before baking as is normally done. Thus the weight from one unit to the next can vary by as much as 40 g. This of course has implications for the overall returns from any batch of dough.

[6] Tables 4 and 5 indicate the costs of locally manufactured graters and oven respectively.

Table 2. Production costs based on sweetpotato flour trials.

	A[a]			B[b]			C[c]		
		Unit price			Unit price			Unit price	
Item	Quantity	(CFA)	Cost	Quantity	(CFA)	Cost	Quantity	(CFA)	Cost
Sweetpotato roots	756 kg	14	10,811	2,436 kg	14	34,835	2,436 kg	14	34,835
Labor[d]	54 persons[e]	300	18,500	173 persons[f]	300	7,000	173 persons[f]	300	57,000
Fuel	302 kg	6	1,812			6,445			6,445
Water	1,470 lt	216 m^3	318	52,651 lt	216 m^3	1,137	52,651 lt		1,137
Depreciation[g]			760			2,738			2,738
Running costs			343			1,233			1,233
Total costs			32,544			103,388			103,388
Output: dried chips	327 kg			1,054 kg			879 kg[h]		
Cost/kg			99			98			118
Milling cost			11			11			11
Flour cost/kg			110			109			129

[a] This data represents actual data collected from the Bassibissi women's group in Babungo during five processing sessions between January 22, 1993 and February 15, 1993.

[b] This data represents 18 processing sessions by Bassibissi group between December 3, 1992 to March 9, 1993. The women stopped processing sweetpotato after this date because of the onset of the rainy season. Indeed the sweetpotatoes processed during the last three sessions (406 kg) were damaged and lost due to heavy rainfall (the following assumption has been made: the sweetpotato chips are equal to 43.28% of the fresh sweetpotato weight).

[c] This data represents the 18 processing sessions as mentioned in b, but estimating the production costs taking into account the 406 kg lost due to rain damage (the following assumption has been made: the sweetpotato chips are equal to 43.28% of the fresh sweetpotato weight).

[d] As mentioned in the text the Bassibissi women's group provide labor for processing of the sweetpotatoes as part of their group activities. If they were to sell their labor in the rural market they would do so at a rate of 1,000 CFA each daily. The 300 CFA rate is however used to calculate the opportunity cost of that labor.

[e] An additional 23 days were required to dry the chips. Only one woman was involved. This task took less than a third of the time required for processing and the opportunity is calculated at 100 CFA per day.

[f] 51 days were used to dry the chips at a cost of 100 CFA/day.

[g] Building, slicer, etc.

[h] The dry chips weight reflect the loss of 406 kg due to rain damage.

Discussion

In introducing this method of bread making to bakeries we had several concerns. Would the bakeries be discouraged by the large expense involved in investing in an electric grater? Would the extra tasks of washing the roots and then grating before mixing the dough pose a problem for bakeries? Finally, the question of availability and supply of sweetpotato roots to bakeries also posed a potential problem.

The bakers we worked with were very impressed with the method of bread making we introduced them to. The baker renting the property was keen to invest in a grater but was unable to do so because of financial constraints. The owner of the bakery has also indicated an interest in buying or having a grater manufactured for the bakery. The lack of liquidity on the part of bakers to have a grating machine manufactured for their enterprise has hindered attempts to introduce this method to other bakeries as well. We recommended a revolving fund to assist them and are presently examining the best way to proceed with such a credit scheme.

The length of time required to wash (10 minutes) and to grate[7] (5 minutes) was not viewed as a constraint.

[7] In order to facilitate the smooth running of the exercise we left the FAO/UNDP project's grater with PEC bakery.

Table 3. Costs and revenue for sweetpotato vs. wheat bread at the PEC bakery, Bamenda.

	Wheat flour			Sweetpotato		
	Price/unit (CFA)	Unit	Total (CFA)	Price/unit (CFA)	Unit	Total (CFA)
Costs						
Wheat flour (kg)	140	50.0	7,000	140	50.0	7,000
Grated sweetpotato (kg)	20	–	–	20	17.0	340
Yeast (kg)	1,890	0.3	567	1,890	0.15	283
Dough improver (kg)	2,500	0.15	375	2,500	0.15	375
Magarine (kg)	750	2.0	1,500	750	0.5	375
Salt (kg)	150	0.3	45	150	0.25	38
Sugar (kg)	150	5.0	1,500	150	2.0	600
Groundnut oil (litre)	300	–	–	300	1	500
Water (litre)	500	30	300	500	16	160
Fuel (litre)[a]	10		2,400	10		2,425
Labor[b]			1,250			1,250
Other costs[c]	1,250		470			540
Total costs			15,407			13,946
Revenue						
Loaf A	200	30	6,000	200	30	6,000
Loaf B	150	80	12,000	150	80	12,000
Loaf C	20	200	4,000	35	200	7,000
Total revenue			22,000			25,000
Net Revenue						
Total revenue - Total costs			6,593			11,054

[a] Firewood, engine oil, diesel and petrol for the grater in the case of sweetpotato bread.
[b] One baker and three assistants.
[c] Depreciation, management, marketing, etc.

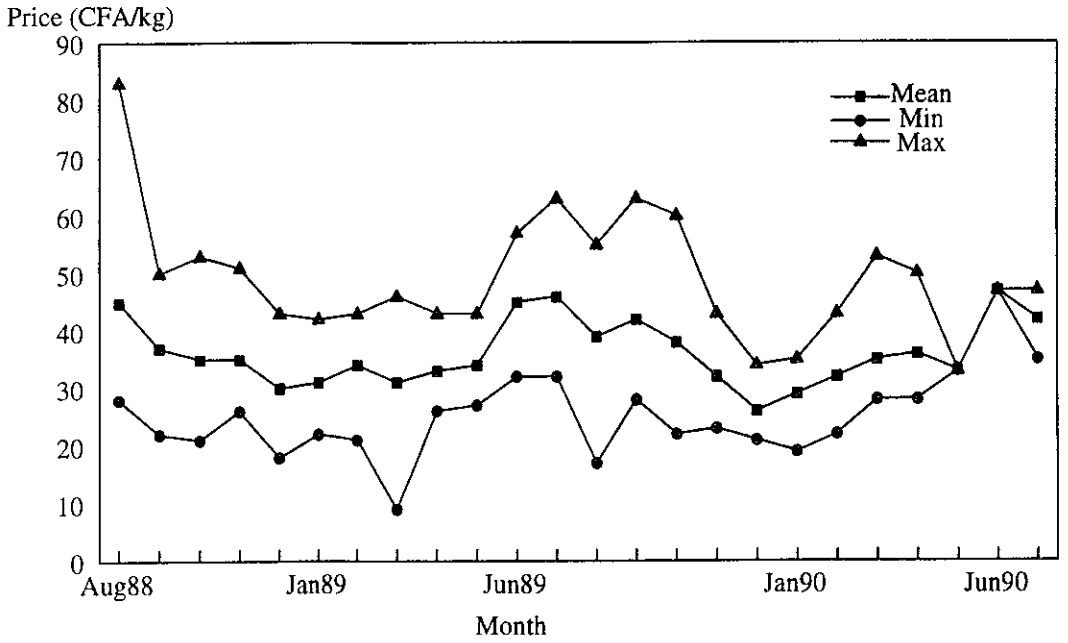
Instead, the long period of time required for the bread to rise posed some problems initially. After the baker became more comfortable with mixing the dough, however, it became less of an issue to the extent that by the time he was making his sixth batch he was no longer mentioning it. Mr. Atangana Benoit, the chef we are working with, has suggested that this problem may be due to the fact that the dough is being hand-mixed. He suggests that if an electric mixer is used there will be no significant difference between the time needed for the 100% wheat dough and composite sweetpotato dough to rise. This proposition will be tested when we introduce this method to modern bakeries who use electric dough mixers.

The extent to which bakeries will have access to fresh sweetpotato to meet their demand all year round was identified as a possible disincentive to adoption of the "wet method". We however did not view this as a major constraint and decided to gain bakeries views on the matter as soon as possible. Discussions with the bakeries so far suggest that they do not view supply as a major problem at all and that they could easily arrange for a regular supply of sweetpotatoes at short notice either from rural sites or locally from urban gardens. The market data presented in Figure 1 indicate that sweetpotatoes are available cheaply all year round.

Conclusion

This paper has presented results of a study on the potential for utilization of sweetpotato in bakery products in Cameroon. The study is being conducted by the Provincial Delegation of Agriculture in the North West Province and the International Potato Center-

Figure 1. Sweetpotato prices in the Cameroon.[a]



Source: FAO-PFL project.

[a] 11 markets of the North West Province.

Cameroon. Data collection has been slower than initially expected and is ongoing. Nonetheless enough data has been accumulated from which some conclusions may be drawn.

- Sweetpotato flour is best used for high value bakery products rather than for bread making.
- A women's group is engaged in processing of sweetpotato into dried chips for flour during the dry season months November to February. Given the relatively high production cost of sweetpotato flour vis-à-vis the low subsidized price of wheat flour, however, much work remains to be done to promote the use of sweetpotato flour for high value bakery products. Data collection to evaluate the economic benefits of using sweetpotato flour has been hampered by the tense political situation in the past year and is ongoing.
- The potential for the use of fresh sweetpotato roots in bread making is tremendous. Sweetpotatoes are available all year round at a very cheap price. The product developed and being introduced to bakers is very much appreciated by the consumers and the potential profit to the bakers is attractive. The use of this method of bread making does, however, require investment in a grater. Given the present economic recession in the country and so long as a revolving fund scheme is not introduced, the bakers will only use the technique until the grater being loaned to them is removed by the project. The project has therefore allocated funds to be used on a revolving basis to provide graters to bakeries.
- Finally, it must be noted that the consumption of bread and other bakery products is much higher in Francophone areas of Cameroon. This study is being carried out in the North West Province of Cameroon, an Anglophone region. The data presented in this paper therefore are only suggestive of what may be obtained in other parts of the country and indeed in other parts of Africa where the consumption of bread and other wheat flour products is as high as in Cameroon.

Our research effort has been boosted by national TV coverage of sweetpotato processing into chips and flour to product development and extension to bakeries. We are confident that by the end of the year the full cost-benefit data for bakery products using sweetpotato will confirm what we believe to be the great commercial potential for utilization and adoption of sweetpotato in local bakery products.

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V. Setting Up Pilot Plants

The pilot plant phase is a critical step in the product development process. At this stage, all the separate components involved in product, equipment, process, and market research must be integrated, then optimized to constitute a functional, economically viable enterprise. This section reviews the various activities undertaken in the pilot plant phase and presents criteria to consider in their successful integration. It also includes a retrospective analysis of the pilot plant experience with cassava in Nigeria and in the Congo. As potato and sweetpotato processing in Africa is rather limited—in part for lack of information about existing processes and products in other regions of the developing world, the section concludes with an account of product development work involving production of mixes made from solar dried potatoes in Peru and transparent noodles from sweetpotato in Vietnam.

Christopher Wheatley provides a set of guidelines for successful **Pilot-scale Operations**. These refer to plant construction, experimental and semi-commercial operation, test marketing, and feasibility studies. He notes that specific issues such as organizational structure of the pilot plant operation, raw material supply, product quality, and promotion must be addressed as well. The guidelines include criteria for helping implement each of these activities. Wheatley stresses the need for continuous monitoring of product production and marketing such that in 12 months a commercially viable enterprise can be established.

Cassava processing is a major activity in Africa where cassava constitutes approximately 60% of the diet. Transformation of the crop is essential because of its perishability and because its toxic substances must be reduced, if not eliminated, to make cassava fit for human consumption. Yet traditional processing is inefficient because of the significant losses during transformation and high labor inputs. In **Pilot Testing of Improved Cassava Processing Technologies in Nigeria: A Case Study**, Y.W. Jeon and L.S. Halos briefly review the strategy employed at the International Institute for Tropical Agriculture (IITA) to develop, evaluate, and diffuse new processing techniques. As they explain, this approach embraces the food system as a whole rather than specific practices (e.g., drying) or activities (e.g., processing versus utilization).

S. Trèche and J. Massamba's **Report on the Study and Improvement of Cassava Utilization in the Congo** describes the results of a research program whose main objective is to adapt cassava processing to consumers' demands in the context of increasing urbanization. The authors emphasize the results of their work on cassava consumption and processing as well as its use in weaning foods. For example, they note that because of the properties of its starch, protein-enriched cassava

flour could constitute an important weaning food. Among the program's limitations are the time needed to foster effective technology transfer and the highly location-specific focus of these efforts.

In **Potatoes, Mixes and Soups: A Case Study of Potato Processing in Peru**, Gregory J. Scott, David Wong, María Alvarez and Alberto Túpac Yupanqui analyze attempts of several institutions to improve simple potato processing over the last 15 years. Traditional potato products and processing techniques are briefly described. Efforts to improve the techniques are evaluated. The development of new products is also examined. The lessons learned from this experience cover three broad areas: technology, marketing, and finance. According to Scott et al., the most important of these, perhaps, is the need to identify clearly at the outset the relevant product characteristics and the target market segment.

Sweetpotatoes have traditionally been transformed into a variety of processed products in Asia. Given the interest in low-cost processing procedures for sweetpotato in Africa and the lack of information about such practices in Asia, Dang Thi Lan and Sarath Ilangantileke describe the **Utilization of Sweetpotato for Transparent Noodles in Vietnam**. Their work involved an analysis of traditional practices for making transparent noodles and subsequent efforts to improve them. Their proposed improvements proved not only technically possible in Vietnam but also of acceptable quality based on a sensory evaluation.

Pilot-scale Operations

Christopher Wheatley[1]

Abstract

A critical step in the product development process takes place at the pilot plant phase. This paper reviews the activities undertaken here including: plant construction, experimental and semi-commercial operation, test marketing, and a feasibility study. It addresses specific issues such as organizational structure of the pilot operation, raw material supply, product quality, shelf-life and packaging, preliminary marketing studies, and product promotion. Continuous evaluation of plant (process and equipment) and product (marketing) performance is stressed throughout. The experience acquired is seen as contributing to the establishment of a technically and financially viable enterprise in the course of about 12 months. Examples are cited based on work with specific root and tuber products.

Key words: processing, roots and tubers, markets, experiments, applied research.

Introduction

Overall Objective

This paper looks at the development of a new or improved prototype of a root/tuber-based product into a commercially successful product; the benefits of which will accrue to small farmers in a given region.

Specific Objectives

Four key factors must be evaluated to develop and operate a pilot plant. They include:

- determine the technical and financial feasibility of the new process being used by a farmers' coop or small-scale industry;
- assess the quality and availability of raw material (fresh roots/tubers);
- assess the quality and acceptability of the final product; and,
- determine the demand for the product.

Strategies

Holistic Focus

The key strategy within the context of an **integrated** project for product development is the simultaneous consideration of three components: production, processing, and marketing (Fig. 1). It is not possible, for example, to discuss marketing in isolation from processing because the activities undertaken in these areas are interdependent. The actual sequence of activity implementation is shown in Figure 1.

Human Resource Development

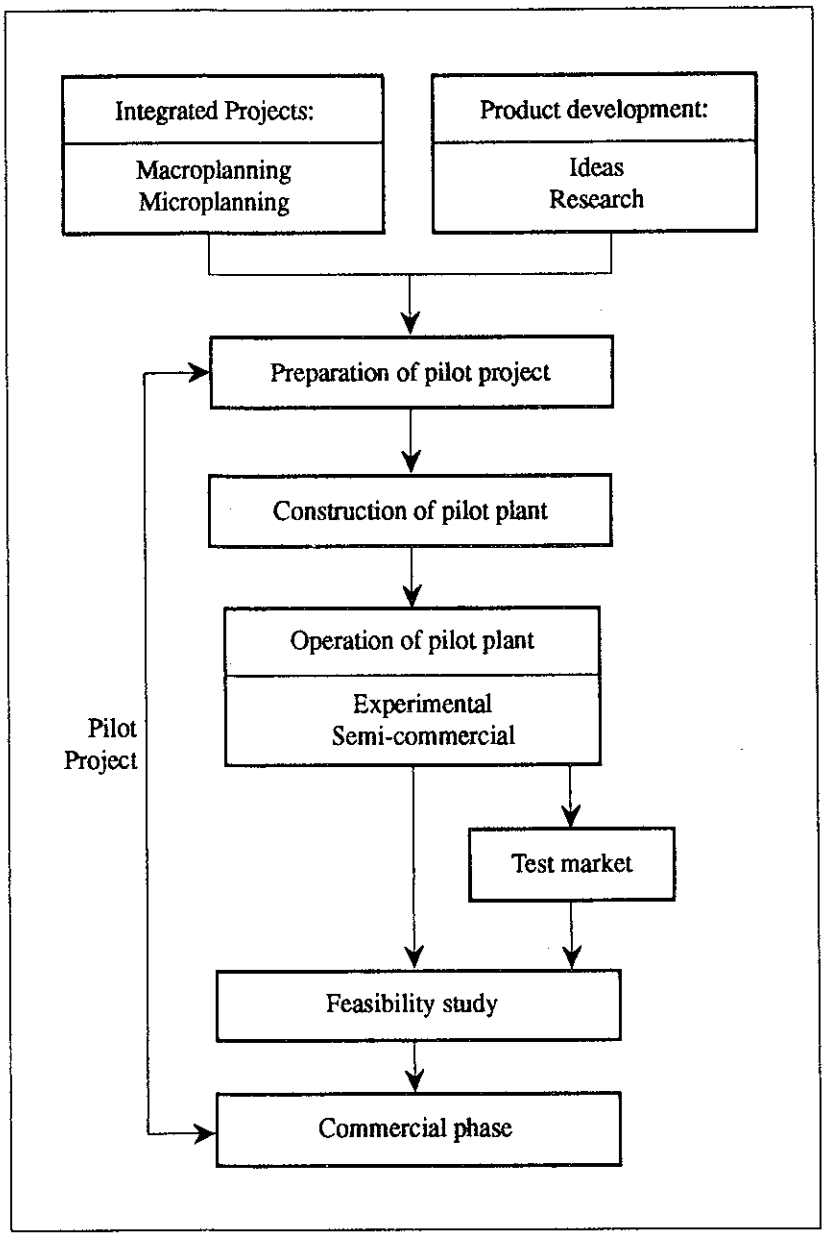
Farmer groups need to learn much more than the technical aspects of processing the raw material. They must acquire skills in operating the plant, monitoring operations and costs, negotiating, controlling quality, analyzing markets, etc.

Monitoring and Evaluation

Data gathered throughout the initial experimental operation and the semi-commercial phase make it possible to determine the feasibility of operating on a commer-

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Figure 1. Position and subdivision of the pilot project in the context of an integrated cassava project and product development.



cial scale and whether the plant should be expanded or others built.

Site Selection

Prior to starting the pilot project, it is necessary to identify the site for locating the plant. Selection criteria are shown in Table 1. The objective of reviewing these criteria is to select the best option for locating the pilot plant; in other words, where there is a sufficient supply of quality raw materials not too distant from the plant (transportation of bulky fresh roots is costly). There should be good roads for transporting the raw material and for shipping the final product to its principal market (which ideally should not be too far away). If the plant operates only seasonally, i.e., during the dry season, then the condition of the roads during the rainy season is not important.

If at all feasible, the pilot plant should be located where there is a group of farmers who have had some

Table 1. Site selection criteria.

Raw material
- Availability (harvest mo/yr)
- Current and future surpluses
- Existence of competitive markets (e.g., fresh cassava)
- Quality factors (e.g., dry matter content, hydrocyanic acid levels)
- Concentration and distance from plant (affects transportation costs)

Processing
- Infrastructure (e.g., water, electricity, access roads)
- Local capacity for building the plant
- Local capacity for building and maintaining equipment

Farmer organization
- Type of association (e.g., cooperative)
- Members' level of education
- Extent of interest in project
- Availability of support (e.g., labor, land)
- Organizational capacity (e.g., leadership, level and quality of participation in decision-making, management of conflict)

Institutional support
- Institutional presence and relative strength of each
- Interest in project
- Delineation of responsibilities
- Assignation of funds for fulfilling responsibilities
- Technicians and field staff with adequate technical knowledge
- Availability of adequate and opportune credit

Market
- Ease of access from the plant
- Ease of commercial contact
- Stability (constant vs. seasonal)
- Size and future growth potential

experience in working together on a cooperative basis. The purpose is to test the new technology and if there are organizational problems, it will not be possible to make a valid test of its feasibility. At the same time, there must be strong institutional support for both technical and organizational aspects in order to ensure that the group functions well. Obviously, it will not be possible to find all these favorable conditions at one site. The criteria may not have equal weight or importance; for example, the provision of electricity at the site may be essential, but that of a paved road less so. The weights assigned to each criterion will depend upon the product and process employed.

Design of Integrated Project

The next step is to combine the prototype process and product to be introduced with the region and site selected into an integrated project. This is basically a plan for adapting the plant design and other elements to the site where the plant is going to be built. The elements to be considered are shown in Table 2.

Construction of Pilot Plant

In addition to steps inherent in any type of construction, which goes from the preliminary land preparation to general cleaning following construction, it is necessary to consider other requirements such as installing water and electricity, building access roads, and manufacturing and installing equipment.

Once all the equipment has been installed, it is necessary to make trial runs in order to optimize their functionality, efficiency, etc. In order to optimize equipment functioning, some adjustments also need to be made because there are always minor details that need to be ironed out.

At the same time, personnel who are going to work in the pilot plant should be carefully selected. If the plant is going to be run as a cooperative or association, then it will be necessary for the members to reach an agreement as to who the operators will be in accordance with the complexity of the process (the minimum feasible number so as not to inflate operating costs). Above all, it is important not to include expenses for an administrative head or secretary at the beginning when the volume of production does not justify it. Once the personnel have been selected, a training plan should be drawn up (Table 2).

Experimental and Semi-commercial Operation of Plant

The most important activity of a pilot project is the experimental and semi-commercial operation of the plant. The former consists of testing the equipment, raw

Table 2. Elements to be considered in a pilot project.

- Establishment of plant capacity in accordance with the market and production of roots/tubers in the plant's zone of influence and the funds available.
- Preparation of the site for building, including study of topography and soils; need for levelling land; permits for installing electricity and/or water.
- Design of the pilot plant, infrastructure, and equipment in accordance with the capacity and characteristics of the lot selected. Where the construction requires technical assistance from professionals such as architects or interventors, a bidding process should be implemented.
- Development of a training plan for plant operators, including important concepts of quality control, hygiene (especially for foodstuffs), and bookkeeping.
- Design of a marketing plan that takes into account the most attractive markets.

material, and operators to the point where the process is efficient and the final product is of an acceptable quality. This means that trial runs must be conducted, for example, to identify optimum variables for the process and determine acceptable characteristics of the raw material. Once the plant's operating parameters have been established and it is possible to produce consistent quality, then it is feasible to proceed with operations on a semi-commercial scale. The product can be sold regularly in order to obtain information regarding its acceptability. The most important aspects of these two processes are discussed for both stages.

Organizational Aspects

There are two critical organizational factors that can affect the success of the pilot plant effort:

- existence of a strong farmer organization; and,
- appropriate support for that organization in the form of technical and organizational backstopping, as well as financial support.

If these two elements are not present throughout this critical phase of the project, everything can fail even if the technology is viable and profitable. Thus, it is preferable not to implement pilot projects with recently formed groups because the introduction of a new technology and the need to work together as a team is risky in a group that has not yet been consolidated. It takes an experienced group who know how to work together to carry out the complex series of activities inherent in processing and commercialization. If this is present, then failure for reasons other than processing, product, or market is much less probable.

Raw Material

Supply. Supply of raw material should be organized so that the roots/tubers are not in the plant for longer than is absolutely necessary before they are processed (e.g., for one or two days in the case of cassava). Rapid perishability of fresh cassava has a strong impact on final product quality. If the plant requires a daily supply of fresh roots, it should coordinate daily deliveries. This complicates the supply side of the operations, especially if the volumes of raw material are not great during the initial phase of plant operation, which could result in dead freight. Other root crops are less problematic in this respect. Nevertheless, root storage times prior to processing should always be minimized in order to speed capital flows.

The cost of transporting fresh roots is always high because they are 65% or more water (although this is eliminated later in most processes). For that reason it is important to construct the plant in a zone where there is sufficient raw material within a short radius of the plant. In the event there is little current production (i.e., the plant was built on the basis of future production potential), then the cost of transporting raw material over greater distances will have to be financed during initial operations.

Harvesting periods. Studies need to be made to determine local harvesting times, which can vary greatly from one micro-region to another, depending upon the months with adequate rainfall for planting and the initial development of the plant. Some areas have two harvesting times a year; and, others with regular rainfall makes it possible to harvest and plant throughout the year. The same applies to irrigation districts where roots/tubers

are planted. Plant operating time of course will depend on harvesting periods and can be reduced even more if other conditions exist (for example, little rainfall making it possible to dry products naturally using the sun).

Price. Root and tuber crops have several actual and potential markets. The new product from the pilot plant will complement existing markets. In most of the Latin American countries, the largest market is for fresh human consumption; in Brazil, it is for *farinha*, a roasted flour. Prices offered for fresh roots vary a great deal during a normal year, being lowest during the most important harvesting season. Preliminary studies can estimate a tentative price that the plant can pay for its raw material. Procuring raw material for operating the plant will depend on whether this price is competitive with prices on the fresh market. This could limit the supply of raw material to the peak harvesting period; or, in the case of plants located in a subsistence agriculture zone, there will be no competitive market and the supply will continue with the harvests. In general, a processing plant that depends on the supply of low-cost raw material will have more success when it is located away from massive consumption centers where the fresh market serves as a magnet for available food stuffs.

Quality. Another factor related to the supply of raw material is product quality. In general, there are fewer critical quality factors for a processing plant than for the fresh market where preferences of intermediaries and consumers can be quite demanding. While it is frequently proposed to supply a pilot plant with roots/tubers that are unacceptable for the fresh market, processes and products that require a high dry matter or starch content do not permit the indiscriminate use of non-commercial or poor quality raw material.

Initial functioning of the pilot plant will determine whether prevailing factors such as quality, price, transportation distance, harvesting periods favor a continuous and opportune supply of raw material.

Processing

Experimental operation. During this phase the necessary adjustments are made in the equipment so that the plant operates at maximum efficiency according to design. In some cases, this is a matter of days; in others, defects in construction (most often in a prototype machine, which is the first of its kind) may require more time and money to modify. Several options for a process may also need to be tested to determine which is the most efficient and easy to manage; for example, artificial drying, with or without a tempering period.

Among the most important factors determining profitability in many processes is the conversion factor (quantity of raw material required to produce a given amount of final product). A good, i.e., a low, conversion factor depends upon the quality of the raw material, dry matter content (high), and the efficiency of the process.

The experimental stage ends when the process is functioning well and the operators are skilled in its management.

Semi-commercial operation

When the supply of raw material permits a continuous operation without further modifications and/or adjustments in the process, semi-commercial operation begins. During this phase, the following aspects are evaluated:

- operators' ease in managing the process;
- efficiency of labor;
- effectiveness of operators' training;
- performance of the equipment under continuous use including energy consumption, efficiency, and performance;
- need for further research related to equipment or its handling;
- possible bottlenecks in the process; and,
- actual operating costs.

By the end of this phase, all necessary adjustments to the process, management, and labor use will have been completed. Often plant workers themselves find practical solutions to problems and can contribute valuable comments and ideas with respect to other aspects of pilot plant operation. Mechanisms should be sought for incorporating their contributions into the evaluation process.

The Product

During the experimental phase of plant operation, it is not enough to optimize the process by taking into account the efficiency of the machinery. The quality and quantity of the final product are also important.

Product quality results from the interaction of raw material and the process. In the case of cassava the most important parameters are dry matter and/or starch content, hydrocyanic acid (HCN), the presence of aflatoxins, and/or pathogenic microbes; and, in the case of products for direct human consumption, product taste, texture, and appearance. For other root and tuber crops, relevant

anti-nutritional factors, e.g., alkaloids, trypsin inhibitors, or nutrients such as protein and vitamins must be included. In the case of products where norms have been established by law or national quality standards exist, analysis or quantitative determination of those norms need to be part with these evaluations. (For example, if the HCN content is below 50 ppm or the microbial count for fecal bacteria is 0.) Should the product not consistently meet quality standards in the experimental phase or under lab conditions in the preliminary stages, the reasons for irregular performance should be sought—whether they lie in the raw material being utilized or in different conditions of the process. With respect to the level of microbial contamination, the environmental conditions of a pilot plant located in a root crop production zone are going to be very different from those in a lab. It is especially important to insist on rigorous control of personal hygiene and of equipment to maintain the cleanliness required for many products of human consumption. Nevertheless, many traditional products made from root crops have high levels of contamination and completely lack any sanitary controls. It may also be necessary to obtain a sanitary license when the product is for human consumption.

In the case of products destined for human consumption, organoleptic characteristics are important. Organoleptic and acceptance tests should be conducted in order to confirm whether the new product is acceptable to both buyers and consumers. There are two ways of conducting this type of test: under controlled conditions, or normal use. The advantage of the former, conducted in the lab with some sensorial analysis, is that the results are clear, and reliable data can be obtained with respect to the taste or acceptability as compared to another product (the traditional one or the competitor). On the other hand, giving samples to homemakers for tasting under normal meal conditions gives a better idea of its acceptability. However, recipes and preparation can easily vary; hence, the ease of making comparisons between products is lost. As an intermediate option, a consumer panel can be formed to evaluate one or more samples so as to compare results. Panels of this type can be costly to set up. The same type of tests (i.e., lab, at home, or panels) are also pertinent for studying other product characteristics such as shelf life or forms of use. It is important that the new product:

- be acceptable to the consumer;
- be acceptable *vis-à-vis* competitive products; and,
- fulfill the desired characteristics (e.g., nutritional, organoleptic).

Shelf Life and Packaging

The commercialization chain—short as it may be—always requires some sort of product durability, to which must be added the storage time until the final user consumes/uses it. It is important that the product characteristics do not undergo any significant change during this period of time. Factors that can affect the product's useful life are as follows:

- product moisture content;
- relative humidity during storage;
- level of contamination by fungi, bacteria, and insects during processing;
- type of packaging used; and,
- size of packaging (product weight/unit).

Packaging is a barrier between the product and its environment. As it may be porous, it can permit the interchange of gases (CO_2, O_2, H_2O) and can be penetrated by insects and rodents, which in turn facilitate contamination by microorganisms. Hence, it is important that the packaging not only be of a reasonable price and easy to obtain, but also serve to protect the product sufficiently for the desired storage time under the environmental conditions found at the storage sites.

In the case of a root crop processing plant, it is not enough to conserve the product until its sale. Training may be required to consider product quality beyond the moment of purchase so that intermediaries and the final users encounter no problems. Consequently, packaging that is not the least expensive, but rather one that permits the greatest storage time, may be necessary.

In the case of products that are transformed by drying to moisture levels under 14%, there are no storage problems because of fungal growth, particularly of aflatoxins. In the case of the feed rations market, commercial firms mill the chips immediately after purchase so packaging is not critical. Where purchases are made by state enterprises in order to regulate prices and markets, storage time can be long so that the packaging used becomes important. It may be best to use new packaging in this case.

Processed products for human consumption such as flours, noodles, and cookies require packaging that resists insect (weevil) attack, above all if product turnaround time is slow. Conserved fresh cassava, for example, requires a polyethylene bag as an integral part of the conservation technology.

Marketing

Two markets exist for pilot plant products: industry and individual consumers. Their characteristics are fundamentally different. Moreover, the marketing process is distinct for each.

The industrial market consists of selling the product to enterprises for a second transformation or incorporation into another product. The consumer market consists of selling the product with no further changes through a wholesale distribution channel. The industrial market is the simplest since there are generally few enterprises and it is possible to have direct contact with the purchasing heads of each one. Moreover, their purchasing decisions are based on logic, price comparisons, availability, and performance of all the suppliers. In addition, the monthly unit of purchase can be very large, equal to, or greater than the plant's production capacity.

The consumer market, on the other hand, is quite complex because it is necessary to sell the product to thousands, possibly millions, of consumers who are daily being bombarded with publicity about competing products. Consumers may make their purchasing decisions on the basis of illogical factors such as product image and status. In order to reach the consumer on a large scale, an efficient distribution system is necessary at terminal markets, as well as the resources and capacity for carrying out mass product promotion. These two activities are not commonly understood by groups of small farmers; thus, other organizations have to be created for product distribution and promotion.

To date, the only improved fresh cassava product developed for the consumer market in Colombia has been that of conserved fresh cassava. It may also be possible to commercialize cassava flour and starch in this market.

Marketing studies. After selecting a site for the pilot plant, it is necessary to carry out a marketing study focusing on markets nearest the plant. The scope of the study depends on the product. In the case of fresh cassava on the Atlantic Coast of Colombia, the urban market of Barranquilla was studied; for cassava flour, national, regional (Atlantic Coast), and local markets were analyzed (Janssen 1986). For a consumer market, the study should include intermediaries, final outlets, and consumers; for the industrial market, only potential clients.

Cassava flour provides an interesting example because it is a potential substitute for a very well-known raw material—wheat flour. Potential clients are manufacturers of foods such as crackers and cookies, pasta, processed meats, and breads. These manufacturers are not familiar with the characteristics of cassava flour because they are somewhat different from those of wheat. The study was therefore designed in two stages. First, a preliminary survey was made on the use of flours in general; and, second, samples were distributed. These samples were recommended for carrying out partial substitution trials in various products, followed by a survey on the trial results, and a review of the amount of interest generated in purchasing the new product. Thus, very concrete information on the potential use of cassava flour in a wide gamut of products was obtained without having to conduct laboratory trials.

Product marketing. The marketing study is the basis for a plan for selling the product produced by the pilot plant. During the initial takeoff and experimental operation of the plant, product quality is not uniform. Optimizing the process leads to an improvement in quality and operational efficiency. It is important that the first samples purchased by the initial clients be of optimal quality. Production that does not meet quality requirements should not be sold to this market. Thus, dried cassava was sold to the animal feed market until it was of a quality acceptable for the cassava flour plants. A project should not expect an experimental plant to be profitable. There should be sufficient funds to cover occasional losses.

These first sales to an industrial market require a detailed follow-up. It is important to know, for example, the client's:

- level of satisfaction with the product;
- use of the product;
- evaluation of its quality;
- comparison with other raw materials;
- opinion of its price;
- estimate of demand and potential for increased purchases;
- view of the consumer's reaction to the final product; and,
- desired unit of purchase and frequency of delivery.

In the case of a consumer market, it is preferable to begin with a limited geographic area, distributing to several shops nearby or to a chain of supermarkets. This facilitates gathering some information without having to use many resources.

During semi-commercial operation, product quality will have become stable and operation costs more controlled. At this point, the market can be developed in accordance with the results obtained in the demand study.

Several options for presenting the product need to be explored:

- size/weight per purchase unit;
- type of packaging;
- design of packaging (logo, brand name, etc.); and,
- price per unit.

The reaction of the market to these alternatives can be very useful in defining some of the alternatives. Once the brand name has been chosen, it is important to register it legally. (It is also important to check whether it has already been registered by another firm before going to the expense of getting the dies made.) With the investment in promotion, the brand name increases in value; and it is important that the owners of the plant (e.g., cooperative members) benefit from that investment.

Termination of the Semi-commercial Phase

When there is sufficient information available for conducting a feasibility study with respect to mounting a full-scale rural industry based on the pilot experience, then the semi-commercial phase ends. The plant generally has to function for an entire year during all the months foreseen as feasible for processing. In the event that the year is abnormal (little production or high prices and low supply of raw material for the plant), it may be necessary to extend operating time to another harvesting season. This requires financial information on production costs, prices, and volumes of sale. It is also necessary to include financial costs in the study even if they are not required for the pilot plant stage.

When the semi-commercial operation ends, it is expected that:

- the supply of raw materials is constant;
- the process is functioning efficiently;
- the operators are trained and working efficiently;
- product quality is good and uniform; and,
- the market is in accordance with the forecasts and in the process of expanding.

Test Marketing

A product that is destined for the consumer market requires activities which organize its distribution and promotion above and beyond what is required for a product to be utilized in industry. These activities are quite complicated and costly; therefore, before launching a full-scale commercial project, it is advisable to begin with a test market. This consists of manufacturing a product for distribution and promotion on a limited scale, albeit in a location typical of the total potential market. The distribution system and the commercial-scale promotional activity therefore can be tested at moderate cost, but within a reduced radius of action; so as to determine the feasibility of launching production on a larger scale. Table 3 shows the requirements for a test market.

Possible options for product distribution within an urban market include: shops, institutions (schools, army stations, etc.), supermarkets, shopkeepers, coops, restaurants, and stalls in wholesale or retail markets.

It is easier to deal with a market that is made up of only a few high-volume clients, than with one consisting of numerous clients, each purchasing only a small amount. Nevertheless, the largest market may be a multitude of low-volume buyers. Options for distributing the product in this case are as follows:

- set up an enterprise specialized in distributing products in urban centers;
- contract a private distributorship on a non-exclusive basis;
- distribute the product to a central warehouse operated by a shopkeepers' association (they may have to be organized around that concept); and,
- obtain warehouse space at a wholesale market where shopkeepers go to purchase other food.

Each of these distribution systems has its advantages and disadvantages. It is important to identify the one that keeps distribution costs at a minimum so that the price of the product is low enough to compete with other products on the market.

When promoting the product, it may be necessary to advertise. The design and execution of a publicity campaign—even with simple, low-cost media—requires experience to make the most efficient investment of money.

Table 3. Requirements for a test market.

• A continuous supply of the product or sufficient inventory to meet the the expected market demand
• A product of the quality specified
• An attractive promotional price
• Promotional materials ready for distribution and airing, together with an advertising campaign based on them
• A distribution system in place for the product, not only for the initial volume, but also for its expansion within a short time period
• A distribution system capable of feeding back the information required by the project to judge its success or not, including weekly data on volumes delivered and sold by shop. This information should be complemented with data on purchases by a sample of consumers, which would provide the rate of repeated purchases compared with initial purchases.

The most important elements for promoting a product on the consumer market are:

- an attractive, duly registered brand name that reflects the product's advantages;
- a logo; and,
- a slogan.

Advertising media include:

- the package (with the logo, slogan, and recipes, instructions for use, packing or expiration dates, name, and sanitary license);
- material for the point of sale: promotional materials such as shelf talkers at the supermarket, posters for shops, leaflets, etc.;
- supermarket promotors/sales representatives;
- newspaper advertisements;
- advertising billboards;
- radio commercials; and,
- TV commercials.

Although an advertising campaign that uses all the foregoing media is very costly and unfeasible for most integrated projects, costs can be reduced and an important impact made if the following are done:

- clear identification of the initial target market (for example, low-income housewives from the poorest residential districts), so that only those media that reach them (e.g., a radio commercial on the station that most of them listen to) are used, thereby not having to spread limited resources too thinly;
- promotion of the product on the news and other programs of public interest to consumers; and,
- special campaigns for shopkeepers (leaflets explaining the benefits of the product, not only for the consumers but also for them) so that they themselves promote the product directly with their clients.

