Biofortified foods
Building Nutritious Food Baskets

High Iron Beans

Participant's Guide

Training of Trainers (ToT) High-Iron Beans: A Biofortified Solution for Iron Deficiency

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Contents

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Foreword

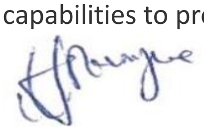
Biofortification is the process of increasing nutritional value of food crops by increasing the density of vitamins and minerals in a crop through either conventional plant breeding, agronomic practices or biotechnology. It is one of the key nutrition interventions that addresses micronutrient malnutrition among populations / groups who consume most of the staple foods that they produce, especially the poor, rural, and other vulnerable populations. Often, they have limited access to diverse diets, supplements, and commercially fortified foods that provide essential micronutrients necessary for ensuring healthy and productive lives. Adoption of biofortified food crops such as vitamin A rich orange-fleshed sweetpotato (OFSP); provitamin A (PVA) maize, high iron and zinc beans and vitamin A cassava, is an effective way of addressing micronutrients malnutrition because it is sustainable, cost-effective and culturally acceptable.

The Building Nutritious Food Baskets (BNFB) project is a three-year project (November 2015 to October 2018) implemented in Nigeria and Tanzania and funded by the Bill & Melinda Gates Foundation. The goal of the project is to accelerate and support scaling up of biofortified crops for food and nutrition security and to help reduce hidden hunger by catalyzing sustainable investment for the utilization of biofortified crops (OFSP, PVA maize, high iron beans and vitamin A cassava) at scale. BNFB develops institutional, community and individual capacities to produce and consume biofortified crops. The objectives of the project are to strengthen the enabling environment for increased investments in biofortified crops and to develop institutional and individual capacities to produce and consume biofortified crops.

To sustainably support the implementation of BNFB's capacity development efforts, the project has developed a training of trainers (ToT) module titled ***Training of Trainers (ToT) High-Iron Beans: A Biofortified Solution for Iron Deficiency***. The module includes a PowerPoint presentation, an annotated facilitator's guide and a handout for participants. Partner institutions; academic institutions and other users are encouraged to adapt and reproduce these instructional materials and where appropriate, integrate the teaching and learning into existing curriculum.

This module is designed to potentially serve a wide variety of audiences (nutritionists and agronomists, policymakers, extension workers, community development workers, farmers etc.). Not all the materials will be relevant to all audiences, but facilitators can adapt the content to their audience and facilitation best practices. To ensure sustainability and wide reach; BNFB will apply a cascading approach in the delivery of training; where key experts (agriculturalists, nutritionists, health workers, marketing and gender experts) will attend more detailed ToT workshops. The experts trained will then become primary facilitators and drive the agenda for biofortification. They will in turn deliver shorter version courses and step-down the training to various levels of audiences (secondary and tertiary). This trend will continue until the training cascades down to "farmer trainers" who finally train the end users in their communities.

This module greatly contributes to BNFB's efforts in strengthening institutional and community capabilities to produce and consume biofortified crops (entire value chains) and to reach a critical mass.



Hilda Munyua
Project Manager - Building Nutritious Food Baskets Project
International Potato Center - March 2018

Acronyms and Abbreviations

ALT	Adult Learning Theory
ARI-Selian	Selian Agricultural Research Institute
BNFB	Building Nutritious Food Baskets
CGIAR	Global Research Partnership for a Food Secure
CIAT	International Center for Tropical Agriculture
CIMMYT	International Wheat and Maize Improvement Center
CIP	International Potato Center
FARA	Forum for Agricultural Research in Africa
GMO	Genetically Modified Organism
GMO	Genetically Modified Organism
HIB	High Iron Beans
IITA	International Institute of Tropical Agriculture
NEPAD	New Partnership for Africa’s Development
NGO	Non-Governmental Organization
OFSP	Orange-Fleshed Sweet potatoes
PABRA	Pan Africa Bean Research Alliance
PVA	Pro-Vitamin A
SSA	Sub-Saharan Africa
TOT	Training of Trainers
TZS	Tanzanian Shillings

High Iron Beans Module Overview

Module Objectives

Upon completing this module, participants should be able to:

- Engage in discussions of micronutrient malnutrition with target groups, specifically about anemia/iron deficiency
- Describe how biofortified high-iron beans (HIB) can address iron deficiency among vulnerable populations
- Summarize how breeders develop new HIB varieties
- Outline a strategy for promoting HIBs to farmers, consumers, partner organizations and the private sector
- Describe how HIBs can be integrated into a healthy diet
- Summarize key studies demonstrating the effectiveness of HIBs for addressing iron deficiency and anemia

