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From lab to life: Making storable orange-fleshed sweetpotato purée a commercial reality

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Abstract: Research in Rwanda demonstrated that orange-fleshed sweetpotato (OFSP) purée (steamed, mashed roots) was an economically viable, vitamin A enhancing ingredient in baked products when the purée was produced and used in the same bakery. Having a storable, packaged OFSP purée produced by a firm to supply bakers is an alternative model. Vacuum-packed OFSP purée with preservatives with a four-month shelf-life at 23°C was developed by the International Potato Center under laboratory conditions in 2015. Turning it into a commercial reality required developing a public-private partnership to establish an OFSP purée-bread value chain. The phases in developing the chain are described. Cost-benefit assessment focuses on two points along the chain: the farmers producing roots for the purée factory and purée production. The first OFSP bread began to be marketed in six Tuskys' stores in June 2015 at a premium price (5 Ksh above its regular bread), reaching 20 stores by August 2016. OFSP bread was well-received by consumers. Purée production became profitable (18% profit margin) when we shifted from using peeled to unpeeled roots--the new product being a "high fiber" purée. Commercial OFSP purée production has been improved and is poised for profitable, larger-scale output.

Keywords: orange-fleshed sweetpotato, purée, value chain, storage, viability, vacuum-packing, food safety, vitamin A, carotenoids

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1 Introduction

There is increasing interest in developing agro-industries in Sub-Saharan Africa (SSA) to expand agriculture's key role in poverty reduction (UNIDO 2009). In part, this recognizes the rapid rate of urbanization in the continent (Jedwab et al. 2014), with greater proportions of the population purchasing rather than growing their own food. Moreover, urban consumers often opt for foods in "convenient" processed forms, which can be consumed immediately or require reduced preparation times (Thiele et al. 2009). There is also increasingly greater interest in integrating the consumption of nutritious foods into agri-value chain development (Henson and Humphrey 2015).

The Sweetpotato for Profit and Health Initiative, led by the International Potato Center (CIP) and launched in 2009, seeks to improve the lives of 10 million households in SSA by 2020 through access to improved varieties of sweetpotato, especially orange-fleshed, pro-vitamin-A-rich varieties and their diversified use (Low 2013). Over 90% of sweetpotato consumed in the continent is boiled, steamed, or fried in contrast to other countries, such as China where sweetpotato is utilized as flour or purée in baked goods, candy, dried strips, juices and noodles (Low et al. 2009).

The CIP and the Rwanda Agricultural Board (RAB) implemented the Rwanda Super Foods project, a five-year effort (2010-2014) that developed an orange-fleshed sweetpotato (OFSP) processed product value chain. Rwanda is a country where sweetpotato is a primary staple food but farmers complain about the lack of adequate markets for their roots. Working in close collaboration with the largest - Rwandan-owned agro-processor (Urwibutso Enterprises), we developed two appropriate economically-viable processed products: 1) a biscuit (cookies), in which 43% of the wheat flour was replaced by OFSP purée (steamed and mashed sweetpotato) and 2) donuts, where 20-50% of the wheat flour was replaced by OFSP purée. Research clearly established that OFSP equivalent baked products using purée were economically viable, but those made with OFSP flour were not (Sindi et al. 2015a). This

was due to the high conversion rate of 4.5-5 kg of fresh root required to produce one kilogram of sweetpotato flour compared to only 1.3-1.6 kg of fresh root needed to produce one kilogram of purée. Moreover, consumers found the organoleptic qualities of the OFSP purée products to be superior to the flour based equivalents (Sindi et al. 2015a). Implementing with three non-governmental agricultural organizations, 500 smallholder farmers (75% women) were successfully organized and linked to the Urwibutso bakery. Roots were peeled, boiled and mashed at the factory, and either used immediately or stored frozen for use within two weeks. Waste was easily dealt with as Urwibutso also had a large-scale piggery. Sales of the two OFSP products over 19 months attained $364,410 USD and the products continue to be made and sold through Urwibutso's eleven stores (Sindi et al. 2015b).