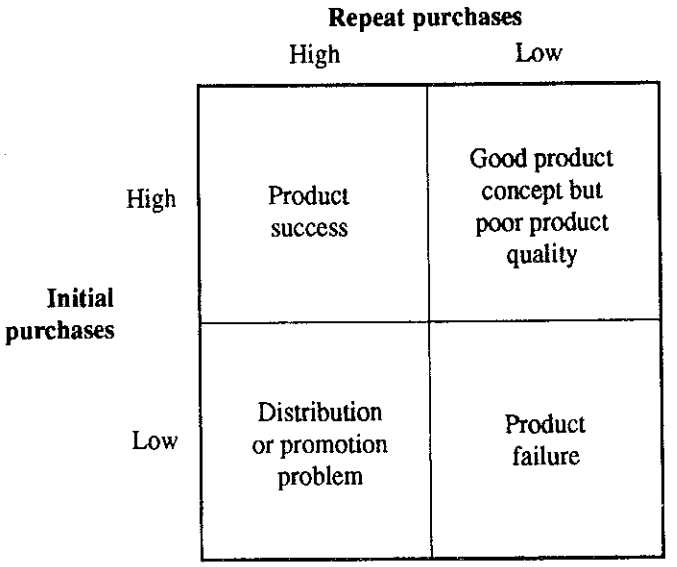
According to Kotler (Fig. 2), if initial purchases are good and a large percentage of the buyers repeat purchases, the product is a success. If initial purchases are high but only a few are made a second time, then the concept of the product is good, but it does not meet its promises—in other words, the consumer is disillusioned. In the case of initially low purchases but most of the consumers buy it again, then the product is good but there are problems in distributing or promoting it. In the last case where both initial sales and repeat purchases are low, the product should be abandoned.

Conducting a test market trial is difficult, but it is equivalent to a commercial-scale launching without having to risk much investment. For that reason, it should be carried out as part of pilot project when the final products are ready for the consumer market.

Feasibility Study

At the end of the pilot-level experience, an assessment is made of the results to date, including a financial analysis based on the assumption that the financing of the project would involve interest payments equal to those that would have to be paid in the commercial

Figure 2. Illustration of Kotler's hypotheses regarding product success.



Source: Kotler 1986.

phase of the project. Table 4 shows the elements that should be included in the feasibility study.

On the basis of the information gathered on the raw material, processing, and on the end product and its commercialization, it is possible to construct a model to determine the plant's profitability.

This model includes financial costs even though they are not incurred during the pilot stage. Calculations are based on the same interest rate as the one that would be charged for the later expansion phase of the project, as well as the same loan conditions including the initial grace period. The return on the capital invested should

Table 4. Elements for the feasibility study.

The process itself:

- Analysis of ways to reduce costs, adjusting the scale of the infrastructure or equipment on the basis of their utilization and function during the pilot plant phase.
- Redesign of the plant with commercial-scale capacity and calculation of budgetary requirements based on the pilot plant experience.

Raw material specifications for defining parameters of acceptable quality.

Specifications for operating the equipment.

Specifications for the final product based on those for the raw material, the process, and in accordance with market requirements detected in the semi-commercial phase.

Quantification of the markets based on the pilot process, taking into account the following:

- Price behaviors of the product and its competitors.
- Transportation and warehouse costs.
- Experiences, both positive and negative, of the businesses or distributors who buy the product in order to define parameters such as levels of substitution in industrial markets.
- Months of production during the year.
- Conversion factor for fresh to processed product.
- Price for raw material and availability during the year.

be greater than that obtained if the funds were invested on the financial market (financial rate of return).

This model also makes it possible to conduct a sensitivity analysis by varying the prices of the raw material, operating costs, the conversion factor, etc., in order to determine how the financial rate of return would respond to these changes. It is also important that the project be in a position to absorb a rise in the cost of the raw material and still make a profit. If the feasibility study is positive, then the decision is made to proceed to the commercial phase, which is dealt with in a subsequent section of this volume.

Conclusion

Pilot-scale operations constitute a critical step in product development. They serve as a testing ground for products, procedures, and personnel prior to initiating commercial processing. This paper has reviewed the various dimensions involved in operating a pilot plant from design of the overall project to construction of the facilities, to experimental operation, to semi-commercial plant activities. Particular attention is paid to the experimental operation of the plant. Issues here include: organizational structure (i.e., farmers' organizations), the supply of raw material, processing and promotion, and sale of the test product. Successful completion of the pilot-scale phase culminates with research for expanding pilot scale operations to full commercial level in which the knowledge and experience acquired in the pilot phase are utilized to evaluate the commercial potential for specific products and processes.

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Pilot Testing of Improved Cassava Processing Technologies in Nigeria: A Case Study

Y. W. Jeon and L. S. Halos[1]

Abstract

This paper reviews the technology development strategy for cassava processing at the International Institute for Tropical Agriculture (IITA) in Nigeria. The strategy focuses on minimizing losses, increasing labor productivity, improving product quality, and providing favorable working conditions for the processor. Special emphasis is placed on alleviation of the drudgery of the task for women. Improved processing technologies were installed in five villages in Nigeria. After one year of operation, losses were gradually reduced by 54% and processing time dropped by 70%.

Key words: equipment, women, cassava.

Introduction

Processing has been an integral part of cassava utilization because of the crop's poor storability and the need to reduce, if not eliminate, the toxic substances that make it unfit for consumption.

Cassava processing is a major activity for the people in Nigeria—and in most parts of Africa—because cassava constitutes approximately 60% of their diets. Yet, food processing carried out at family or village levels has been mostly traditional. These methods are inefficient because of tremendous losses during processing and high labor inputs. These problems persist primarily due to the lack of appropriate postharvest facilities.

To address this situation, scientists at the International Institute of Tropical Agriculture (IITA) have designed simple, low-cost, labor-saving devices using locally available materials affordable to even small-scale processors. These technologies have been tested at various operating levels in different parts of Nigeria and are attaining popularity.

Technology Development Strategy

The current state-of-the-art of cassava food processing dictates that the strategy for technological development to improve system efficiency should focus on minimizing losses, increasing labor productivity, improving product quality, and providing favorable working conditions for the processor thereby making the industry more beneficial in the broadest sense.

Recognizing that cassava contains very high moisture in addition to its bulkiness, the difficulty in transporting and the excessive amount of loss due to deterioration and handling must be eliminated. This can be done efficiently and profitably by processing the tubers soon after harvest at, or near, production sites.

The strategy also examines the food system as a whole rather than specific or isolated commodities, techniques, or processes. The aim is to provide a sustainable and "balanced" operation. Researchers at IITA, therefore, embarked on developing a postharvest equipment package for farm- and village-level operations.

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The design of the technological package has been based on the required capacity and the nature of end-users. While the present organizational setup and social norms constrain a village-level operation, development of technology for a group operation is also being pursued. In an economy under stress, individual investments can be difficult and organized groups have more access to government support programs.

In Africa, where processing is done mainly by women, a special emphasis is placed on alleviating the drudgery of the task for women.

Testing and Evaluation

The package of cassava processing technologies includes the peeler, grater, fermenting stand, dewatering device, chipping machine, grinder, stoves, and *gari* fryer.

Capacity ratings of the equipment are based on an average yield of 10 t/ha harvested on a staggered basis to supply the requirements of processing centers, ranging from 0.5 t/day, for a manual operation, to 5.0 t/day for a semi-mechanized operation.

The technical features of the different equipment are being evaluated in the research center, after which they are packaged and tested under field conditions. Field testing and evaluation provides information on the technical and economic feasibility of the project. During field testing, modifications are being made to adapt the technology to the environment. Development work is continuing with the direct involvement of end-users to ensure a better understanding of the impact of the technology and its environment.

Site Selection

The selection of the pilot sites is a critical process. Once needs in a locality are perceived or a problem message is communicated to the research center, a comprehensive survey of the area is undertaken to analyze and prioritize the needs accordingly.

Village and Family Study

At the beginning of development activities, background information in the form of family and village profiles are collected to establish design criteria and a database which is used in the analysis of the technology's impact. Information such as family income and their sources, expenditures and their nature, agricultural production data and potentials, and technical information such as available equipment, capacities, and operational requirements are collected. A local staff is hired and trained to do the survey and observations at the site. Data are recorded in a diary-type notebook and analyzed in the research center.

Performance Analysis

The developed cassava processing technologies were packaged, installed, and tested in five villages in Nigeria at different levels of operation (Table 1).

The objective is twofold: (1) to generate information and feedback on machine performance for further development, and (2) to assess the impact on system efficiency in terms of product recovery and labor productivity. Some socioeconomic implications are also considered because the technology is being introduced into a unique social structure.

Processing centers equipped with the improved technologies were established for women's groups and groups of commercial processors. These centers focus on process improvement, providing better quality food, eliminating the constraints of individual food processing, and increasing the income of small-scale processors.

Effect on Loss and Labor Input

The introduction of the package of technology in the village processing center improved system efficiency in terms of reduction in losses and labor input. After one year of operation in the centers, the losses were gradually reduced by 54.7% and the processing time dropped by 70%.

Table 1. Operating levels and production capacity of cassava processing operations.

Operating level	Design capacity (tubers, t/day)
Family operation	less than 0.5
Women's group operation	1.0 to 3.0
Commercial operation (small to medium scale)	3.0 to 5.0
Village operation	up to 5.0

The improvement in system performance is attributed not only to the individual technological components but also to system arrangement, attitude change, and training. Their effect is equally important in terms of labor input. The reduction in losses is contributed mainly by the technology.

System arrangement improved material and activity flow in the centers. The centers also provide a venue for the processors to understand the process as related to their traditional practices. This creates awareness and apparently has contributed to a change in attitude. Training and familiarization on the functionality and maintenance of the different technologies contributed to efficiency.

Seventy five percent (75%) of homemakers' time once spent for traditional processing is now available for other productive tasks. This can partly account for the increase in hired labor contributions.

Socioeconomic Impact

The impact of the technology package on the well-being of users is now evident. Interesting observations are: (1) the widespread adoption of a Food Exchange Scheme which has evolved because the village processors are better equipped to process more and better food; and (2) a notable change in the quality of life of the villagers.

The Food Exchange Scheme

The scheme is designed to provide better quality food for the family and eliminate the drudgery of traditional processing. It was first introduced to the women's group processing center in Moniya, Akinyele Local Government Area, Nigeria. The Food Exchange Scheme, illustrated in Figure 1, eliminates individual or family-based processing. Processing activities are now concentrated in the processing center equipped with the improved technologies. The women process cassava foods in the center regularly and maintain a store of processed food products such as *gari, lafun*, and *foufou.*

The arrangement minimizes losses, eliminates unnecessary labor input, improves product quality, and allows women to devote more time to their families and participate in other income generating activities. Women and children come to the center to work and get paid, or simply to exchange food for the family. The center gives out an additional one kilo of any desired products to the consumer over that normally produced through individual processing in exchange for an equivalent weight of fresh cassava tubers. The remaining quantity is sold to defray operating costs.

The center has been a model in revolutionizing the small-scale processing industry. It has been expanding operations and increasing capacity up to 3-5 t of fresh tubers daily which are processed into food, as well as non-food products.

The introduction of improved processing technologies has created awareness among the processors of production potentials and facilitated the adoption of the Food Exchange Scheme. The Food Exchange Scheme has been found to be viable in most rural settings in Nigeria and is being adopted in the villages.

Improvement in the Quality of Life

The effect of the technology on the socioeconomic status of the processors has been favorable. A reduction in postharvest losses, labor input, and fuel consumption resulted in increases in the volume of production of better quality products sold at competitive prices.

An increase in activities in the center brought a favorable change in the quality of life of villagers. The improvement is manifested by better and healthier environments, more income-generating activities, more active participation in civic and social functions, and better opportunities for children's education.

The "holistic" or system approach coupled with applied research are effective strategies for the design of any development program. This approach made possible the development of the appropriate cassava postharvest technologies which are now finding their way to end-users.

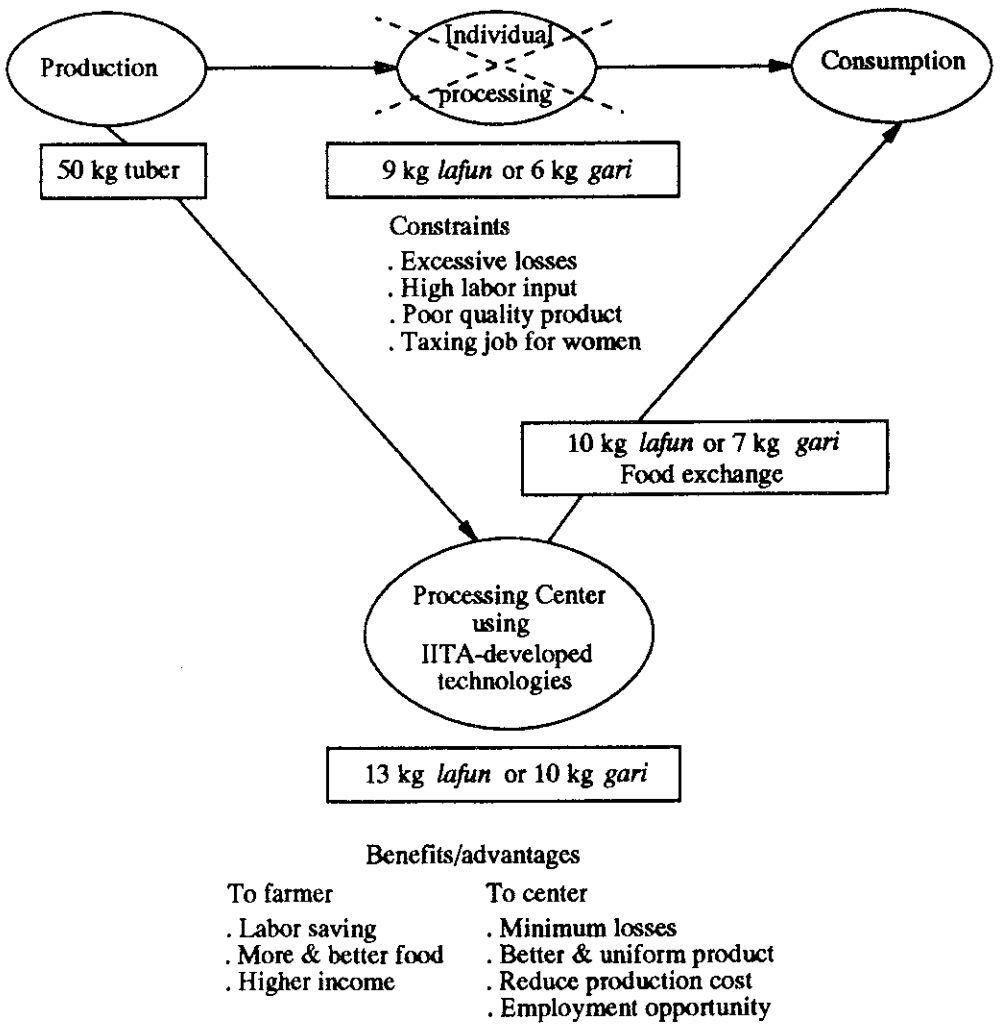
The Chairman of the Women's Group Cassava Processing Center commented:

"All these equipment save time, money and reduce the health hazards to our women processors. These improvements have resulted in the production of more and better quality of processed foods with less labor and in shorter time. Women are now happy, have more food, and can earn money from the once burdensome food processing." (Laniyonu 1991).

Conclusion

Cassava processing is a major activity in Africa where cassava constitutes approximately 60% of the diet. Transformation is an integral part of cassava utilization because of the crop's perishability and because its toxic

Figure 1. Cassava food exchange by women's group in Oyo State, Nigeria.



substances must be reduced, if not eliminated, to make it fit for human consumption. This paper has briefly reviewed the strategy employed at IITA in developing, evaluating, and diffusing improved cassava processing technology. In addition to minimizing losses, increasing labor productivity, and providing favorable working conditions, the strategy also embraces the food system as a whole rather than specific or isolated commodities. Testing in five villages in Nigeria showed a 54% reduction in processing losses and 70% drop in processing time after one year. The effect of the technology on the socioeconomic status and quality of life of the processors has also been favorable.

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Report on the Study and Improvement of Cassava Utilization in the Congo

S. Trèche and J. Massamba[1]

Abstract

A research program whose main objective is to adapt cassava processing to consumers' demands in the context of increasing urbanization was begun in Congo in January 1989. The program uses a multidisciplinary approach, associating Congolese and French research institutions with an institute of development, to undertake both descriptive studies and experiments in order to propose innovations. The descriptive studies are both on traditional cassava processing and consumption and on the biological and physicochemical mechanisms of cassava. Anticipated innovations were to reduce the difficulty of processing roots into *foufou* and *chikwangue*, the main cassava foods in the Congo, and also to propose new products.

Research methodology consisted of conducting surveys in rural and urban areas, laboratory and pilot-plant assays, quality control testing in laboratories, sensory evaluations, and feasibility studies. The results obtained to date and presented in this report are mainly related to descriptive aspects, the knowledge of which is necessary for formulating and beginning innovations. However, technological processes have already been proposed for a *chikwangue* semi-mechanized production unit and for a cassava-based weaning food pilot-plant.

Key words: cassava, *chikwangue*, consumption, *foufou*, gruel, processing.

Introduction

The Congo imports considerable quantities of corn by-products from which ensues a serious dependence upon foreign foodstuffs. Moreover, faced with the country's increasing urbanization, extreme foodstuff mutations are taking place. In such a context, we think it necessary to carry out research on traditional utilization of cassava, the main food staple of the country, and to propose improvements which are likely to coincide with those foodstuff mutations.

The Research Project

Research Objectives

The project is based on four fundamental activities which correspond to the main objectives:

- Project staff have made an accurate inventory and description of traditional ways of cassava processing and consumption in the Congo in order to identify those endogenous variants and innovations likely to spread once possible improvements have been made.
- Researchers increased their knowledge of microorganisms, particularly of the role of the lactic flora during the process of retting and of their influence upon the nutritional and organoleptic qualities of final products.
- Project staff studied the optimization of process parameters at different steps of *foufou* flour and *chikwangue* production.

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- Feasibility, acceptability, and nutritional studies were made of new cassava-based products: weaning food, fortified *foufou* flour, and *chikwangue*.

Project Organization

General Information

The project is part of a wider program carried out with partners in Africa, South America, and Europe. That program is entitled: "Improvement of the quality of cassava-based fermented foodstuffs." It has been financed by the Economic Community (EC) (programme CEE-TS2A-0226) since January 1989 and is expected to continue until May 1992. The project also enjoys financial help from the French Ministry of Research and Technology and from the *Transformation des Products Agricolas et Alimentaires* (TPA) network.

The work has been done in various locations. Facilities at the following institutes were used:

- *Institut francais de Recherche Scientifique pour le Développement en Cooperation* (ORSTOM), Brazzaville, Congo: (1) *Laboratoire d'Études sur la Nutrition et l'Alimentation* (LENA) and (2) *Laboratoire de Microbiologie* (LM);
- *Faculté des Sciences* (Brazzaville, Congo): (1) *Laboratoire des Études et des Recherches sur la Physiologie, l'Alimentation et la Nutrition* (LERPAN) and (2) *Laboratoire de Biotechnologie* (LBT);
- (*Institut de Recherche pour l'Appui au Développement Agricole en Zones Tropicales,* Brazzaville, Congo) AGRICONGO: (1) *Département des Transformations Agro-alimentaires* and (2) *Département des Études Économiques*; and,
- ORSTOM (Montpellier, France): (1) *Laboratoire de Nutrition Tropicale* (LNT) and (2) *Laboratoire de Physiologie et Métabolisme Cellulaire* (LPMC).

External Collaboration

Laboratories at different research institutions have hosted researchers from the Congolese General Direction for Scientific Research (DGRST), as well as students from the Institute for Development Research (IDR) as part of the project. There has also been close collaboration between all research organizations and the Nutrition Services of the Congolese Health Ministry.

Aspects of Processing and Consumption

Overview

Surveys using representative samples have been carried out in both rural and urban areas to study traditional ways of cassava processing and consumption (Trèche and Massamba 1989a, 1989b, 1989c, 1989d, 1989e, 1990, 1991a, 1991c; Massamba and Trèche 1989, 1991b; Trèche 1990; Bourangon-Dit-Ontali 1991). At the same time, special interest has been taken in weaning practices (Trèche 1989; Cornu et al. 1991; Trèche and Massamba 1991b; Massamba and Trèche 1991a; Dinga 1991; Bouquet and Adam 1990).

Studies on the retting process—an important stage of cassava processing in Central Africa—consist of characterizing both the bacterial microflora and the products of their metabolism. Retting effects on end products have been studied using sensory tests (Trèche and Massamba 1989b; de Labbey 1989; Trèche et al. 1991; Brauman et al. 1991a, 1991b; Ampe et al. 1991; Adoua-Oyila 1991; Tchiloemba-Poba 1991).

Sensory evaluation studies have also been made to optimize the parameters for making *chikwangue* and *foufou* flour. These have mainly been done on the products of the semi-mechanized *chikwangue* production unit built by AGRICONGO (Ngo 1989; Trèche et al. 1991; Adoua-Oyila 1991).

The main objectives of work done on cassava-based weaning flours have been to solve problems resulting from the low caloric density (dietary bulk) and the poor nutritional quality of traditional gruels (Avouampo et al. 1991; Legros and Trèche 1991; Miambi et al. 1991; Giamarchi and Trèche 1991; Trèche and Giamarchi 1991; Trèche et al. 1991).

For this report, we have chosen to display some results obtained from our work on cassava consumption and processing and its use in weaning foods.

Cassava Consumption and Processing

Survey data on cassava processing and consumption in rural areas have allowed evaluation of the consumption frequencies of different cassava final products and provided the information necessary to create flow diagrams of the main processes (Massamba and Trèche 1989; Trèche and Massamba 1989b, 1991c). The flow diagram for *chikwangue* and *foufou* from cooked roots is shown in Figure 1. Survey data show a strong environ-

mental influence on the ways that cassava is consumed (Massamba and Trèche 1991b) (Fig. 2) and processed (Trèche and Massamba 1991c). Three environmental factors explain this: (1) natural constraints, (2) communication difficulties, and (3) sociological, cultural, and economical characteristics of households.

The part that cassava-based products play in weaning practices and the nutritive value of traditional gruels have been studied (Cornu et al. 1991; Trèche and Massamba 1991b; Dinga 1991; Bouquet and Adam 1990). The results of these studies show the product's low protein and energy content (Table 1) and need for improvement.

Surveys carried out in Brazzaville with workers in small urban factories, which turn cassava retted roots into *chikwangue* and *foufou*, are still in their early stages. These surveys, however, have already enabled an assessment of the percentage of households in different districts of Brazzaville which are transforming cassava. Supply, work organization, and type of end products of these operations are summarized in Table 2. Presently, project staff are monitoring the operation of 60 of these small factories.

In collaboration with researchers from AGRICONGO, prices of the main staple foods, *chikwangue, foufou*, plantain, corn, potato, bread, and rice sold and consumed in Brazzaville, have been recorded since January 1991. Based on this research, comparisons of prices on a dry weight basis show that cassava products are still competitive in urban markets (Table 3). The average price of *chikwangue* at C.CFE 36.1 is less than all other prepared foods.

In Brazzaville, characterization of *chikwange* consumers' preferences (Adoua-Oyila 1991) brings to light relationships between some cultural, economic, and sociological factors and ways of consumption.

Cassava Flour in Weaning Foods

Increasing the energy density of gruels is possible by limiting the swelling of starch by using amylases. Extensive studies on the utilization of different sources of amylase have been performed (Trèche 1990; Miambi et al. 1991; Giamarchi and Trèche 1991; Trèche and Giamarchi 1991; Trèche et al. 1991). Because of the properties of its starch, protein-enriched cassava flour could constitute an excellent weaning food for developing country infants. Fouler-Guilluy (1991) has studied making weaning food from cassava flour. This flour has had the cyanogenic glycosides removed through the process of retting and is complemented by adequate plant protein sources, e.g., soybean or kidney bean.

At the moment, the best procedures to reduce dietary bulk seem to be adding appropriate alpha-amylase sources: malted cereal flour at the household level (Fig. 3); and industrial food-grade enzyme at the cottage industry level (Fig. 4). Another possible solution would be fermenting roots under conditions favoring the action of amylolytic microflora. Future research efforts should be made in this direction. To continue work in this area, a pilot plant for cassava-based weaning foods is being set up with the help of the Institute of Research and Development, AGRICONGO (Avouampo et al. 1991; Legros and Trèche 1991).

Constraints and Limitations

The main constraints are those usually come across in the transfer of laboratory results to small-scale experimental units and from these units to the real environment. The most important of these are time constraints, and collaboration in follow-up research with entrepreneurs (businessmen) interested in using developed innovations. Mediation by AGRICONGO has partly solved this latter problem.

Table 1. Influence of basic ingredient on concentration and protein content of traditional gruels.

Products	Gruel concentration (g dry weight/100 g) n[a]	Gruel concentration (g dry weight/100 g) Average[b]	Protein n content (g dry weight/100 g) n[a]	Protein n content (g dry weight/100 g) Average[b]
Cassava	176	15.75b	124	1.84a
Corn	211	14.49c	135	5.21b
Other local products	9	24.63ab	9	11.07c
Imported flours	27	18.04a	27	9.79c

[a] n = Number of determinations.

[b] Values in the same row followed by the same letter are not significantly different ($P > 0.05$).

Figure 1. Flow diagram for *chikwangue*.

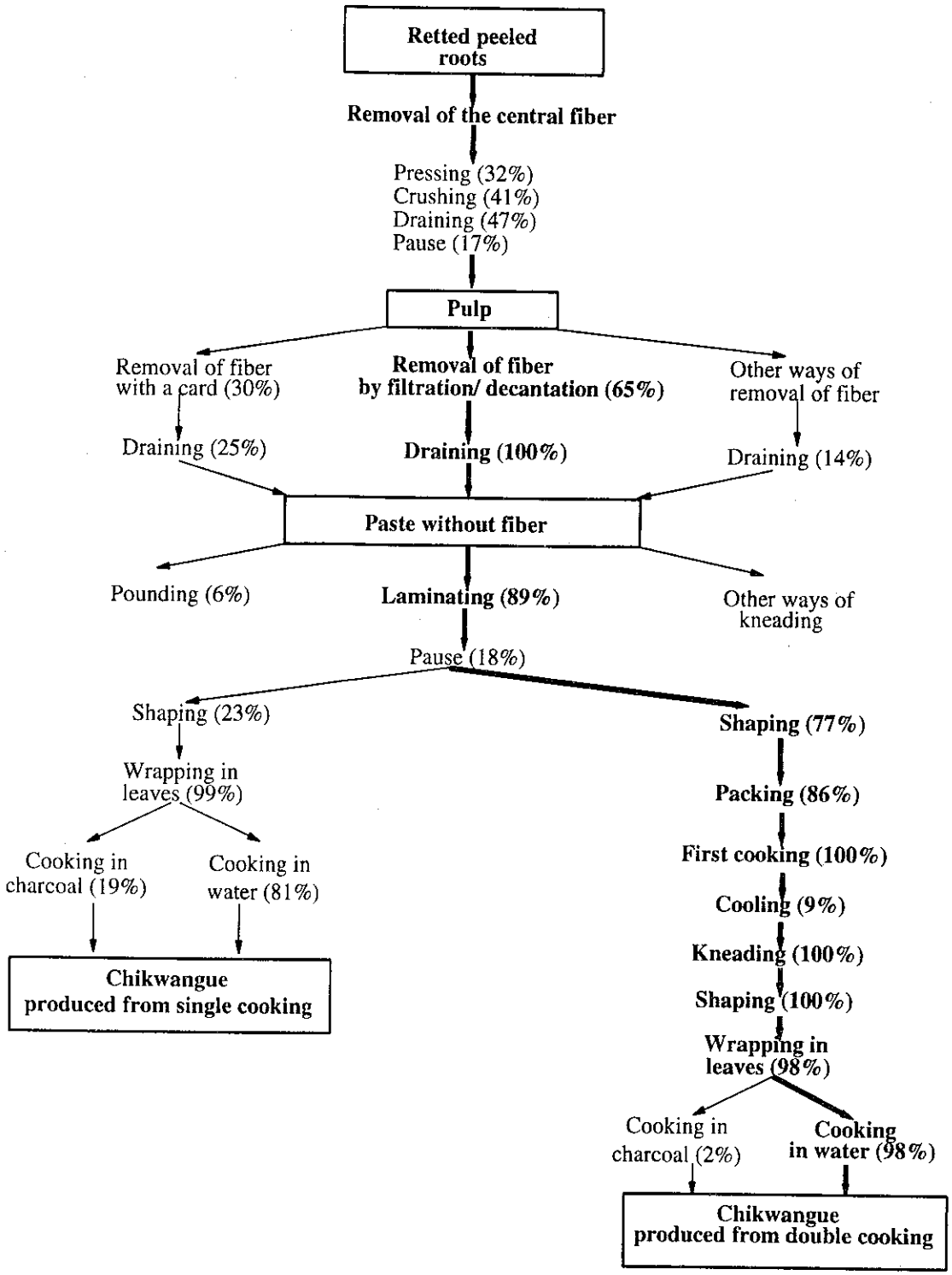


Figure 2. Consumption frequencies of different products derived from cassava roots in the Congo.

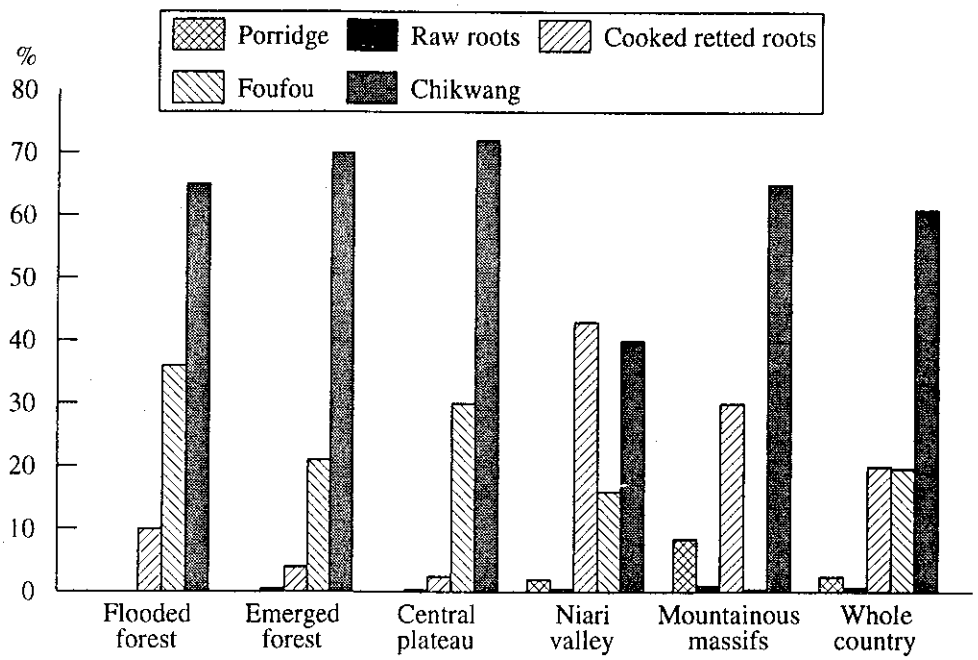


Figure 3. Effect of addition of malted sorghum flour on the gruel concentration at the viscosity level of 2 Pa.s.

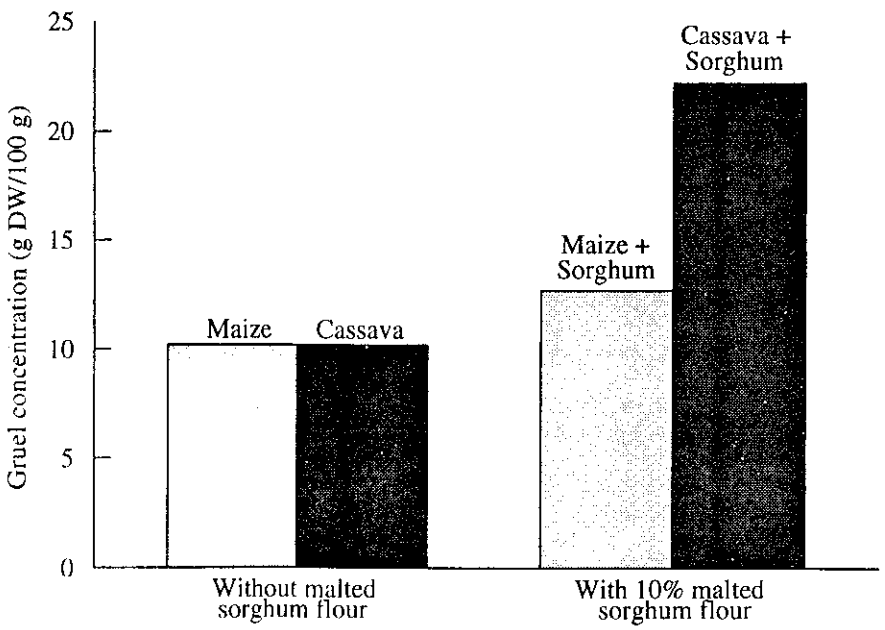


Table 2. Working order of cassava processing small factories in Brazzaville.

	(% of total)
Household operations for processing:	
Foufou	0.68
Chikwangue	1.93
Chikwangue factories	
- Number of processing operations by month:	
0-4	35.2
5-8	60.0
8	4.8
- Type of raw products	
Raw roots	0.3
Whole retted roots	1.0
Retted paste	98.7
- Raw product origin	
North (by stream)	57.7
South (by rail)	42.3
- Amount of *chikwangue* sold every week	
20-69	40.1
70-139	49.7
140-300	10.2

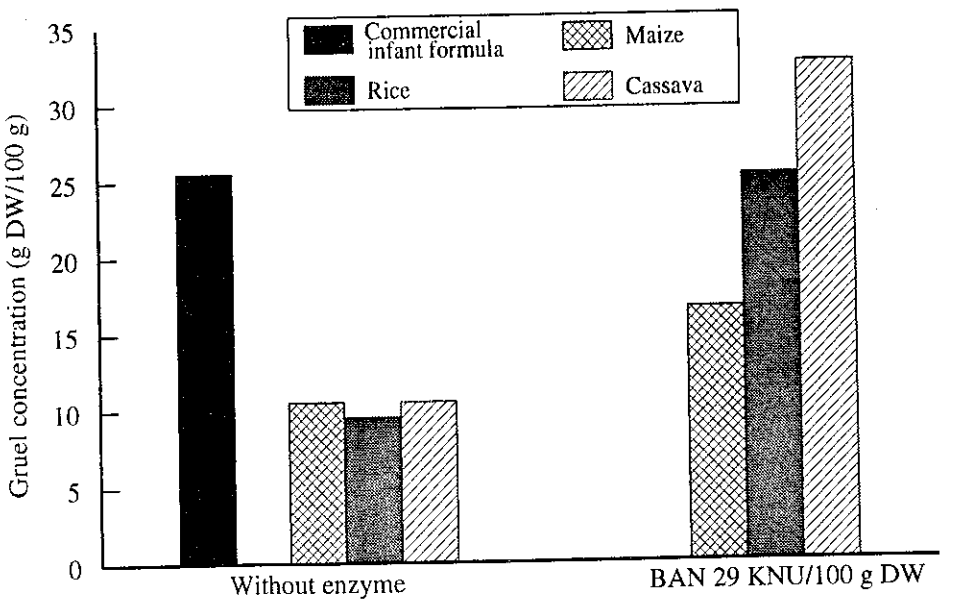
The main limitation of the project lies in the fact that it has a highly location-specific focus. One way to foster more acelerated adaption of available innovations would be to expand the coverage to the Greater Central Africa area.

Table 3. Staple food prices in Brazzaville (on a dry weight basis).

Type of food		Cost[a] (F.cfa/100g)
Chikwangue	Ngudi-yaka	34.5
	Fabrique	42.1
	Moungouele North	36.1
	Moungouele BZV	39.1
Average price		36.1
Foufou (cassava)	Dry retted roots	18.9
	To sell retail	45.8
Plantain		86.7
Corn	Grain	37.6
	Fermented dough	100.7
Potato		249.0
Bread		47.7
Rice		28.6

[a]F.cfa 100 = US$ 0,0037

Figure 4. Effect of the addition of industrial amylase on gruel concentration at the viscosity level of 2 Pa.s.



Evaluation of Results

We are making good progress in our work. Results obtained based on the project's objectives are adequate. There is, however, still much work to be done concerning the transfer and the diffusion of identified or finalized technological innovations.

Future Prospects

Exploitation of data obtained within the framework of identifying processing and consumption patterns in Congo has to be completed. A quantitative estimation of cassava consumption in urban areas remains to be done. Transfer of results obtained from our studies on the retting of cassava roots remains incomplete.

A means of financing is being sought to support the work necessary to optimize *foufou* flour and *chikwangue* production and determine the feasibility, acceptability, and nutrition of fortified cassava-based products. A new project is envisioned which would be directed toward development.

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Potatoes, Mixes and Soups: A Case Study of Potato Processing in Peru

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Abstract

Simple potato processing is an age-old Peruvian tradition. Present day techniques bear great resemblance to those utilized many hundreds of years ago. Recent interest in improving potato processing was spurred by production and marketing developments, particularly those concerning product development for mass consumption in urban markets. Efforts to improve traditional processing covered both products and processes. Initial work on potato drying processes gave way to experiences using potato products in mixes with other Andean products, building of a pilot plant and the introduction of appropriate, simple machines. Transfer of the technology through a rural development project resulted in a series of modifications intended to develop adequate processed products, alter plant size and design, and improve final product processing. Although the project was not replicated in its entirety for financial, technical, and organizational reasons, new ideas and useful knowledge were disseminated.

Key words: postharvest technology; equipment; pilot plant; marketing; rural development organization; Peru.

Introduction

Potatoes have been processed in Peru and Bolivia for hundreds of years. This activity permits potato consumption long after harvest and facilitates their transport and exchange for other products. During the last two decades, interest in improving traditional processing techniques has grown, particularly in years of abundant supply. While potato remains a traditional part of the rural diet in many Andean countries, the vast majority of consumers have moved to the cities. Consequently, supplying urban areas with food has become an increasingly important concern; and efforts to reduce transportation costs, as a component of marketing costs, a major priority. Furthermore, food consumption habits have changed, with processed products taking on added importance because their preparation requires less time and energy, their shelf life is longer because they are less perishable, and their utilization promoted through mass media advertising. Such activity is also seen as a way to give rural families an additional source of employment and income by expanding the market for increased potato production.

This paper analyzes attempts of several institutions at improving simple potato processing over the last 15 years in Peru. First, traditional potato products and processing techniques are briefly described. Second, efforts to improve these techniques are evaluated. The third section deals with the development of new products through mixing of potatoes with other staples. The closing section summarizes the lessons learned for those interested in developing similar projects in the future.

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The Potato in Peru

Production

Potatoes cover 10% of the total cultivated area in Peru. Only corn covers a larger area (15%). During the 1970s, average annual cultivated area was approximately 268,000 ha. In the 1980s, harvested area fell to an average 196,000 ha per year. Average annual production was 1,735,000 t in the 1970s. It fell to 1,619,000 t in the 1980s. Average yields per hectare rose from 6.5 t to 8.3 t over the same period. Despite this increase, yields remain well below the technically feasible 30 t/ha.