Module Outline

The 'High Iron Beans' module is divided into units and sub-units, as follows:

1) Introductions and housekeeping
2) Micronutrients and biofortification: An introduction
    a) The problem of "hidden hunger"
    b) Biofortification: An intervention for "hidden hunger"
3) Iron Deficiency and High Iron Beans
    a) Iron deficiency and anemia
    b) High Iron Beans (HIBs)
4) Breeding High Iron Beans
    a) Breeding High Iron Bean varieties
    b) The breeding process
5) Fostering demand for High Iron Beans
    a) Variety release
    b) Seed systems
    c) Promoting farmer adoption
    d) Case study: Rwanda impact assessment
    e) Promoting consumer demand
    f) Challenges
6) Scaling HIBs
7) Integrating HIBs into a healthy diet
8) Conclusion

Unit 1- Introductions and Housekeeping

1.1 Ground Rules

- Mobile phones off
- In addition to lecturing, there will be opportunities for discussions and asking questions.
  - To keep things moving, we might have to cut some conversations short and move on to the next topic
  - Not everyone will get to answer every question, but everyone will get multiple chances to speak and be heard throughout the session
  - If one or two people are answering every question, we will politely ask them to give someone else a chance to speak.
- As participants in this learning experience, we need to:
  - Share our ideas without fear of criticism, and listen to the ideas of others without criticizing
  - Engage in discussions without arguing
  - Help other participants and accept help from others
  - Create a safe, supportive environment for everyone to learn
  - Have fun

Unit 2 - Micronutrients and Biofortification

2.1 Objectives

By the end of this unit, participants should be able to:

- List and describe the three types of malnutrition
- Define 'hidden hunger' and explain the importance of micronutrients for good health
- Identify natural sources of micronutrients
- List and describe common interventions for micronutrient deficiency
- Define 'biofortification'
- Compare biofortification to other interventions and summarize its major advantages and challenges
- Differentiate between biofortified crops produced through selective breeding and GMOs

2.2 Synopsis

This unit introduces the basic concepts of micronutrient malnutrition and biofortification.

2.3 Key Points

- Micronutrient malnutrition is a serious public health issue
- While everyone is affected, children and women of reproductive age are most vulnerable
- Biofortification is a promising new intervention for micronutrient malnutrition that can be quite effective for vulnerable populations, especially in combination with other interventions
- Biofortification involves the development and distribution of new staple crop varieties with higher micronutrient levels than traditional varieties
- The crops discussed in this program are all the product of *selective breeding* (i.e., natural reproduction) and are **not** GMOs

Unit 3 – Iron Deficiency and High Iron Beans

3.1 Objectives

By the end of this unit, participants should be able to:

- Summarise the effects of iron deficiency on human body
- Identify populations particularly vulnerable to iron deficiency
- Describe nutritional and agronomic characteristics of iron beans
- Distinguish between climbing and bush beans
- Explain key benefits of High Iron Beans
- Summarise key challenges with High Iron Beans adoption
- Define Biofortification Priority Index

3.2 Synopsis

This unit reviews the effects of iron deficiency on human health and introduces High Iron Beans as a potential intervention for iron deficiency.

3.3 Key Points

- Iron deficiency is one of the most comment micronutrient deficiencies in the world, and disproportionately affects children and women of reproductive age
- The effects of iron deficiency can be severe and devastating, including increased risk of death during childbirth, decreased physical and cognitive performance and depression, among others
- Beans are a natural source of iron that is easily absorbed by the body.
- Beans are grown and consumed in large quantities in many regions with high rates of iron deficiency
- Beans have agronomic qualities that make them attractive to farmers
- Biofortified High Iron Beans have been bred to contain higher levels of iron, to help alleviate iron deficiency.

Unit 4 – Breeding High Iron Beans

4.1 Objectives

By the end of this unit, participants should be able to:

- List the factors nutritionists consider while setting micronutrient targets for biofortified crops
- Identify causes of micronutrient loss
- List the characteristics that farmers and consumers find desirable in bean varieties
- Outline the key steps of the breeding process and summarize what happens at each step

4.2 Synopsis

This unit reviews the process for breeding high iron bean varieties, from setting nutritional targets through breeding and testing new varieties.