Recognizing that most bakeries do not want to concern themselves with root processing and waste, CIP initiated in 2015 research to develop a packed, storable OFSP purée that is well accepted by bakers who find the product as easy to use as flour. In other countries, purée is preserved by refrigerated and frozen storage, canning or aseptic packaging. High costs and poor product quality are associated with canning, and frozen products require significant infrastructure (Truong and Avula 2010). A relatively new technology in the United States using a continuous flow microwave system for rapid sterilization and aseptic packaging produces a high quality, shelf-stable purée for at least 12 months (Steed 2008). However, this technology is expensive and under patent protection. Thus, our goal is to develop a viable commercial OFSP purée enterprise that provides a purée for bakeries that is shelf-stable for at least 4 months, which in turn would produce commercially viable OFSP bread. Ultimately, we envision that the existence of purée factory will stimulate the adoption of OFSP as a functional ingredient in baked and potentially other products.

This paper documents progress to date for the value chain linking the Organi purée factory in Homa Bay County to a supermarket chain bakery (Tuskys) in Nairobi, Kenya. Sweetpotato is widely grown in Kenya and it is important for commercial and food security purposes. Prospects for commercial success are quite positive as critical technical constraints have been resolved. Other major crops grown in this area include maize, beans and sugarcane.

2 Methods

An agri-value chain encompasses all the steps of bringing a product from the initial input stage influencing the crop's level of output, through the various processing phases, to its final destination, including disposal of packaging and product waste. We adopted the United Nations Industrial Development Organization's (UNIDO) approach to developing and understanding value chains by identifying and understanding the chain actors and roles at each step in the process, facilitating and strengthening the chain, and recognizing the cost and added-value of each step along the chain (UNIDO 2009). CIP led the design with the interest in developing value chains that are inclusive of smallholder sweetpotato farmers, identified the key partners needed in the chain, and facilitated its development technically and with limited financial support for equipment and labor for testing. The four major components of the chain are

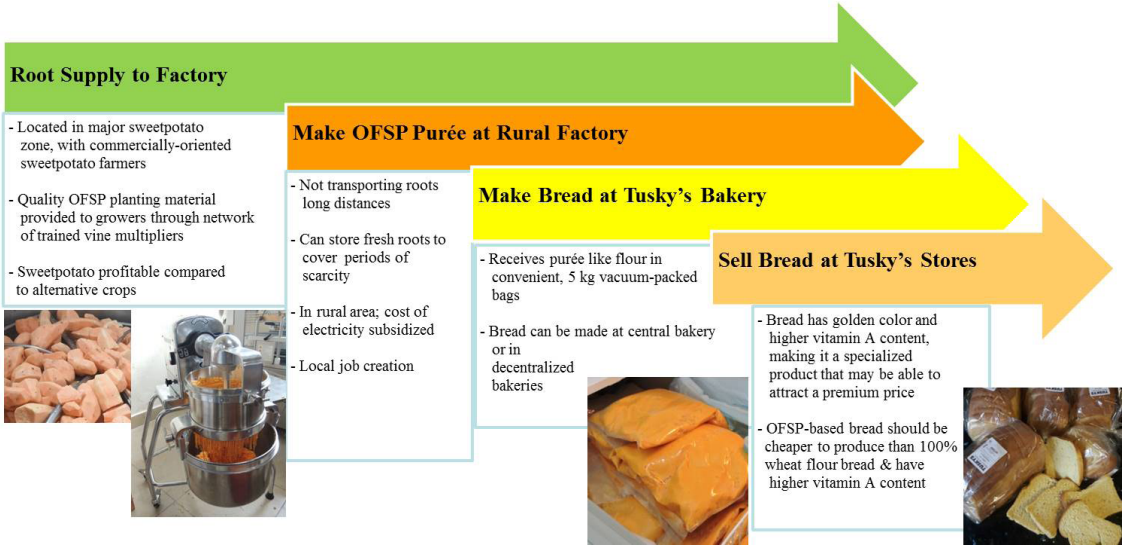

Figure 1: Major Components of the OFSP Purée-Bread Value Chain

shown in Figure 1.