Potatoes are grown in all Peruvian regions. However, 95% of the potatoes are grown in the highlands (sierra). Only 4.5% are grown on the coast, and 0.5% in the Amazon jungle region (Scott 1986). In the highlands, potatoes are grown on 20% of the total planted area, compared to 17% for corn. In the central highlands, in particular in the Department of Junin, east of Lima, the capital city, (Map 1) potatoes cover 48% of the total harvested area.

Potatoes are grown by small, medium, and large farmers depending on (1) area planted; (2) type of production; and (3) utilization patterns. Small farmers plant less than one ha of potatoes, in combination with other crops and mainly for home consumption. Medium-size farmers plant up to 3 ha of potatoes, generally in combination with other produce but are market-oriented. Large growers are profit-oriented and specialized in seed and ware potato production. They plant up to 100 ha. Approximately 90% of all potato growers in Peru are small farmers, 9% are medium-size farmers, and only 1% are large growers according to available estimates (Ibid.).

Due to the agroecological diversity of the country, potatoes are grown in Peru all year round. Hence, they are harvested in at least one producing area at any one time during the year. However, due to varying soil and climatic conditions of the producing areas, only potatoes from a particular area will reach Lima markets at any given time of year (Gomez and Wong 1989). For example, during the first half of the year potatoes are harvested in Junin, in the central highlands, while the harvest in Moquegua, in the south, takes place in the last quarter. This ensures a constant supply of fresh potatoes to the Lima market.

Marketing

Commercial potato production has grown in relative importance in Peru with the decline of subsistence-oriented potato cultivation as in the southern Peruvian highlands. Improvement and expansion of roads have fostered the development of regional and interregional commerce. This led in turn to an increased interest in new potato uses, products, and markets.

The search for new markets is also due to the peculiarities of potato marketing in Peru itself. Given the long distances from producing areas in the highlands to consumption centers on the coast, transportation costs long have been an important component of marketing margins. The relative importance of these costs has mushroomed in recent years with the sharp rise in fuel prices. Thus, processing that could shrink the large (80%) water content of the potato would reduce the depressing effect of transportation costs on farm-gate prices. Processing technologies could also help farmers manage the release of surpluses onto the market in response to favorable price movements. By using technologies to preserve potatoes when prices are low, farmers could sell potato products at a later time when prices are high.

Demographic and income changes have also spurred interest in processed potato products. Traditionally processed potatoes are an important component of the family diet in the highlands. However, these products typically are consumed on the coast only on special occasions (Werge 1979). Therefore, though there are no detailed statistics in this respect, regional variation in consumption patterns reflect the fact that traditional potato products vary greatly in quality and presentation (color, appearance, and purity) as well as price. The absence of suitable technologies to reduce water content has generally meant higher consumer prices for processed potato products in urban markets on the coast. Consequently, a potential market for inexpensive, good quality, potato products was identified contingent upon the improvement of processing technologies to produce a better and cheaper product.

Traditional Processing

Although potatoes have been processed in Peru for several hundred years, little has been written about the products and processes involved. Yamamoto (1988) argues that many contemporary scientists see these products as part of a traditional activity with little relevance to modern life.

Map 1. Peru: Location of potato production.



Source: Scott 1985.

Nevertheless, Werge (1979) identified two main reasons for the continued prevalence of traditional potato processing. One is to obtain a product from potatoes that cannot be consumed fresh. For example, bitter potatoes used to make *chuño* must be processed due to their high content of glycoalkaloids; damaged and rotten potatoes which cannot be consumed directly, must also be processed. Secondly, storage is a vital concern in areas where the potato is an important component of the diet, but where seasonality prevents uninterrupted consumption of fresh tubers. Under such circumstances, part of the potato harvest has to be processed to ensure a constant supply of food.

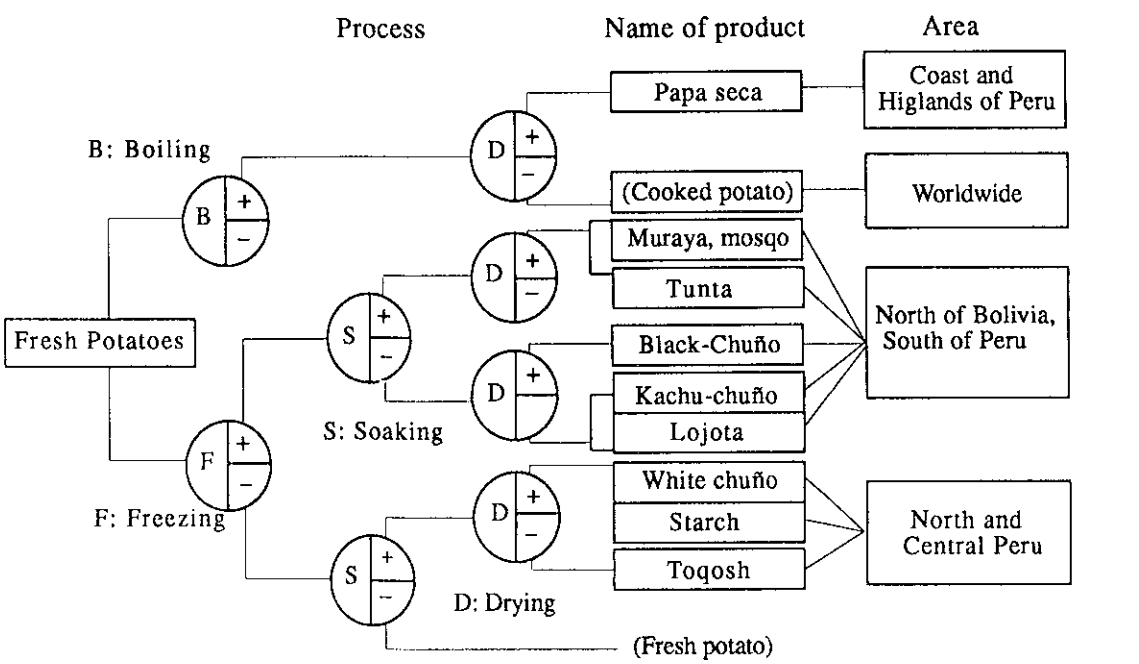
Traditional potato processing also has several important advantages over other techniques. First, these processes do not require the use of inputs other than solar energy, water, and labor (usually family labor). This fact is particularly relevant in environments like the upper Peruvian highlands (*puna*), where natural (i.e., firewood) or generated (i.e., electricity) sources of energy are scarce. Additionally, these processing techniques provide employment for family labor immediately after the harvest season when local job opportunities are scarce.

The extent of use of such technologies was revealed by a survey among a sample of 1,200 farmers in the Mantaro valley, an important potato producing area in the central highlands (Franco et al. 1979). Results of that survey showed that 33% of those interviewed were *chuño* producers, 11% produced dried potatoes, and 2% produced starch.

The potato products obtained with traditional technologies listed by Yamamoto (loc. cit.) include: *lojota, kachu-chuño, tunta, moraya, mosqo-chuño, toqosh, chuño,* dried potatoes (*papa seca*), and potato starch (*almidón de papa*). However, the first six products are merely different forms of *papa seca.* Thus, only three major types of traditional processed products are made from potatoes: *chuño, papa seca*, and starch (Fig. 1).

A comparison based on the accounts found in 16th and 17th century chronicles and observations of present-day processing techniques reveals few, if any, changes. Processing of potatoes in the Peruvian highlands takes place in June and July during the night-frost season. *Lojota* and *kachu-chuño* are obtained by selection of bitter potatoes which are then frozen in the open air, thawed, ground, and cooked (Table 1). However, larger tubers must be used to obtain *chuño.* The potatoes also must be sun-dried, making the processing generally longer. *Chuño* is used in soups and porridges (*mazamorra*), and annual per capita consumption is estimated at 5-6 kg. Consumption is greatest in the rural south of

Figure 1. Potato processing in the highlands of Peru and Bolivia.



Source: Yamamoto 1988.

Table 1. Processed potato products in Peru and Bolivia.

Product	Type of potato	Time needed for processing	Storage
Lojota	Mainly bitter	1-2 days	No
Kachu-chuño	Small	1-2 days	No
Chuño	Small and medium	2 weeks	Yes
Tunta	Mainly bitter	1 month	Yes
Muraya	Damaged potatoes	1 month	Yes
Mosqo-chuño	All	3 months	Yes
Toqosh	Mainly bitter	2 weeks-1 year	Yes/No
Chuño	Not bitter	1 month	Yes
Dried potato	Not bitter	2-3 days	Yes
Starch	Not bitter	1-3 days	Yes

Source: Yamamoto 1988.

Peru (Scott 1986). *Tunta, moraya,* and *mosqo-chuño* are obtained by immersion of tubers in running water. The processing of *toqosh* does not require drying.

The processing of *papa seca* requires boiling of the chosen tubers, peeling and slicing, sun-drying and grinding into small pieces (Werge 1979). According to Benavides and Horton (1979), statistics for the 1970s reveal that production of *papa seca* was mainly in the departments of La Libertad (59%), Junin (21%), Lima (11%), and Ica (3%). Also, *papa seca* typically is used only for the preparation of a dish served on special occasions (e.g., *carapulcra*). Thus, increased consumption of *papa seca* results from simple population growth rather than higher per capita consumption.

Potato starch is obtained by mashing potatoes that are then soaked in water for several days. The water is changed regularly, and the starch precipitates. After straining with a fine mesh cloth, the starch is sun-dried. Potato starch is used as a thickener, and to make desserts and cakes.

Development of Improved Technology

First Attempts

Given the growing interest in the commercial potential of traditional potato products, and the variable time required to make them, scientists at the International Potato Center (CIP) became interested in finding faster drying methods for *papa seca*. These improvements were intended to allow producers to increase and accelerate production, diminish production costs per kg, and ensure a larger commercial supply for the one traditional processed potato product thought to have an untapped market potential. This concern led to the development of the black box technology.

The Black Box

This technology consists of a simple, black wooden box with a removable plastic lid that can be used as an improved solar drier. It was envisioned that the black box would reduce dehydration time while preserving the nutritional and culinary properties of the potato. A number of experiments were carried out in Concepcion (3,200 m) in the Mantaro valley in June and July, 1977 to compare black box performance vis à vis traditional drying methods. Participant farmers supplied the tubers.

The black box was tested against drying methods such as drying on jute cloth, other thin fabrics, and layers of straw. One-kilo lots of potatoes were placed in the black box and on the other drying surfaces. The samples were weighed daily to assess loss of water content until total dryness was achieved. Farmers helped to determine any noticeable differences between results obtained with the black box versus other drying methods.

Initial water loss was significant with all techniques used. However, no method showed clear superiority in drying speed. Furthermore, farmers did not perceive differences in quality amongst techniques. One negative aspect of the black box was the lack of adequate ventilation. Humidity was trapped by the plastic lid. Removal of the cover did not result in substantial improvements as compared to the other methods. Additional findings showed that tuber size was of foremost importance for all techniques employed.

More importantly, although manufacturing of *chuño* and *papa seca* was seen as highly labor-intensive, the degree of difficulty varied at different stages of the process. For example, in the case of *papa seca*, the peeling of potatoes after cooking was seen as the most labor-intensive stage of processing. The participant farmers did not consider the labor required for sun-drying of the potatoes as a constraint. Nor did they think that sun-drying was too time-consuming, or that faster drying techniques would be an important innovation.

The Muquiyauyo Experience

In a related experience, the rural community of Muquiyauyo in the Mantaro valley showed interest in reaching an agreement with the National University of Agriculture to develop large-scale production of *papa seca*. This lead to the purchase of heavy equipment and the building of appropriate infrastructure. However, these facilities were never utilized as planned due to the high market price of potatoes and the small consumer market. At the same time, factory management and coordination of technical assistance required too much dedication on the part of participant farmers. As a consequence, the plant was abandoned for all practical purposes. Scientists learned two main lessons from this experience.

First, new potato products had to be developed that would be less vulnerable to seasonal potato supply and price fluctuations. This innovation would allow the plant to operate with a continuous supply of low-cost raw material. It would also ensure a sustainable flow of finished product for interested buyers. Second, consumers should be able to use these products in more than just one way of food preparation. This marketing strategy was intended to increase utilization, per capita consumption, and the demand for processed potatoes.

The M6 Mix

Work started on the development of highly-nutritious, low-cost processed potato products using combinations or mixes of local crops as an outgrowth of the above-mentioned experience. Low income consumers were chosen as the target beneficiaries of these efforts for two reasons. CIP's mandate as a non-profit international organization calls for the center to assist less well off groups. Furthermore, these consumers are the largest segment of the local market. Gaining access to this market segment, it was reasoned, would allow larger-scale operation and, thereby, reduce unit production costs.

Plans were made to: (1) experiment with several crop mixes; (2) build a pilot plant; (3) test consumer preferences; (4) conduct marketing studies; and (5) carry out a brief study of the economic feasibility of this type of processing.

Experimenting with Different Crops

Small farmers and potential rural processors in the highlands of Peru grow a variety of crops including *quinua*, lupine, broad beans, oats, and barley, among others. These crops were evaluated for their compatibility with potatoes, and the resulting mixes were tested for their organoleptic acceptability by consumers. The highest ranking prototypes were then evaluated for their nutritional characteristics.

The M6 mix was rated as the most acceptable. It consists of 30% fresh potato combined with rice, oats, barley, and corn flours. It can be reconstituted by adding approximately one liter of water for every 80 g of dry mix. The product then has to be boiled for 25 min until thickening to be used as a breakfast cereal, with other savoury foods, or as a dessert.

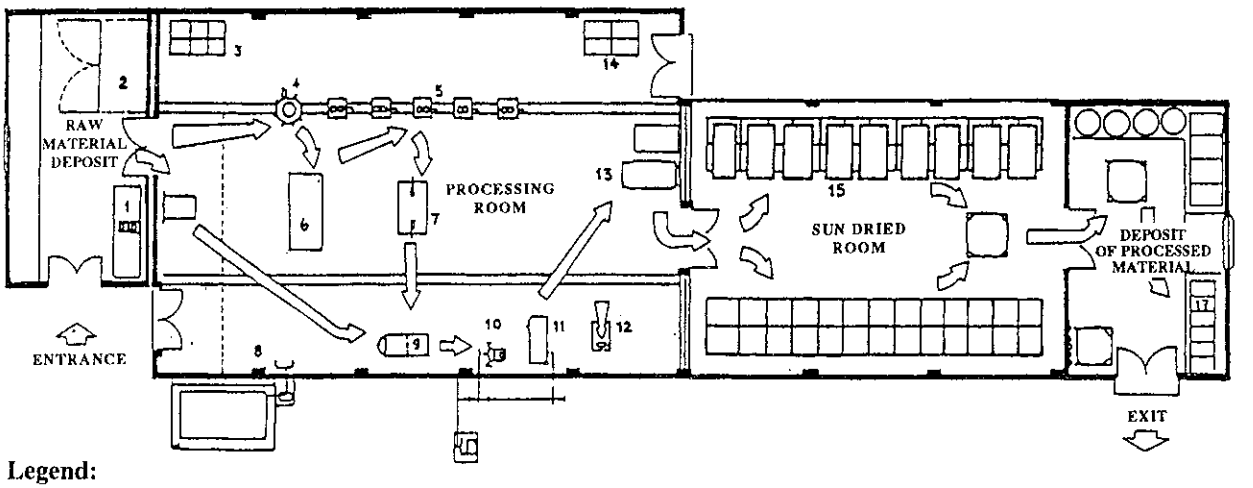
The approximate nutritional value of the mix is measured by its 10.6% protein and 333 kcal calorie content per 100 g of mix. The probable protein efficiency measure using the Food and Agricultural Organization of the United Nations (FAO)/World Health Organization (WHO) method is 86%, compared to 82%, 70%, and 41% for potato, rice, and broad beans, respectively.

The Pilot Plant

A pilot processing plant was built at the CIP's high altitude experiment station outside the city of Huancayo. Construction work concluded in July 1984. The facilities include a drying area with a capacity to process 1 t of M6 per week. The processing plant itself includes four main components: (1) a reception and storage area for potatoes and other supplies; (2) a processing unit; (3) a drying chamber; and (4) a finished product store (Fig. 2).

Processing unit. The processing unit is 14.35 m long and 9.78 m wide. The walls are made with local materials, i.e., eucalyptus boards and trunks. Two drainage ditches on the cement floor allow easy cleaning of the facilities. The aluminium sheet metal roof has a few fiberglass-covered openings for lighting above the work areas.

Figure 2. Processing plant and work flow chart.



Legend:

1. Platform scale
2. Closet
3. Closet for pots and plastic ware
4. Potato peeler
5. Kerosene stove
6. Inspection table
7. Press
8. Water source
9. Mixer
10. Masher
11. Strainer
12. Hammer mill
13. Cart conveyor
14. Dry box closet
15. Drying shelves
16. Fiberglass deposit
17. Sacks with finished product

Source: Booth et al. 1986.

Drying chamber. The solar energy collector in the drying chamber is made of eucalyptus boards and mud bricks (adobe). The ceiling and the north wall are covered with no. 14 plastic (PVC) conduit pipe. The floor is polished cement, and the walls and floor are painted black for greater solar heat absorption. The remaining walls have six windows 0.5 m above the floor for improved ventilation and an air extractor helps remove saturated air. In the drying chamber, two metal racks at each end of the drier are used to place trays with the homogenized, humid mix ready for drying.

Equipment

The location of the processing equipment in the plant is depicted in Figure 2. The equipment includes the following.

Peeler. The mechanical peeler is a galvanized metal drum with a rotating bottom. The abrasive surfaces inside the drum help remove the peel. The peeler's approximate capacity is 300 kg of peeled potatoes per hour and it is powered by a 1.8 hp, 220 volt electric motor with a 1.32 kw/hour energy consumption.

Inspection table. Inspection and rectification of peeled potatoes is carried out on this 2 x 1 m table. Two workers on each side of the table perform potato inspection while 0.10 m sidewalls prevent potatoes from falling off the table. A formica sheet tabletop allows easy cleaning.

Cooking pots. Cooking is made in 40-liter aluminium drums with two side-handles for easy manipulation.

Stove. The steel angle bar stove is 0.5 x 0.5 m^2 and 0.6 m high, and is provided with two kerosene burners, a kerosene tank, and a pump. Fuel consumption is 800 cm^3 per hour.

Potato grinder. The grinder is a drum with a helix axle, a rotating knife, and a perforated disc. An external hand crank enables the grinder to be operated manually. The disc has 3 mm holes. Output is about 75 kg of potatoes per hour.

Mixer. The stainless steel mixer has a double mixing helix along the rectangular body. At the bottom a dispenser allows to empty the container. The mixer rests on four steel legs and is driven by a 2.4 hp, 220 volt electric motor. Capacity is 50-100 kg at a time, and ideal mixing time is half a minute.

Masher. The work surface of the potato masher is made of a circular cutting dish to which the product is sent through a funnel. The material is mashed by the rotation of the dish and sent to the bottom. Capacity is 200

kg/hour and the machine is driven by a 11 hp oil engine. Oil consumption is 900 cc per hour.

Processing

The production of mixes involves a simple process (Fig. 3). The potatoes are boiled and mashed. Cereal and legume flours are then added to the humid potato mash.

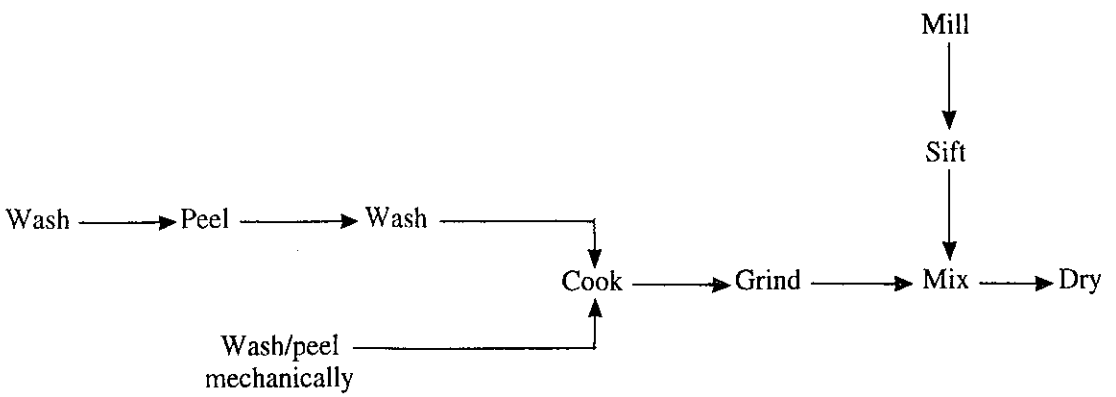
The humidity of the potato mash is transferred to the mix thus making drying easier. Drying can be by solar radiation or artificial means though at a higher cost. The approximate quantities of raw material and processed raw material appear in Table 2.

The processing plant designed for this project had a 1 to 2.5 t operating capacity. One ton of the processed product yields 50,000, 20 g or 250 ml rations of rehydrated mix which can feed 396 six-member families three times a day for a week.

After harvest, the potatoes are stored at approximately 12°C. Processing takes place once tubers have been selected and bad tubers discarded.

Washing and peeling. Dirt and other foreign matter must be washed away from tubers. Peeling is made with a peeling machine with a 0.5 m^3/hr water jet. The undulating bottom turns and pushes the potatoes against the abrasive walls, and makes the potatoes rub against each other. The resulting softening of the skin makes the dirt and the skin fall off the tubers to the bottom where they are then removed by the water jet. Tubers not properly peeled are rectified by hand. Maximum peeling capacity of the machine is 300 kg/hr and energy consumption is 1.324 kw/hr. Chemical peeling with sodium hydroxide (caustic soda) may also be used.

Figure 3. Flow diagram for production of M6, 1-2.5 t per week.



Source: Booth et al 1986.

Table 2. Input requirements (kg) per 100 kg of M6.

Raw matter	Potato	Rice	Lima beans	Oats	Barley	Corn	Salt
Requirements	170	17	21	21	23	12.5	4
Processed	Potato	Flours					
Raw matter	mash	Rice	Lima beans	Oats	Barley	Corn	Salt
Requirements	120	16	16	16	16	12	4

Source: CIP.

Cooking. Washed and peeled tubers are placed in 40 kg-capacity pots. It is advisable to place the potatoes in 15 liters of boiling water at the most. Total cooking time depends on the variety of potatoes though usually a mix of varieties will require, on average, 2 hrs for a maximum 40 kg-capacity pot.

Grinding. This is performed manually using two meat grinders.

Mixing. Cereal and legume flours are mixed with the potato mash as follows: (1) 60% humid potato mash; (2) 8% broad bean flour; (3) 8% rice flour; (4) 8% oat flour; (5) 6% corn flour; (6) 8% barley flour; and, (7) 2% salt. The ingredients are homogenized in the mixer.

Shredding. After mixing the product is shredded into 1-2 mm granules for easy drying.

Drying. The fine mix is placed on wooden trays at a rate of 5 kg/m^2 for 52% average humidity of the mix. The trays are placed on metal shelves in the drying chamber. Temperature in the chamber is 40°C, average ambient humidity is 30% and wind speed is 0.4 m/sec. The plant has a 500 kg drying capacity and an output of 250 kg of M6 mix every 48 hrs.

Consumer Acceptability Tests

As part of the evaluation of the potential product, 1,000 consumers were asked to taste the mix. After a demonstration, they received a half kilo of the mix. The mix also was consumed for a whole year at a community restaurant (*comedor popular*) in a low-income neighborhood in Huancayo. Results of both tests showed good consumer acceptability (Booth et al. 1986).

Other consumer acceptability tests were carried out at 12, low-income municipalities (*pueblos jóvenes*) in Lima; for two years at the low-income restaurant "*Señor de los Milagros*" also in the capital, and with 2,000 school children in the central highlands for two months. These consumers reported that the product's taste and texture were highly acceptable (Table 3). Acceptance among sample homemakers was increased by the product's high nutritional content.

Table 3. M6 consumer acceptability tests.

Location	Use of M6	Result
UNI-Lima restaurant	beef stew (thickener)	good
(1,800 people)	*carapulcra* (side dish)	good
	fish stew (thickener)	bad
Low-income restaurant	chicken stew (thickener)	good
Ate Vitarte (900 people)	*carapulcra* (side dish)	good
	noodle soup (thickener)	good
	vegetable soup (substitute)	good
	cream soup (substitute)	good
	milk drink (substitute)	good
	beef stew (thickener)	good
	beef soup (substitute)	bad
Low-income restaurant	chicken stew	good
Lurigancho (350 people)	cream soup	good
	drink	
Low-income restaurant	cream soup (substitute)	good
130 people	porridge (substitute)	good
University of Cajamarca	drink (complement)	good
(800 people)	fritters (complement)	good
	porridge (substitute)	good

Source: Centro de IDEAS.

Socioeconomic Feasibility

Analysis of the economic feasibility of the mix assumed an investment of US$ 15,000 to be financed by a loan at an annual interest rate of 12.5%. This investment excluded the cost of the land. The proposed selling price for the M6 was set at US$ 1.00. Approximate production costs were estimated at US$ 0.60, depending on production levels. However, calculations done for the feasibility study were intuitive.

An anthropological study of food consumption habits in shanty towns around Lima aimed at assessing the possibility of including M6 in the daily diet of low income consumers (Benavides and Rhoades 1987). Results of that study showed that processed products are relatively expensive, and underscored the skepticism prevalent among some CIP scientists as to the real potential of M6 for this group of consumers. Others argued these findings were too pessimistic. Meanwhile, the process was refined and arrangements made for commercial testing by transfer of the technology to a local, non-governmental organization, the *Centro de Investigación, Documentación, Educación, Asesoramiento y Servicios* (*IDEAS*).

Transfer of Technology

Centro de IDEAS is a private research and development organization devoted to the improvement of living standards among low income urban dwellers, and the development of agricultural and handicraft production. These efforts take into consideration the conservation of natural resources, national food security, and the use of integrated development policies.

Since its inception, *Centro de IDEAS* has placed great emphasis on rural development by making alternative policy proposals to increase productivity and production, develop alternative agricultural technologies, foster the efficient utilization of natural resources, and support grassroots organizations. In its search for new challenges, *Centro de IDEAS* chose to promote the development of agroindustry. This led to a growing interest in processing to increase agricultural value-added and open new markets. The Agroindustry Program therefore was created in 1985 to develop solutions to rural problems.

The Centro de IDEAS Project

By 1985, the Agroindustry Program at *Centro de IDEAS* proposed a project to build four small plants for processing potatoes and Andean cereals. The project's goal was to test the technical and economic feasibility of rural agroindustry. The project was funded by a U.S.-based, non-governmental organization, Appropriate Technology International (ATI). CIP scientists helped *Centro de IDEAS* staff prepare project documentation and establish links with ATI.

The proposed project had four objectives:

- Introduce small-scale technology suitable to rural areas that would be profitable and could be replicated elsewhere;
- Process highly nutritious and cheap potato products for low-income consumers;
- Increase small farmer income by creating a new market for excess potato supplies; and
- Establish a rural simple processing training center for low income people.

This experience went through five stages: assimilation; development; investment; implementation; and replication and impact.

Assimilation of CIP Technology

The above-mentioned Industria de Derivados Alimenticios del Agro (IDEAGRO) project was implemented in the framework of *Centro de IDEAS* principles, i.e, an orientation toward low-income people and possibility of replication by other enterprises. The project included an engineering study based on CIP's design, a basic financial analysis, and a market study.

CIP's initial process and equipment design was accepted, although it did not include technical specifications for the processing of cereal and legume flours. A second drying chamber was added, and plant capacity was expanded to 9.6 t from the original 4 t.

IDEAGRO proposed a simple organization in which *Centro de IDEAS* would be the owner and set the general policies, while IDEAGRO would be the project operator with a capacity to make autonomous decisions on sales, supplies, production, and other matters. Project staff included an industrial engineer or a food technician, an administrator, a plant manager, a secretary-sales assistant, and eight factory workers. Sales personnel were not included. The project did not take into consideration accounting and managerial aspects of the operation. It overlooked legal requirements as well (e.g., building and municipal authorizations, sanitary and quality control regulations, and registration of trademarks).

One pilot plant was to be built in Huancayo and three others in Puno, Cajamarca, and Piura. Investment for the first plant was estimated at US$ 33,833. This included US$ 8,750 for equipment, US$ 7,000 for land, and US$ 18,083 for construction. Working capital was estimated at US$ 10,000. The investment was higher than originally planned by CIP because it included the cost of land, buildings, a hammer mill, and a large-capacity potato press.

The most optimistic cost and return estimates assumed growing sales, constant positive margins of around US$ 0.22 (at a product price of US$ 0.86 and variable costs of US$ 0.64), and no price distortions. More realistic estimates showed negative net income. *Centro de IDEAS* considered that given the experimental and training nature of the project, optimism should prevail.

The marketing study complemented work already done by social scientists at CIP, though with slightly different results. Consumer acceptability tests were carried out at student cafeterias at the Universidad Nacional de Ingeniería in Lima (UNI-Lima) and the University of Cajamarca, as well as at low-income restaurants in the Lima districts of Ate, Vitarte, and Lurigancho. Although responses were generally favorable, negative comments pointed to a smell of oil, or a disagreeable smell in the food; rancid or bitter taste; and poor yield and bad thickening qualities of the product. IDEAGRO issued recommendations to improve the product in all three respects.

The marketing strategy proposed by *Centro de IDEAS* emphasized sales in Huancayo, in the Mantaro valley, and to state institutions such as schools and restaurants for low-income consumers through public sector contracts. The reasons for this strategy were two-fold. These sectors constitute the largest share of a potential consumer market. This segment of population was in most urgent need of food assistance.

Development of New Products

Project strategy changed radically after six months. Some underlying assumptions associated with M6 product came under criticism. Initially, the product did not suit consumer tastes. Introducing the product to the market would imply heavy promotional expenses. Finally, the product could not compete in price with other processed products (i.e., those made with imported wheat). For these reasons, among others, new time-saving, quality products were to be developed. Marketing efforts shifted from the countryside to big cities. Production at the plant was to be increased from 9.6 to 16 t.

The decision to increase production was based mainly on financial considerations. The price of M6 could not be significantly increased as it was directed to low-income consumers. However, escalating costs reduced project profitability (net profit/sales) from 28.2% to 2.81%. Higher prices could be charged for the new products since they were aimed at higher-income consumers thereby allowing profits to rise to previous levels (23.5%). Maintaining the initial strategy would have led to a default on loans.

The M6 mix became M5. This product is made of potato, rice, peas, barley, and corn. The marketing strategy required that all ingredients be precooked. Oats were not used due to supply difficulties, and peas replaced broad beans to eliminate the slightly bitter after taste. Cooking time for the new mix was reduced from 25 to 15 min.

Versatility was still considered one of the product's main features. However, what was initially perceived as an advantage, gradually became a problem because potential consumers did not clearly identify the product with any specific use. This, in turn, created marketing difficulties as the product did not fit easily into existing food consumption patterns. Changes introduced in the mix did not contribute to overcome this difficulty. However, other product characteristics, such as ease of preparation and high protein content, were regarded as highly desirable.

Market surveys indicated that consumers objected to the size of the granules and the undefined taste of the mix. Thus, rice flour was removed to eliminate roughness. A new mix M4 (*Ricarina*) resulted from new product testing made possible by the use of CIP's plant. M4 was made with precooked potato, corn, barley, and pea flours. Another product (*Chicolac*) was developed. It consists of potatoes, corn, milk, sugar, and chocolate (Table 4). New products (split, precooked peas and broad beans; pea and broad bean powdered soups; peeled barley and wheat; quality *papa seca*; potato powdered soup and potato semolina) were also developed and introduced in well-known regional markets (Huancayo).

The process of experimentation and new product development was accompanied by an evolution in project goals. Gradually, the improvement of living standards among the poor, peasant productivity levels, and rural food security received lower priority. Instead, the project increasingly focused on profitability and the need for self-financing to sustain operation.

Table 4. Transformations of the M6 mix.

Stage	Name of Product	Ingredients
First	M6	potato (30%) barley (14%) corn (14%) rice (14%) lima beans (14%) oats (14%)
Second	M4 (Ricarina)	potato barley corn peas
Third	Chicolac	potato (4%) corn (70%) milk (18) sugar (4%) chocolate powder (4%)

Source: Centro de IDEAS.

IDEAGRO eventually implemented three product lines: potatoes, cereals and legumes, and complementary production lines. Potato processing technologies included peeling, cutting, cooking, drying, grinding, and straining. Techniques for cereals included cleaning and selection, roasting, peeling, ventilation, grinding, and screening. Complementary production techniques included mixing, dosage, sealing, and packaging.

Potato processing required the use of peelers, steam cookers, solar drying chambers, fuel drying chambers, and mills. Cereal processing required stone removers, roasters, wheat peelers, fans, stone mills, hammer mills, and screens for straining. Complementary processing used mixers, dosers, and seal packers.

The new products and processes required a 540 m^2 area for facilities. Additional potato processing equipment consisted of a brick and cement solar drier to replace the rustic CIP design; a fuel drier; steam cookers to replace the kerosene stoves; and, a stainless steel cutter. Additional equipment for the processing of other grains were a sorting machine with interchangeable screens, a roaster, and a hammer mill.

Investments

Plant modifications to accommodate the expanded line of products meant the required investments almost doubled from US$ 43,833 to US$ 97,115. Higher costs accounted for 57% of the additional investment; only 43% was due to larger plant size and new processes. Higher costs resulted from exchange rate control measures, an undervalued currency, and hyperinflation. As a consequence of these budgetary changes, working capital fell as a percentage of the total investment. This became a progressively more severe problem.

Direct investments in the IDEAGRO project were estimated at US$ 162,451 of which US$ 97,116 were supplied by ATI and the rest by a loan from the *Banco Industrial del Perú* (Peruvian Industrial Bank). This amount did not include personal services, such as those provided free of charge by CIP scientists and *Centro de IDEAS* staff members.

ATI funds for *Centro de IDEAS* were loaned to IDEAGRO. Repayment of the loan would go towards a revolving fund to finance other enterprises wishing to replicate the experience. In fact, IDEAGRO would pay a negative interest rate and thus make a financial profit. However, by June 1989, the revolving fund amounted to only US$ 7,609 out of total funds of US$ 97,116 provided by ATI. This partly reflected the economic crisis the country as a whole was experiencing.

IDEAGRO was started at a critical time. From 1986 to 1989, Peru's Gross Domestic Product (GDP) fell at a 9% annual rate. A 26% negative growth rate was registered in 1988 alone. The September 1988 economic crisis and government's adjustment measures coincided with the beginning of IDEAGRO's financial difficulties. Although the agricultural sector grew at a 12% annual rate during those same four years, this was achieved through an artificial increase of purchasing power financed by the depletion of the country's foreign currency reserves.

Price distortions due to inflation generated variations in product terms of trade, particularly after 1988 when annual inflation skyrocketed to over 1,700%. Prices for tubers, other vegetables, legumes and wheat—all inputs or substitutes for IDEAGRO's products—were considerably affected. For example, the price index for the first nine months of 1988 rose faster for wheat than for potatoes (118% to 100%). During 1989, the price index for potatoes shot up while wheat showed little change (135% for potatoes and 101% for wheat).

The real monthly interest rate charged by banks was approximately 2% as a result of rapidly accelerating inflation. This led to a decrease of the real worth of credit funds during those years. The agricultural sector was also subjected to massive imports of staples (wheat

and rice), subsidized fertilizer prices, a severe drought at the end of 1989, and agricultural support prices. Ironically, these support prices did not benefit IDEAGRO; rather, they contributed to unstable input prices.

Marketing

IDEAGRO's marketing strategy must be analyzed bearing in mind the meager information available on prices, consumer tastes and preferences, marketing channels, advertising, and sales for the above-mentioned products.

Prices. Data are available only for *papa seca*. Prices vary depending on the segment of the market where the product is sold. The better quality—including more attractive packaging, of IDEAGRO's *papa seca* resulted in higher prices, when compared to prices at Lima's municipal markets and small retail stores. In supermarkets, IDEAGRO's *papa seca* competed directly with expensive "Sureña" and slightly cheaper "Dieprosa" *papa seca*.

Consumer tastes and preference. Gomez and Wong (1987) examined tastes and preferences for *chuño, papa seca*, a potato powder to make creamy soups and semolina. Their study asked 199 high-, middle-, and low-income Lima consumers their opinion about *papa seca, chuño*, and imported potato flakes. Questions included product awareness, quantities purchased, frequency of and reasons for buying, preferences, and potential substitutes. All three types of consumers are aware of *papa seca*. Those products are consumed by 70% of the high-income consumers and 90% of the middle- and low-income consumers. However, high-income consumers buy dried potatoes occasionally (once a month or less); middle-income consumers buy them every 15 days, while low-income consumers may buy potatoes weekly.

Stated reasons for buying *papa seca* products are their filling flavor, nutritious value, good taste, and habit. Negative considerations include dirt and foreign matter found in the contents, bitterness and granule size (too large or too small). Potential substitutes for *papa seca* are beans, lentils, and split peas. IDEAGRO's products had not yet been introduced at the time of the survey, but they are free of these negative characteristics.

Survey data for imported potatoes flakes can shed some light on consumer opinions about potato powder to make creamy soups. Potato flakes were known to 100%, 80%, and 70% of the high-, middle-, and low-income consumers, respectively. However, only 80%, 50%, and 30% of the corresponding consumer groups bought the product. Frequency of purchase ranged from occasionally for the low-income buyers, to weekly for middle-income consumers, to at least once a month for high-income households. Ease of preparation, good taste, nutritional value and high yield were among the reasons mentioned for buying imported potato flakes. While IDEAGRO's potato powder seems to have too strong a taste for Lima consumers, the imported product was considered too acidic. Home-made mashed potatoes, rice, and mashed sweetpotatoes were mentioned as substitutes for potato flakes.

Marketing channels. With the shift in market orientation towards high-income consumers, IDEAGRO's marketing channels became narrower. Initially each segment of the market was to be reached through a specific marketing channel. The municipal milk distribution program in Huancayo was to serve as an outlet for low-income consumers. Small retail stores in Huancayo were to sell these products to middle-income groups. Supermarket chains were the marketing outlet chosen for high income, Lima consumers. By the end of 1989, IDEAGRO's marketing efforts concentrated just on Lima's high-income consumers. In this regard, one supermarket sales manager stated that IDEAGRO's products ranked better in terms of product quality, packaging, presentation, and price than those of their competitors. However, he thought that these products were for low-income householders and consumers from the highlands, i.e., the types of buyers who were not among the supermarket's target public.

Advertising. *Papa seca, chuño*, potato powder to make soups, and other products (roasted split peas and broad beans, pea and broad bean cream soup, and peeled barley and wheat) are marketed by IDEAGRO under the "*Abril*" brand name. Significant impact and consumer acceptance were achieved for the *Abril* brand through sales promotions in supermarkets. *Chicolac* demonstrations were made for officials in charge of the Huancayo milk program. At the Huancayo agricultural fair, IDEAGRO's products won first prize in the agroindustrial category.

Poor sales were considered to be the result of insufficient knowledge among homemakers of the ways to use *Abril* products. This in turn led to the preparation of recipe leaflets for distribution in shops.