4.3 Key Points

- Nutritional targets are set based on the dietary needs of women and children – the most vulnerable groups – and must account for micronutrients lost during storage, processing and/or preparation
- Breeders must also account for agronomic qualities and consumer preferences
- Selectively breeding varieties with the desired traits involves years of work, crossing different varieties of beans with desirable traits to create new lines with all the best qualities of the parent lines
- New varieties are tested for nutrient content in the lab and tested for their agronomic performance in the field
- Breeders might "fast track" release of promising varieties that do not fully meet the targets, in order to help vulnerable populations benefit from biofortified crops sooner

4.4 Activities

Activity

HIB Releases

- Spend 5-10 minutes reviewing the sample release documents.
  - Based on what you read, which varieties do you think would be most appealing to the populations you work with? Might certain varieties be more appealing to different groups of farmers/consumers?
  - Did any of the criteria covered in the release documents surprise you?

1. Proposal for release of new improved common bean (Phaseolus vulgaris) variety – KATB9

VARIETY DESCRIPTION

1. a) Name of the crop: Common bean
   b) Botanical name: *Phaseolus vulgaris*
   c) Genus name: Phaseolus
   d) Family name: ***Leguminosae***
   e) Chromosome number 2n=2x= 22
   f) Mode of pollination Self pollination

2. a) Proposed release name: **SELIAN 12**
   b) Name under which it is tested: KATB9
   c) Agency responsible for development: ARI-Selian
   d) Cultivar pedigree: Selection from introduced germplasm

3. a) Proposed area for release: Tanzania
   b) Proposed elevation: Above 1000m a.s.l
   c) Agency responsible for supply of breeder seed: ARI-Selian
   d) Agency responsible for maintenance: ARI-Selian

4. Points of merit
   - Early maturing
   - Fast cooking

S/N	Morphological characteristics	Expression
1.	Plant: growth type	dwarf

2. Dwarf beans only: plant: type	non-trailing
3. Dwarf beans only: plant: height	medium
4. Leaf: intensity of green colour	medium
5. Leaf: rugosity	medium
6. Terminal leaflet: size	medium
7. Terminal leaflet: shape	triangular
8. Terminal leaflet: length of tip	long
9. Dwarf beans only: inflorescence: position (at full flowering)	predominantly in foliage
10. Flower: size of bracts	medium
11. Flower: colour of standar	pinkish white
12. Flower: colour of wing	pinkish white
13. Dwarf beans only: pod: length (excluding beak)	short
14. Pod: width	medium
15. Pod: thickness	medium
16. Pod: shape in cross section (through seed)	ovate
17. Pod: ratio thickness/width	medium
18. Pod: ground colour	green
19. Pod: intensity of ground colour	light
20. Pod: presence of secondary colour	absent
21. Pod: stringiness of ventral suture	present
22. Pod: degree of curvature	absent or very slight
23. Pod: shape of curvature	concave
24. Pod: shape of distal part (excluding beak)	acute to truncate
25. Pod: length of the beak	medium
26. Pod: curvature of beak	medium
27. Pod: texture of surface	smooth or slightly rough
28. Pod: constrictions (at dry stage)	moderate
29. Seed: weight	medium
30. Seed: shape in longitudinal section	circular to elliptic
31. Seed: shape in cross section	narrow elliptic
32. Seed: width in cross section	medium
33. Seed: length	medium
34. Seed: Number of colours	one
35. Seed: main colour	red
36. Seed: secondary colour	n/a
37. Seed: distribution of secondary colour	n/a
38. Seed: veining	n/a
39. Time of flowering (50% of the plants with at least one flower	32 days
40. Resistance to bean anthracnose (*Colletotrichum lindemuthianum*)	present
41. Resistance to Bean Common Mosaic Necrosis Virus (BCMNV)	present
42. Resistance to halo blight (*Pseudomonas syringae pv. Phaseolicola*)	present
43. Resistance to common blight (*Xanthomonas campestris pv. Phaseoli*)	present

2. *Proposal for release of new improved common bean (Phaseolus vulgaris) variety – KATB1*

VARIETY DESCRIPTION:

1. a) Name of the crop: Common bean
   b) Botanical name: *Phaseolus vulgaris*
   c) Genus name: Phaseolus
   d) Family name: ***Leguminosae***
   e) Chromosome number 2n=2x = 22
   f) Mode of pollination Self pollination

2. a) Proposed release name: **SELIAN 13**
   b) Name under which it is tested: KATB1
   c) Agency responsible for development: ARI-Selian
   d) Cultivar pedigree: Selection from introduced germplasm