2.1 Actors Selected for Participation in the Chain and Their Respective Roles in Different Phases of its Development

Phase 1. Preparatory Period (2014). Building on the Rwanda experience, the food technology specialist at Euro Ingredients Ltd (EIL) improved OFSP bread, buns, and queen cake recipes during the first half of 2014. EIL also identified Kenyan-owned Tusky's supermarket in Kenya as the potential private sector partner for OFSP bakery product sales, as they sell baked products in 52 stores throughout the nation. Additionally, EIL supplied appropriate processing equipment made in Italy, which can be maintained and repaired in Kenya. During this same period, the CIP food scientist was hired and a Food and Nutritional Evaluation Laboratory (FANEL) was established for carotenoid analysis at the Biosciences for East and Southern Africa laboratory (Nairobi, Kenya) in February 2015.

In August 2014, the CIP food scientist led a consumer assessment of the OFSP baked products among 698 bread purchasing customers in four of Tusky's Nairobi-based stores. The positive findings from that study (Muzhingi, unpublished paper) led Tusky's management into agreeing to participate in an OFSP value chain in September 2014. In December 2014, Natural Resources Institute researchers concluded that the existence of a processing facility committed to purchasing OFSP would facilitate the acceptance of the produce by the market, given that sweetpotato growers in the area already had strong existing market linkages for red-skinned, white-fleshed sweetpotatoes. Following a newspaper ad, Organi Ltd, a Kenya owned small-scale bakery, presented its expression of interest and a preliminary business plan and was then selected as the private sector partner to develop OFSP purée as a business in October 2014. CIP identified, recruited and trained a network of farmers as quality vine (planting material) multipliers (VMs), supplying them with disease-free cuttings of two OFSP varieties: Kabode and Vita.

Phase 2. Start-Up Period for Farmer Engagement and Factory Establishment (2015). In the first quarter, CIP began recruiting farmers for OFSP root production, linking them to VMs for quality vines. In April 2015, CIP facilitated a meeting with Tusky's, Organi Ltd. and EIL and subsequently signed a memorandum of cooperation among the partners. Equipment was installed and OFSP purée production initiated based on a method which roots were peeled by hand before boiling, vacuum-sealed in food quality bags, and stored frozen until shipped in cool boxes to Tusky's central bakery in Nairobi. OFSP bread loaves and bun sales began in six Tusky's stores in Nairobi in June 2015. Both purée and bread samples were subjected to microbial analysis capability at FANEL in July 2015. The CIP food scientist conducted two rounds of research in the laboratory and developed a vacuum-packed purée in December 2015. Using the preservatives benzoate, sorbate and citric acid, the product could be stored for four months at 23°C. The first round of food safety training was conducted by CIP at Organi Ltd in October 2015. A fresh root post-harvest handling and short-term (two weeks) storage trial in a customized 4-ton storage facility established at the Organi factory was conducted in late 2015.

Phase 3. Intensification and Improvement of Purée Processing (January 2016-June 2016). In January 2016, roots from the second season of planting in 2015 began to come to the factory in significant quantities and the manager of the Organi factory was replaced, principally for failing to adequately implement food safety and improve food quality procedures. More staff training in food safety was conducted, with staff earning certificates upon successful completion. This period focused on increasing purée output and reducing costs at all points along the chain.

Phase 4. Introduction of High Fiber Purée and Improved Root Washing (July 2016-September 2016). The major cost-reducing innovation was the testing and introduction of purée made from unpeeled roots, which increased dietary fiber, iron and zinc levels in the final product. This required new procedures for thoroughly grading and washing roots prior to cooking and a new and stronger puréeing machine. The only parts of the root removed are the tips at both ends. Roots with evidence of weevil are rejected.