Sales. Gomez and Wong (1987) estimated the potential size of the Lima market at 113 t of *papa seca* and 7 t of potato flakes per month. IDEAGRO's average monthly sales from January 1988 to June 1989 were 8.17 t (Table 5).

Table 5. IDEAGRO production and sales (1988-89).

Year	Month	Production (t/month)	Sales
1988	Ene	1.50	1.51
	Feb	4.50	4.51
	Mar	5.70	5.77
	Abr	4.30	2.06
	May	12.40	5.59
	Jun	18.70	15.18
	Jul	15.00	12.63
	Ago	21.20	22.86
	Set	13.90	10.97
	Oct	5.70	8.47
	Nov	18.70	11.17
	Dic	18.30	1.20
1989	Ene	13.86	
	Feb	2.43	
	Mar	6.68	
	Abr	8.58	
	May	7.45	
	Jun	6.19	
Average		11.66	8.17

Source: Seminario 1989.

Data supplied by a high income, supermarket chain on sales and shopping frequency for *papa seca*, potato powder, and semolina in August 1990 may be used to estimate total sales. This supermarket chain buys 600 to 800 half-kilo bags of *papa seca* per week, i.e., approximately 1.6 t/mo, showing an increase from the average monthly buying volume of 0.5 t in 1987. However, IDEAGRO supplied only 80 to 100 bags, or 12% of these purchases. Due to political difficulties in the central highlands in 1989, IDEAGRO adopted a lower profile which contributed to a decline in sales and a loss of market share. Weekly potato powder and semolina purchases by the supermarket consequently fell to 50 half-kilo bags for each product, i.e., 0.1 t/mo per product.

Average monthly production was approximately 12 t. This figure rises to 15 t per month if the first four months of 1988 are excluded (Table 5), thus revealing that plant capacity was underutilized by about 50%.

Management

IDEAGRO also suffered from management problems. When decisions were required at critical times, *Centro de IDEAS* staff procrastinated. This was partly a function of how each viewed the project. While *Centro de IDEAS* personnel assumed an educational posture, IDEAGRO's management was profit-oriented. One IDEAGRO management member felt that the main problem was the simultaneous holding of top-level positions by some staffers at both institutions. This amplified the differences in goals and strategies in the two organizations.

From May to December 1988, the plant employed 30 workers mostly under Government-sponsored, emergency employment work contracts (*Programa de Empleo de Emergencia*). Two other workers were in charge of marketing and distribution. By the second quarter of 1990, only six workers were left.

According to one of the members of the board of directors and the manager of the company, the project never reached profitability. However, only financial aspects of the project can be analyzed. The lack of reliable data is due partly to inflation-induced price distortions and the absence of adequate reporting during the time of operation. IDEAGRO's profits were made possible only thanks to the ATI loan in local currency. The interest rate for this loan eventually fell below the inflation rate, thus allowing the operation to show a financial profit on paper.

Three factors prevented profitability in an operational sense. First, money was lost by giving credit to customers, i.e., delays in canceling accounts payable meant IDEAGRO had to assume the loss associated with rampant inflation. Next, salaries were paid even when the plant was not in operation. Finally, prices for IDEAGRO's products were not increased at the same rate as other prices.

The company was unable to honor its short-term debt for several reasons. First, investments in fixed assets absorbed most (75%) of the company's total assets. In similar businesses in Peru, this percentage rarely exceeds 25% thereby leaving considerable working capital. Some capital was also used to supply credit to customers. However, as payments by customers took up to two months, these company funds were unavailable to run (or expand) the operation.

Replication and Impact

The processing facilities have not been replicated to date. Farmers, in particular, showed little interest in plant replication. According to IDEAGRO staff, this was foreseeable from the outset since the project was originally conceived as a pilot program, leaving ample room for experimentation with different processes, products, and markets. However, replication was neither directed nor institutionally oriented. It was rather the result of a "trickle-down effect."

The experience was successful in the dissemination and partial replication of equipment, processes, products and marketing strategies by processors, equipment manufacturers, and retailers. The scale of operations at the *Centro de IDEAS* facility made it an interesting alternative for small entrepreneurs with the resources and managerial skills to start a business and adopt innovations. Thus, at least five companies copied IDEAGRO's product presentation and marketing strategies. Three of these companies now supply the same supermarkets where IDEAGRO first sold its processed products.

As an outgrowth of the project, wholesalers were forced to improve their quality control procedures and adopt sales strategies depending on prospects in different segments of the market. Potential plant, process, and product replication by farmers was made easier in that new products were already being marketed. Equipment manufacturers who built machines for IDEAGRO benefited from the experience acquired through manufacturing improved hammer mills. This type of impact stopped when the technology development process was interrupted. However, in early 1992 IDEAGRO's plant was again operating. This time with purchasing orders from the local affiliate of an international relief organization to produce more processed product than current capacity permits. Requests for information about village-level processing also have sprung up again.

Lessons Learned

The experience with potato processing in Peru generated lessons in three broad areas: (1) technology; (2) marketing; and, (3) finance and management.

Technology

1. Actual improvements of existing technologies require time not only for the transfer of the presumed improvements but also to develop new processes and products that will respond to changing market conditions. Some scientists assumed that the development of the M6 mix and the construction of the plant would mean the technology was ready to use (Seminario 1989). IDEAGRO's experience shows that a long road lay ahead.

2. More technical work was required because the receivers of the technology did not possess industrial production experience, nor did the transferring agents have much experience in this domain.

3. The original design was for a small-scale plant. However, such scale of operations proved unprofitable. Consequently, utmost care must be put in the consideration of both economic and technical requirements for appropiate plant-size (Alvarez 1990).

4. Although technological aspects are important in this kind of project, they must not become an absolute priority and impede consideration of other factors.

Marketing

5. Initially the project included only potato products, e.g., *papa seca, chuño*. Later mixes (e.g., M6) were developed in which the potato was the most important ingredient. In the last stage of the project, potatoes were only a minor ingredient in the processed products (*Chicolac*) being produced and marketed. These modifications became necessary as changes in the price and availability of potatoes meant that potato mixes and potato powder for soups could not compete with other low-price, processed products. However, a huge market exists for some processed potato products as evidenced the growing demand in Peru for french fries and chips. The black box, M6, and IDEAGRO all started with production of the product followed by efforts to sell it. All three experiences point to the strategic importance of thinking about the marketing aspect first. Product characteristics and the target market segment as well as sources of inputs and marketing channels of processed products must be clearly identified at the outset.

6. Market segmentation poses an additional challenge. In the case of IDEAGRO, three products aimed at three different groups of consumers were introduced, though emphasis was placed on the lower end of the income scale. This proved too ambitious. Projects probably need to concentrate at least initially on one product for one segment of the market.

Priority needs to be given to the product capable of generating enough profits to get the business going.

7. IDEAGRO also attempted to influence the supply-side of the process. Procurement of raw material was done directly from producers, **not** from established wholesalers. Experience later showed that this meant higher costs and unstable supplies (Alvarez 1990). The plant was built in a farming area to be closer to producers. IDEAGRO staff later found that easy access to markets, marketing facilities (e.g., the Huancayo wholesale market), and channels were much more effective for procuring supplies.

8. A marketing program needs to include not only buying and selling activities but also advertising, package design, and quality control.

9. The IDEAGRO experience also shows that consumers' perceived needs play an important role in product development. For example, the M6 mix had versatility as one of its main attributes. However, this led to confusion among consumers who could not assign it any specific, clearly defined use.

Finance and Management

10. Credit was not a problem for IDEAGRO, but heavy investments in plant and equipment generated cash flow difficulties. More realistic cost and cash flow estimates would have helped anticipate, and thereby overcome, this problem.

11. The cost of customer credit was high. More importantly, it was not taken into consideration when capital requirements for operating the plant were estimated.

12. It was not easy for a non-profit organization to compete with other well-established businesses. Although IDEAGRO eventually adapted to market competition, the project would have benefited from a priori consideration of this fact by the clear separation of responsibilities and staff between IDEAGRO and *Centro de IDEAS.*

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Utilization of Sweetpotato For Transparent Noodles in Vietnam

Dang Thi Lan and Sarath Ilangantileke[1]

Abstract

A survey was done to study utilization of sweetpotato in Habac Province and Hiephoa district in Vietnam. Sweetpotato was found to be the second most important crop in this province and used mainly for fermented animal feed and sometimes processed for food especially when other staples were in short supply. Important processing methods to utilize sweetpotato were observed and were mostly for the production of chips, fermented animal feed and in some cases, limited processing of starch into noodles. In general, the major constraint to increased production of sweetpotato was the lack of utilization processes and techniques for the edible root.

The production of transparent noodles was selected as the most promising method of utilization. Processing parameters for noodle production on a small-scale were evaluated by laboratory experimentation. The process of liming, or chemical treatment, was the best method to obtain the whiteness in the produced starch, as compared to the method existing in Vietnam. The starch prepared by the existing method was dark and not acceptable for making noodles. The experiments to obtain the best processing conditions for quality noodles revealed that the optimum proportion of gelatinized starch to be mixed to produce good quality noodles was 30%. The tests of physical parameters on dry and cooked noodles such as whiteness, strand diameter, hardness, WAI, and solids loss indicated that optimum soaking temperature and time combinations and the optimum drying temperature and methods were soaking at 0°C for 1 to 5 hr (or 30°C for 30 minutes), and drying at 45°C (or solar drying) respectively. A sensory evaluation was done and the acceptability of quality compared favorably with the physical tests.

A complete process flow for transparent noodle production, including equipment needs and optimum processing conditions for a small-scale noodle production process was recommended.

Key words: processing, starch, noodles, small-scale processing.

Introduction

Given its ease in cultivation and its nutritional value, sweetpotato has been identified as a crop with great potential to meet the food requirements of the world, particularly in the tropics. Statistics from the Food and Agricultural Organization indicate an average production of 128.4 million metric tons from 1986 to 1988, ranking sixth among food crops (FAO 1989). As a food crop, it is capable of making a significant nutritional contribution, producing much needed calories. Large parts of Asia and the Pacific region, including Vietnam have a tropical climate which is suitable for sweetpotato cultivation. The role it can play in the region is immense, but yet unexplored.

Although sweetpotato is identified as a crop which has great potential particularly in meeting food requirements of the poor in Asia and in the Pacific region, sufficient attention has not been paid to its development. Traditionally, sweetpotato has played an important role

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as a foodstuff in most of these countries. However, sweetpotato has a short storage life, generally less than four weeks, in the tropics. The thin skin of the sweetpotato is easily damaged during harvest and postharvest handling making the crop highly perishable. It is therefore usually consumed soon after harvesting.

Sweetpotato is traditionally a very popular staple crop in Vietnam and the total area under sweetpotato cultivation is 4.8% of the total area of food crops. The production of sweetpotato equals 9.7% of the total production of food crops. Sweetpotato is the third most important crop produced after rice and maize. The average yield per hectare of sweetpotato in Vietnam was estimated at 6 tons, which is lower than yields reported for Japan, Korea, and some other countries (Table 1).

Ho and Van der Zaag (1987), presented primary information about production and consumption of harvested sweetpotato, and reported that sweetpotato is widely adapted to all eight regions of Vietnam. Approximately 75% of the root harvest is stored fresh for one month and up to a maximum of three months in the home, on the floors or suspended from the ceiling. Post harvest slicing and solar drying are done with the remainder of the harvest. The dried chips are stored in clay pots for an indefinite period. Hoanh et al. (1990) indicated that of the three major constraints to sweetpotato production for northern Vietnam, the lack of suitable processing technology into popular food products was most significant.

In Vietnam, production, marketing, utilization, and processing of root crops including sweetpotato are considered as one of the important components in the Foodstuff program of the Third Major Economic Program. Studies made on sweetpotato in Central Vietnam include a survey of farmer practices and constraints conducted by Kim et al. (1990) that emphasizes the need to develop new processing methods on a priority basis and therefore the need for research on processing of sweetpotato into noodles, crackers, cake, and alcohol.

Studies on low-cost technologies for sweetpotato processing at the village level in Vietnam by Nghiem (1989) revealed technologies that could process fresh roots into intermediate products, without the necessity of drying the product in the villages. These processed sweetpotato products, such as wet starch can be processed into pure starch, high quality noodles, bread and cakes, starch paper, gluco-syrup, chips, and alcohol at the household level. A newly developed low cost tech-

Table 1. Area harvested, average yield, and production of sweetpotato in Asia and the Pacific.

Country / territory	Area harvested (000 ha)	Yield (kg/ha)	Production (000 t)	Consumption (kg/person/year)
China	6,371	17,369	110,660	n. a.
Japan	63	22,222	1,400	11.4
Korea	29	25,655	744	17.5
Bangladesh	51	10,924	558	5.2
India	176	8,241	1,453	1.8
Indonesia	226	9,062	2,048	11.8
Malaysia	3	11,935	37	2.2
Philippines	162	4,802	778	13.2
Sri Lanka	12	6,250	75	4.6
Thailand	41	8,901	368	6.7
Vietnam	400	5,250	2,100	32.6
Papua New Guinea	105	4,526	473	132.9
Asia total	7,593	15,927	120,927	n. a.
World total	9,258	14,081	130,335	n. a.

Source: FAO Production Year Book 1988; Statistic Indicator For Asia and Pacific 1989.
n. a. = not available.

nology for sweetpotato noodle has been reported, (Nghiem 1989). The process is divided into 2 steps: (i) starch or flour preparation from fresh sweetpotato roots; and, (ii) noodle preparation from sweetpotato starch.

Vietnamese people consume large quantities of noodles made from rice, white flour, cassava, cana, and mungbean. Currently people consume cana noodles which have an excellent cooking quality but have very low nutrient values and are hard to digest. The development of noodles from sweetpotato will satisfy the market demand for high quality noodles in Vietnam.

Very little detailed published information and data are available on postharvest handling and utilization of sweetpotato in Vietnam. Therefore, more research is necessary on these important aspects in order to improve the existing processes to upgrade the quality of these products. This could be achieved by research on better and improved noodle processing technologies at different technology levels aimed to suit the socio-economic conditions of the population.

The overall objectives of the present study were: (i) to analyze the utilization potential for sweetpotato in Vietnam; and (ii) to study existing processing methods in order to develop a small-scale noodle processing system from sweetpotato for a selected district in Vietnam. The specific objectives included: a) the study by survey of the potential for sweetpotato utilization in the Hiephoa district of Habac Province of Vietnam; b) the study of a popular transparent noodle making process for utilization of sweetpotato which would be suitable for adoption within the socio-economic environment of a village community of Vietnam; and c) the development of a small-scale production system for a selected district in Vietnam.

Methodology

Survey for Utilization Potential of Sweetpotato

The study was be made to determine the potential for developing the utilization of sweetpotato and to determine possible markets in the district of Hiephoa. Two villages, Maitrung and Hungson were selected and surveyed by means of a questionnaire.

The important processing parameters for transparent noodle production, process component flow and the existing production and product quality were analyzed in detail. Improvements to the existing systems were sought based on the information obtained. The socio-economic aspects of the processing system in the villages and the districts were studied to determine the feasibility of introducing new technologies.

Development of a Noodle Production Process

The development process was divided into two parts. The starch making process came first; and, second was the noodle-making process.

Method of Starch Preparation

The machine used in the study for grating the sweetpotato consisted of a cylinder made from good hardwood. Many rows of nails, 6-8 cm long are fixed on the wooden cylinder. The nails are made from discarded steel cables. The cylinder is turned at a high speed of about 3,500 rpm, resulting in a grinder/grater with a capacity of about 100 kg per hr.

Preparation of starch by existing methods in Vietnam (Method 1)

Sweetpotato varietes SP 1, SP 2, and SP 3, grown in Thailand, were bought from a wholesale market in Bangkok. SP 1 has a red skin and yellow flesh. SP 2 has a red skin and white flesh. SP 3 has white skin and yellow flesh making starch. The starch was made by the method described by Nghiem (1989). The existing starch-making process is given in Figure 1.

Preparation of starch by the general method (Method 2)

Another 120 kg of sweetpotato (SP 1, SP 2, and SP 3) were made into starch using the general method, or method using lime treatment (Method 2) as shown in Figure 2.

The following steps were used to make the starch:

- **Cleaning:** fresh sweetpotato roots were soaked with water for 2-3 hr and cleaned.
- **Lime treatment:** saturated lime water was used to keep the process of grating and sieving alkaline (pH 8.6 to 9.2).
- **Grating**: 100 kg of fresh sweetpotato were grated using the wooden grating cylinder having cable steel wires to grate the sweetpotato pieces.
- **Separation:** the grated sweetpotato was separated using the separator. The separator divided the material into coarse material and slurry.

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Figure 1. Method 1 for making starch out of sweetpotato.

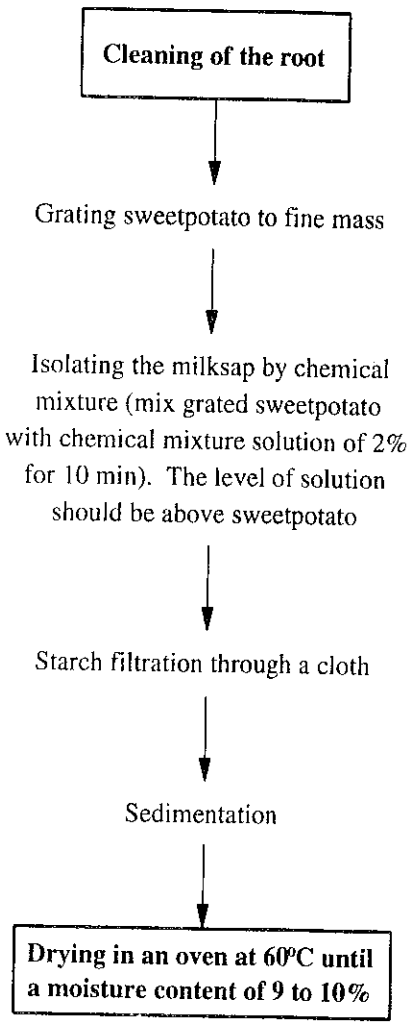
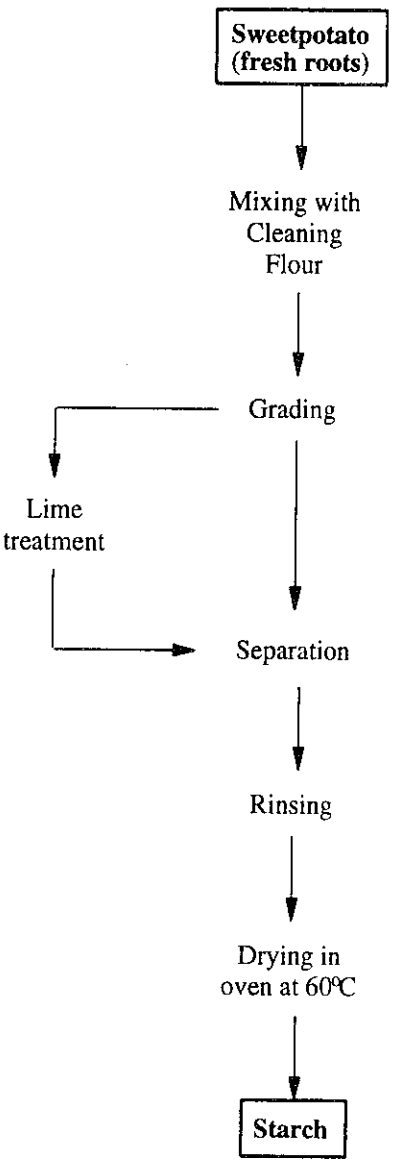


Figure 2. General method of starch preparation (Method 2).



- **Rinsing:** the slurry was passed into a sedimentation container and set still for 1 to 4 hr depending on the concentration of the slurry. After the starch settled to the bottom of the tank, water was added into the container to rinse the protein. The starch was rinsed at least three times in order to obtain a good quality noodle.

- **Drying of starch:** the wet flour was dried either under the sun or in a hot air oven to reduce the moisture content to around 9%. In the experiment, wet starch was dried in the oven at 60°C. A dehydrator may be used before drying. The water content of starch was reduced to about 40%.

- **Chemical treatment:** The starch from SP1, SP2, and SP3 was treated by chemicals. The chemicals used and the procedure of treatment were based on the existing method in Vietnam. Water was added into dry starch and the starch slurry was treated with H_2SO_4 until it reached a pH of 3.5-4.0. The slurry was then mixed with $KMnO_4$ solution until a pink color appeared. After 5 to 10 minutes, $NaHSO_3$ solution was gradually poured into the slurry until it became white. The slurry was sedimented in a tank rinsed at least 5 times and then dried.

After chemical treatment, the starch was used for measurement of whiteness, chemical analysis, and for the production of transparent noodles.

The quality of starch was assessed in terms of the following factors: Whiteness; moisture content; crude protein; fat; ash; crude fibre; carbohydrate; and percentage starch.

Method of Noodle Preparation

The following operational steps were used. (Fig. 3):

- **Mixing with gelatinized starch:** The starch was cooked in water until it was gelatinized. This mixture was mixed with ungelatinized starch in a Z blade mixer for about 20 min.

- **Extrusion, hot water treatment, and cold water treatment:** After mixing, the starch paste was extruded through a stainless steel cylinder having holes. Each hole had a diameter of 1.6 mm. The strands of the extruded mixture were allowed to descend into a hot water bath underneath, maintained at 90-95°C. The starch mixture transformed into a noodle in the hot water and was then transferred to cold water for 20 minutes.

- **Drying** : The noodle was then dried in the open air on bamboo poles or in a hot air oven at two temperatures until the moisture content was reduced to 12-14%.

Study on the Effect of Mixing with Gelatinized Starch

The starch was mixed with gelatinized starch in ratios of 40%, 30% and 20%, respectively, then extruded, passed though hot and cold water, and dried as outlined. Dried noodle samples were kept in an open tray for 5 days to let the moisture content come to equilibrium. Each sample was packed in a sealed plastic bag until quality evaluation.

Quality evaluation was done to select the best mixing proportion for optimum quality. The best gelatinized starch ratio was used in further studies.

Studies on the Soaking Time and Temperature on Quality of Noodle

The starch was mixed according to the best proportion of gelatinized starch, based on experiments from above. The mixture was extruded, and passed into hot water for 1.5 min. The noodles produced were divided into two batches and soaked in water at 30°C and at 0°C for soaking times of 0 hr (30 seconds), 5 hr, and 10 hr.

Studies of Drying Temperature on the Quality of Noodle

Samples was dried at 45°C and 60°C in an oven and also solar dried. Drying was done until the moisture content was in a range of 12 to 14% w.b. The samples were set in an open tray for 5 days and then packed in sealed plastic bags to maintain the moisture content until the test for noodle quality was made.

Methods for Quality Evaluation

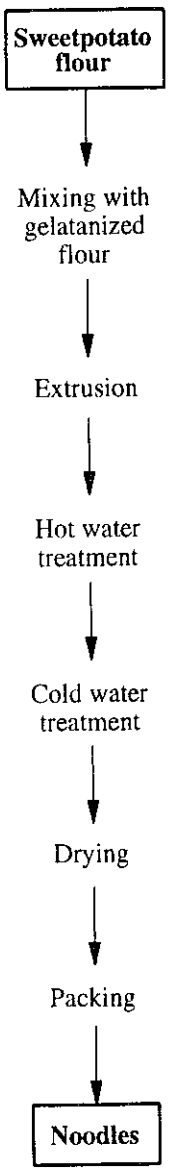
Evaluation of Dry Noodle

The dry noodle was evaluated for moisture content; diameter; hardness; and water absorption.

Evaluation of the cooked noodle

The cooked noodle was evaluated for diameter; water absorption index (WAI); the solid loss; hardness (Back extrusion test, Banjong 1986).

Figure 3. General method of noodle preparation.



Sensory Evaluation

A panel consisting of volunteers was used to test the dry and cooked noodle. The questionnaires were evaluated by scaling and ranking methods. For dry noodle, the panelists were asked to evaluate color, clustering, general feel, and the acceptability.

For cooking, the noodles were dipped first in boiling water for 1 min and then in cold water. Plain cooked noodles were served to the panelists for evaluation.

The statistical difference among the panel test scores for the samples and each effect of quality were determined by one way analysis of variance and Duncan's multiple range test at 5% significance level.

Survey on Sweetpotato Utilization

The survey was done in Habac Province of North Vietnam. Habac is a small province in the northern mountains and produces a large quantity of sweetpotato, ranking third amongst other provinces in the country. Habac Province has the highest reported sweetpotato yields among all the provinces in North Vietnam, producing about 8.5 t/ha. Sweetpotato is the major and traditional crop grown in Hiephoa district and is at present mainly used for animal feed by simple processing such as slicing and boiling. The emphasis placed on sweetpotato yields in the survey area indicates the importance of the crop as feed for animals and as a main staple for human consumption by using it as a buffer at times when there is a lack of rice and cash crops.

The price of sweetpotato fluctuates seasonally and varies from one region to another. On average, the price of one kg of rice is equivalent to the price of 2.5 to 3.5 kg of sweetpotato. On a starch equivalent basis, the sweetpotato is more efficient than rice for the same fixed price. The average price for December to February 1991, was 290-300 VN D/kg (0.042-0.044 US $/kg) in the survey areas and the price of one kg of rice was equivalent to 4.3 kg of sweetpotato.

Between 30 and 90% of the sweetpotato roots produced in the surveyed area are used for animal feed. Between 10 and 25% is used for human consumption, and about 0 to 30% that is left in the households is sold in the fresh market. Most sales of the sweetpotato roots for consumption take place after household needs are satisfied. However, at times the roots may be utilized to make sweetpotato cakes, but very little is otherwise processed. A few families ferment sweetpotato in order that it could be used as animal feed mainly for pigs. Some households make alcohol with sweetpotato for home consumption. However, cassava is now preferred as a base to make alcohol, because of the better quality product in terms of taste and color. In the survey area, sweetpotato was not used to make noodles. The farmers interviewed indicated that they stored sweetpotato roots on floors and had no special structure for storage under fresh conditions. The storage life of sweetpotato is

relatively short and not more than three months in the winters of North Vietnam, so the problems of processing and storage of sweetpotato have been identified as important factors to be addressed for future development of sweetpotato production and utilization.

All farmers interviewed indicated that the major constraints to efficient sweetpotato production and postharvest handling systems are the lack of proven processing technologies. In this instance, the established methods for processing the roots into sweetpotato cake, alcohol, and fermentation of roots for animal feed should be improved and the manufacturing processes for noodles and other, value added food products should be explored.

Status of Transparent Noodle Making

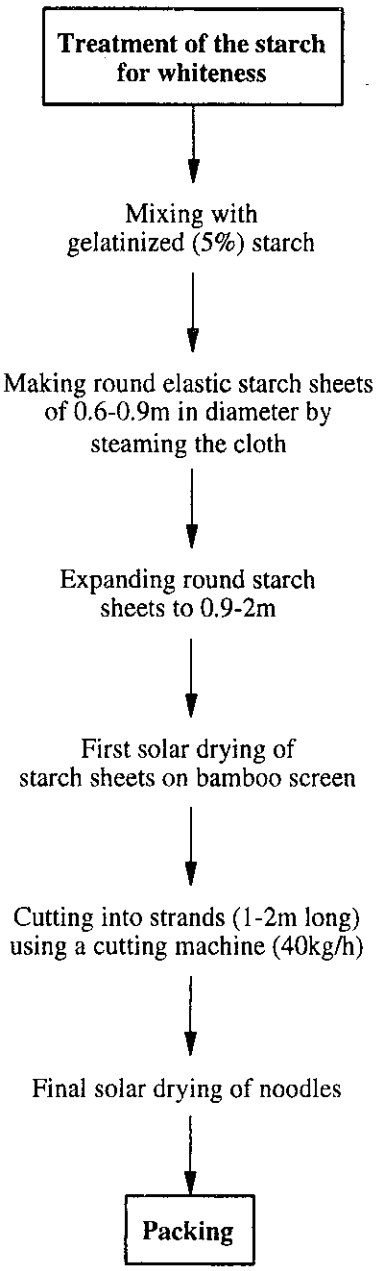
A large quantity of noodles of varying kinds, including transparent noodles, are consumed in Vietnam. Some surveys in Vietnam have estimated that the average quantity of all different kinds of noodles consumed is 12-20 kg/capita, annually. Among the noodles consumed, the transparent noodle (or glass noodle) is the traditional dish which is consumed in most important domestic functions such as weddings, and New Year celebrations. In North Vietnam, the biggest market for transparent noodles is in Hanoi and traditionally many noodle production units in villages situated around Hanoi supply the city with noodles. Some villages specialize in processing flour into starch in order to supply the noodle processors.

The production of transparent noodles was studied in Cuda village which specializes in noodle production. About 70% of the families are involved in the production of transparent noodles. The production of starch was also studied in Tanhoa village, in the Hoaiduc district of Hanoi Province, situated about 20 km from Cuda.

Almost all the commercial transparent noodles found in the market are made from cana flour; only a small proportion is made from mungbean. The production of transparent noodles from cana starch is about 60-70% lower in cost, than if mungbean is used as the raw material. Processing is small scale, and the noodles are handmade, resulting in non-uniform quality. Producing transparent noodles from cana involves 2 steps. These are the initial starch production from cana root and then the conversion of the starch into noodles. (Fig. 4).

Although most of the commercial transparent noodles are made from cana starch, there are some constraints to producing such noodles. The nutritional

Figure 4. The production process for cana noodle.



quality is low and the noodles are stodgy. Due to the increasing demand for transparent noodles, estimated to be about 45,000 t per year, it is necessary to find other sources of raw materials for their production. If the noodles are produced from mungbean, the quantity of raw material required would be 250,000 t per year.

Some farmers have experimented with making transparent noodles from potato and have obtained noo-

dles of good quality, but the cost of production is high (i.e. the same as for mungbean noodle). These experiments were therefore not practical since the price was not competitive in the market.

Many scientists have looked for other methods of producing transparent noodles using cheaper root starch such as cassava and sweetpotato. This is especially true for sweetpotato, which can be supplied all year around. Initially, transparent noodles were made from cassava starch. This was a research activity of the Post-harvest Technology Institute in Hanoi as well as some other institutes. Characteristics of transparent noodles prepared from cassava, cana, and sweetpotato are comparised in Table 2, which confirms that sweetpotato starch is suitable to produce transparent noodles.

However, there are some difficulties associated with the production of transparent noodles with sweetpotato. Firstly, sweetpotato starch is difficult to be extracted because it is difficult to separate the milksap from the starch. Due to this the sweetpotato starch has a dark grayish color after extraction. Secondly, the sweetpotato noodle is weak after cooking and is difficult to be formed into starch sheets after semi-drying.

Although research had been done on the possibility of making transparent noodles from sweetpotato, survey results indicated that transparent sweetpotato noodles were not available in the market. The survey in Cuda village showed that some scientists had asked volunteers to experiment with making noodles from sweetpotato, instead of cana. However, this process is still not accepted by farm processors, since this technology has still to be improved.

One difficulty is to get white sweetpotato starch, even if chemical mixtures are used for separating the milk sap. The same chemical used to make white starch from cana starch is needed for this purpose. However, there is little information on refining sweetpotato starch to a high quality white color.

At the National Institute for Agronomic Sciences (INSA), scientists have suggested that the former technology of making cana transparent noodle should be modified for sweetpotato by using a chemical mixture which separates milksap prior to extracting the sweetpotato starch and to add aluminum sulfate to increase the strength of the noodle after cooking and also to increase noodle elasticity. The INSA study concluded that the cooking quality was better than that of cana and cassava noodle. Production costs for sweetpotato noodle is only 60% of cana noodle.

The starch sheets after steaming are more elastic than cana starch, but cannot be removed from the bamboo screens easily and then cut afterwards. The stickiness that causes difficulty in removing the sheets from the bamboo screens could be reduced by mixing at least 30-40% cana starch into sweetpotato starch before the noodles are made. A further constraint in the use of sweetpotato is that unlike with cana there are no constant supply networks of sweetpotato starch to noodle processors. The effects of processing and market acceptability of transparent noodles from sweetpotato have to be carefully studied. The survey therefore concludes that it is necessary to improve starch production from sweetpotato to the level that when sweetpotato starch is transformed into transparent noodles, the product should have a transparent appearance with a white color.

Experiment on Noodle Production

Methods of Starch Preparation

Farmers in Vietnam prefer not to use sweetpotato flour to make noodles because of the difficulty in obtaining white color starch. Lime is still not used to obtain white

Table 2. Evaluation of characteristics of different transparent noodles.

Characteristic	Cassava	Sweetpotato	Cana
Tenacity after 15 min of cooking (kg/cm^2)	4.9	7.8	7.4
Dry matter lost after 1 hr of cooking (%)	24-30	3-5	3-5

sweetpotato starch. For whiteness, chemical treatment is used. This treatment is costly and the effects of chemicals on health are still unknown.

In this study, sweetpotato starch was first prepared by Method 1, which uses a chemical mixture described by Nghiem (1991).

The starch prepared by Method 2 had a lime treatment, and is described as the general method. This method did not affect the chemical composition of starch. However, the whiteness of starch extracted by different methods was significantly different (Table 3).

The results showed that the whiteness of the starch before treatment in all cases, was significantly lower than after treatment (Fig. 5).

Determining Optimum Gelatinized starch Mixture

The sweetpotato starch was mixed with gelatinized starch in ratios of 40%, 30%, and 20%. The pastes were extruded, passed through boiling water for 1.5 minutes, then transferred immediately into cold water at 30°C for about 30 minutes to 1 hour and dried in a oven at 45°C. Quality tests indicated that a paste ratio of 30% was best for making noodles. The paste was prepared at 56-58% moisture content. In order to gelatinize the paste, the amount of water needed was 3 times that of flour resulting in a moisture content of 9-10%. If the moisture content of paste is low, it is difficult to extrude the paste. If the moisture content of the paste is high, the noodle strands become weak after being extruded into the boiling water.

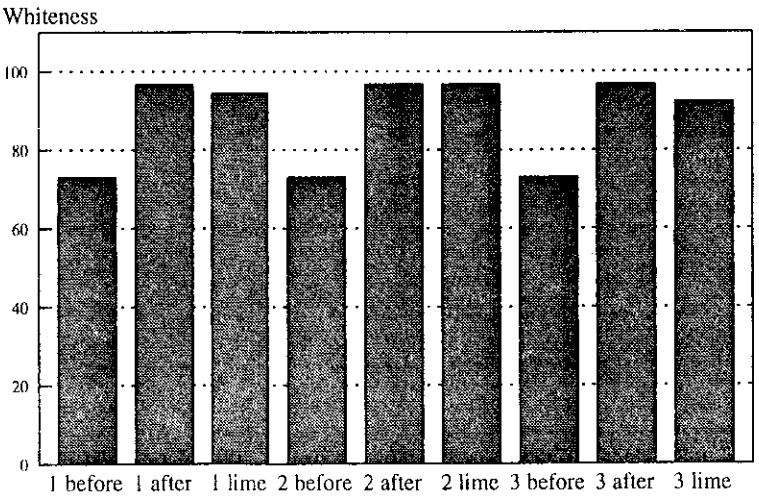
Results revealed that the diameters of the dry noodles varied significantly and the diameters increased with increasing percents of gelatinization. The properties of cooked noodles indicated that the diameter of cooked noodles was significantly different than the dry noodle for the different gelatinized treatments. Noodles made of 30% gelatinized starch were observed to have the best quality, with a minimum swelling ratio, solid loss, WAI, and hardness.

Table 3. Whiteness and chemical composition of starch.[a]

Material	Whiteness	Protein	Fat %	Ash %	Fibre %	Carbohydrate %
Starch of chiemdau VN (method 1)	70.5	1.42	0.04	0.18	0.46	98.90
Starch of SP1 TL (method 1)	75.0b	0.56a	0.12a	0.15a	0.37a	98.8a
Starch of SP1 TL (method 2)	95.7a	0.54a	0.16a	0.13a	0.48a	98.69a
Starch of SP2 TL (method 1)	76.0b	0.50a	0.10a	0.13a	0.50a	98.77a
Starch of SP2 TL (method 2)	97.6a	0.49a	0.11a	0.1a	0.54a	8.76a
Starch of SP3 TL (method 1)	75.2b	0.43a	0.13a	0.09a	0.51a	98.84a
Starch of SP3 TL (method 2)	92.5a	0.38a	0.71a	0.11a	0.16a	98.64a

[a]Values in the same column followed by the same letters are not significantly different (P>0.05).

Figure 5. Effect of chemical treatment on whiteness of starch.



Methods of Starch Preparation to Test Optimum Processing Conditions

Three starch preparation methods were used to make starch from a Thailand variety of sweetpotato SP 1, (similar to the Vietnamese variety in all properties), in order to test for the best processing conditions using the optimum 30% gelatinization. The starch was prepared by Method 1 (before and after chemical treatment) and also by Method 2 using lime treatment. The pastes were extruded and soaked and then immediately dried as before.

The indices of quality were not significantly different, indicating that the methods of starch preparation does not have any effect on the quality indices of dry and cooked noodles. However, the whiteness of the noodles was significantly different.

Processing Conditions on Noodle Quality

The different processing conditions studied were soaking times, soaking temperatures, drying temperatures, and methods of drying. The proportion of gelatinized flour for making noodles was 30%.

The starch was made by Method 2. The extruded noodles were transferred into water of 0°C and 30°C for soaking at less than 1 hr, 5 hr, and 10 hr and then dried at 45°C, 60°C or in the sun.

At a soaking temperature of 30°C, the strands of noodle became weak and broke easily while being taken out from the water and dried. However, the strands did not break when the soaking time was about 30 min to 1 hr. The noodles soaked in 0°C water had stronger strands and could be easily removed from the soaking water for drying (Table 4).

The soaking temperature significantly affected the appearance of dry noodles. At a soaking temperature of 0°C, the dry noodle became transparent, and increased in transparency with an increase in soaking time. But if the soaking time was more than 10 hrs, the noodles became curly and were not acceptable.

The difference in the final moisture content of the dry noodle was not significant and was assumed to have no effect on the measured quality parameters. The differences in diameter of the noodles for all treatments were not significant.

The diameter of the cooked noodle was significantly different to that of the dry noodles. The solid loss and WAI were similar to the dry noodles. The hardness of cooked noodles decreased with an increase in temperature. At soaking temperatures of 30°C and a soaking time of <1 hr, the hardness was lowest. The maximum hardness of noodle was achieved when the noodle was soaked in cold water at 0°C. The best quality noodles were observed when the soaking temperature was 0°C

Table 4. The effect of soaking temperature on the noodle-making process.

Temp. °C	Time hr	Consistency of noodle strand after soaking in water	Form of noodle strand after drying	Transparency of dry noodle
30	<1	Elastic, easy to dry	A little flat	Yes
	5	A little weak, difficult to dry	Flat	Little
	10	Very weak, difficult to dry	Flat	Little
0	<1	Elastic, easy to dry	Round	Yes
	5	Strong, easy to dry	Round	Yes
	10	Strong, easy to dry	Round, a little curly	Yes

and the noodle strands were kept for a less than 1 hr treatment.