3. a) Proposed area for release: Tanzania
   b) Proposed elevation: Above 1000m a.s.l
   c) Agency responsible for supply of breeder seed: ARI-Selian
   d) Agency responsible for maintenance: ARI-Selian

4. Points of merit

- Early maturing
- Fast cooking

S/N	Morphological characteristics	Expression
1.	Plant: growth type	dwarf
2.	Dwarf beans only: plant: type	non-trailing
3.	Dwarf beans only: plant: height	medium
4.	Leaf: intensity of green colour	medium
5.	Leaf: rugosity	weak
6.	Terminal leaflet: size	medium
7.	Terminal leaflet: shape	triangular
8.	Terminal leaflet: length of tip	medium
9.	Dwarf beans only: inflorescence: position (at full flowering)	intermediate
10.	Flower: size of bracts	medium
11.	Flower: colour of standar	pinkish white
12.	Flower: colour of wing	pinkish white

13. Dwarf beans only: pod: length (excluding beak)	short
14. Pod: width	medium
15. Pod: thickness	medium
16. Pod: shape in cross section (through seed)	elliptic
17. Pod: ratio thickness/width	medium
18. Pod: ground colour	violet
19. Pod: intensity of ground colour	light
20. Pod: presence of secondary colour	present
21. Pod: secondary colour	red
22. Pod: density of flecks of secondary colour	sparse
23. Pod: stringiness of ventral suture	present
24. Pod: degree of curvature	absent or very slight
25. Pod: shape of curvature	concave
26. Pod: shape of distal part (excluding beak)	acute to truncate
27. Pod: length of the beak	medium
28. Pod: curvature of beak	medium
29. Pod: texture of surface	moderately rough
30. Pod: constrictions (at dry stage)	moderate
31. Seed: weight	medium
32. Seed: shape in longitudinal section	circular
33. Seed: shape in cross section	circular
34. Seed: width in cross section	medium
35. Seed: length	short
36. Seed: Number of colours	one
37. Seed: main colour	yellow
38. Seed: secondary colour	n/a
39. Seed: distribution of secondary colour	n/a
40. Seed: veining	weak
41. Time of flowering (50% of the plants with at least one flower	33 days
42. Resistance to bean anthracnose (*Colletotrichum lindemuthianum*)	present
43. Resistance to Bean Common Mosaic Necrosis Virus (BCMNV)	present
44. Resistance to halo blight (*Pseudomonas syringae pv. Phaseolicola*)	present
45. Resistance to common blight (*Xanthomonas campestris pv. Phaseoli*)	present

3. Proposal for release of new improved common bean (Phaseolus vulgaris) variety – MAC44

1. a) Name of the crop:	Common bean
b) Botanical name:	*Phaseolus vulgaris*
c) Genus name:	Phaseolus
d) Family name:	***Leguminosae***
e) Chromosome number	2n=2x =22
f) Mode of pollination	Self pollination

2. a) Proposed release name: **SELIAN 14**
   b) Name under which it is tested: MAC44
   c) Agency responsible for development: ARI-Selian
   d) Cultivar pedigree: Selection from introduced germplasm

3. a) Proposed area for release: Tanzania
   b) Proposed elevation: Above 1300m a.s.l
   c) Agency responsible for supply of breeder seed: ARI-Selian
   d) Agency responsible for maintenance: ARI-Selian

4. Points of merit

- Resistant to Anthracnose and Bean Common Mosaic Virus
- Yield >2t/ha
- Fast cooking
- High Iron (Fe) and Zinc (Zn) grain levels

S/N	Morphological characteristics	Expression
1.	Plant: growth type	climbing
2.	Climbing beans only: plant: architecture	pyramidal
3.	Climbing beans only: plant: start of climbing (80% of plants)	medium
4.	Climbing beans only: plant: speed of climbing	medium
5.	Leaf: intensity of green colour	medium
6.	Leaf: rugosity	medium
7.	Terminal leaflet: size	medium
8.	Terminal leaflet: shape	triangular
9.	Terminal leaflet: length of tip	long
10.	Flower: size of bracts	medium
11.	Flower: colour of standar	white
12.	Flower: colour of wing	white
13.	Climbing beans only: pod: length (as for 18)	medium
14.	Pod: width	broad
15.	Pod: thickness	medium
16.	Pod: shape in cross section (through seed)	elliptic
17.	Pod: ratio thickness/width	medium
18.	Pod: ground colour	green
19.	Pod: intensity of ground colour	medium
20.	Pod: presence of secondary colour	absent
21.	Pod: stringiness of ventral suture	present
22.	Pod: degree of curvature	weak
23.	Pod: shape of curvature	concave
24.	Pod: shape of distal part (excluding beak)	acute to truncate