2.2 Assessment of Costs and Benefits

For this study, the assessment of the costs and benefits focused on two points of the chain: the farmers producing roots for the Organi purée factory and purée production at the factory.

2.2.1 OFSP Root production

Data were collected from 14-20 July, 2016. Ten farmers producing for the factory from Kasipul, Rachonyo East,

and Kabondo sub-counties (in western Kenya) were purposely selected based on discussions with local agricultural extension experts. Representative farmers for the following characteristics were included in the sample: gender, farm size, and agronomic variations. Five male and five female owned plots were selected, 40% of the sweetpotato plots were between 0.03 to 0.1 ha; 40% plots were between 0.15 and 0.2 ha, and 20% between 0.5 and 1.5 ha. Yields were estimated by combining recall and crop-cut methods for each field. The crop-cut experiment involved randomly selecting a 2 x 3 m plot from the farmer's field by walking half way on the longest side of the plot; turning 90 degrees and walking one-third to the middle of the plot; then demarcating 2 m by 3 m taking 1.5 m from the center to the longest side and 1 m to the shortest side from the pivot point. All plants in the plot were harvested. Farmers were interviewed concerning all input uses, the source and cost of their planting material for the most recent OFSP harvest.

2.2.2 Purée Profitability Analysis

Data were principally obtained from the factory record book. The factory has well-organized registration book, where all the inputs and output production and supply history is registered as they happen. Daily and weekly input expenses and sale volume were converted to monthly values, considering a month having twenty-five working days. Profit is one of the indicators to measure the shape of the business and adjust production process to secure its sustainability. In its simplest form, profit is the difference between total revenue and total cost. Total revenue is the total of the sales of the product, which includes income from operations and sales and any other revenue sources. Cost is the total expense or cost incurred in the production process, including rent of buildings, salaries and wages, raw materials (sweetpotato roots), supplies, among others. The gross profit margin is the revenue gained from sale value minus the cost of the sold goods, divided by the revenue. The net profit margin is the revenue minus all costs (including operating expenses, taxes), divided by revenue times 100 (presented in percentage terms).

3 Results

Assuming the ten selected farmers were sufficiently representative of farmers supplying the Organi Factory with OFSP roots, and after controlling for all costs with cash outlays, the return to family labor was US$655/ha (Table 1), which was reasonable given that the 2015 GDP per capita, adjusted for purchasing power parity, in Kenya is US$2,901[1]. Actual yields (13.7 tons per ha) were lower than expected (18-25 ton/ha) given that all farmers were using high quality planting material purchased from trained, mostly commercially-oriented vine multipliers. The major cost was planting material (Table 1). Farmers often retained their planting material for several seasons, lowering their subsequent cost of production, until virus accumulation lowered yields to the point where quality material needed to be purchased again. Hired labor use, particularly for weeding, was the second highest cost. Two-thirds of the 334 farmers selling roots to Organi during this period were women.

At the Organi Factory, significant purée production started in January 2016, but initially there was much inefficiency in the system for procuring roots and peeling. Under supervision during the 2015 testing period, 61% of the total roots were converted into purée. However, this percentage often dropped to 33% between January and June 2016. There were two major problems: the factory accepted a great number of weevil-affected[2] or over-mature roots and had insufficient supervision of the peeling process. One major innovation developed was to test the viability of "high fiber" purée, which uses unpeeled roots. The peels of sweetpotato have significant dietary fiber, plus iron and zinc, two essential micronutrients for human health. Tests proved that high fiber purée made a good OFSP bread product. Puréeing cooked roots with peels required a stronger purée machine than for peeled roots and required improvements in the washing process to ensure thorough soil removal off the roots prior to cooking. These changes led to > 50% conversion of raw roots to purée (improvements are still needed in enforcing grading of roots at purchase) and a positive net profit margin (Table 2). The cost of producing 1 kg of OFSP purée declined to 53 Ksh per kilogram, which is lower than the current price of wheat flour (61 Ksh per kilogram). Moreover, with the addition of one boiler to the current set of equipment, the factory has the potential to utilize 35 tons of roots per month, with a net profit margin of 42%. Basically, the potentially improved scenario is more profitable than the current Phase 4 scenario (Table 2), with more roots converted into purée per unit of labor (Figure 2).