The consistency of the soaked noodle strands for the different soaking times was different. The consistency of the noodles soaked for <1 hr at room temperature was elastic, and the noodles were easy to dry. However, the consistency of strands was weak if soaking was for 10 hrs. When strands were soaked for <1 hr, 5 hr, and 10 hr at 0°C, the strands were strong and easy to dry. However when soaked for 10 hr, 0°C, curly noodle strands were obtained and were not acceptable.

For a soaking time of <1 hr at 30°C, the dry noodle was more cylindrical than the other treatments. All soaking treatment times resulted in dry noodles having a cylindrical shape which is important in commercial appearance and acceptability.

The best quality noodles were observed for a 0°C soaking treatment, at all soaking times. There was no significant difference in solid loss, WAI, and hardness. The swelling ratio of the 0°C, 10 hr treatment was greater, but the hardness was lower. For the 30°C treatments, a soaking time of <1 hr gave the best quality indices of minimum swelling ratio, solid loss, and hardness.

The swelling ratio best indicated the interrelationship between dry and cooked noodle. The lower the swelling ratio, the better the quality of noodle. The 0°C water temperature and soaking for <1 hr and 5 hr, and soaking in 30°C water for <1 hr gave the lowest swelling ratio, indicating the best quality among all the samples.

The noodle samples from the different soaking times and temperature treatments were dried in an oven at 45°C and 60°C, as well as in the sun. There were no significant differences among the quality indices such as moisture content, diameter, hardness, and WAI, except for the sample soaked at 30°C for 10 hr.

For the cooked noodle samples, the solid losses were greater at drying temperatures of 45°C and sun drying. These losses were greater than that experienced at 60°C in the earlier experiments. The hardness measured by the back extrusion method for all treatments revealed that noodle samples dried at 45°C were softer than those dried at 60°C or sun dried. Higher drying temperatures were observed to have an inverse effect on the quality of the noodles.

Sensory Evaluation of Noodle Quality

Mixing portions with gelatinized starch

The color and clustering of strands of dry noodles were not significantly different among all treatments. The noodles consisting of 30% gelatinized starch were the best in appearance, general feel, and acceptability. The cooked noodle prepared from starch of 30% gelatinized were better than noodles with 40% and 20% gelatinized starch.

Quality affected by methods of starch preparation

The clustering of strands of the three dry noodles were not significantly different. All quality indices of dry

noodles from starch of Method 1, after chemical treatment and starch from Method 2 were not significantly different. Noodles prepared from starch of Method 1, before chemical treatment had poorer appearance, color, general feel, and acceptability. The computed acceptability test indicated that panelists did not accept noodles made from starch without the chemical treatment. This is the existing method of starch preparation in Vietnam.

Cooked noodles prepared from starch extracted by Method 1 (after chemical treatment) and that from Method 2 had no significant differences. Noodles cooked from starch extracted by Method 1 (without chemical treatment), had low scores for color, appearance, clustering and acceptability.

Quality as affected by soaking temperature

The dry noodles soaked at 30°C for <1 hr had lower scores for appearance, general feel, and acceptability in comparison with noodles soaked at 0°C for <1 hr. The computed and total acceptability values showed that the panelist accepted noodles soaked in water at 0°C for <1 hr, 5 hr, and 10 hr and at 30°C for <1 hr and 5 hr.

The cooked noodles soaked for ten hours showed significant differences at water temperatures of 0°C and 30°C. The panelists did not accept noodles soaked at 30°C for 10 hr. The total acceptance was highest in the case of soaking times of 5 hr at 0°C.

Quality as affected by soaking time

The quality indices of dry noodles, soaked at 0°C for <1 hr and 5 hr were very high. Soaking for 5 hr was found to be best amongst all samples at this temperature. The noodles soaked at 30°C for 10 hr had low scores for appearance, color, clustering, general feel, and acceptability.

There was no difference in total acceptance, for soaking times of <1 hr and 5 hr for cooked noodles. The panelists preferred the noodles made after 5 hr of soaking at 0°C and did not accept the noodles soaked at a water temperature of 30°C for 10 hr.

Quality as affected by drying temperature

The effects of drying temperature were not statistically different for all cooked noodle samples dried in the oven at 45°C, as well as those that were sun dried, at soaking temperatures of 0°C and 30°C for soaking times of <1 hr and 5 hr. The cooked noodles that were dried at 60°C had lower scores for appearance, acceptability, total acceptability and color.

Selection of Optimum Parameters for the Total Process

From the results of the experiments, the most acceptable combination of processing conditions for transparent noodle production were from starch prepared by the lime treatment method. If the method existing in Vietnam is used, chemical treatment is necessary prior to starch production and therefore it would also be necessary to test the effect of the chemical clinically.

The paste with 30% gelatinized starch is the optimum composition for making transparent sweetpotato noodles. The acceptable processing conditions are soaking at 30°C for 30 minutes or soaking at 0°C from 30 minutes to 5 hr. If additional transparency is required, soaking at 0°C is optimum. The transparency of noodle increases with an increase in soaking time at this temperature. The noodles should be dried in the sun or in a drier at a temperature of 45°C. The best combinations of process conditions are shown in Figure 6.

The equipment required for processing are:

a) A grating machine

b) A separator or filtration by cloth

c) A cement tank for natural sedimentation of starch

d) A mixer or mixing manually

e) An extrusion machine

f) An aluminum pot and cooker for boiling water

g) A tank for soaking with cold water

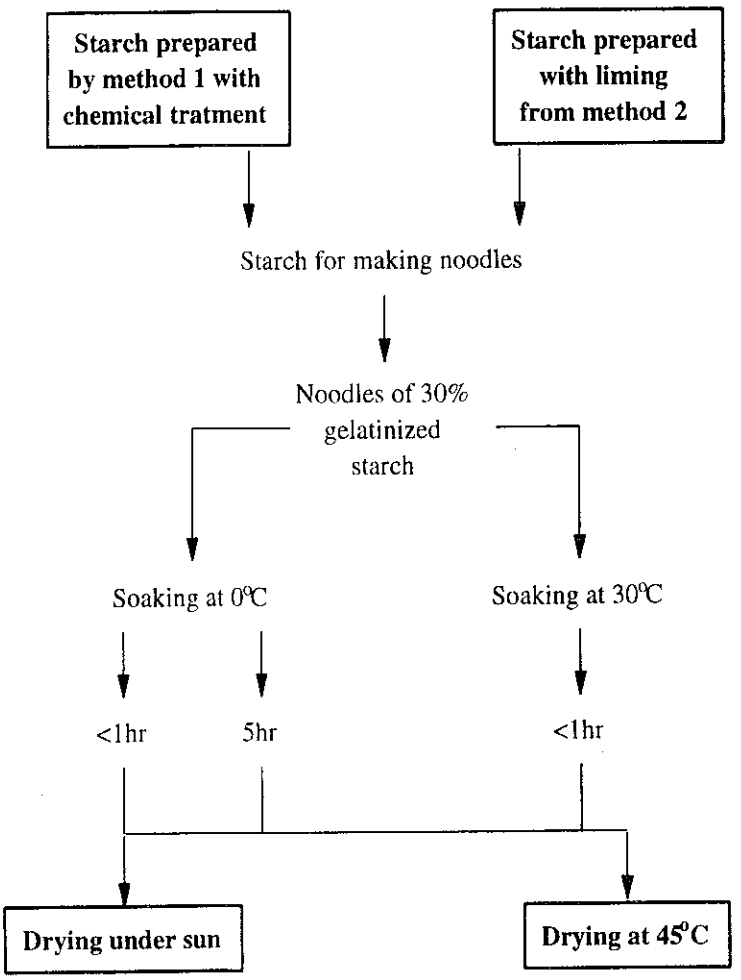
h) Bamboo or plastic screens for drying

The flow of equipment requirements and an approximate cost comparisons between sweetpotato noodle and the cana noodle is given in Figure 7.

Conclusion

Of the utilization processes surveyed, the production of transparent noodles had the highest potential as a food product. The production of transparent noodles was therefore studied in detail, in order to determine optimum processing conditions to produce acceptable quality noodles. Criteria such as soaking time and temperature, drying temperature as well as methods of starch preparation were compared. Parameters such as whiteness, diameter, water absorption, solid loss, and hardness were considered for both dry and cooked noodles. The following conclusions were made based on the study.

Figure 6. Process flow for the best combination of process conditions for sweetpotato noodle as obtained from the experiments.



1) Commercial transparent noodles are made of cana. The major constraint to increased sweetpotato production is the lack of processing technologies.

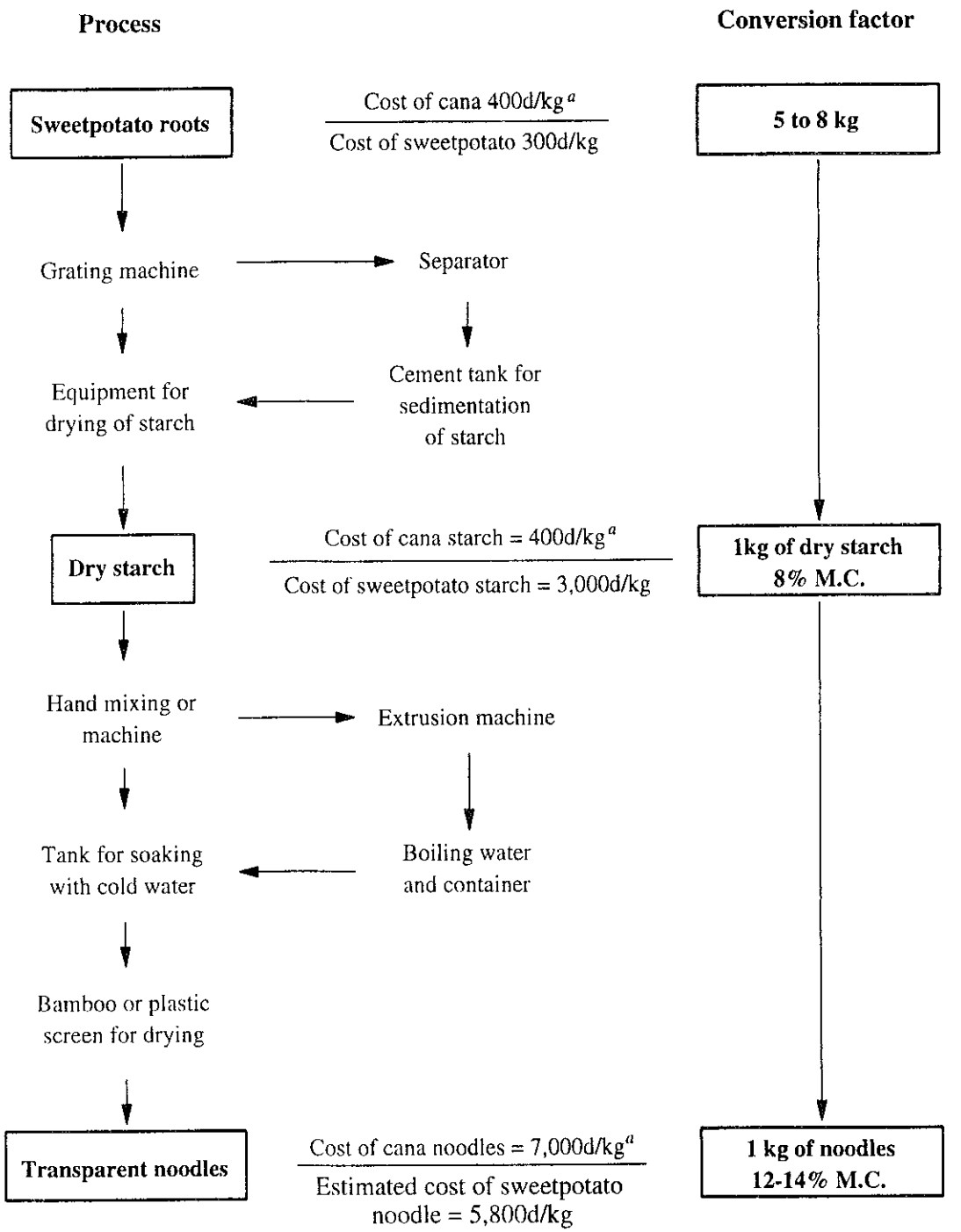
2) Sweetpotato starch can be prepared by two methods. The starch prepared from the existing method in Vietnam does not give acceptable whiteness to the noodle and the starch has to be treated with chemicals to increase whiteness. Liming was used to keep the pH of starch slurry to about 8.6 - 9.2 during the grating and separation processes. The starch of this method had the highest whiteness.

3) The mixing of gelatinized starch with raw starch in the proportion of 30% and 70% on dry weight basis was the optimum mix to give best quality noodles. The mixing of starch for 15 to 20 minutes with gradual addition of water appeared to be adequate for experimental preparations.

4) A soaking treatment following strand formation in boiling water was essential to give a transparent appearance. Soaking in water at 0°C resulted in best quality based on color, hardness, diameter, WAI, and solid loss of both dry and cooked noodle for soaking periods of 30 minutes to 5 hr. However, soaking at 30°C could also be done provided the soaking period is limited to 1 hr.

5) The noodles should be dried gradually and the drying temperature should not exceed 45°C for maintaining

Figure 7. Flow of equipment requirements and use for making noodles.



[a] *dong (d) 6,900 = US$ 1.00.*
M.C. = Moisture Content.

optimum quality. The final moisture content of dried noodles ranged from 12 to 14% on a wet basis.

6) The conversion factor of fresh root to noodle was:

5 - 8 kg of fresh sweetpotatoes roots

≈ 1 kg of dry starch (8 -9 % MC)

≈ 1 kg of noodle (12 - 14% MC)

7) The process flow and equipment requirements for a small-scale production process were determined based on the experimental procedures.

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VI. Expansion into Commercial Production

When a pilot plant becomes technically and economically viable, decisions must be made whether and how to expand to full commercial operation. These require consideration of a variety of factors including the social objectives of the enterprise, raw material supply, market requirements, economic analyses, and credit. This section begins by reviewing these and other elements to be taken into account when contemplating expansion into commercial production. A series of questions or issues to be resolved are outlined for each with the aim to provide flexible, but systematic guidelines for the principal points to be addressed at this stage of new product and process development. The section also provides three illustrative examples from different parts of Africa each involving a different commodity. The use of dehydrated potato flour in Kenya is one. Another focuses on commercial viability of small-scale product and processing operations for cassava in the Congo. The third case involves private sector involvement in the development of a convenient, tasty substitute for pounded yam in Nigeria. As expansion into commercial production completes the product development process, the section includes a case study from the Philippines that describes a number of new processed products made from sweetpotatoes and the technology transfer process associated with each. The paper concludes with a brief synthesis of the lessons learned in this instance. The section concludes with an assessment of the impact of product development in the case of cassava drying plants in Colombia. The Latin American experience may also provide useful ideas for African scientists, enterpreneurs, and policy makers.

As Christopher Wheatley points out in his review of the **Commercial Expansion Phase**, a number of aspects need to be considered carefully as the basis for deciding whether and how to expand operations of a pilot plant to that of a regular business enterprise. Wheatley enumerates these factors, then sets out specific issues to be resolved in relation to each. For example, in the case of raw material supply, he notes that it is necessary to identify actual and potential production regions, contact farmers' groups to ensure an adequate supply, and study competing markets to determine whether the price to be paid for raw material is sufficient to interest growers. Wheatley also notes the need for monitoring and evaluation of the commercial operation. The set of ideas presented are intended as a useful aid for successful processing of roots and tubers at the commercial level.

Wheat flour is utilized in many food items in Kenya. However, if current trends continue, over half of national wheat requirements will be imported in the near future. In **Use of**

Dehydrated Potato in Composite Flours: A Case Study of Potato Flour in Kenya, Jackson N. Kabira explores the feasibility of milling raw potato slices dried by on-farm solar dehydration and blending the flour with various types of cereal flours. Results indicate that potato flour can substitute for other flour up to 20% in commercially baked bread and to 40% in home-baked products. Kabira then suggests that this substitution could be economically attractive if government price supports for imported grains were to be modified so as to be less prejudicial to locally produced products.

As urbanization accelerates at a breakneck pace throughout much of sub-Saharan Africa, innovative initiatives are increasingly needed so as to satisfy the mushrooming demand for food by low-income, urban consumers. In **Peri-urban Farming Systems and Food Processing in the Congo,** J. Brochier, G. Boukambou, O. Legros, and S. Trèche describe product development efforts to encourage city dwellers to get into small-scale production and processing of cassava. The authors present preliminary findings from 20 such nearly established farming/processing enterprises set up near Brazzaville. Among the products produced are cassava bread and cassava-based mixed flour for infant food.

Private sector involvement in product development of root and tuber crops is increasingly evident in developing countries. J.S.T. Bogunjoko describes one such African experience in his paper on **Research and Development into Commercial Yam Processing in Nigeria: Cadbury's Poundo Yam.** Although yam is a staple food crop, preparation of traditional pounded yam is very laborious and time-consuming. Hence, Cadbury Nigeria set about developing a product that could serve as a tasty and convenient substitute. As Bogunjoko indicates, the Cadbury experience highlights the need to satisfy both consumers' tastes and preferences as well as packaging and preparation-time requirements.

A variety of processed sweetpotato products for human consumption have gained widespread popularity in many parts of Asia. In **Development and Transfer of Processing Technologies for Sweetpotato in the Philippines,** Truong Van Den presents the Philippine experience. He begins by describing the technical aspects of new products made from sweetpotato including catsup, candy, jam, and a beverage. He then goes on to analyze the three modes of technology transfer, i.e., direct transfer, exclusive contract, and non-exclusive contract. In conclusion, Truong enumerates some key lessons learned so as to accelerate the technology transfer process including a rigorous evaluation of a product's commercial potential before transfer to end-users and creative procedures for information dissemination.

New types of cassava processing and product development have expanded into commercial operation in a number of countries in Latin America in recent years. In **Adoption, Modification and Impact of Cassava Drying Technology: The Case of the Colombian North Coast,** Guy Henry describes the model on which these activities were originally based including the processing techniques, marketing patterns and social organization of the drying plants. The impact of these developments on cassava production and utilization, as well as the associated benefits in the form of improved farm incomes, employment generation, and foreign exchange savings, are also documented. Such experience may well provide useful lessons for similar efforts with cassava or other roots and tubers currently being planned or already under way in Africa.

Commercial Expansion Phase

Christopher Wheatley[1]

Abstract

Commercial expansion of pilot processing facilities requires attention to various considerations including: social objectives, the nature of the market for the processed product, site selection, raw material supply, product promotion and distribution, and credit, as well as monitoring and evaluation. This paper examines these and other factors involved in developing commercially viable processing enterprises intended to be operated by small farmer associations, or small rural or urban entrepreneurs. Specific issues related to each factor are also treated in some detail with examples cited based on the author's professional experience. The integration of technical, economic, and organizational components is stressed throughout the review of this process.

Key words: processing, roots and tubers, developing countries, small farmer associations, markets.

Introduction

When the operation of a pilot plant reaches the point at which it has become economically and technically feasible, a decision must be made whether or not to expand to a fully commercial scale. A number of aspects need to be considered carefully as a basis for making this decision include: social objectives, the nature of the market including demand estimates, product packaging and promotion, raw material supply, distribution channels, administrative capability, economic and financial analyses, and financing the expanded capacity.

Social Objectives

When designing the commercial expansion phase, the social objectives of the project and any inherent constraints that can affect these should be borne in mind. Primary processing of root and tuber crops needs to be done at the rural level, either as cooperatives, associations, or small business ventures. This means that expanding from a pilot to a commercial scale will involve the formation of several plants rather than one or two large ones.

The actual distribution of the products, or any secondary processing that may be required, could be done by a special enterprise located near large urban markets or could be done by a second-order organization.

The formation and consolidation of these rural enterprises is a relatively slow process, which is complicated by the fact that the legal registration of these groups entails bureaucratic processes that can take considerable time and effort to complete. Moreover, the administrators, who generally have limited formal education, may have difficulties in completing these steps on their own. Without legal status, it is practically impossible to receive credit, which can act as a significant deterrent to rapid expansion of demand for the product unless measures are implemented to facilitate this process well in advance.

It is usually difficult if not impossible for small farmer groups to obtain credit, not only because of their legal status but also because of their lack of (or poor) credit history. In many countries, a coop or association cannot be incorporated as a legal entity unless all members have a title to their land. Where tenure rights have never been legally regulated, as is typically the case with small root and tuber farmers, this is a major limitation.

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This situation becomes even more critical if landless members are included because they have no land and are therefore considered too risky to fund. Throughout the Third World, a need exists for an institution specializing in granting credit to these groups or one that can provide surety or guarantees to the regular credit agencies. This issue must be addressed in the project if it is to reach a commercial expansion phase and if benefits are to reach the target groups—the small farmers and landless laborers.

Nature of the Market

Roots and tubers have a wide variety of end uses including human consumption, animal feed, and industrial uses. The type of market affects the quality of raw materials required, marketing strategy, and financing requirements.

Industrial Markets

The number of potential industrial clients in a country is generally relatively small; thus it is feasible to establish personal contact with most of them. Typically, decisions to purchase a new product are made by company purchasing agents who take into consideration price, quality, continuity of supply, and competing products. Since demand is relatively easy to estimate, market testing is not usually required, and large-scale product promotion is not needed. In some cases industrialists may not be aware of the advantages of using root and tuber products and it may be necessary to provide samples so that they can test them first.

Once the demand has been established, projections have to be made as to:

- the association's or coop's capacity to meet that demand;
- the industry's quality and packaging requirements, if any;
- the possibilities of establishing contracts or pricing agreements; and,
- the terms of payment (this is critical for determining cash flow requirements).

The root and tuber processors can normally handle marketing and distribution aspects themselves. Care needs to be taken to program product supply realistically in order to avoid entering into agreements that cannot be met. Product supply can be gradually increased to meet unfulfilled demand and to take on new clients.

Consumer Markets

This type of market is much more complex and requires significant testing of consumer demand before a realistic marketing strategy can be developed. Consumers' decisions to purchase are not always taken on a logical basis. Rather, factors such as product image and sensory stimuli can have more impact than nutritional value on the final decision to buy. Advertising plays an important role in promoting that image.

Product distribution is also much more complicated because purchasing habits differ significantly among social strata and also depend on location of the residence relative to access to the retail outlet.

The foregoing is made much more complex when one considers the numbers involved and the problems inherent in trying to characterize the "typical" urban (or rural) consumer or retail outlet. Surveys must be conducted, organoleptic tests run, and a market plan devised if it has been shown that:

- the product meets an identified need of consumers;
- packaging (size and appearance) is acceptable;
- there appears to be good intent to purchase at a given price; and,
- distributors and retailers find the product and profit margins acceptable.

Consumer awareness of a new product does not just happen. In order to make consumers aware that a product exists, let alone inform them of its advantages as compared to those of the competition, requires substantial product promotion. A campaign to promote consumer products emphasizes price, convenience, quality, uses (e.g., recipes), nutritional value, and where it can be purchased. When the decision is made to implement such a campaign, the association or coop must be sure that it is capable of fulfilling that demand. Creation of unfulfilled demand for a consumer market is a costly error, besides being frustrating for a consumer who cannot find an advertised product. This situation can be avoided by:

- ensuring an adequate raw material supply;
- maintaining sufficient product inventory to meet expected demand;
- expanding promotional activities in accordance with plant capacity to meet the additional demand; and,
- monitoring distribution channels.

If the product is to reach a significant number of consumers, it must be made available through a corresponding number of retail shops or markets. This implies the organization of an efficient distribution network that covers the target markets adequately. Given that farmer associations or coops are located in rural areas and that product distribution will most likely focus on urban markets, the logical option is to create a separate service operation. The skills required to run a distribution business are quite different from those needed to process roots and tubers.

The Market Plan

Prior to initiating commercial-scale activities, a market plan should be prepared taking into account the factors indicated at the beginning of this paper. This plan should integrate the following aspects: raw material supply, processing operations, packaging and other operations, product distribution, and promotion. The result is a series of planned activities aimed at reaching specific markets or profit targets based on estimates of percent market share, geographic distribution, and rates of return.

Site Selection

The pilot plant typically is located at the best possible site in order to maximize its potential for success. In order to expand the number of plants, these may have to be located at sites that are not so favorable. At the same time, the experience acquired in constructing and operating the pilot plant may have modified some of the variables for selecting the plant site. At this point, it should be possible to identify the more important points and those that are not so critical in order to establish the minimum rather than the optimum conditions for locating a plant. For example, the availability of electricity and water may be necessary, but the existence of organized and well-consolidated farmer groups may not be since this can be dealt with during the construction of the plant. In some cases, it may not be necessary to have large quantities of roots and tubers available for processing if the plant is able to offer an attractive price for fresh roots and tubers, which would be sufficient to motivate farmers to plant more roots and tubers for sale than for on-farm consumption.

Raw Material Supply

In order to make an accurate estimate of the availability of raw materials within a reasonable distance from the processing plant, it is necessary to:

- identify actual and potential production regions;
- identify farmer groups in each region which are interested in ensuring an adequate supply (quantity and quality) of raw materials and who may be interested in participating as primary processors; and,
- study competing markets to ensure that the price that can be paid for the raw material is sufficient to motivate farmers to sell to the plant.

Where there is a competing fresh market for roots and tubers, an effort should be made to obtain data on historical prices to identify seasonal patterns. The creation of a new market for a root or tuber crop should act to stabilize prices.

Given that roots and tubers are highly perishable, it is critical to take seasonal factors into account. Is it economically feasible to store fresh product for later processing? Or, will the plant have to operate only during harvest periods? Moreover, if the process involves sun drying of the raw material, climatic variables also need to be studied to ensure that the dry season coincides with harvest time. Experience in Latin America suggests that planting and harvest times, as well as dry season months, can be highly variable, even within one region of a country. It is not safe to assume, therefore, that the conditions at the site of the pilot plant can be extrapolated to the whole region. An important step in this direction is the effort being made by the International Agricultural Research Centers (IARCs) to map root and tuber production areas by agro-climatic zone. The more detailed the information, the more accurate will be the identification and prioritization of the main target production areas.

Processing Operations

The associations and coops involved in primary processing in rural areas usually require substantial technical assistance in processing operations. The members or plant operatives often have relatively little formal education and limited experience with machinery operation and maintenance. Although the processing operations and equipment tested in the pilot plant are appropriate for small-scale, urban operations, operatives will still require substantial training.

Few changes in the actual process itself should be required when moving from the pilot to the fully commercial scale, especially if the scale of plant operations are maintained; i.e., in the case where commercialization is based on replicating the pilot plant in other locations rather than expanding the initial pilot plant

itself. Some increase in scale may be required, however, and it is important to identify the stages of the process that could present bottlenecks as the plant increases in capacity. In any case, capacity should not increase beyond the managerial capabilities of the small coop or association.

Timing of new plant construction is crucial, especially where processing seasons are well-defined. The date for plant completion should allow for a period of start up and training prior to the main harvest season. Construction activities almost always suffer some delays (e.g., shortage of labor at peak harvest times of other crops, shortage of building materials, untimely arrival of credit). Thus, some flexibility should be built into the timetable of activities.

If a coop is formed to operate a new plant, members should participate in the construction activities to as great an extent as possible (under the supervision of an experienced journeyman or master workman). This not only helps reduce costs but also serves to consolidate the group as they collaborate on joint activities.

Maintaining good product quality is an important consideration when expanding the number of plants. The existence of many small processing operations makes quality control complicated. In order to obtain a product of consistent quality, it is important to standardize as many components as possible across the different coops. Reception of raw materials, selection, and storage time to processing can have important effects on product quality. Both managers and operatives of these small plants need to understand the vital nature of establishing and maintaining rigid standards of quality control. If there is a second-level organization that is responsible for commercializing the product, this process can be facilitated by their active involvement. In the case of products destined for human consumption or, to a lesser extent, for animal feed, sanitary and hygiene regulations become critical. Some of these may be difficult to implement for technical reasons, i.e., inadequate water quality, or lack of knowledge, e.g., no hygiene education. These factors need to be taken into account before plant operation starts, both from the standpoint of technical adjustments and processes, and training requirements. Local, regional, and national health regulations and licensing requirements also need to be checked before the plant has been built.

In order to ensure that the plants are operated efficiently and economically, substantial training and backstopping is required in the areas of administration and accounting. It is in the interests of the agency responsible for providing credit that funds are well used; thus training in these areas should be considered an integral part of credit activities.

A training plan needs to be drawn up in order to ensure that there are sufficient plants operating to meet the expected demand for products. State entities and non-government organizations (NGOs) have a crucial role to play in technical assistance and training, but much of the practical training can be horizontal. This process can be facilitated by creating a second-order organization of coops, which can assume some of the training functions themselves. The pilot plant can fulfill a useful training and demonstration role at this stage. Operatives of new enterprises can spend time working in the pilot plant to gain hands-on experience in processing operations, etc. In addition, people who have acquired experience in operating the pilot plant can spend time assisting those who are starting new plants; however, this has to be organized carefully in order to not make too heavy demands on their time.

Packaging and Other Operations

When the processing group is ready to enter into commercial-scale operation, it is time to establish a trademark or a brand name. The advantages of this include:

- the product is readily distinguished by both retailers and consumers;
- the product and name become associated with certain quality characteristics which should be maintained;
- promotional material can be developed around the product name; and,
- competitors will not benefit from generic advertising.

The brand name should be selected carefully in order to ensure that it reflects the advantages of the product as perceived by the consumer. Technical factors of the raw material or process—irrelevant to consumer acceptance—should not be included. Several names should be tested in several potential markets in order to select the one that is most widely acceptable.

Product Distribution

As pointed out earlier, a product targeted at the industrial market can be distributed by the processing groups themselves; whereas those destined for the consumer market will need a specialized network. Should the product be an improvement of a traditional product, the existing distribution network may be considered as

an option. Nevertheless, this will usually involve several levels of intermediaries, each one requiring a marketing margin sufficient to cover expenses and provide an income. At the same time, with the evolution of the processing enterprises, they will almost certainly want to participate in the marketing chain to a greater extent than before, taking over some of the intermediaries' functions and margins.

A decision must be made on how far to take the distribution of the product: whether to rely on independent wholesalers or a second-order enterprise to take charge of wholesale activities, or to include retail-level sales within the scope of distribution. This decision has to be made on the basis of product characteristics, market characteristics, and consumer purchasing habits.

It is absolutely essential that this enterprise be operated on a purely commercial basis. Should it be under the umbrella of a second-level coop, for example, it should be administratively and financially separate. Only in this way can the enterprise be truly competitive and maximize profits for its members.

The distribution enterprise should manage the following aspects.

- Product supply from the different production enterprises; i.e., coordination of supply with market demand.
- Quality control of the finished product; and, if required, selection into different quality products.
- Management of warehousing, stocks, and inventories.
- Sale and distribution of the product to wholesalers and retailers.
- Coordination of promotion campaign activities to complement those of distribution.
- Monitoring and evaluation of sales volumes, including those of the competitors, as well as profit margins of wholesalers and retailers.
- Feedback to both the processing groups and product development research organizations.

The actual location of the central offices and warehouse is very important. If the product is to be sold in small shops, then the warehouse should be located near the central wholesale market where small shopkeepers purchase most of their goods.

It can be seen from the foregoing that the skills required to manage such an operation are quite different from those of the processing enterprise. Marketing and business skills are essential, as well as technical skills in the area of product storage and warehousing. These skills are not to be found in government agencies as they themselves do not function along commercial lines. Rather, it is necessary to seek input from organizations that support small businesses and who will be in a position to cover these aspects in training and technical assistance.

Product Promotion

In order to meet the objectives outlined in the market plan, promotion of the product is needed to make consumers aware of it, its advantages, and where it can be purchased. A number of texts have been written on planning and executing a promotional campaign; but there are several basic factors that need to be considered when deciding what media to use. Characteristics of the target consumers must be taken into consideration, e.g., newspaper advertisements will not reach the barely literate, low-income strata. When developing materials, the use of regional terms, dialect, and the like should be avoided so that they can be used for as wide a geographic scope as possible. The brand name, logo, and slogan should figure prominently in all materials developed.

A small coop cannot afford a wide-scale launching of a new product traditionally associated with large food companies who bombard the consumer with a fanfare of publicity. A safer alternative is to increase promotional activities gradually as the distribution network expands and product supply increases. A sudden increase in demand would be most difficult to fulfill and could cause problems.

Creating a market is expensive even though it should pay for itself in the long run. Financing of these activities, which require considerable investment, is discussed in the introductory paper of this volume.

Funding

Pilot-scale activities are normally funded through special projects in view of the fact that no business or cooperative enterprise could be expected to finance something that has not proven to be technically and economically feasible. Once the plant reaches the point of expanding to a commercial level, however, provision of credit for replicating and/or expanding the manufacturing capability and providing sufficient working capital to cover initial expenses should, theoretically, be feasible. Nevertheless, there is still an element of risk in

that these projects are based on integrating small farmers into cooperative ventures.

When the product is destined for consumers, promotional activities are essential for breaking into the market. Small producers/processors rarely have capital of their own to engage in a commercial-scale enterprise. Unless there is a second-order organization, it will be impossible for the plants to cover the costs of these promotional activities.

Given the foregoing, credit will generally have to be provided at reasonable rates and terms by an organization in the public sector, accompanied by well-designed training and technical and administrative backstopping, either by the public or private sector. Funds for institutional support can be generally found in the budgets of the state organizations involved, if their development priorities are in accord with those of the project. In many countries, however, root and tuber crops are not of high priority. Therefore, funds may have to be sought from appropriate NGOs active in rural development or working with small farmer groups. The most difficult area to support is product promotion, which is not considered an element of a rural development project. One avenue to explore is with organizations interested in improving availability of staple foods in urban areas.

To reduce producers/processors' dependence on external credit, they should be encouraged to build up their capital. This means that the coops must reach a balance between profit distribution (pressures are great for this among the poorer groups) and reinvestment. Some groups have a policy of paying high prices for the raw material in order to encourage non-members to sell to the coops rather than to a competitive market, e.g., fresh consumption. In the long run, however, the coop may suffer from this policy, which does not permit them to strengthen their organization.

Technical Assistance

To the extent that the industry grows and the number of plants and coops increases, the need for technical assistance also increases. In the short term, it is possible to expand the technical teams of the entities responsible for processing, production, commercialization, organization, etc.; but this is very costly over time and the coops will never stop depending on them. Another alternative consists of creating a team of persons trained for this purpose within the coops themselves. This model (farmer-to-farmer or promoters) is much less costly and more responsive, but it requires a significant training effort. The experience with projects in Colombia highlights the importance of technical assistance—especially for accounting and maintaining equipment—even for those drying plants that had been operating for several years (Bode 1991).

Monitoring and Evaluation

Once the decision has been made to implement the commercial process, it is necessary to monitor the progress of the product's introduction and market penetration in order to ensure that objectives are being met in accordance with the market plan. The success of this operation depends upon the quality of the market plan, which must be detailed and yet flexible.

Information input is essential to ensure that changes are made in accordance with developments in the areas of production, processing, and commercialization. If, for example, there has been a poor growing season and the supply of roots or tubers has fallen, processing activities will then have to be reduced or other supply sources will have to be sought. If the organization has to depend on funds from the public sector, it is important to monitor changes in government. Activities related to the formation and consolidation of coops, provision of credit, and plant construction all tend to suffer delays, which if not taken into account, could lead to other project activities getting out of phase. It is also important to document experiences learned at the onset of the commercialization phase because this information will invariably serve to improve planning for breaking into other markets.

A monitoring system should cover three important areas.

- volumes as well as volumes by market outlet and a breakdown of the socio-economic status of the consumers.
- Consumer behavior with respect to first and repeat sales data.
- Consumer satisfaction with product quality, usefulness, price.

The monitoring system has to be in place when the project begins and is an ongoing activity to be carried out by the organizations themselves.

Evaluation of the commercial process should be done not only in terms of the financial viability of the system but also the distribution of benefits. Benefits can

accrue to farmer-producers, landless laborers, rural transporters, urban distributors, retail shopkeepers, and consumers. At the same time, it is important to determine whether there are any adverse effects from the enterprise. This evaluation should be done by the organization(s) that provided some sort of support to the process and who wish to learn whether the investment has been sound.

Data generated by the monitoring and evaluation of the project can also serve to generate ideas for new markets or new products. This information should feed back to the technical research components of the project for further evaluation.

Conclusion

The decision to expand pilot plant activities to commercial operation has important implications for the product and process as well as the farmers and consumers potentially involved. In this paper, the various considerations to be evaluated in making this decision have been briefly discussed and their respective components analyzed. Concisely stated they include: social objectives, market and technical requirements, promotional and logistical factors as well as funding and technical assistance. Should commercial processing begin, then monitoring and evaluation of these operations become imperative so as to ensure not only effective implementation of the original plans but also that the guidelines set forward are adhered to (or adjusted) in light of emerging developments. While the issues mentioned here and their treatment may not be all inclusive, they hopefully should serve as a useful aid for launching successful processing of roots and tubers at the commercial level.

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Use of Dehydrated Potato in Composite Flours: A Case Study of Potato Flour in Kenya

Jackson N. Kabira[1]

Abstract

A case study on the feasibility of using dehydrated potato flour in composite flours in Kenya is presented. Dehydrated potato flour can be produced from surplus potatoes and used to supplement maize and wheat flour to feed a rapidly increasing Kenyan population. Potato flour was produced through milling raw potato slices dried by on-farm solar dehydration. The potato flour was blended with wheat flour or maize, sorghum, and millet flours and used to prepare commercially baked breads, home-baked products (*chapatis* and *mandazis*), and traditional foods (*ugali* and *uji*). The quality and acceptability of the food products—established under experimental conditions—indicated that dehydrated potato flour can be mixed with other flours up to 20% by weight in commercially baked bread and with up to 40% in home-baked products. Consumer acceptable traditional *uji* and *ugali* can be prepared with up to 50% potato flour. Partial substitution of potato flour for wheat flour and maize meal can be commercially feasible if current government price supports for imported grains are modified.

Key words: product, marketing, processing, economics, bread, baked goods.

Introduction

Maize, maize-based, and to a smaller extent, wheat-based foods are major staples in Kenya. Over half of national wheat requirements will be imported in the 1990s to supplement local production. In view of Kenya's foreign exchange problems, substitution of imported cereals by locally produced cereals, roots, and tubers is seen as one way of coping with the increasing food demand of Kenyans. This situation has created a need for a composite flour program which has the potential of reducing over-reliance on cereal imports.

Sufficient supplies of maize are sometimes not available for making *ugali* (stiff porridge) and *uji* (regular or fermented thin porridge), the most commonly consumed traditional foods in Kenya. Lately, there have been promising signs of increasing availability in small stores and supermarkets of composite meals (of flours) for *uji*, often based on finger millet, which is traditionally popular for weaning porridge. Pearl millet and cassava flours are also found. Dehydrated potatoes have a potentially important role to play in the proposed Kenyan composite flour program (NCPB 1991).

This paper is a case study on product development based on experiences with dehydrated potato in composite flours in Kenya. Specific objectives were to: (1) develop an appropriate low cost process for on-farm production of dehydrated potato flour, and (2) determine the potential use of the product in composite flours.