25. Pod: length of the beak	long
26. Pod: curvature of beak	medium
27. Pod: texture of surface	moderately rough
28. Pod: constrictions (at dry stage)	moderate
29. Seed: weight	high
30. Seed: shape in longitudinal section	rectangular
31. Seed: shape in cross section	flat
32. Seed: width in cross section	medium
33. Seed: length	medium
34. Seed: Number of colours	two
35. Seed: main colour	red
36. Seed: secondary colour	beige
37. Seed: distribution of secondary colour	on entire grain
38. Seed: veining	n/a
39. Time of flowering (50% of the plants with at least one flower	45 days
40. Resistance to bean anthracnose (*Colletotrichum lindemuthianum*)	present
41. Resistance to Bean Common Mosaic Necrosis Virus (BCMNV)	present
42. Resistance to halo blight (*Pseudomonas syringae pv. Phaseolicola*)	present
43. Resistance to common blight (*Xanthomonas campestris pv. Phaseoli*)	present

4. Proposal for release of new improved common bean (Phaseolus vulgaris) variety – RWV 1129

1.	a) Name of the crop:	Common bean
	b) Botanical name:	*Phaseolus vulgaris*
	c) Genus name:	Phaseolus
	d) Family name:	***Leguminosae***
	e) Chromosome number	2n=2x =22
	f) Mode of pollination	Self pollination
2.	a) Proposed release name:	**SELIAN 15**
	b) Name under which it is tested:	RWV1129
	c) Agency responsible for development:	ARI-Selian
	d) Cultivar pedigree:	Introduction
3.	a) Proposed area for release:	Tanzania
	b) Proposed elevation:	1000-2024m a.s.l
	c) Agency responsible for supply of breeder seed:	ARI-Selian
	d) Agency responsible for maintenance:	ARI-Selian

4. Points of merit

- Resistant to Anthracnose and blights
- Yield >2t/ha
- Fast cooking
- High Iron (Fe) and Zinc (Zn) grain levels

S/N	Morphological characteristics	Expression
1.	Plant: growth type	climbing
2.	Climbing beans only: plant: architecture	pyramidal
3.	Climbing beans only: plant: start of climbing (80% of plants)	early
4.	Climbing beans only: plant: speed of climbing	fast
5.	Leaf: intensity of green colour	medium
6.	Leaf: rugosity	strong
7.	Terminal leaflet: size	large
8.	Terminal leaflet: shape	triangular
9.	Terminal leaflet: length of tip	long
10.	Flower: size of bracts	medium
11.	Flower: colour of standar	white
12.	Flower: colour of wing	white

13. Climbing beans only: pod: length (as for 18)	very long
14. Pod: width	medium
15. Pod: thickness	medium
16. Pod: shape in cross section (through seed)	elliptic
17. Pod: ratio thickness/width	medium
18. Pod: ground colour	green
19. Pod: intensity of ground colour	medium
20. Pod: presence of secondary colour	absent
21. Pod: stringiness of ventral suture	present
22. Pod: degree of curvature	absent or very slight
23. Pod: shape of curvature	concave
24. Pod: shape of distal part (excluding beak)	acute to truncate
25. Pod: length of the beak	long
26. Pod: curvature of beak	weak
27. Pod: texture of surface	moderately rough
28. Pod: constrictions (at dry stage)	moderate
29. Seed: weight	high
30. Seed: shape in longitudinal section	rectangular
31. Seed: shape in cross section	flat
32. Seed: width in cross section	medium
33. Seed: length	long
34. Seed: Number of colours	more than 2
35. Seed: main colour	violet
36. Seed: secondary colour	violet
37. Seed: distribution of secondary colour	on entire grain
38. Seed: veining	n/a
39. Time of flowering (50% of the plants with at least one flower	46 days
40. Resistance to bean anthracnose (*Colletotrichum lindemuthianum*)	present
41. Resistance to Bean Common Mosaic Necrosis Virus (BCMNV)	present
42. Resistance to halo blight (*Pseudomonas syringae pv. Phaseolicola*)	present
43. Resistance to common blight (*Xanthomonas campestris pv. Phaseoli*)	present

Unit 5 - Fostering Demand for High Iron Beans

5.1 Objectives

By the end of this unit participants should be able to:

- Outline the steps for "scaling" and "anchoring" HIBs in local food systems
- List key activities for introducing a new crop
- Differentiate between different seed systems
- Explain advantages and disadvantages of self-pollinated crops (as they relate to biofortification)
- Summarise advantages of HIB for the farmers
- Summarise advantages of HIB for the consumers
- List some of challenges for HIB introduction and adoption

5.2 Synopsis

This unit focuses on strategies for supporting the introduction of High Iron Beans within a country and influencing farmers, consumers and partner organizations to support HIB adoption.