1 GDP data for Kenya from: http://www.tradingeconomics.com/kenya/gdp-per-capita-ppp

2 Sweetpotato weevil is the major pest problem of sweetpotato. The emergence of the larvae leaves dark holes in the root, making that part of the root inedible

Table 1: Sweetpotato root production gross margin analysis model in Western Kenya

OUTPUTS	UNIT	VALUE	
Yield	tons/ha	13.7	
Price (14 Ksh/kg)	US$/ton*	140	
Total value of Production	US$/ha	1,918	
Total variable cost	US$/ha	1,263	
INPUTS	UNIT	VALUE	% OF TOTAL COST
Hired labor cultivation/ploughing	US$/ha	106	8%
Hired labor harrowing	US$/ha	80	6%
Hired labor ridging	US$/ha	97	8%
Hired labor planting	US$/ha	93	7%
Hired labor for weeding	US$/ha	139	11%
Hired labor harvesting	US$/ha	118	9%
Planting materials	US$/ha	494	39%
Packaging	US$/ha	50	4%
Transportation	US$/ha	88	7%
CALCULATED RETURNS	UNIT	VALUE	
Cash outflow (total cost) =A	US$/ha	1,263	
Cash inflow (total revenue) =B	US$/ha	1,918	
Profit C=B-A	US$/ha	655	
Profit margin D=C/A*100	%	52%	
Percentage gross margin=C/B*100		34%	

Source: Authors estimation based on 10 farmers, August, 2016

*Source: Organi Sweetpotato purée processing factory record, September, 2016. *Monthly average Kenyan Shilling to USD exchange rate (Central Bank of Kenya, Nov., 2016)*

Table 2: Change in Profit Margins and Unit Costs Since January 2016 and Desired Target

Description	Raw Roots (kgs) Used per Month	Net Profit Margin per month	Per Kg Production Cost (Ksh)
Phase 3: Jan-June 2016	15,000	-13%	75
Phase 4: July-Sept 2016	10,530	18%	53
Potential Improved Scenario: Additional Boiler	35,000	42%	36

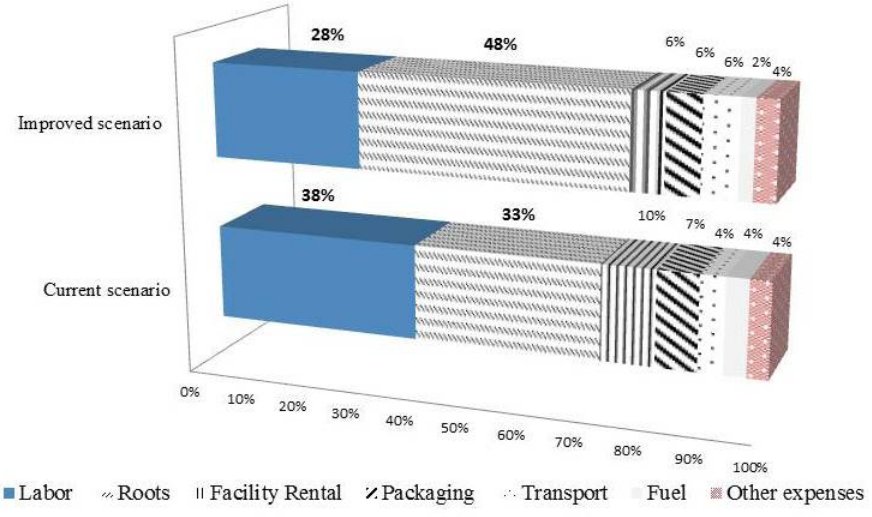

Figure 2: Component costs of OFSP purée production for Phase 4 (current) and with the additional of a second boiler