The Potato in Kenya

Production

Over 80,000 ha were planted with potatoes in Kenya in 1991. Only maize covers a larger area. Most of the crop is produced by small-scale producers on family farms with an average size of 2 ha. The area under potatoes has increased by 56,000 ha, an increase of 206% since

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1961 (Scott 1991). Average annual production increased by 269% in the 1980s to over 500,000 t due to use of improved varieties, certified seeds, and other technological improvements. Average yields increased by 21%, but have remained at about 10 t/ha although yields of 20-40 t/ha have been recorded under experimental research and large-scale commercial growing conditions.

Potato production is confined primarily to the highland areas (1,800-3,000 m) where the crop has higher yields than other food crops. Potatoes are grown twice a year in two distinct rainfall seasons (April-May and October-November) with peak harvest periods in July/August and January/February.

In Kenya, potatoes are used for food mainly in fresh form, consumption being highest in highland rural growing areas and large urban centers. Consumption is usually highest immediately following each of the two harvest periods when prices are at their lowest. In the urban centers, potatoes are becoming increasingly popular in the form of crisps (called potato chips in the USA) and freshly prepared chips (called french fries in the USA).

Marketing and Processing

Potatoes in Kenya are second only to maize in food and market value; however, due to bulkiness and perishability, their full potential is not realized. In times of overproduction, farmers sell off their surplus immediately after harvest, leading to an over supply in the market which forces prices to drop.

Potato storage for commercial gain is rarely practiced in Kenya. Processing has been proposed as an alternative in facilitating the distribution and wider availability of potatoes, while improving profit margins and ensuring a more stable market supply. A modest approach is the reduction of the potato's high water content by appropriate on-farm solar dehydration technology followed by milling the dried product into flour. Dehydrated potato flour could be used in composite flours for wheat-based and maize-based food preparations at home and in industry.

Processing the Potatoes

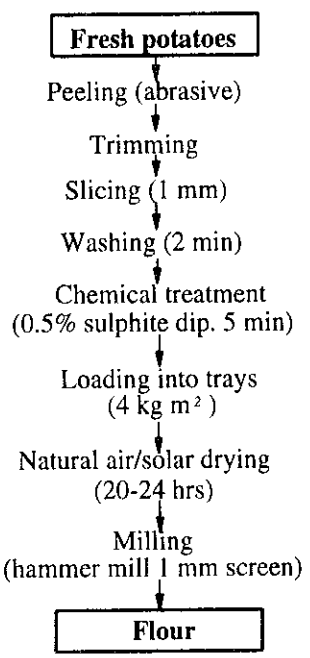
Solar Dehydration

Sound, fully mature potato tubers of the variety *Desirée* were used for processing. The flow diagram for dehydration and production of potato flour is given in Figure 1. Pre-processing treatments were sorting, washing, peeling abrasively, and trimming. The peeled and trimmed potatoes were cut, using a manual slicer, into 1 mm thick slices and washed in running tap water to remove surface starch. The slices were then dipped in a 0.5% solution of sodium metabisulphite for 5 min to prevent discoloration during dehydration and subsequent storage.

Treated potato slices were loaded onto 0.5 m^2 screen-bottomed galvanized wire mesh trays at the rate of 4 kg/m^2. The trays were loaded into a three-tier open-sided air/solar dryer (Shaw and Booth 1982) or a five-tier air/solar dryer with ventilation controls (Keane et al. 1986) and dried to final moisture content of approximately 10%. The dehydration process lasted for 20-24 hr during favorable weather (August-October, and December-March) utilizing natural night air flow and daytime direct solar radiation and natural air convection.

Although combined air and solar dehydration was useful during dry weather in December-March, most of Kenya's potatoes are harvested during the cool, overcast

Figure 1. Flow diagram for manufacturing uncooked dehydrated potato flour.



Source: Kabira 1990.

period in July/August making the use of solar energy almost impossible in some seasons. Solar drying may require a backup system, i.e., using fuelwood, diesel, or electricity, to process potatoes during the August-October period.

Potato Flour

Dried potato slices were milled into flour using a hammer mill or the experimental Buhler (roller) mill. The hammer mill was found to be appropriate for milling dehydrated potatoes because it is readily available for maize milling within potato growing areas. Furthermore, the hammer mill is inexpensive and locally made unlike the roller mill which is imported. The roller mill, commonly used for production of sifted maize meal and white wheat flour in urban areas could, however, be important if manufacture of composite flours is carried out at the flour mills (ECA 1985; NCPB 1991). Millers have expressed interest in doing the milling themselves, after farmers and other enterpreneurs have dried the potatoes.

Dehydration of sulphited raw potato slices gave acceptable products while reducing energy costs associated with the usual commercial practices of blanching and pre-cooking. Electricity is not widely available in potato growing areas and other forms of cooking fuel, including fuelwood, are in short supply. Microbial counts of uncooked potato flour were found to be compatible with Kenya Bureau of Standards' specifications for cereal flours even after nine months of storage at ambient temperatures (22-30°C). The flour had a reasonable level of protein (8.6%) containing all essential amino acids, except methionine and cystine (Kabira et al. 1991). The flour is also a good source of potassium, phosphorous, and magnesium. The high levels of lysine make potato flour ideal for protein complementation with cereals.

Economic Considerations

Cost analyses were conducted to determine the cost per kilogram of dehydrated potato flour based on the assumed farm-gate prices normally prevailing during harvest in potato growing areas. Cost analyses were based on two small-scale plants with a capacity for processing 85 and 236 kg of fresh potatoes per day (equivalent to 72 and 200 kg of prepared slices) to yield approximately 14 and 40 kg of flour (Table 1).

The calculations indicated that processing more than 200 kg of potatoes per day to produce flour could be profitable due to the lower costs of production associated with economies of scale. The calculations also demonstrated the importance of the cost of the raw material and labor in determining unit production costs.

Table 1. Cost analysis[a] of producing dehydrated potato flour in two small-scale plants of different sizes.

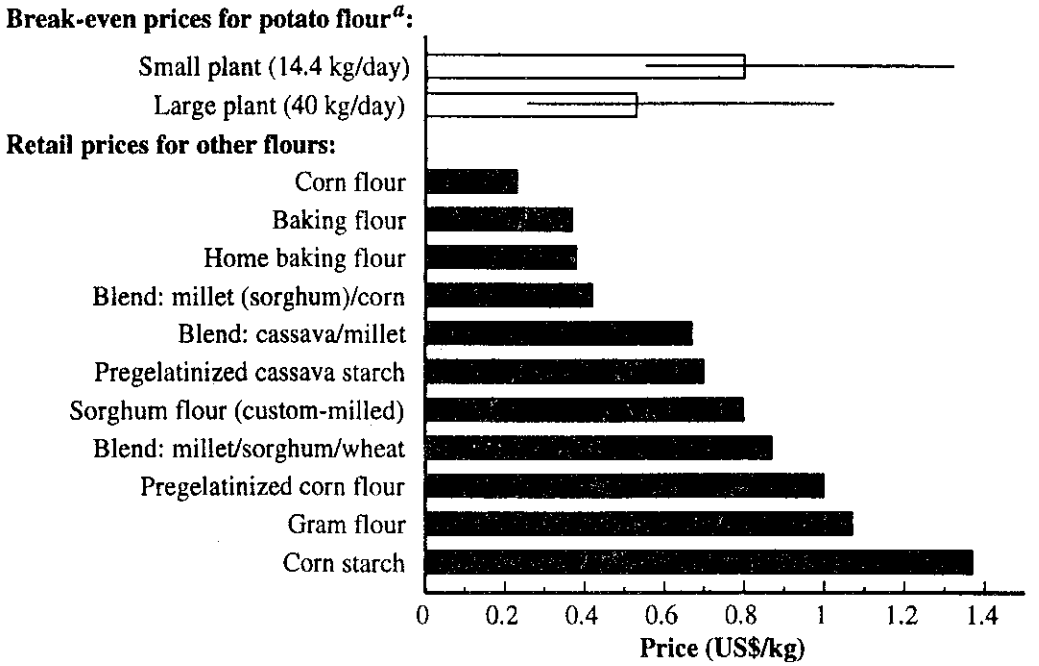
Cost parameter	Plant 1[b] (85 kg raw material)	Plant 2[c] (236 kg raw material)
Fixed costs		
Interest (13% per year, half life basis)	$ 0.30	$ 0.45
Depreciation (10-year life span)	0.47	0.68
Subtotal	0.77	1.13
Variable costs		
Potatoes[d]	3.64	10.11
Chemicals	0.17	0.50
Labor	5.48	6.67
Packaging	0.24	0.67
Milling	0.20	0.57
Maintenance (5% of capital costs)	0.23	0.34
Subtotal	9.96	18.86
Total costs/day	10.74	19.98
Total output/day (kg)	14.40	40.00
Cost of producing 1 kg of flour	0.75	0.50

[a] In US$.
[b] Dryer based on that of Shaw and Booth (1982).
[c] Dryer based on that of Keane et al. (1986).
[d] Calculated on the basis of farm-gate prices (10% of production costs).

Economic Feasibility of Using Potato Flour in Composite Flours

Using different fresh potatoes prices, break-even prices per kilogram of potato flour were calculated and compared with retail prices of common flours, flour blends, and starches available in Kenyan supermarkets (Fig. 2). The estimated break-even prices of potato flour ranged

Figure 2. Estimated break-even prices of experimental potato flour compared with flours, flour blends, and starches available in Kenyan supermarkets.



Source: Kabira 1990.

from US$ 0.36-1.00 when producing 40 kg of potato flour per day.

At a selling price of US$ 0.55 and below, it was considered that marketing potato flour for blending with wheat flour would not be a problem since the competing alternative flours (sorghum, starches, and various flour blends) would be more expensive. Blending with maize, which like wheat is price-controlled, was considered uneconomical. However, due to recurrent periods of maize shortage, potato flour from cheaper sources of raw material can be used to advantage in extending the available maize supply. Partial substitution of potato flour in maize and wheat flour can be commercially feasible if current price supports on imported grains were modified.

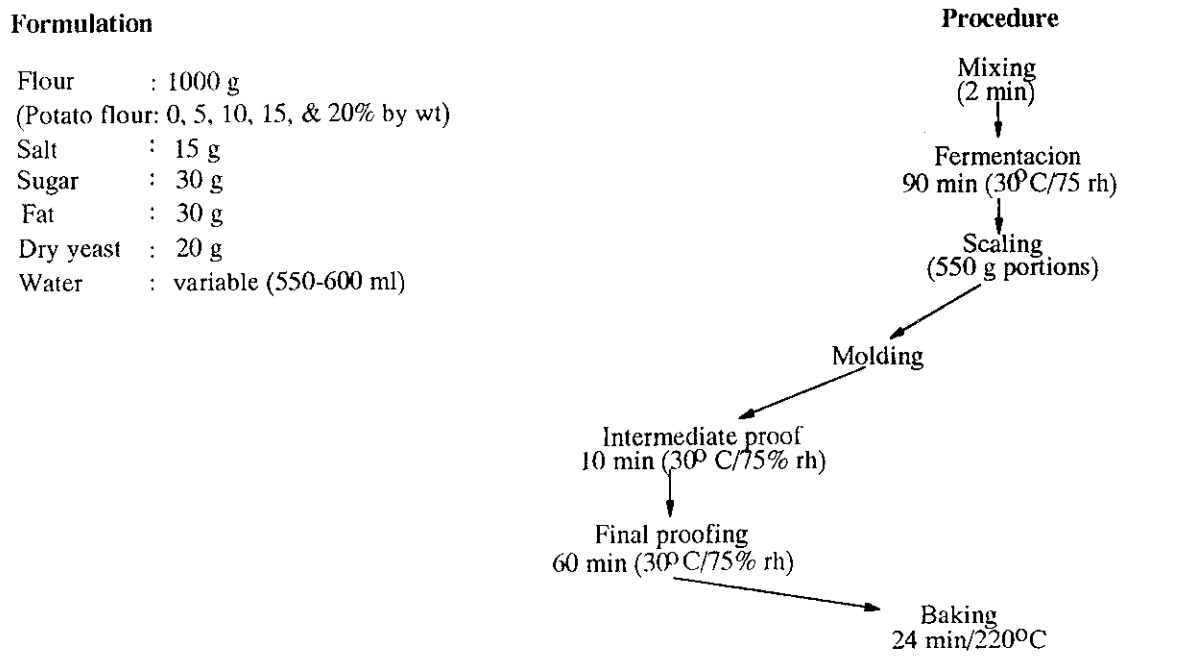
Substitution of Potato Flour in Kenyan Foods

The sensory acceptability of dehydrated potato flour in commercially baked bread, home-baked goods (*chapatis*, flat unleavened bread and *mandazis*, chemically leavened doughnut), and traditional foods (*ugali* and *uji*) was determined by pilot (in-house) consumer panels. The products were evaluated on a hedonic scale of 1-8 (1 = extremely unacceptable; 8 = extremely acceptable). Scores of 5 and above were considered acceptable.

Commercially Baked Bread

Straight grade wheat flour with a protein content (N x 5.7) of 13.6% and an ash content of 0.6% (on a dry matter basis) was blended with potato flour at 5, 10, 15, and 20% by weight and used for making "white pan bread". All test-baking trials were conducted at the Quality Control Laboratory of Unga Ltd., a large flour milling company in Nairobi, using the straight dough procedure. The breadmaking formula consisted of 100 parts wheat flour; 1.5 parts salt; 3.0 parts sugar; 3.0 parts hydrogenated vegetable shortening; 2.0 parts active dry yeast; and quantities of water which increased as the level of potato flour increased to give uniform dough consistency. The bread formulation and baking procedure are given in Figure 3.

Figure 3. Formulation and baking procedure for potato breads.



The water absorption of baker's flour increased by addition of potato flour. Potato flour enhances the retention of moisture in baked products and can, therefore, be used to advantage in improving the shelf life of bread. Baking strength of wheat flour was decreased by potato flour, indicating an impairment of the ability of bread to rise due to dilution of the wheat gluten.

Results of the baking trials showed that it is feasible to incorporate high levels of potato flour in white pan bread. Incorporation of potato flour reduced loaf volume, but increased loaf weight (Table 2). Substitution of wheat flour by potato flour up to 20% did not affect the acceptability of the bread to any appreciable extent.

Home-baked Goods

Potato flour was blended with commercially available home-baking flour at 10, 20, 30, and 40% by weight. The flour blends were mixed in a Henry Simon tumbler mixer for 5 min and used for preparing *chapatis*, and *mandazis*. The formulation and preparation procedures are given in Figure 4.

Approximately 200 g of flour and 2 g of salt were mixed with water (48-55%), with the level increasing relative to that of potato flour, and kneaded by hand for *chapati* preparation. The dough was then divided into 200 g portions which were individually rolled out on a floured pastry board using a wooden rolling pin. A little maize oil was brushed onto the dough which was kneaded into a ball, rolled out again and the *chapatis* sheeted to a final circular shape 2 mm thick and 20 mm in diameter. The *chapatis* were then transferred to a cast iron griddle, preheated to 200°C over an electric plate, and baked on each side for approximately 2 min or until sufficiently browned.

Mandazis were made as shown in Figure 4. Two hundred grams (200 g) of the dry ingredients were placed in a bowl and the water added. The dough was kneaded by hand and rolled as for the *chapatis* to a sheet approximately 4 mm thick. The sheeted dough was cut with a biscuit cutter into circular portions approximately 6.5 cm in diameter. The *mandazis* were deep-fried in maize oil at 170-180°C for 2-3 min or until golden brown in color.

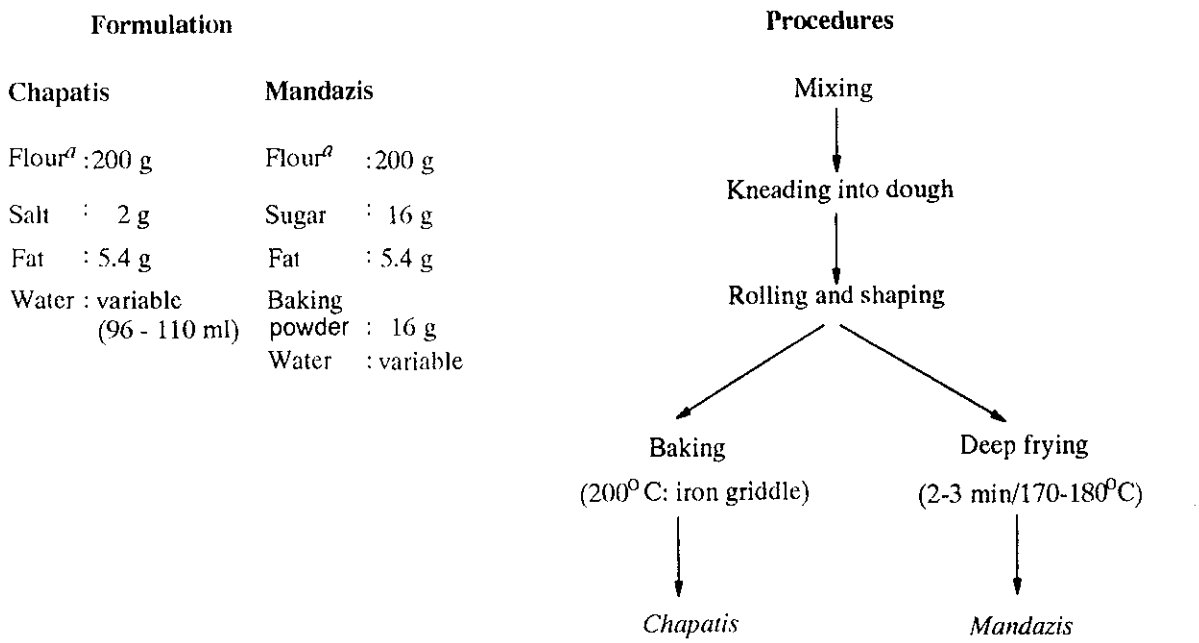
The home-baking trials indicated the possibility of incorporating up to 40% potato flour in home-baking flour without adversely affecting the consumer acceptability of the products. (Table 3). The flour blends could also be used to make biscuits, cakes, cookies, and other commercially baked goods.

Table 2. Baking performance of potato/wheat flour blends.

Potato flour (%)	Loaf weight (g)	Loaf volume (ml)	Relative volume (%)[a]	Acceptability scores[b] (n=52)
0	513	3,081	100	6.5
5	520	2,953	96	6.7
10	529	2,790	91	6.5
15	523	2,748	89	6.3
20	524	2,581	84	5.9

[a]Relative volume = Bread volume/volume of control x 100.
[b]On a hedonic scale of 1-8, scores of 5 and above are acceptable.

Figure 4. Formulation and baking procedure for potato *chapatis* and *mandazis*.



Traditional Foods

Regular sifted maize meal was obtained from a local supermarket in Nairobi and used to prepare flour blends containing 10, 20, 30, and 40% potato flour by weight. The flour blends were mixed in a manual food mixer until uniformly blended. These blends were used for preparation of *ugali* and *uji*. A further trial was conducted involving flour blends with millets and sorghum for preparation of *uji*. The *ugali* was prepared by procedures commonly used in Kenyan households and hotels. Approximately 150 g of flour was mixed thoroughly into 300 ml of boiling water. The resulting paste was cooked for about 20 min with occasional mixing.

Uji was prepared by mixing approximately 150 g of flour with 75 g of sugar and the mixture stirred in 500 ml of cold tap water. The slurry was slowly added to 1.5 liters of boiling water and cooked with continuous stirring for 12 min. Fermented porridge was made by leaving flour slurries of about 30% (w/v) at room temperature (22-25°C) for 24-72 hr and subsequently diluting to 6-8% (w/v) with water before cooking.

Table 3. In-house consumer acceptability scores[a] of potato/wheat flour blends in *chapatis* and *mandazis*.

Potato/flour (%)	*Chapatis* (n=52)	*Mandazis* (n=54)
0	5.9	6.5
10	5.9	6.6
20	5.9	6.5
30	5.8	6.4
40	5.3	5.9

[a]Overall acceptability scores on a hedonic scale of 1-8; scores of 5 and above are acceptable.

Incorporation of dehydrated potato flour up to a level of 40% had no adverse effects on the acceptability of *ugali* and *uji*. Dehydrated potato flour can be substituted in maize meal and used in preparing soft *ugali* which can be eaten without the usual stews. This is advantageous to small children and the elderly who require soft foods. Incorporation of dehydrated potato flour into maize meal up to a level of 40% did not affect the sensory quality of *uji* to any appreciable extent. Potato flour can be suitable for preparation of fermented *uji* due to the outstanding ability of potato constituents to stimulate fermentation of sugar (Kabira and Imungi 1992). Potato flour can also be used up to a level of 50% in sorghum and millet composite flours for making porridge (Bolo 1991).

Lessons Learned

Farm-level solar dehydration of uncooked potato slices and milling with widely available, low-cost hammer mills is a feasible technology which produces stable, good quality flour. Nevertheless, the drying rate under cloudy, wet, cool conditions are slow, so farmers may need a supplemental source of energy during the period of the year when both potatoes are in surplus and weather is overcast and cooler.

Dehydrated potato flour can be used for partial substitution of maize and wheat in popular local foods. For use in commercially baked bread, potato flour can be mixed with wheat flour up to 20% by weight with little decline in quality. Composite potato/wheat flours could be used if sufficient amounts of cheap potato flour were available for blending with locally produced wheat flour.

In home-baked goods, potato flour can be mixed with potato flour up to 40% by weight without altering the consumer properties of *chapatis* and *mandazis*. Other industrially baked goods, such as biscuits, cookies, and cakes, can be made from potato/home-baking flour blends because dilution of the gluten is not critical for these products as for bread.

In traditional foods, such as *uji* and *ugali*, potato flour can be mixed with maize meal up to 40% by weight. Potato flour can be mixed with up to 50% in traditional weaning porridges from flours such as sorghum, finger millet, or bulrush millet.

Acknowlegment

The assistance of Dr. Peter Ewell, CIP regional economist, Nairobi, during write-up is gratefully acknowledged.

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Peri-urban Farming Systems and Food Processing in the Congo

J. Brochier, G.Boukambou, O. Legros, and S. Trèche[1]

Abstract

AGRICONGO (*Institut de recherche et d'appui pour le développement agricole en zones tropicales*) developed a project entitled new farming systems (NSF). This project is intended to implement peri-urban agriculture for city dwellers who want to go into small farm businesses. Because the Congo is importing a large part of its food, the project's first goal was to identify products for development. A basic project assumption was that the best way to reduce these imports was to modernize traditional foods. There was also a need to develop appropriate technologies in agronomy and food science. Work was done to design both a 1.5 ha NFS farm and an integrated food processing facility. Farming techniques were tested at the research station level and the study included socioeconomic issues and farmer-level implementation of product marketing and commercialization.

This report presents preliminary findings from 20 pilot NFS farms that were tested near Brazzaville. Food processing lines and their management are also described. Processed products made available to urban markets through the project were *chikwangue* (cassava bread) and cassava-based mixed flour for infant food.

Key words: processing, traditional, rehabilitation, integration, farming system, modeling.

Introduction

In recent years, the Congo has had very rapid migration from rural to urban areas. Presently, more than two-thirds of the population live in cities. This population is very young; and although most of the city dwellers have been educated, most are unemployed. Farm production in the countryside has not been able to cope with high food demands from the cities and, therefore, the Congo is importing most of its food.

The attempts to develop large mechanized farms have failed because of management difficulties and technical problems such as soil infertility and pests; the disorganized traditional shifting cultivation system in the rural areas; and desertified forests along the roads and around villages and cities.

A research and development approach was designed in 1986 with the objectives of developing new farming systems (NSF):

- to create job opportunities (in the field of agriculture and related activities) with an attractive financial potential;
- to produce food for the cities and reduce imports; and
- to protect the environment by proposing more efficient systems in the field of soil conservation and income than shifting cultivation.

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The project was headed by the AGRICONGO Center and the AGRISUD Research Institute, through scientific partnerships with the University of Brazzaville, and the *Institut Francais de Recherche Scientifique pour le Développement en Cooperation* (ORSTOM). *The École Nationale Superieure D'Enseignement Technique* (ENSET), Brazzaville, participated in the design of food processing machines. Funding was also provided by ELF-Congo, the People's Republic of the Congo; and French and Canadian aid agencies.

The Project Structure

Project Objectives

Specific objectives identified for the project were to:

- establish a research station near Brazzaville;
- conduct a market survey in the cities to identify demands for specific products which could be economically interesting to produce;
- do crop research using different agronomic approaches on cassava, groundnut, soybean, corn, bananas, pineapple, and forestry products;
- do research on food technologies aimed toward modernizing traditional products;
- develop model farming systems and processing units;
- test the farm and processing units on experimental stations using independent operators;
- test the developed farming system as pilots which would integrate processing and marketing by the farmers; and
- develop, on a large scale, a new farming system in peri-urban areas and along the roads on rehabilitated soils.

Organizational Aspects

AGRICONGO Center of AGRISUD Institute was created as a private non-profit organization. A research and development (R&D) station was established near Brazzaville and research partners were involved in projects in the field of social science, agronomy, nutrition, and food technology. The staff was selected from among young, newly graduated people who also represented the target group.

Development Aspects

The developed farming systems were 2-3 ha parcels with 0.6 ha of their edges used for alley cropping. The food crops planted were divided into short-, medium-, and long-cycle crops. In the short cycle were rainfed vegetables (*solanum* sp. and *amaranthus* sp.) and miscellaneous leafy vegetables. Medium-cycle food crops were groundnut, soybean, *wouanzou*, and corn. Long-cycle crops were cassava, pineapple, banana, and perennial crops, fruits and multipurpose fast-growing trees.

Table 1. Annual harvests from project farms.

Crops	Area	Minimum yield
Cassava[a]	0.5 (ha)	12 t/ha
Groundnut[b]	0.3 (ha)	700 kg/ha
Soybean[a]	0.15 (ha)	700 kg/ha
Pineapple	20,000 (plants)	40,000 fruits/ha
Banana	250 (plants)	12 kg/plant
Acacia mangium	75 (trees)	100 kg/tree

[a]Cassava and soybean are processed for flour and *chikwangue*.
[b]Groundnut is processed into peanut butter.

Two cows were included in the design primarily for draft animal use. Each farm contained a family home, stable, water tank, and storage barn. For every 15 farms there were three processing lines. The average total harvests from pilot farms are shown in Table 1.

Processing Aspects

Chikwangue

Chikwangue processing machines were designed and built in the Congo. The processing line (Fig. 1) requires—under local conditions—two workers and one manager for the transformation of 3 t of cassava or for the production of 1.5 t of *chikwangue*. The yield, after processing, is 40-55 kg of *chikwangue* from 100 kg of fresh roots. Produced *chikwangue* contains 60% water. The level of investment necessary to set-up a *chikwangue* processing unit and the monthly operating costs are shown in Table 2.

Figure 1. Flow chart for processing *chikwangue* using NFS technology.

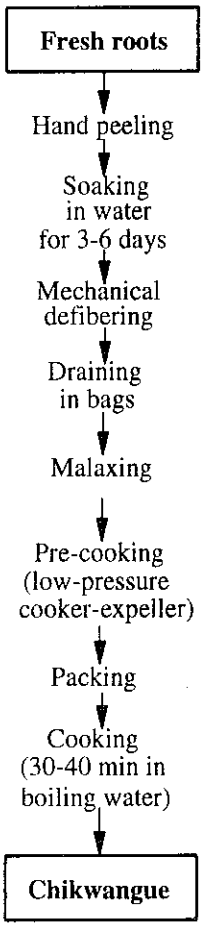


Table 2. Investment and operating costs of a *chikwangue* processing unit (prices given are in local currency)[a].

	Cost (FCFA)
Initial investment cost	
Building	1,550,000
Machinery	2,500,000
Furniture and tools	495,000
Total	4,545,000
Economic survey per month	
Variable costs per month:	
roots	650,000
fixed costs	260,000
monthly sales	1,060,000
monthly income	150,000
Annual cash flow	2,800,000

[a]10 FCFA = US$ 0.36.

Mixed Flours

The project has also experimented with mixed flours. This involves combining cassava-based flour with soybean flour in order to improve the final product's nutritional content (Fig. 2). The mixed flour consists of roughly two-thirds cassava flour and one-third soybean flour.

Economic Aspects

For a production line of 2,695 kg/month of mixed flour packed in 250 g plastic bags and sold for 105 FCFA to retailers, the financial aspects that must be considered are shown in Table 3.

Mixed flour has a good potential for economic returns. It can be used as baby food which has a nutritive value close to that of the imported product and which costs 66% less. Also, it is 40% less expensive than the traditional flour based on corn which has a protein content unsuitable for young babies.

The mixed flour gives good additional value to farmers' products, reduces food imports, and makes traditional food crop production economically feasible when the cost of raw products are calculated at 155 FCFA/kg for cassava pellets and 200 FCFA/kg for soybean.

Commercialization Aspects

Peri-urban agriculture is being developed for many reasons:

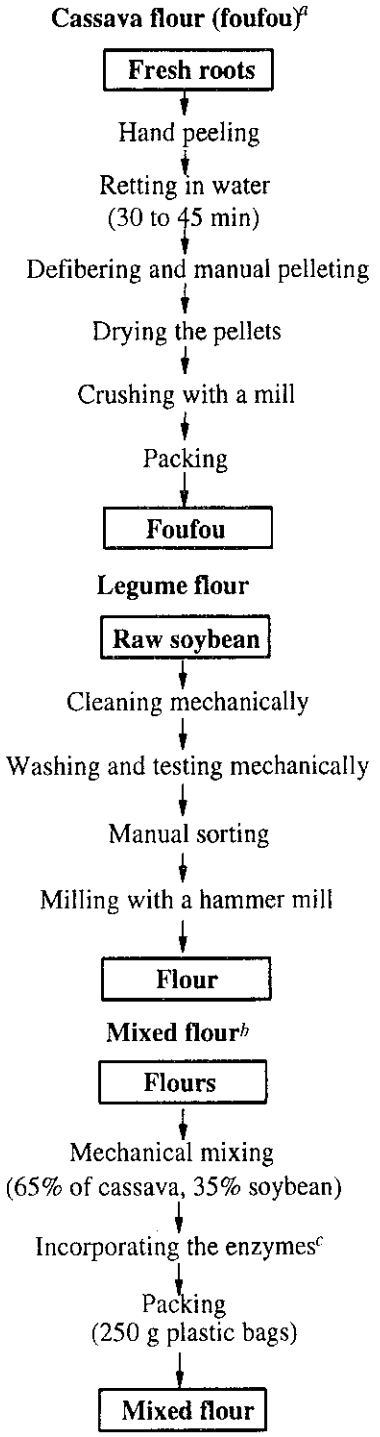
- to give a social choice to young people;
- to create synergy between city and countryside; and,
- to gain market proximity.

Product marketing is done individually by the farmers, through the informal sector and through members of a farmer's family living in town. Socioeconomic studies of these marketing pathways are being conducted to learn more about the potential of these informal methods of commercialization.

Experience to date suggests that the NFS products will find a market niche between locally produced processed foods and those that are imported.

For example, the comparative market prices of products of interest are:

Figure 2. Processing methods for mixed flours and yields of processed products.



[a] The transformation yield is 20-30% (25 kg of flour for 100 kg 100 kg of fresh cassava roots). The moisture content of flour does not exceed 10%.

[b] Care must be taken to keep the flour below 10% humidity.

[c] Amylase (BAN 800 mg from Novo Industry Enzyme SA) 15 g per 100 kg of dry product.

Table 3. Cost of investment and production and return from mixed flour.[a]

	Cost (FCFA)[b]
Investment	
Buildings and facilities	1,525,000
Machines and equipments	2,650,000
Tools and furniture	420,000
Total	4,600,000
Operating Account	
Variable costs:	
raw products	585,000
packing products	55,000
energy	5,000
labor cost	30,000
Distribution costs:	
depreciation	65,000
financial cost	20,000
labor cost	100,000
taxes	70,000
Total expenses	930,000
Sales	1,130,000
Result per month	200,000

[a] The production capacity of this line can be increased from 2.5 t/month to 8 t/month with improved management.

[b] 10 FCFA = US$ 0.36.

Peanut Butter

- local peanut butter 500-900 FCFA/kg
- imported peanut butter 1,700-2,300 FCFA/kg
- modernized peanut butter 1,000 FCFA/kg

Chikwangue

- local *chikwangue* 125-175 FCFA/kg
- modernized *chikwangue* 210 FCFA/kg

Baby Weaning Food

- local *foufou* 175-200 FCFA/kg
- imported baby flour 1,400-2,080 FCFA/kg
- local modernized mixed flour 500 FCFA/kg.

Beyond the profitability of any specific activity, there's the question of the returns to the new farming system units and the project as a whole. In analyzing

the actual data on costs and returns, we were able to make a economic evaluation of the system. These figures are summarized in Table 4. The preliminary estimates clearly suggest that the project is financially viable.

Table 4. Final economic evaluation of the farming system.

Financial requirements	Credit[a]
Grants	1,986,000
Medium-term loans	880,000
Leasing	935,000
Short-term loans	1,300,000
Total	5,151,000
Economic data:	
Average monthly income per farm	80,000
Cash-flow month	120,000
Monthly repayment	45,000

[a]10 FCFA = US$ 0.36.

Conclusion

Through the NSF Project, the experience gained will bring insights for future direction of this and similar projects. Among the most significant findings are the following:

- Peri-urban agriculture on rehabilitated soil is a good way to develop new farming systems because of market proximity, easy communication with services, handicrafts, workshops, banks, and shops.
- Processing food at the farm level is the only way to make agriculture economically feasible for small family farms.
- Locally designed and built food processing machines give better results than imported equipment.
- Integrated research—including social, commercial, and technical aspects—in the field of agriculture and related activities appears to be efficient for new farming system development.

Acknowledgement

This work has been possible because of a good partnership between national and international research institutions and the development project at the AGRICONGO Research Station and pilot farms.

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Research and Development into Commercial Yam Processing in Nigeria: Cadbury's Poundo Yam

J. S. T. Bogunjoko[1]

Abstract

Yam is a staple food crop in Nigeria. Annual output is about 15 million t. Among the most popular dishes made from this root is the traditional pounded yam. Preparation of pounded yam is very laborious and time-consuming. This paper describes efforts by Cadbury Nigeria to develop a processed product to serve as a convenient substitute for pounded yam. The experience emphasizes the need for well-focused research and development efforts to ensure the new product satisfies consumers' tastes and market requirements in terms of packaging and preparation time.

Key words: consumers' tastes, convenience food, pounded yam.

Introduction

Yam is a tropical crop which produces edible tubers that are very rich in carbohydrates. Statistics on yam production are varied, but the Food and Agricultural Organization of the United Nations (FAO) estimates that globally about 20-25 million t/yr are harvested, with Nigeria accounting for 60-70% of the total world production. It is estimated that 10-15% of yam annual output is lost to waste resulting from improper storage conditions and damage by insects and pests. Hence, acceptable and economic ways are needed to preserve yams through processing.

Yam is a major staple food, and a major source of carbohydrates for Nigerians. While total annual production is believed to be roughly equivalent to demand, cropping patterns, hence supplies, are highly seasonal. As a result, periods of both abundance and scarcity exist during the year. Yam processing for domestic consumption can take a number of forms which include boiling, frying, roasting, soaking with pepper and tomatoes (yam pottage), processing into flour, and pounding. By far the most popular form in Nigeria is pounded yam whose preparation can be time-consuming and laborious. The traditional method for pounded yam preparation involves: (1) peeling, (2) cooking, and (3) pounding the yam. Preparing an amount sufficient to feed a family of five can take as much as 2-3 hr.

In Nigeria today, more and more people, including women, are leaving traditional rural settings for the more populated urban centers in search of better opportunities. Cadbury Nigeria recognizes this phenomenon and also the fact that more of these women are leaving their homes to become gainfully employed. There are therefore more career women in Nigeria today than at any other time during the relatively short industrialized history of this country.

Since women are the traditional keepers of the home and are generally responsible for meal preparation for the family in Nigeria, it is expected that anything done to introduce convenience into the performance of this traditional role will be greatly welcome. It is in the light of this possibility that Cadbury Nigeria decided to make pounded yam preparation easier and more convenient for its millions of potential consumers.

The other reason for developing Poundo Yam is that during harvest yam prices are usually low and postproduction losses high. Processing, therefore, reduces the level of postproduction loss and preserves the yam (in

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this modified form) for a period of approximately one year or more.

Research and Development

The research and development (R&D) work on yam processing at Cadbury focused on the need to:

- develop a product from yam that could be easily prepared as pounded yam;
- determine the level of acceptance of the experimental product; and,
- make the product affordable.

Product Development

The development of Poundo Yam was divided into several phases.

Product Concept Evaluation

First, the product concept was clearly defined to outline the main goal which was to develop a partly-processed yam product that could be easily prepared within minutes into Poundo Yam, a convenience food substitute for traditional pounded yam. The definition emphasizes the fact that convenience in preparation would be guaranteed for the consumer. Following product conceptualization, research was carried out to determine if the need for such a product existed.

Experimental Production and Evaluation

The development phase took a long time to complete because it involved several stages. They included the following.

Ingredient sourcing. Because there are many yam species, it was initially very difficult to select the best cultivar especially when the same species may have different names depending on the area or locality. At this stage, Cadbury Nigeria collaborated with the International Institute for Tropical Agriculture (IITA). It turned out to be a very fruitful relationship because at the end of the extensive collaborative work, two commonly available yam species were successfully identified for the project.

Process technology selection and development. The following pounded yam characteristics are those that the processor must take into account to produce an acceptable processed pounded yam (i.e., Poundo Yam).

- *Color.* The finished product must be between white and cream white. The appearance must be opaque, but not translucent.
- *Texture and rheology.* The finished product must be smooth, uniform, and have no lumps. The hand-feel must be non-sticky and smooth. The product should also be reasonably firm and elastic when pulled.
- *Smell.* There must be no astringent, burnt, or cooked smell. The aroma should be very real (yammy).
- *Mouth feel.* The product must be very smooth in the mouth.
- *Taste.* It must not have a "burnt" taste. The taste must be real and acceptable. It should be significantly like that of cooked yam.

To build all the quality attributes highlighted above into Poundo Yam, the production process outlined in Figure 1 was developed.

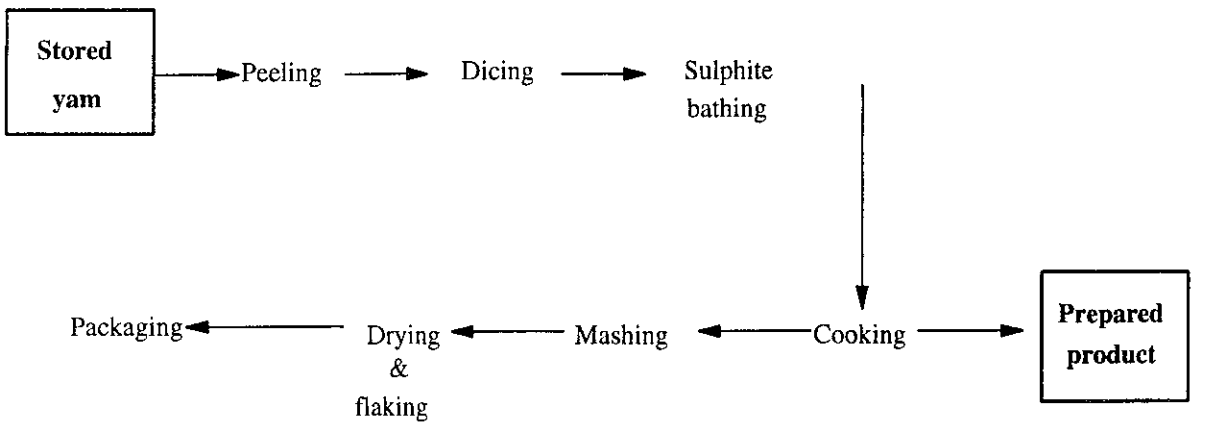
Poundo Yam flakes processed as indicated above were shown, through series of sensory evaluations, to have all necessary quality attributes. Evaluation methods used to confirm this were:

- in-house sensory evaluation panel respondents;
- home placement test using selected respondents; and,
- consumer acceptance tests (large-scale market research) across Nigeria.

In addition to the organoleptic quality attributes, compared to traditionally prepared pounded yam, Poundo Yam offers the following advantages.

- It can keep for a minimum of 12 months in the bag-in-a-box packaging method that was adopted. The bag keeps moisture away and seals in the flavor of the yam flakes. It is made from a three-layer (LDPE/HDPE/LDPE) co-extruder film about 100 microns thickness. The box forming the secondary packaging facilitates stacking and shelf display.
- Poundo Yam takes a maximum of 8 min to prepare and is very easy to reconstitute. Poundo Yam can be prepared off fire because no extra cooking is required; therefore, it can be prepared right on the dining table.
- The ultimate advantage, however, is that there is little or no difference between pounded yam made in the traditional way and Poundo Yam.

Figure 1. Poundo Yam production process.



Market Research

At this stage, the newly developed product undergoes market acceptance tests. Basically, this involves test-marketing the product in specific locations and getting consumers reaction to the innovation. It is necessary to sensitize potential consumers to its availability and to get their reactions to its presentation, price, ease of reconstitution, and overall quality and acceptability.

Product Launching

Having confirmed the quality of the product to be acceptable, the product is formally launched. This means that its life cycle has begun. In fact, having successfully completed the introductory stage, the product is now in the growth phase.

The sales strategy has been designed in such a way that the distribution potential for both local and export markets are explored.

Conclusion

Yam is a traditional food crop in Nigeria. Although production averages around 15 million t per year, seasonal growing patterns limit widespread, year-round consumption in fresh form.

Seasonal supplies along with the perishability of the roots also contribute to postproduction losses due to inadequate traditional processing. This paper has presented efforts by Cadbury Nigeria to introduce a convenient, tasty substitute for pounded yam. Poundo Yam is intended to reduce preparation time from over 2 hr to about 8 min, while maintaining the real taste of pounded yam. Extensive research and development efforts were successful in incorporating these characteristics and Poundo Yam is now undergoing market testing. Precise identification of and incorporation of desired product characteristics including taste, texture, smell were key elements in this process.

Development and Transfer of Processing Technologies for Sweetpotato in the Philippines

Truong Van Den[1]

Abstract

In an attempt to increase the economic value of sweetpotato, efforts have focused on processing the starchy roots into fruity-food products, e.g., dried sweet-sour sweetpotato, sweetpotato leather, catsup, jam, and a beverage. These sweetpotato products have comparable appearance, taste, and nutrient content to other processed fruit and vegetable products; and, they have a higher Vitamin A content. The developed products were also rated high in sensory scores in consumer acceptability tests. Formulation, nutrient composition, and factors affecting the quality of the products are presented. Technology transfer has been carried out through seminars, workshops, training, and demonstrations. The technology for making sweetpotato catsup and sweetpotato beverage has been transferred to farmers' cooperatives and food processing companies in the Philippines. Products with sweetpotato as an ingredient and a brand name of Sweetpotato Catsup are presently available in the domestic market. Factors that could accelerate transfer of technology to the private sector are also discussed.

Key words: sweetpotato catsup, sweetpotato jam, sweetpotato beverage, Philippines.

Introduction

In many countries, sweetpotato (*Ipomoea batatas*) is an important food crop because it is higher yielding and has wider ecological adaptability, lower input requirements, and a shorter growing period than other root crops. More importantly, sweetpotato is a starchy commodity with its proximate composition and mineral and vitamin content—particularly Vitamin A—comparable to various fruits (Truong 1989).

The similarity in composition of sweetpotato and fruits served as the basis for development of several fruity food products, e. g., (1) dried sweet-sour sweetpotato, (2) sweetpotato catsup, (3) sweetpotato jam, (4) sweetpotato beverage, and (5) sweetpotato leather. The goal of this exercise was to increase the economic value of sweetpotato. Processing into products with a taste and appearance similar to processed fruit items has proven to be cost-effective enough to make them competitive in the market (Abejuela et al. 1989).

The technologies for processing the first four products have been transferred to the private sector. Large-scale production of these products would benefit the following target clientele.

- **Farmers** through creation of better markets for their sweetpotato and participation in an integrated production-processing-marketing system to add value to their produce.
- **Food processors** because sweetpotato is relatively cheap and non-seasonal, compared to fruit, and is a nutrient-rich raw material.
- **Consumers** through having access to low-priced and nutritious products.

The paper briefly reports the development of processing technologies for fruity-food products and

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discusses the factors accelerating the transfer of technologies to the private sector.

Technology Development

Dried Sweet-sour Sweetpotato

This product has the sweet and sour taste of dried fruits. It was originally named Delicious-SP (Truong et al. 1988). The most acceptable product was made with boiled sweetpotato slices 0.3 mm thick which were soaked in 60° Brix syrup containing 0.8-1.0% citric acid and dried at 65°C. The Delicious-SP prepared from sweetpotato variety VSP-1, which is a "moist" type sweetpotato with low dry matter and starch content, obtained the highest sensory scores due to its attractive orange color and soft texture. Dried sweet-sour sweetpotato contains 13,033 I.U. of Vitamin A per 100 g which is higher than both dried mango and dried apricot (Truong 1989).

Sweetpotato Catsup

A formula for sweetpotato catsup which consisted of 32.3% (w/v) sweetpotato, 42% water, 12.9% vinegar, 11.3% sugar, 1.0% salt, 0.3% spices, and food coloring has been developed. Roots are washed, trimmed, chopped into chunks, and boiled. The cooked chunks are blended with water and other ingredients and boiled to the desired consistency before bottling. Various sweetpotato cultivars having cooked flesh colors which range from yellow to orange and a "moist" texture can be used for catsup making. Sweetpotato catsup had viscosity, total soluble solids, pH, and intermediate Vitamin A content comparable to values found in banana catsup. In consumer acceptability tests, sweetpotato catsup was ranked statistically equal to the leading brand of banana and tomato catsup in terms of color, flavor, consistency, and general acceptability (Truong et al. 1990a). Sweetpotato catsup stored for four months at ambient temperature was given comparable sensory scores to that of freshly prepared samples.

Sweetpotato Jam

The jam formula containing 20.7% (w/v) sweetpotato, 45% sugar, 34% water, and 0.3% citric acid proved most acceptable by the trained taste panel. The initial steps in preparing sweetpotato roots are similar to those for sweetpotato catsup. The cooked chunks are blended with water, sugar, citric acid, and optionally with flavorings. The slurry is then cooked until a total soluble solids of 68° Brix was obtained (Truong et al. 1991c).

Due to the high starch content of sweetpotato roots as compared to fruits, the proportions of sweetpotato and sugar are different from the standard formula of 45% fruit and 55% sugar in fruit jams (Gross 1974).

The jams processed from different varieties of sweetpotato are in various colors, e.g., light yellow, orange, or purple. The orange-fleshed type (VSP-1 and VSP-2) produces an orange colored product which is rich in Vitamin A. A laboratory taste panel rated sweetpotato jam with and without the addition of 0.5% (w/v) of the locally semi-processed agar, *gulaman*, as comparable to various commercial fruit jams, in terms of color, consistency, and general acceptability. The addition of artificial orange flavor at 0.05% (w/v) significantly increases the aroma score of sweetpotato jam. In consumer acceptability tests, orange flavored jam was preferred over a popular orange marmalade, but was rated lower than a commercial guava jelly. The quality characteristics of sweetpotato jam have been reported by Truong et al. (1991c).

Sweetpotato Beverage

The processing steps for sweetpotato beverage involve washing, peeling, trimming to remove damaged parts, steaming, extracting, and formulating with 12% (w/v) sugar, 20% (w/v) citric acid, and 232 mg/l ascorbic acid as Vitamin C fortification (Truong and Fementira 1990). The formulated beverage is bottled in 150 ml glass containers and pasteurized at 90-95°C.

Various sweetpotato varieties were evaluated for their suitability in processing into the beverage. In general, the orange colored beverage is preferred to other colored products. Addition of the juice or pulp of different fruits, e.g., guava, pineapple, or Philippine lemon, at concentrations of 0.6-2.4% (w/v) significantly improved aroma scores. Similar to jam, incorporation of artificial orange flavoring also enhanced the aroma of sweetpotato beverage. More than 85% of consumer respondents rated "like" for the sweetpotato beverage, and 96% liked guava-flavored sweetpotato beverage (Truong and Fementira 1990).

The physical properties, e.g., total soluble solids, (13° Brix) insoluble solids (9.4 mg/100 g), pH (3.2), appearance, and color of sweetpotato beverage, are similar to that of the yellow-orange fruit juices and drinks commercially available. According to product labels, artificial colors and flavorings were added to

most commercial fruit juices. Natural orange color, an indicator of a high Vitamin A content when added at 1,844 I.U./100 g, is equivalent to 41% of the Recommended Daily Allowance of Vitamin A. The Vitamin C and mineral contents of sweetpotato beverage are also comparable with that of commercial fruit drinks (Truong 1991a). In tests, no significant difference in all sensory attributes was noted between sweetpotato beverage and the commercial fruit products.

Sweetpotato Leather

In processing sweetpotato leather, steamed sweetpotato chunks are blended with water, sugar, salt, citric acid, and optionally with artificial fruit flavors. The slurry is then thinly spread on plastic sheets and dried in a mechanical drier until the desired moisture content and texture of the product are obtained. A loading density of 4 kg slurry per m^2 produced the sweetpotato leather which was rated with high sensory scores for thickness, texture, and general acceptability. The product also obtained scores of over 7.0 for color, sweetness, and sourness on the 9-point hedonic scale. Addition of pectin at 0.05-0.15% w/w did not improve the texture of the product (Truong et al. 1991d). Apparently the pectin content of sweetpotato is sufficient to produce a leathery textured product.

Orange sweetpotato leather produced from VSP-1 and VSP-7, which have orange colored flesh, was scored over 8.0 for color, texture, and general acceptability. Sensory evaluation by a trained taste panel was performed in comparison with "orange roll-ups," an imported fruit leather, and mango leather which was prepared from ripe mango following the procedure described by Tanafranca et al. (1987). No significant difference in the scores for color, flavor, and general acceptability was noted for the three products. However, in an acceptability test by a consumer panel, mango leather was rated first, followed by SP leather and "orange roll-ups" (Truong et al. 1991d).

Sweetpotato leather had a pH of 3.6 which is within the range of fruit leather, higher total sugar content (69.9%), and lower reducing sugar content (14.2%) than the fruit leathers. Due to its starchy nature, sweetpotato leather has a starch content 14.2% which is five times higher than mango leather, but is much lower than orange roll-ups (21.5%). Nonetheless, the exact formula of "orange roll-ups" is unknown. Sweetpotato and mango leather have a very rich Vitamin A content (14,067 and 16,689 I.U./100 g) as compared with "orange roll-ups" (387 I.U./100 g).

Technology Transfer

Information on the developed technologies was disseminated to the public through announcements on the radio and in newspapers, seminars, scientific reports, and investment forums held in various provinces of the Philippines. The products were also displayed in science and technology fairs organized by government and non-government organizations.

Based on originality of the technology, capability of the potential users, and technology level, i.e., its suitability for village level and small or large scale, three modes of technology transfer were adopted:

- direct transfer;
- exclusive contract; and,
- non-exclusive contract.

The sweetpotato catsup technology was shown to entrepreneurs and farmers through direct extension by hands-on training and demonstrations. Recently, dried sweet-sour sweetpotato was transferred through the same mode. Initially, the technology for dried sweet-sour sweetpotato was transferred to an entrepreneur who was establishing a food processing enterprise on an exclusive contract basis for five years. A non-exclusive basis was adopted for the transfer of the patented sweetpotato beverage technology to a large food and beverage company.

Extent of Technology Adoption

The sweetpotato catsup technology has been adopted by farmers' organizations, small-scale food processors, and catsup processing companies throughout the Philippines. Catsup made with sweetpotato as well as one product under the brand name "Sweetpotato Catsup" are presently available in domestic markets. A banana catsup company adopted the sweetpotato catsup technology and made a substantial profit in 1990. This factory has a production capacity of 10,000 bottles of catsup per day. With respect to sweetpotato jam, the technology has been adopted by a farmers' organization and integrated with sweetpotato catsup processing.

The technology for processing "Delicious-Sweetpotato" was exclusively transferred to an established food processing enterprise. By means of a mutual agreement, the company has agreed to pay a royalty for five years to the Visayas State College of Agriculture (ViSCA) in the amount of 1.5% of its annual gross sales.

Delicious-sweetpotato was packaged in attractive plastic material and named Tropical Delights. However, due to inadequate facilities and a lack of experience in food product marketing, the enterprise encountered difficulties. They were unable to produce a quality product or develop markets. A fire destroyed the company's processing plant. As a result, the agreement was made void by mutual consent. An association of sweetpotato growers and processors in the locality has since adopted the technology for small-scale production of Delicious-Sweetpotato.

A non-exclusive contract was signed by ViSCA and a large food and beverage company for the transfer of sweetpotato beverage. In return, the company donated equipment to ViSCA for research and development (R&D) in food processing. The company became interested in the sweetpotato beverage because of its high Vitamin A content. The product fits very well in the company's current thrusts which focus on using local raw materials for processing nutritious, low-priced food products, and contracting small farmers to produce the raw materials. In other words, the company's orientation matches the project's objectives. More importantly, however, ViSCA's target clientele, root crop farmers, can derive benefits through producing the raw material. Adoption of the technology by a large company would help facilitate market penetration by the sweetpotato beverage. The company and ViSCA undertook a joint pilot project for scaling up the beverage-making process for commercialization. Details of translating the laboratory process into a pilot-scale operation have been reported elsewhere (Truong 1991a).

Technically, there were no major problems in the trial runs for processing sweetpotato at company facilities. Commercial launching of the product was delayed, however, due to an unexpectedly inadequate supply of fresh roots (VSP-1 variety) and, possibly, other managerial matters. Being a new variety, VSP-1 is not widely grown by farmers in the locality. Also, programming production of VSP-1 roots to match the operation of company facilities during the off season for fruits proved to be problematic.

Accelerating the Technology Transfer Process

The potential for commercial use of a developed technology should be incubated at the project conceptualization stage and nurtured along the way to ensure its successful transfer and sustain its viability in the commercialization phase. Kefford (1984) stated that a systems approach from idea to market is the most likely way to succeed.

Among the lessons learned in the transfer of processing technology for fruity sweetpotato products has been the recognition that a close relationship amongst the government, a research institution, and private sector and the technical capability of technology users are of vital importance in translating research results into commercial products. In addition, the following key elements could accelerate transfer of the developed technologies to end users. Hence, they merit analysis with respect to technology generation and transfer.

Technology Generation Phase

One of the steps involved in product development is product idea/opportunity identification through idea generation and screening, product concept testing, analysis of potential market demand, and profitability (Earle and Anderson 1985). However, this step is often bypassed. As a consequence, the research result may not reach the target clientele because market potential eventually proves negative.

The product idea can be generated through consumer and market research (Truong et al. 1990c). While this may reduce the risk of failure, it may limit the researcher's innovativeness as well. Alternatively, the researcher's analyses based on observations of existing products and their marketability, raw material characteristics (physico-chemical and nutritional), and cost can point to a potential product idea. The similarity in composition between sweetpotato and fruits—in terms of Vitamin A, C, and mineral contents—provided the inspiration for development of fruity sweetpotato products. A good understanding of the market and the researcher's creativity are, apparently, the key factors in determining the commercial potential of research results.

Secondly, a rigorous evaluation of the potential commercialization of a developed technology should be evaluated before it is recommended for transfer to end users. An evaluation procedure which takes into account three primary criteria, technical feasibility, marketability, and profitability, has been developed (Abejuela et al. 1991). Based on such criteria, Delicious-sweetpotato and sweetpotato catsup technologies were rated favorably for commercial utilization. Suggestions about lowering the input costs to sweetpotato catsup (Abejuela et al. 1989) were taken, resulting in a

reduction of 50% from the original formulation. This improved the economic attractiveness of the technology, and thus accelerated the adoption of the technology by end-users.

Technology Transfer Phase

Various barriers for commercialization of research results have been identified (Habito 1991). Among these, inadequate information on available new and promising technologies and "immaturity" of available technologies are considered to be direct impediments to the technology transfer process. Factors affecting the adoption of the processing technology for fruity sweetpotato products during the technology transfer phase were the following.

Information dissemination. The technologies for processing fruity-food products from sweetpotato were widely disseminated to the public through various investment forums organized by the Department of Trade and Industry, national/regional science and technology fairs, seminars, and training sessions. These helped create awareness in farmers, food processors, and companies about new sweetpotato products and, therefore, accelerated the adoption of the developed technologies. The important role which the government can play is to link potential investors with technology generators through providing appropriate opportunities for interactions between the two sectors.

Pilot testing. Implementing a pilot project as a step toward commercialization aims to generate information needed to confirm the "maturity" of developed technologies, in terms of technical and economic feasibility for commercial production. The various factors contributing to a successful pilot project have been discussed in Truong (1991b).

Pilot testing of Delicious-Sweetpotato technology was performed at the research laboratory. Equipment needed for the pilot processing line was fabricated and assembled. Data were used for cost and return analysis which confirmed its feasibility for commercialization (Abejuela et al. 1989).

Sweetpotato catsup technology was adopted by a banana catsup manufacturer who has the established facilities and experiences in processing and marketing the product. The rapid adoption of the technology by catsup manufacturers can be attributed to the cost effectiveness of the process and product quality. Indeed, several advantages of manufacturing sweetpotato over banana catsup have been recognized. Among these are that sweetpotato is cheaper than banana; its supply is less susceptible to adverse weather; due to favorable chemical properties of sweetpotato, addition of a stabilizer as commonly practiced in banana catsup making, is not necessary; and sweetpotato catsup has a higher Vitamin A content than banana catsup (Dignos et al. 1990).

The close partnership between the company and the researcher in dissemination and refinement of the technology for commercialization is an important element which benefits both parties. Several requirements for developing the capabilities in operating a food processing unit and marketing of the processed products have been identified for small-scale food processors and farmers' organizations adopting sweetpotato catsup technology. Most important among these is that entrepreneurship development is vital to equip potential users with technical skills and business management capabilities. It may be costly and time-consuming to attain these goals. Nevertheless, based on my experience, it is the only way to help small, start-up enterprises survive in a competitive business environment.

ViSCA does not have the facilities required for pilot testing the industrial potential of sweetpotato beverage technology. Collaboration with a private company is considered to be a strategy which would accelerate the commercialization of the developed product. Successful pilot testing would depend on the capability of the company, which determines the pace toward commercialization; a partnership between private company and research institution; and a regular supply of raw material. A good production plan to ensure an adequate and regular supply of raw materials is necessary. This is particularly critical for new varieties (e.g., VSP-1) which are not grown in the locality.

Regardless of how much effort is put into bringing the results to end-users, a reasonable lag time prior to the commercialization phase must be expected. This is particularly true for sweetpotato, since well designed marketing strategies are needed to gain consumer acceptance of the products, and thus, accelerate their penetration of the market.

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Adoption, Modification and Impact of Cassava Drying Technology: The Case of the Colombian North Coast

Guy Henry[1]

Abstract

The techniques, commercial procedures, and social organization for cassava drying plants have experienced rapid diffusion and adoption in a number of Latin American countries in recent years. This paper briefly reviews the evolution of the model on which the diffusion of this technology was frequently based. The performance of the initial plants over time is examined. The paper then analyzes the impact of this technology on cassava consumption and utilization as well as area planted and yields. Benefits associated with the proliferation of the drying plants in the form of employment generation and foreign exchange savings are also estimated. The impact of changes in the cassava production system, resulting from the drying plant technology, on the natural resource base is among the topics suggested for future research.

Key words: drying plants, cassava markets, utilization, consumption, production, profits.

Introduction

The underlying philosophy behind the Integrated Cassava Projects was that declining traditional cassava markets did not offer incentives for cassava farmers to adopt technologies that would increase production. Therefore, cassava product and/or market diversification (e.g., dried cassava chips) were required to broaden demand, stabilize prices, and create incentives for the adoption of improved cassava production technologies at the farm level (Perez-Crespo 1991).

In 1982 on Colombia's North Coast, the first cassava drying pilot plant was built, based on a small farmers' cooperative model. Since then, this model has been rapidly adopted in other parts of Colombia and throughout the region. In addition, during the project's later years, a strong commercial interest expanded drying activities into many different forms, thereby modifying the original farmers' cooperative model. The Integrated Cassava Projects, as piloted in Colombia, has served as a model for other countries in Latin America, as well as for other continents.

The rapid adoption of cassava drying technology in Colombia has had a significant impact at producer, processor, and consumer levels. This paper will demonstrate some aspects of adoption and impact of the technology, based on monitoring and survey data from the Centro Internacional de Agricultura Tropical (CIAT).

The first section presents adoption and modification of the Integrated Cassava Project model. Following that is a section on the relative performance of cassava processing plants. Then the paper outlines how on-farm cassava consumption and sales have changed as a result of the broader marketing. A subsequent section on the changes in cassava yields shows several impacts of the Integrated Cassava Projects. This is followed by some general conclusions.

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Cassava Drying Technology Adoption

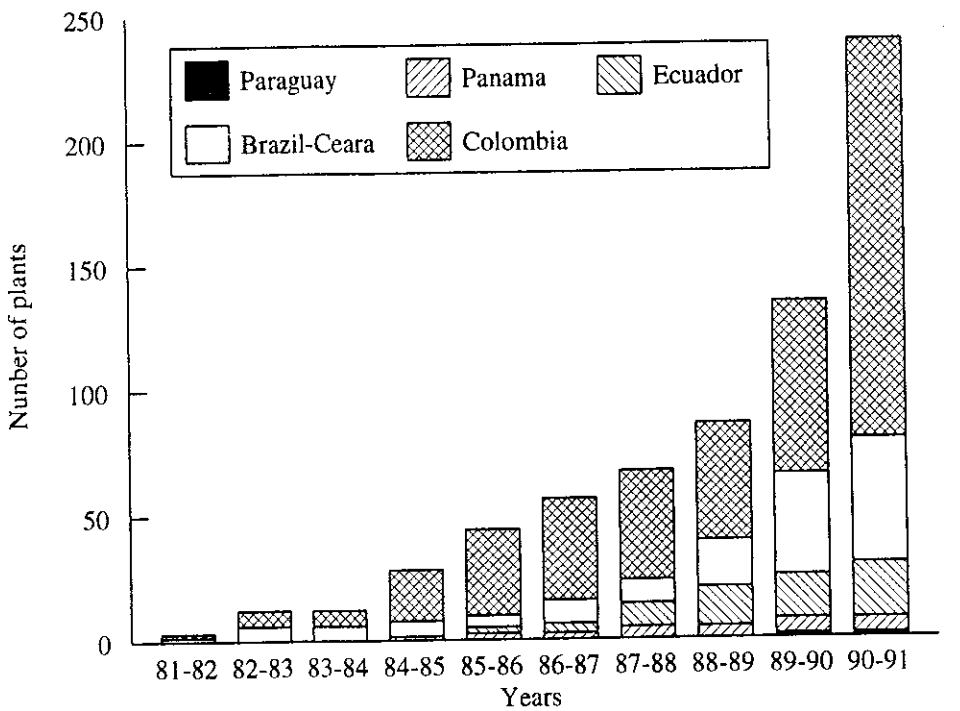
In recent years, information has been presented about the rapid diffusion and adoption of cassava drying plants in Latin America.[2] This section will expand on this and show that, in addition to rapid adoption in time and location, there has been dynamic adoption by different user groups. Also, the basic "cooperative model" has been adapted by the commercial sector to serve different objectives and market structures.

Figure 1 shows the total number of cassava processing plants in Latin America. It is estimated that currently there are approximately 240 cassava drying plants in operation, with the majority located in Colombia. Accelerating plant adoption has been very clear during the last two years. This has been caused, to a major extent, by rapid adoption by Brazilian cooperatives and by the increasing number of commercial plants in Colombia (Fig. 2). It should be noted that in the near future the number of plants in Brazil will surpass those in Colombia. There are currently more than 50 new plants under construction in the Brazilian state of Ceara. Moreover, a project has been funded to diffuse the cassava drying technology to other states in Northeast Brazil. Data for 1991 are estimated because it has not been possible to keep an accurate count through monitoring activities given the fast, widespread, and diverse types of cassava drying.

Dynamics of the Drying Technology

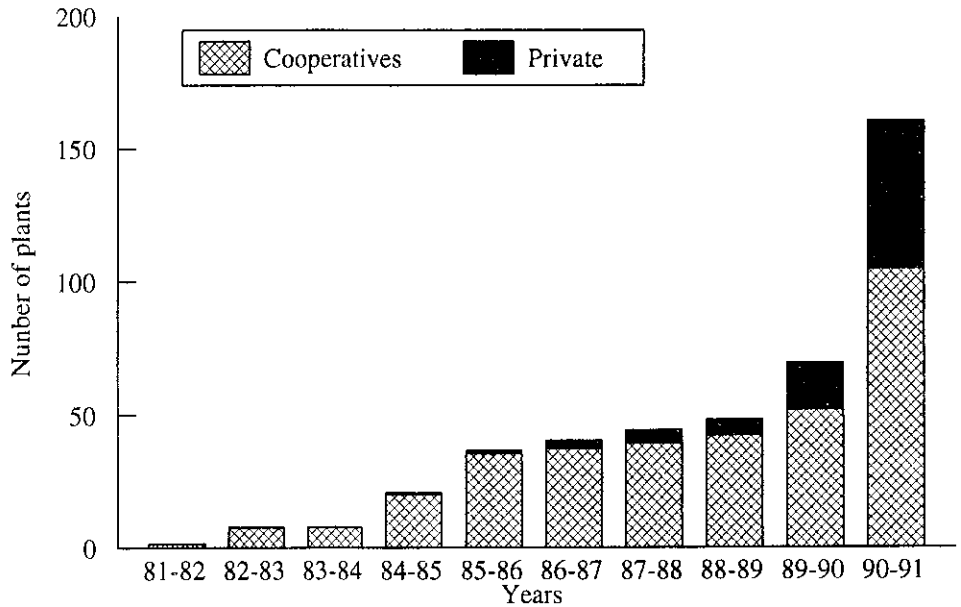
During the initial phase of the project in Colombia, the cassava-drying cooperatives sold dried chips to several large animal feed manufacturers near large urban centers—Barranquilla, Bucaramanga, and Medellin, on

Figure 1. Adoption of cassava drying plants in Latin America.



[2] See also the Cassava Program Annual Report 1990.

Figure 2. Adoption of cassava drying plants in Colombia, 1981-91.



Colombia's North Coast. However during the last couple of years, several changes have been observed (CIAT 1991c).

The market for dried chips has broadened to central and southern Colombia, including large feed companies in Bogotá, Buga, and Cali. It is believed that the majority of the chips for these markets are being supplied by plants on the North Coast. However, the share supplied by plants based in southern Colombia and private chippers has been increasing significantly. This is another indication that cassava processing technology is spreading into new areas.

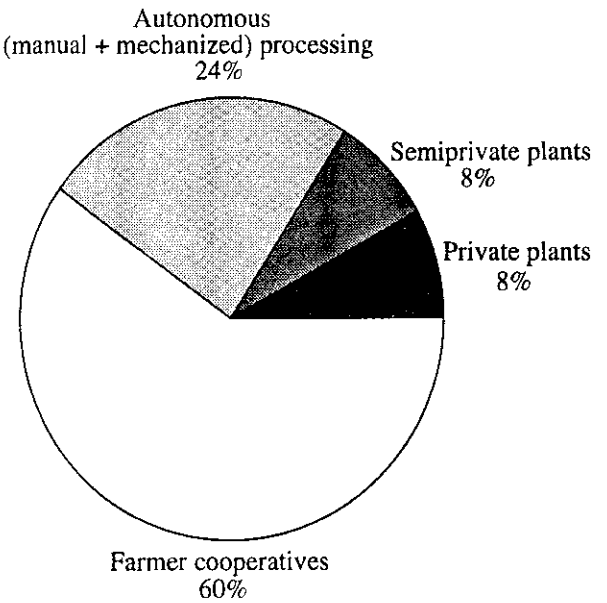
While the initial chip buyers were largely animal feed factories, the current user group is much less homogenous. An increasing demand has been observed from swine, broiler, and egg producers who mix their own feed rations, and from cattle operations that need an on-farm energy source. Cattle raisers use chips to reduce animal weight loss during the dry season, which fortunately coincides with the cassava processing season. In addition, a growing demand has become evident from cassava starch producers who have started buying cassava chips in addition to fresh roots.

The initial cassava processing model as started in Sucre in 1982 was based on a small-scale cassava farmers' cooperative concept. During the last couple of years, this model has been adapted to different commercial objectives and markets. Figure 3 shows that in 1990 an estimated 60% of dry chips (sold only to factories) were produced according to the basic model.[3] The rest was produced by a heterogenous group of processors, based on a large variety of models. It is estimated that for 1991 the latter group has surpassed production of the former. Currently, the following cassava drying models have been identified.

- A small-scale cassava farmer cooperative having an average of 20 legal members.
- A cooperative as above, but with 100-400 members.

[3] Sales to feed factories are the only reliable information that currently exists. It is estimated that these sales comprise between 50-75% of total chip production.

Figure 3. Adoption of cassava drying technology in Colombia by user groups.



Note: Total feed industry usage, 16,500 t.

- An association with 2-4 members who on the average cultivate more land. The drying plant is on one of the member's farm (typical for the Department of Santander).
- Both large and small private commercial plants, owned by one or more people, purchasing all roots from local farmers.
- Private entrepreneur who rents to local cassava farmers his floor and chipper by unit of weight or time.
- Private entrepreneur who visits cassava areas with a mobile cassava drying unit (drying on plastic sheets).
- On-farm small- to medium-scale drying plant as part of a cattle operation.
- Cassava starch processors (Cauca Department) who, when starch prices are low, produce dried cassava chips.
- Individual small-scale cassava farmers who manually chip and dry (on any kind of surface) cassava from secondary quality roots, when the cassava fresh price is too low, or because they are isolated from the fresh cassava market.

Initial dry chip marketing was basically direct negotiating between chip producing plants (or its marketing association) and feed factories. Due to the increasing diversity of producers and consumers, volume traded, and the geographical dispersion of demand and supply zones, intermediaries have entered the marketing channels and introduced one or more pricing points. Among other things, this has made it possible for isolated small-scale, sporadic, and low-volume cassava chippers to sell their product. The introduction of intermediation has increased the marketing margin.

It is evident that this cassava processing technology has been rapidly and widely adopted, in time and space, for different uses and user groups. Strong commercial interest and adoption are probably fair indicators of the potential benefits to be gained from the technology. Also, the adaptation of the original model into a wide array of applied models increases the sustainability of the technology, other things being equal.

Relative Performance of Drying Plants

As part of long-term monitoring, the cassava drying plants on the North Coast were assessed for their individual performance. The objective of the study was to identify and analyze the most important factors that contributed to a plant's success (or failure). In 1991, 29 cassava cooperatives were surveyed. Criteria chosen to rate success were: dried cassava production, profits, capacity utilization, and profits per ton of dried cassava. The general conclusion of this study is that the prevailing factor for a plant's success is adequate root supply commensurate with its floor size, and sufficient working capital (Downing 1991).

With respect to output efficiency, it could be concluded that drying plants situated in the savannah area were more successful than plants in other areas (cassava is a more predominant crop in the savannah, because of harsh agro-climatic conditions). A positive correlation exists between dried cassava production and profits. Assured root supply is more important than processing efficiency and relates directly to the importance of the plant's location. The degree of utilized capacity has some influence on success. More than 60% of successful plants in the savannah utilized at least 50% of their capacities.

When looking at profits per ton of dried cassava, the issue of plant size became apparent. A large drying floor and large dried cassava production were not necessarily a key to success. Although in theory larger plants should enjoy some economies of scale, this was offset by the major problem of coordinating a sufficient supply of fresh roots to operate such plants at efficient capacity. As such, larger plants have had problems with limited transportation (number of tractors), and hauling larger supplies across longer distances.

When it was established that root supply and working capital were the critical factors for a plant's success, both were further analyzed across individual plants. The following issues were directly influencing fresh root supply:

Fresh root purchase price competitiveness. During the processing season drying plants compete for supplies with the demand for fresh roots from urban centers, and to a lesser extent with root demand for starch processing. It was found that during the main harvest, root prices allowed healthy competition. During the dry season, the price offered at plants justified the transport of roots from as far away as 250 km.

Farm size distribution near the drying plant. It was found that two types of farm size distribution had a positive effect on assured root supplies: first, a large number of small (1-2 ha) farms within a 1-5 km distance from the plant; and second, a smaller number (15-25) of medium-sized (2-4 ha) sized farms within a 5-10 km radius. As such, it was demonstrated that a concentration of production in the vicinity of the plant is important.

Tractor availability is an important factor for land preparation as well as for transportating roots from farms to the plant. Under existing conditions, farmers need tractors in order to expand to new planted areas.

Collective cassava fields. A drying plant with collective cassava plantings increases its independence from competing markets. As such, it increases its own-produced supplies and lowers the risk of under-supply. In addition, cooperative cassava plots are a way for farmers to increase production in the absence of individually owned land. In the Department of Sucre, with the assistance of low-cost financing by local institutions, 25-60 ha cooperative plots are common. The majority of these plots produce cassava with improved technologies.

Besides an assured root supply, sufficient working capital has proven to be a major critical factor in a plant's success. When plants have insufficient funds, purchasing is hampered. This directly influences production efficiency. The principal issues behind this are: the absence of savings from the previous processing season; delays in the release of loans to purchase roots; and delays in payments for dried chip sales by feed factories or marketing organizations.

The information that has been generated with this study is of great value in the decision-making process for the expansion of old plants and the establishment of new plants. The feedback of monitoring information serves to increase the successful performance and continued adoption and impact of cassava drying plants.

Cassava Production and Utilization Changes

The formula of integrating cassava utilization, marketing, and production aspects in this research has offered the opportunity to use the drying plants (farmers' associations) as a vehicle to develop, test, and diffuse improved cassava production and management technologies. One methodology to realize this is with pre-production plots, where the best available production

ɔcommendations are tested and validated on-farm in ɔmmercial-sized plots in areas were cassava drying lants have been established.[4] Another method has been) directly involve drying plants in the multiplication ɪd diffusion of improved cassava (and corn) varieties, ɪd in stake selection and treatment methodologies.

For many years, the Colombian National Program CA) (assisted by CIAT) has been developing and dif- ɪsing technology components and several improved arieties through its Division of Technology Transfer. .s a result, there has been diffusion and adoption of a 'ide array of cassava technologies throughout Colom- ia, with most in the predominantly cassava producing epartments of the Atlantic Coast. However, it has ecome impossible to distinguish one specific technol- gy, in a defined area introduced during a specific year, 'om others in different areas and years. What one bserves is a mixture of technologies with different ɔvels of diffusion, adoption, and impact.

)bjectives of the Study

ɪ assessing the adoption of cassava production technol- gy in the North Coast, the first step was to define bjectives and specific hypotheses to be tested. The bjective of the study was:

To analyze the adoption of improved cassava roduction technologies and its effect on the farm roduction, marketing, and utilization system, given ɪcreased cassava demand after the introduction of cas- ava drying plants.

Figure 4 attempts to show in a simplified manner ow production and processing technologies and their doption and impact are interrelated. Dried cassava ɛchnology and the cassava production technology ackage are at the adoption level. The newly created emand will influence on-farm cassava consumption nd sales and will stimulate cassava production at the arm level in two ways. In the short run, the farmer is ble to react by increasing cassava area in the production ystem using traditional technology. In the intermediate un, the farmer will attempt to increase productivity. 'his increases the demand for improved cassava roduction technology. In the intermediate to long run oth productivity and area increase will augment aggregate supply. As such, the following hypotheses are of interest to test:

- increased cassava demand creates demand for improved production technology at the farm level;
- in the short run, farmers increase planted cassava area, decrease fallow period and area, and decrease non-harvested cassava area;
- in the intermediate run, the adoption of technologies will increase cassava productivity;
- increased expected returns on cassava and possibilities of obtaining cooperative credit will intensify cassava production through increased input and tractor usage; and,
- in areas with cassava drying plants, the rate and extent of production technology adoption is greater than in areas without drying plants.

As can be seen from the hypotheses, the current study does not limit itself to adoption only, but includes analysis of impact on production, marketing, and utilization.

Ex-ante Stratification

Three levels of technology influence were identified based on the presence of cassava drying plants and institutions: level 1 representing a high level of influence, level 3 having least influence. The level of technology influence—along with 1985 census data on cassava area by municipality—formed the basis for a representative sample frame and size selection which covered seven departments in Northern Colombia. A farm household survey was developed and tested. Surveying of the first five departments took place in July-October 1991. The preliminary results that follow are from the departments of Sucre, Bolívar, and Córdoba only (N = 299).[5]

On-farm Consumption and Utilization Changes

The newly created demand for cassava dried chips will see an immediate effect on on-farm cassava

For further information on this methodology see the Cassava Program Annual Report 1987-1991, CIAT, 1991a (pp. 186).

It should be noted that, since data for only three departments are available, the results have been adjusted accordingly.

Figure 4. Diagram of the adoption and impact of cassava technologies related to the Integrated Cassava Projects, Colombia, 1991.