Table 3: Constraints Emerging During Implementation and Their Resolution

Emerging constraints	Solution(s)
Farmers near factory unwilling to substitute their white-fleshed varieties with orange-fleshed	Red-skin, white-fleshed sweetpotato well-established as a commercial crop in this area 1st season brought OFSP roots from a neighboring county to demonstrate that factory was buying. Gross margin for maize 25% lower than for OFSP
Contaminated purée	1) Food safety training (repeated 3 times) & inspections; 2) Standard operating practices posted on walls 3) Replacement of factory manager
High transport cost of roots to factory	1) Increased recruitment of nearby growers 2) Started ensuring that truck is filled with roots when pickup in community is made 3) Engaged with traders for them to bring roots from farmers to the factory
Seasonality of root supply *Short rains: November-January* *Long rains: March-June*	1) Fresh root storage facility that operates on solar power (still in development) 2) Improved production planning with farmers 3) Construction of purée storage room that keeps temperatures below 25°C using evaporative coolings
Poor conversion rate of fresh roots to purée	1) Improved grading of roots at point of origin (rejecting those with weevil); 2) Improved peeling supervision 3) Introduction of high fiber purée and improved puréeing machine; taste tests conducted on bread made from high fiber purée found that it is widely accepted by consumers 4) Renegotiation of price Tuskys' paid
Irregular amounts of purée purchased by Tuskys	1) Facilitated team meetings to resolve issues 2) Decision to expand to other bakers
High cost of packaging	1) Adjusted the vacuum packaging machine so that it could work with food grade quality plastic packaging; packaging now 0.04 USD/kg purée

The major technical bottlenecks in the value chain had been resolved through innovation and improved management by July 1st, 2016. Since June 2015, Organi Ltd has produced 71,958 kg of purée over 15 months. As of 1st September 2016, Tuskys has been selling more than 3,000 loaves of OFSP bread per day in 20 stores. From the outset, it sells a 400 g loaf at 55 Ksh, 5 Ksh more than the 100% white wheat flour loaf. Lab analysis showed that OFSP purée bread is a good source of pro-vitamin A (beta-carotene), providing 50 Retinol Activity Equivalents (RAE) per 30g slice (Muzhingi, personal communication)[3]. A child needs 400 RAEs of vitamin A per day.

4 Discussion

Given the rapid development of the shelf-storable product in the laboratory under high hygiene conditions, one might have thought that its transfer to a commercial enterprise would be simple. In reality, moving from "lab to life" has demonstrated the importance of having a partnership with an operational private sector company when developing a product, so that it can be tested under real world conditions, with the research team available to resolve technical difficulties and facilitate meetings between the different partners. Table 3 captures the key constraints which emerged and their resolution.

Clearly, the willingness of the senior management at Organi Ltd. to adopt recommendations was fundamental for this endeavor. CIP also covered some of the unexpected costs needed to improve efficiency of the production process. Periodic feedback meetings at various levels, including with the private sector and farmers, provided valuable information in the step-by-step progress made towards this commercialization journey.

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3 The Food Analysis and Nutrition Evaluation Laboratory (FANEL) opened on the Biosciences for East and Central Africa (BecA) campus in January 2016

Abbreviations

CIP	International Potato Center-Centro Internacional de las Papas
EIL	Euro-Ingredients Ltd.
FANEL	Food and Nutritional Evaluation Laboratory
OFSP	Orange-fleshed sweetpotato
RAB	Rwanda Agricultural Board
RAE	Retinol Activity Equivalents
SSA	Sub-Saharan Africa
UNIDO	United Nations Industrial Development Organization
VM	Vine multipliers

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