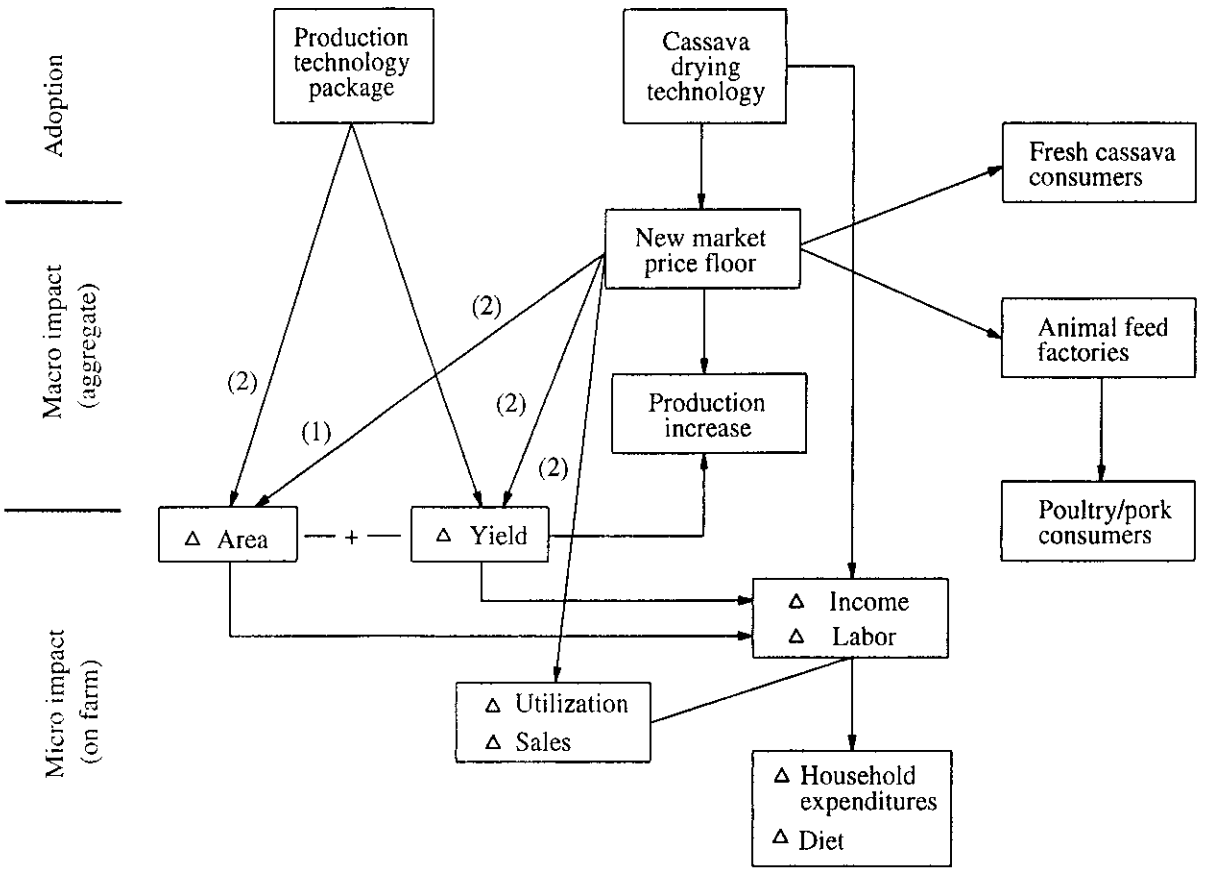


Table 1. Comparison of cassava on-farm consumption and sales[a] in selected states of Colombia by level of technology influence, 1991.

	Average	Technology influence level 1	2	3
On-farm consumption				
family	3.6 (16)	2.7 (12)	5.0 (19)	3.3 (16)
animals	2.3 (6)	1.3 (5)	3.0 (6)	2.7 (7)
Sales to:				
fresh market	13.7 (55)	10.5 (42)	19.4 (66)	11.8 (56)
drying plants	14.6 (16)	15.3 (40)	11.9 (8)	—
other	2.8 (7)	6.0 (1)	18.9 (1)	2.6 (21)
Total production	37.0	35.8	47.2	23.3

Source: CIAT 1991c.

[a]Values are in tons and those in parentheses denote percentage of total production.

consumption and sales. Table 1 demonstrates that farmers consumed 22% of cassava production on-farm, with the majority going to human consumption. While on-farm cassava consumption by farm animals is virtually the same across levels, level 1 typically retains (percentage-wise) less cassava for on-farm household consumption and sells more to the market than level-3 farmers. This is also true when calculated in absolute volume of cassava (Table 1). In other words, cassava farmers in high technology influence areas have become more market-oriented. Cassava farmers have started to substitute cassava for other starches in their diets.

Even more striking is that, currently, 22% of cassava production is sold to drying plants. The remainder is sold to the fresh consumption market. Given the criteria for selection of the different levels used in this study, it is consistent to observe that level-1 farmers sell twice as much cassava to drying plants as level-3 farmers. The latter sell relatively more cassava to the fresh market.

Given the strong influence of cassava drying technology and its demand across technology levels, it would be useful to compare (the little existing) data over time. Table 2 compares cassava consumption and sales data between 1982 and 1991. The differences are significant and consistent with the analysis across levels. It shows that the share of cassava production consumed on the farm (as a percentage of total production) has halved during this period. While the production share sold to the fresh market in Córdoba and Bolívar virtually remained the same, Sucre experienced a major decline in this market from 62% in 1982 to 35% in 1991. The main and most obvious explanation for this is the high concentration of drying plants in this department. This is also the reason for 47% of cassava production being sold to drying plants in Sucre. While Córdoba shows a respectable 24%, farmers in Bolívar sell only 2% for chip production. Compared to 9 years ago, this trend is evidence of the adoption of cassava drying technology. In addition, effects of this adoption have not been restricted to areas with a relatively higher level of technology influence and institutional presence, but also to areas with fewer or no processing plants or institutional presence.

Changes in Cassava Area and Yield

A broader market and more stable prices have induced an increasing adoption of various improved cassava production components. As such, these factors in addition to other exogenous effects have resulted in a change in yield (and of course, a change in cassava net revenues). Data, by level, shows an overall cassava yield average of 12.0 t/ha in a cassava/corn intercrop. Considering that significant technology adoption has also taken place in level 3, this will not correctly serve as an approximation of a traditional (absolute) base. Hence, current data were analyzed by department and compared with results from an earlier survey (Janssen 1982). The comparison (Table 3) shows that since 1982, cassava yields have increased by 52% in Bolívar, 56% in Sucre, and 76% in Córdoba. In addition, comparing current yield averages with the national statistical estimates (Table 4) does not show any significant differences. However, the yield results of the studies need to be interpreted with caution, since they do not capture any fluctuations due to climatological factors.

Table 2. Comparison of cassava yield, consumption, and sales in selected states of Colombia, 1982 and 1991.

	Sucre	Córdova	Bolívar
On-farm cassava consumption[a] (% total production)			
1982 study	34	38	37
1991 study	17	18	28
Sale to fresh market (% total production)			
1982 study	62	53	60
1991 study	35	57	69
Sales to drying plants (% total production)			
1982 study	0	0	0
1991 study	47	24	2

Source: 1982 study: Janssen 1982; 1991 study: CIAT 1991b.

[a]This includes both human and animal cassava consumption.

Table 3. Comparison of cassava yields (cassava /corn intercrop) among selected states in Colombia, 1982 and 1991.[a]

	Sucre	Córdova	Bolívar
1982 study	7.0	6.8	7.5
1991 study	10.7	12.0	11.4

Source: 1982 study: Janssen 1982; 1991 study: CIAT 1991b.

[a]Values given in t/ha.

A farmer can increase cassava production by augmenting cassava area in several ways, assuming that, in the short run, total farm size remains the same and that improved technology is not (yet) adopted. These options are: (1) increase planted area by reducing area in fallow or pasture or other crop; and (2) increase area in cassava mono-culture. In addition, traditionally non-cassava growing farmers can start to plant it.

Table 5 shows that total crop area, both in absolute terms (ha) and as a percentage of total farm area, is larger at level 1 than at level 3. Hence, cassava farmers in areas of technology influence on the average plant a larger area with crops. The share of crops versus other farm activities is also larger than on cassava farms in areas with low technology influence. This seems consistent with the observation that farmers at level 3 dedicate relatively more of their farm area to pastures than in level 1. These areas are 68% at level 3 and 57.8% at level 1. Also, the absolute size of pasture land in level 3 is more than twice as large as at level 1.

On the average, 27.7% of cassava farmers in the sample keep land in fallow. The size of fallow land compared with the size of crop land averages 20%. However, while for level-1 cassava farmers this is only 14%, it is 40% for level-3 farmers. This implies that cassava farmers in high technology influence areas have significantly decreased their fallow land. Percentage-wise, more level-3 farmers have more land in fallow than level-1 farmers.

Table 4. Cassava area, yield, and production in Colombia, 1986-91.

	1986	1987	1988	1989	1990	1991[a]	Annual growth (%)	Absolute growth (%)
				area (100 ha)				
Sucre	8.0	11.5	7.1	11.0	17.0	20.0	17.7	150
Córdova	7.3	10.0	6.9	14.0	16.8	15.9	17.5	118
Bolívar	17.0	20.0	18.0	23.0	28.4	24.2	8.7	42
Atlantic Coast	61.1	8.7	69.8	84.5	109.1	112.4	12.0	84
Colombia	153.3	159.1	148.8	170.6	207.3	219.7	7.8	43
				yield (t/ha)				
Sucre	8.0	8.9	10.0	11.0	10.0	12.0	17.7	50
Córdova	7.8	7.0	5.0	8.3	11.3	11.3	11.8	55
Bolívar	7.5	7.0	7.5	8.5	9.2	9.3	5.8	24
Atlantic Coast	7.8	7.7	8.1	8.7	9.1	9.8	4.9	26
Colombia	8.7	7.9	8.6	8.8	9.3	9.5	2.7	9
				production (000 t)				
Sucre	64.0	102	71.0	121.0	170.0	240.0	24.8	275
Córdova	53.3	70	34.5	116.2	190.0	179.5	29.4	237
Bolívar	127.5	140	135.0	195.5	261.7	226.4	14.6	78
Atlantic Coast	475.0	604.0	568.4	734.4	990.6	1,097.0	16.9	131
Colombia	1,335	1,260	1,282	1,509	1,939	2,079	10.5	56

Source: Ministry of Agriculture, Bogotá 1991.

[a]Preliminary estimate.

When analyzing the relative importance of cassava in the cropping system (Table 5), the data indicate that cassava at all levels takes an important place. We even see that the cassava area as a share of crop land is larger with level-3 farmers.

Information from previous cassava production surveys showed that because of large cassava price fluctuations, at times it was not economical to harvest part of the cassava area. Harvesting labor outweighed the low revenues from cassava sales. However, when we analyze the current data, on average 86% of the farmers in the sample contested that they **always** harvested the same cassava area as was planted. This answer was given by 98% of level-1 farmers compared to 89% of level-3 farmers. The small difference between these two levels is because of the influence that all levels enjoy from stabilized cassava prices. This results from the dried cassava price functioning as a price floor in the fresh cassava market.

These data show that for all aspects, in the short run, cassava farmers are increasing cassava production by reorganizing areas in cassava and in fallow, and in harvested area. Secondary time-series data on cassava area, yield, and production seem consistent with the above notion. Table 4 demonstrates that between 1986-91 the cassava area in Sucre experienced an annual growth of 17.7% and in Córdoba 17.5%.

Impact of Cassava Drying Plants

Cassava drying plants have caused an impact at various levels and for different beneficiaries. As shown in Figure 4, increased market opportunities and more stable prices result in a cassava area increase at the farm level. In the intermediate run, farmers start to adopt production technologies in order to intensify production, resulting in higher productivity. The augmented supply under better market conditions improves farmers' cassava revenues. In addition, cassava producers slowly change from subsistence farmers to market-oriented farmers. This results in less on-farm cassava consumption. At the farm household level, this will gradually change expenditure patterns and diets.

One of the final goals of development and diffusion of cassava production and utilization technologies has been to improve small farmer incomes. When looking at overall production technology adoption figures, Table 6 shows that 71% of the surveyed farmers had adopted at least one production technology component. Again, this figure was significantly higher at level 1. It also shows that 59% of cassava farmers have experienced increased cassava demand and a broader market over the last half decade. In order to capture the effect of introduced technologies, the farmers were asked if they had experienced a gain in cassava revenues resulting from technology adoption. Eighty percent of the farmers agreed to this statement. The reasons for this

Table 5. Changes in area utilization of cassava farms by level of technology influence in several states of Colombia, 1991.

	Average	Technology influence level		
		1	2	3
Total crop area (ha)	3.5	4.1	3.4	3.1
Crop area, (%) total farm area	29.0	34.0	35.0	22.0
(%) farmers with pasture	55.0	71.0	49.5	45.5
Average pasture area (ha)	13.7	9.9	11.8	21.1
Pastures, (%) total farm area	62.6	57.8	60.0	68.0
Average cassava area (ha)	2.5	2.7	2.4	2.3
Casava area, (%) total crop area	70.0	66.5	70.0	74.0
(%) farmers with fallow land	27.7	25.5	19.6	37.6
Average fallow area (ha)	2.5	2.3	1.4	3.3
Fallow area, (%) total crop area	20.0	14.0	8.1	40.0

Source: CIAT Cassava Economics 1991b.

Table 6. Comparison of cassava technology component adoption in selected states of Colombia, by level of technology influence, 1991.[a]

	Average	Technology influence level 1	2	3
Adoption of at least one production technology component	71	85	69	59
Increased demand and broader market	59	71	57	49
Income improvement from cassava technology	80	91	73	75
Reasons for income improvement				
better prices	43	33	53	49
better markets	40	48	26	41
better production	9	16	7	1

Source: CIAT Cassava Economics 1991b.

[a]Values given are in the percentage of surveyed respondents who had adopted the technology.

income improvement could be divided into "better prices," "better markets," and "better production." Better markets and prices captured 83%, while the reason "better cassava production" was 9%. It is especially interesting to analyze these results across levels. More farmers at level 3 find better cassava prices important for income improvement than at level 1. The latter showed a relatively higher response for better production. This is very consistent with observed adoption levels. Level-1 farmers have experienced more adoption of production technologies than level-3 farmers. In the latter group, prices and markets are relatively more important.

When analyzing benefits from technology at the consumer level, Figure 4 shows that increased cassava supplies will decrease fresh root prices. Given cassava demand elasticities and relative prices of substitute carbohydrates, it is visualized that fresh cassava consumption in the lower income strata of the population will increase. In this manner, cassava consumers are directly benefitting from lower retail cassava prices. These benefits are currently being quantified by CIAT's cassava economics section.

However, it can be shown that the additional value of dried cassava currently amounts to US$ 7.5 million/year. Animal feed factories on the average reduce costs by US$ 10/t of substituted sorghum, which means an accumulated direct gain of US$ 500,000 for this industry in 1991. In addition, the decreased (partial) reliance of the Colombian animal feed industry on sorghum imports, translates into an annual foreign exchange savings of US$ 5.1 million. Part of this sum represents government savings on decreased domestic sorghum subsidies (in the form of high support prices), since dried cassava substitutes for imported and/or domestically produced sorghum. As such, this has decreased the social cost (Henry and Best 1991).

Besides direct and indirect monetary benefits, the cassava drying technology has generated substantial employment opportunities. It is estimated that with current production, approximately 1,263 man/yr of labor are being directly generated each year. In addition, cassava drying has produced backward and forward linkages in other industries and services. This is estimated to amount to 252 man/yr (Henry and Best 1991). Creation of employment opportunities in these marginal cassava producing areas is crucial, since poverty and unemployment indices are most often the highest (as is the case for Brazil, Ecuador, and Colombia).

The above measures of technology impact have been relatively easy to quantify. However, additional indirect impacts on community welfare, institutional support, and the environment can only be described qualitatively at this stage. It has been observed that the introduction of cassava drying cooperatives has increased community development in general. Cooperatives form an incentive to start other non-cassava related community activities. Moreover, cooperatives serve as a vehicle for strengthening local institutional support and technical assistance in the area. Also, cassava

drying activities have sparked a dialogue between local institutions.

Cassava has traditionally been discriminated against in the allocation of national research, extension, and credit resources in favor of primary crops like grains. With the introduction of cassava drying activities and the subsequent increase of institutional collaboration and awareness about the significant benefits and future potential for this crop, cassava is gaining more political clout. This will positively benefit future national cassava research and development.

Conclusion

In the previous sections it was shown that cassava drying technology has achieved significant adoption levels. And that the cassava drying model which was originally introduced has been modified to fit different interests, objectives, and environments. It was also demonstrated that on-farm consumption and sales patterns have changed. Cassava farmers currently can maximize cassava sales by selling their roots to either the fresh or dried cassava markets. Increasing adoption of cassava production technologies, together with a wider market, have increased farmers incomes, while consumers, processors, and government are also reaping benefits from cassava technologies.

When relating these results with the stated hypotheses, they indicate that all the hypotheses hold. The data have shown that given increased cassava demand, farmers augment cassava production area and adopt technology components to increase productivity. Thus, increased cassava demand has increased the demand for improved production technologies. It also holds that in areas with a higher concentration of cassava drying plants and institutional presence, the level of production technology adoption is greater than in areas with few (or no) drying plants and little institutional presence. In addition, it seems that cassava drying cooperatives can very well serve as an efficient and effective vehicle for production technology diffusion. However, the analysis so far presented is based on an incomplete sample. As soon as all the data are collected and analyzed, a more in-depth study of some of these aspects can be made.

Besides further in-depth analyses on adoption aspects, assessment needs to be done on how changes in the cassava production system affect the preservation of the natural resource base. This is important, given that the predominantly cassava production areas are mainly in regions with highly fragile soils. Another aspect regarding the sustainability of improved cassava technologies is the effect of governmental policies on the comparative cost advantage that cassava enjoys in substituting sorghum in animal feed rations. The opening of Latin American economies to world markets and its effect on the future potential of cassava is a subject for detailed investigation.

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A Note on Writing Research Reports

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The Three "R's" of Writing a Research Report: Getting It Written, Getting It Right, Getting It Read

Gregory J. Scott[1]

Abstract

Many researchers often find it easier to collect and analyze data than to synthesize their findings in a research report. This paper provides some practical suggestions on how to make the report writing exercise less tedious and the final product more effective. Examples are frequently cited based on the author's own experience or procedures of others as gleaned from the literature. Key elements emphasized in the paper are planning, and breaking larger tasks into more doable endeavors. A checklist of questions for effective report writing is included in a supplement.

Key words: writing, research report, planning, procedures.

Introduction

Most agricultural research projects are judged on the basis of methods, findings, and recommendations presented in a written report. Few people have time to go to the field to review procedures, to re-analyze data collected or to talk to researchers about results. Despite the importance of preparing a well-written report for the success of applied agricultural research, the literature has emphasized instead the theoretical or conceptual underpinnings of such work or ways to improve (e.g., speed-up) data collection and analysis. Relatively little has been said about how to go about writing the research report itself.[2] The purpose of this paper is to provide some practical suggestions on how to do this more efficiently and more effectively. The first part presents tips for preparing a first draft of a research report. The next part proposes guidelines on polishing that first draft into a truly readable final version. The final part offers some advice on how to broaden the diffusion of the report's central findings. Though the term report is used throughout, it applies to all forms of reporting research results including articles, papers, and studies. Supplement 1 consists of a checklist that summarizes many of the points raised in the paper.

Getting It Written: Putting Together a First Draft

Psychologists tell us that it is often easier to tackle a complex job by breaking it down into separate pieces of work which can be finished more easily. In the case of agricultural research, one commonly thinks of three phases: (1) research design; (2) data collection and analysis; and, (3) writing the final report. The first two phases are the most interesting. Writing the final report frequently proves much more tedious. One way to try and make this job less onerous is to break down the preparation of a final report into smaller bits of work. The most obvious distinction here is between preparing a draft and completing a final version. This part of the paper suggests ways to make a writing of a first draft less demanding; the following part offers similar ideas for finishing a final version.

Beginning at the End: Think of the Report First

Research reports are typically prepared at the **end** of a research project. Holtzman (1986) suggests another approach. He proposes thinking very carefully at the begin-

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[2] This problem is touched on albeit briefly, in Casley and Lury (1981:166-167, 174-182); Holtzman (1986:63-65); and, for policy memos, Monke and Pearson (1989:242-252).

ning about a tentative table of contents (see below) that includes a list of topics to be covered in the final report. More specific ideas then can be jotted down under the section headings for easy reference. This serves as a sort of checklist or guide—in addition to the original research proposal—as to what sort of data are essential versus information that need not be collected. It also makes it easier to separate sections (e.g., literature review and analysis of secondary data) that can be written as the study progresses rather than wait till the end to write up everything. The basic point is that a first draft of a research report is easier to prepare if one doesn't wait to begin doing so until the end, when the researcher is mentally tired, frequently short of time, and under pressure to complete the job.

Budgeting the Time and Resources

Successful agricultural research requires many things, but perhaps none more important than the planning needed to complete a final report. Writing a good report is not easy, but writing such a report in one-tenth or one-twentieth of the time necessary is impossible. How much time is necessary? A rough estimate is nearly the amount of time needed to collect the data. Remember: writing not only takes time but also mental and financial resources. If you exhaust yourself in the data collection, you simply won't have the powers of concentration needed to complete a report. Furthermore, preparing and publishing a report costs money. Many researchers are unable to complete their reports because they failed to consider at the outset the resources necessary to do so.

Taking too much time to write a report can also be a problem. Some researchers want to prepare **the** definitive statement on the topic i.e., definitive in detail, in length, in coverage. In so doing, they themselves create an insurmountable obstacle to completion of their report simply because there is never enough time for a perfect report. Remember an imperfect report can be made better with revisions, editing; hence, a report always has to be finished first, then improved on.

Getting Started: State a Question, then Answer it

Some people have difficulty preparing a draft report because they have so much material, so many ideas that they don't know where to begin. One way to overcome this difficulty is to specify the key research question (or hypothesis) the report is intended to address. If that question can be clearly identified at the beginning of the report and the reason(s) why it is important, then what follows becomes simply an attempt to answer the question (or to address the issue).

In formulating the key question for the research report, utmost care should be taken to ensure that it focuses on the original objectives of the research project. Some reports pose, then answer extremely interesting questions; but fail to consider the project's objectives in so doing. Clearly, a research report needs to do both.

Different researchers use different techniques for writing the opening paragraphs of a report. Three of the most common include a statement of: (1) a key question to be addressed; (2) the purpose or objective of the study; or (3) the principal theme or subject matter to be discussed. These techniques are not mutually exclusive. For example, the author may state a question, "Under such circumstances, the following key question frequently arises: if growers produce more potatoes, where will they be marketed?" He then may follow this with a statement of purpose such as, "the purpose of this study is (1) to provide an answer to this question, in the particular case of Thailand, and (2) to present an example for similar studies in other Southeast Asian countries." Additional examples may be found in the **Preface** or **Introduction** of most research reports. Other studies therefore may provide some useful ideas on how to begin your own report.

Building Blocks for a Research Report

Once the topic has been defined and its importance indicated, the report should contain treatments of a series of related subjects. These include: (1) the methodology used; (2) the results and what they mean; (3) the conclusion, followed by a discussion of the implications for policy and for future research; and, (4) and a list of references. Although these are essential components of almost any research report, how they are structured can vary according to each author's own judgement. Ideas on how to organize a report can be found by looking through the table of contents of different reports. The important point here is that any report should include these essential components.

Once these building blocks are in place, the first draft is well on its way to completion. Nevertheless, it's easy to become overwhelmed by the prospect of writing a report, especially if you envision the task as something to be completed in one tremendous burst of energy. A more practical approach is to build on the ideas (possibly paragraphs) noted down in the course of the data collection and analysis as alluded to earlier. If the writ-

ing does not flow freely—or to make it easier, it may be useful to prepare a fairly detailed outline with chapter and sub-sections. Topics to be discussed under each sub-section can then be briefly written under each heading in a few words or a phrase or two. Utilizing this outline, one can then spend time each day writing one or two subsections of a chapter. Getting a little done over several days gradually builds self-confidence and a sense of momentum. As the sub-sections and then chapters are written up, the report itself becomes easier to work on because one can see the final product materializing.

Balance and Focus

In drafting paragraphs or chapters for a final report, one might well ask: how much space should I devote to discussing a particular section? A helpful guideline is to remember that the bulk of the study should be devoted to the presentation and discussion of the research findings. As such it should represent well over 50% of the body of the report. Another 10-15% should go to the **Introduction** and **Conclusions**; the remainder should cover the methodology used, the review of the literature, etc.

Report writing (**and** reading) can get bogged down if a disproportionate share of space is devoted to defining the topic or explaining the methodology. If there is more to say about methods for example, the most important points can perhaps be summarized in the main body of the report and the rest presented in an appendix. Put somewhat differently, a first draft should get quickly through the preliminary sections or chapters to emphasize the discussion of results. Furthermore, many reports present page after page of data but then only the briefest **Conclusions** (if any at all). Or many an author, apparently in a rush to finish the report, will overlook the recommendations or simply list them without any explanation. The contents of this section of the report may seem redundant or obvious to the author-researcher, but they clearly need extra attention if they are to be easily understood by others. Other studies can provide additional ideas on the proper proportions to give a report.

Focusing on only **relevant** research results can also help speed-up the report writing process. Many people confuse writing up their research results with writing down **every** research result. Remember: keep the report focused on the question to be answered; if need be, some—even a lot—of the data collected may have to be left out. By focusing on the pertinent material, the preparation of a first draft can be made that much easier.

Working Around Writer's Block

Some researchers can prepare a detailed outline, start out writing a draft report, but then find that their mind goes blank. They complain that they can't seem to write anything on the next topic. They try doing something else for a few days, but often this results in their falling completely out of the writing frame of mind. An alternative approach is to go beyond the topic that one has nothing to say on for the moment to one somewhere else in the table of contents that one can more easily write about. Once one or two sub-sections are finished, one can more easily go back to the more demanding parts and write those up.

The combination of these suggestions should help you plan the time required to write the first draft, organize and develop the basic topics to be covered in such a document, and complete the initial version of your final report by not overextending the coverage and working around momentary lapses in concentration. The next part suggests ways to transform the rough draft into a polished final report.

Getting it Right: Preparing the Final Version

Once the draft of a research report has been completed, the author shifts his attention to sharpening the analysis and improving the style. The following ideas are intended as suggestions to help facilitate this process.

Seeking and Using Comments

Some researchers assume that they are solely responsible for the contents of their reports, only to be completely dismayed when key readers cannot follow certain passages in the text or when an important policy maker points out that a critical issue has been overlooked. Even the most renowned scientists solicit comments. The point is to not take such criticisms personally (sometimes a lot easier said than done) and to look for the useful comments and react to those, ignoring the rest. One test of validity is to discuss comments with a colleague who understands your work. There is often more objectivity from a friendly, not objective other.

A prospective policy maker is more likely to respond positively to a report's recommendations if he is given the opportunity to provide some input into the conclusions and policy proposals. Nobody likes to be presented with a *fait accompli*. On the contrary, many

policy makers and administrators may be flattered that someone actually asks them for their opinion. Moreover, if you ask someone for comments and they fail to respond, then they can't complain about the contents of the final report.

Researchers can also make the opposite mistake by circulating a draft that contains so many errors and omissions that, in effect, they expect the commentators to help them write the report. One consequence of passing around a poor quality draft is that the serious reader can readily correct so many basic mistakes in spelling, syntax and data presentation that he or she never has to grapple with substantive issues. If one hopes to receive quality comments from reviewers, then provide them with as good a draft as possible.

Stating the Obvious First

When one writes a research report, one tends to emphasize less what is certain and more what remains to be studied. Remember: a research report is for people who know less about the topic than the author. One therefore may need to explain certain basic facts that may seem obvious to the researcher, but that are much less evident to the reader. For example, if the report discusses farm production problems, then a **brief** discussion of the various types of crops grown, their relative importance in terms of total production would help orient the reader. Alternatively, if it analyzes consumption patterns for a given commodity, some information on the composition of the overall diet would also be helpful.

Some studies dedicate considerable space to explaining and qualifying specific information about particular producers, consumers, or traders without mentioning any of their common traits or predicaments. For example, it may be interesting that different types of producers paid different prices for labor, fertilizer, and pesticides; but, this fact should not obscure general results like the number of producers interviewed, or, that no producers used mechanical equipment in their crop production. Therefore, after completing the presentation of this type of data, re-read the results and ask yourself: have I included the most obvious relevant information?

Presenting Both Sides of the Issue

A research report is always much more convincing if it acknowledges different points of view, explains their respective strengths and weaknesses, and offers evidence to support one position rather than another. Most serious readers tend to be sceptical. If you expect to convince them, you have to indicate that you are aware of other points of view, that you understand them and can account for them in your interpretation of the evidence. In contrast, reports that only present the author's point of view can be dismissed by policy makers as "narrow" or refuted by critics whose own arguments (quite possibly erroneous) sound more persuasive because they mention both sides of the issue.

Being Accurate and Consistent

There is always a temptation in applied research to overstate the case. The interpretation of the evidence tends to go beyond what the facts themselves would allow. Although this may only be true for a tiny portion of the report, it tends to discredit the entire study. If the results offer indications that something is true without confirming it beyond a doubt, it is best to say instead, "it appears that..." or "the weight of the evidence suggests."

The careful reader will also detect inconsistencies in a report. For example, if you are going to say something about food consumption when discussing food production, then subsequent statements about production when analyzing consumption had better be consistent. In individual chapters, the inconsistencies may not be apparent. Therefore, during the revision of the rough draft, this is something to watch out for in particular.

Spelling, Syntax, and Grammar

Any draft report may contain spelling errors or errors of syntax.[3] Nevertheless, a final report that is riddled with these mistakes may disconcert the reader as readily as one with obvious errors of fact. Careful re-reading can eliminate them. Even the most experienced researcher recognizes the need for this type of text editing.

[3] Standard guides to professional writing include: *The Chicago Manual of Style*, 1982 (13th edition,) University of Chicago Press; *Words into Type*, 1974 (3rd edition), Pretince-Hall, Inc.; *CBE Style Manual*, 1983 (5th edition), Council of Biological Editors, Inc. See a major library near you for additional materials of this type. Note as well that some research institutes have specific guidelines for the diffusion of research results. For example, in Peru, the Ministry of Agriculture has published a manual on how to go about this, *Manual Normativo para l Difusión de los Resultados de la Investigación Agropecuaria*, 1977, Ministerio de Agricultura, Peru.

The same attention is required in the presentation of data. Any time sources and citations are not present in a research report, the credibility of the document comes into question (even if the data presented and references made could be completely verified). It suggests that the author is careless and therefore implies that his policy recommendations may be similarly flawed. If the report includes data in the text or tables, include a source for these figures. If they are data from a project survey, simply put "Source: Survey for this study." Similarly, all tables should be constructed alike: numbers, title, sub-headings, sources, and notes (I also like to put sources on all figures and maps). If the presentation varies markedly from table to table, it makes it more likely that there will be errors or omissions that are overlooked in revisions. Check the presentation in similar studies to get an idea of the different acceptable formats and to appreciate how professional writers adhere to them throughout their publications.[4]

Breaking Up the Text

The longer the report, the more complicated the argument, the greater the need to try and set up certain "signposts" to guide the reader and some "rest stops" for him to collect his thoughts before moving on. Most reports are easier to follow if they include a brief (1-2 paragraphs) introduction at the beginning of each chapter in which the topics to be taken up in that chapter are identified. Such chapters can also conclude with a brief summary and a phrase or two which provides a transition to the next chapter.

Within segments of the report (be they chapters or sections), it is also a good idea to put subject headings every time the focus of the text shifts from one major topic to another. In so doing, the heading alerts the reader to changes in subject matter. It also allows for easier, later reference to the discussion of particular topics.

Rewriting: Less is More; Too Little Not Enough

In addition to the other improvements mentioned above, rewriting should aim to minimize repetition, to shorten phrases or paragraphs that are simply too wordy and to eliminate irrelevant sections or data. The basic objective of report writing is, after all, to **inform** the reader, not to bore him.

One of the most effective ways to shorten a report without necessarily eliminating relevant information is to put all but the essential tables in an appendix. If the main body of the report contains more data than analysis, the critical reader suspects that the researcher may not have known precisely what it was he was looking for, nor what to make of the data collected. When the text refers to data in the appendix, the reader is less likely to get bogged down reviewing number after number while remaining appreciative that the figures are readily accessible if they need to be consulted.

There is, however, a danger in being so concise that the text becomes cryptic. Effective rewriting requires both eliminating the unnecessary and clarifying the essential. Policy recommendations deserve special attention so that decision makers (who want to take the researcher's advice) know precisely what it is that is being proposed.

These practical suggestions should help in the preparation of a well written, final research report. But that's only part of the job. If the research is to have an impact at the local, regional or national level, the next task is getting the findings read.

Getting It Read: Circulating Your Own Research

Agricultural scientists sometimes take the attitude that once they've finished the report and provided written recommendations it is up to a benevolent (or omniscient?) policy maker to recognize the brilliance in the findings and policy implications. Things rarely work that way. Alternatively, these researchers may assume that most of their potential readers could care less so why bother trying to reach a broader audience? The fact is that scientists have to edit their results differently for policy makers and fellow researchers. Here are some practical suggestions on how to go about this.

The Abstract

The purpose of the **Abstract** is to provide the reader with an encapsulated version of the entire report: the problem to be analyzed, the most salient research find-

[4] See the publications listed under Footnote 3 for more detailed advice on this issue.

ings, and the implications for policy and future research. Ideally, this brief paragraph focuses on only the key components of the entire study. Some authors prefer an **Executive Summary** (see below) instead. However, the **Abstract** can be an effective way of getting the message to interested readers who simply do not have time to read more. If done well, it can even prompt those who may have never bothered to read the report to actually do so.

Style and content are also (if not more) important in an **Abstract**. A crisply written **Abstract** crammed with results and policy recommendations can stimulate interest; a flat bit of prose bores readers. Likewise an **Abstract** need not answer all questions posed in the report, but it certainly should address one or two. Readers need something substantive if they are to consider reading the main report let alone grasp the essential findings.

The Executive Summary

A second way to provide busy readers with the report's basic message is an **Executive Summary**. Many people might want to examine the entire study, but simply do not have time, e.g., they may need to make a decision now. If the report provides a 1-3 page summary at the beginning, this can stimulate someone to at least familiarize himself with the essential findings. People who read the **Executive Summary** might even be motivated to look at the complete report. It should be emphasized that the **Executive Summary** must provide a complete and accurate synthesis of the findings and recommendations so that those who only read this abbreviated version get the same information (just without the detail) as those who read the full length report. Particular attention must be given to include a succinct, but complete review of the policy recommendations. A quick look at copies of other studies that include such summaries can provide some specific examples of how to go about this.

A Concise Version of the Report

A separate, short report in which you include only the most essential data and a bibliography (which cites the main report) is another option. It may not be possible to duplicate numerous copies of the complete final report—including the **Abstract** and **Executive Summary**—given its length and the resources required for such a job. A thinner version can be circulated to a much larger number of people. Those that are interested can consult the complete version for more detail or to examine the data.

Finally, many reports are not widely read because they simply are not available, e.g., the author has one copy and his immediate boss (long ago transferred to another position) another. In many research institutes, the researcher is required to furnish one or two copies of his research report for the institution's main library. This procedure is to be recommended as a general practice.

Published Summaries and Popular Articles

In many research organizations, it may not be feasible to distribute sufficient copies of your final report to ensure proper diffusion of the findings. Nevertheless, such institutions frequently have research bulletins or magazines in which an abbreviated version of the report might well be printed. For example, the National Agricultural Research Institute in Peru (INIAA), publishes the *Revista del INIAA*; in the Philippines, the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) prints the *PCARRD Monitor.*

Developing countries typically have various publications in which articles will appear on agriculture and rural development. In Peru, for example, popularized articles often appear in such magazines as *Agro-Noticias* while short research pieces appear in *Actualidad Económica del Perú.* Results of a recently completed, original piece of applied research is just what readers of these publications find of interest. A small summary for publication in this type of press enables the results to reach an audience that the researcher perhaps does not normally come in contact with.

Conference and Seminar Papers

Meetings of professional associations, conferences, and seminars organized on particular topics are another avenue for presenting the results of your research. While such meetings typically have particular requirements in terms of topics to emphasize and the acceptable length and style of paper, they do offer the opportunity to reach an audience that one may not have come in contact with and therefore it is worth the extra effort. If the report itself has been written up, it usually does not require that much additional work to prepare another paper.

The advantages of this type of vehicle for publishing a segment of the report's findings are twofold. First, it gives one the chance, perhaps, to put a different slant on the ideas presented in the report in addition to presenting the basic findings in a new forum. Second, some ideas that may not have been as clear or as well developed as one might have wished in the original paper can now be clarified or elaborated on.

Refereed Journals at Home and Abroad

In nearly all developing countries, professional journals are published by local universities, development institutes or professional associations, e.g., *The Philippine Agriculturalist, Bulletin Agricole du Rwanda*, or *India Journal of Agricultural Economics*. Although publishing in such specialized journals frequently will require rewriting the final report to conform to the publication requirements of the journal in question, this bit of additional work is modest in comparison with the time and effort that went into preparing the original study.[5] And, publishing in a specialized journal brings the results to the attention of the professional research community—a group often more diverse than simply those who do research in Ministries or National Agricultural Research Institutes.

Some researchers assume that the only appropriate professional journals to publish in are those abroad. However, those journals published in the country where the research is carried out are likely to be much more interested in the results because their readers may be planning to do research on a similar topic. Such publications are also more likely to come to the attention of policy makers in the countries in question.

Professional journals in foreign countries are another possibility. Each journal has its own particular readership, requirements in terms of style, as well as topics about which they are most likely to publish articles. Such information can be gathered by visiting a major library and perusing back issues.[6]

Conclusion

This paper has presented a set of practical suggestions for preparing a first draft, polishing a final version, and diffusing the results of a research report. The information contained in the accompanying Notes, References, and Supplements offer additional suggestions. After reviewing these materials, readers may want to consult a major library for additional ideas on one or more of the points mentioned.

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[5] A useful publication in this field is Robert Day. 1983 (2nd edition). How to Write and Publish a Scientific Paper. Professional Writing SCR. Institute for Scientific Information. Philadelphia, PA, USA.

[6] A complete guide to refereed journals can be found in Ulrich's International Periodicals Directory (1986-1987). 1986 (25th edition). Vols. I and II. R. R. Bowker. New York, NY, USA.

Supplement 1

A Checklist for Effective Report Writing

1. Have you developed a tentative table of contents for the final report at the beginning of your research project?
2. Have you set aside enough time to write, revise, and print your research report? Have you included report writing and printing costs in the research budget?
3. Have you prepared a detailed outline for the final draft? Does it include sections on methodology, results, conclusions, and recommendations with specific topics to be discussed under each? How does it compare with the table of contents in similar studies?
4. Does the Introduction of your report identify a key research question(s) to be answered? And indicate its importance?
5. In your report, do you explain the methodology you used? Are detailed methodological facts placed in an Appendix?
6. Does your report include Conclusions? Are there recommendations to policy makers? Have you identified topics for future research?
7. Does the report include a list of references?
8. Do tables, figures, etc., all follow the same format? Do they include necessary information such as source, units of measure, economic values, etc.? Have you checked other publications to see how the format you use compares?
9. Have you eliminated all basic mistakes such as spelling errors, typos, inclusion of sources from your draft **before** you circulate it for comments? Have you corrected errors in syntax and grammar?
10. Have you checked for inconsistences in the data presented in different sections of the study?
11. Does the report devote most of the text to research results and discussion?
12. Have you sought out comments on a first draft from key decision makers?
13. Does the report present both sides of key issues?
14. Have irrelevant data and repetition been eliminated in the rewriting of the first draft? Can large sets of numbers be placed in an Appendix?
15. Are the policy recommendations fully developed and easy to understand?
16. Does the report include an Abstract? an Executive Summary?
17. Have you considered preparing brief summaries for publication in the Institute's own research bulletin or in popular magazines?
18. Have you checked at a research library for local refereed journals that might publish an article based on your report?

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