5.3 Key Points

- Biofortification cannot succeed unless farmers can be persuaded to grow biofortified crops and consumers can be persuaded to purchase and eat them
- Ensuring a secure seed system is critical (if farmers cannot acquire seeds, they cannot grow biofortified crops)
- High Iron Beans are self-pollinated, and as such can be replanted year after year without a significant loss of their nutritional and agronomic qualities.
- The fact that farmers can replant seed year over year makes beans less appealing to commercial seed companies, though if enough demand can be generated they might get involved. In the meantime government agencies, farmers organizations and NGOs can ensure seed supply
- Emphasizing the agronomic qualities of HIBs is often an effective way of promoting adoption among farmers
- Consumers generally prefer the sensory qualities of biofortified varieties, and providing them with nutrition information can further increase demand
- There are many possible channels and media for distributing promotional messages, though studies have shown that broadcast media such as radio is often more cost-effective than delivering messaging face-to-face
- Potential partners for promoting biofortified crops include local governments, seed companies, NGOs, multilateral organizations and various participants in the agricultural value chain (e.g., food processors)

5.4 Activities

Tanzania Consumer Survey

- Take 5-10 minutes to review the findings.
  - What were some of the key findings/trends related to:
    - Purchasing/consumption habits
    - Preferences
    - Beliefs about beans and nutrition
    - Willingness to pay
  - Did any of the criteria covered in the release documents surprise you?

(Original referencing and numbering preserved)

Frequency and quantity of beans consumed in the households

Bean consumption frequency varies across locations and districts (Table 9). Overall, 34% of households across locations consumed beans two times in seven days preceding the survey, 28% three times 17% once, 11% four times and 7% more than 4 times. More (35%) urban households consumed beans two times in seven days preceding the survey than rural households (33%). However, more (33%) rural households consumed beans three times in the same period. Similarly, more (22%) rural households consumed beans 4 to 7 times than urban households (16%) in the same period. Overall, only 2% of households did not consume beans in the same period in both urban and rural locations, while in Babati, all households consumed beans at least once within the seven days before the survey; with the highest mean of 2.9 times. Also, Babati recorded the highest mean quantity of beans prepared per meal at 0.81 kg with Arusha having 0.69 kg and Moshi 0.57 kg. This could be as a result of the slightly larger household sizes in Babati.

Table 1: Household bean consumption in the past 7 days

Number of days consumed beans (%)	District			Location		Overall
	Arusha	**Babati**	**Moshi**	**Urban**	**Rural**	
0	4	0	1	4	1	2
1	21	13	11	21	12	17
2	35	33	32	35	33	34
3	24	32	34	24	33	28
4	12	11	9	12	10	11
5	2	5	9	2	7	4
6	2	1	3	2	2	2
7	0	5	1	0	3	1
Mean number of days consumed beans	2.3	2.9	2.8	2.3	2.8	2.6
Quantity in kg prepared per meal (mean)	0.69	0.81	0.57	0.69	0.69	0.69

While 65% of respondents across the locations agreed that the quantities of beans consumed were sufficient for the respective households, 27% felt that the quantities were more than enough and 8% felt they were less than sufficient.

Main source of beans for home consumption

A majority of the households consume beans from a combination of sources including own production, purchase from the market, and gifts/handouts (Figure 10). Overall, the market is the main source of beans for 47% of the households, while 37% mostly consume beans they produce, and 16% combine own production and market as sources of beans on an equal basis. None of the respondents received beans as gifts except in Babati (1%). More (61%) rural households mainly consume beans they produce than urban households (14%). Across the districts, Moshi has the highest proportion (71%) of households with own production as the main source of beans compared to Babati (51%), with Arusha having the least (14%). On the other hand, more (75%) households in Arusha mainly obtain the beans they consume from the market than Moshi (19%) and Babati (14%).

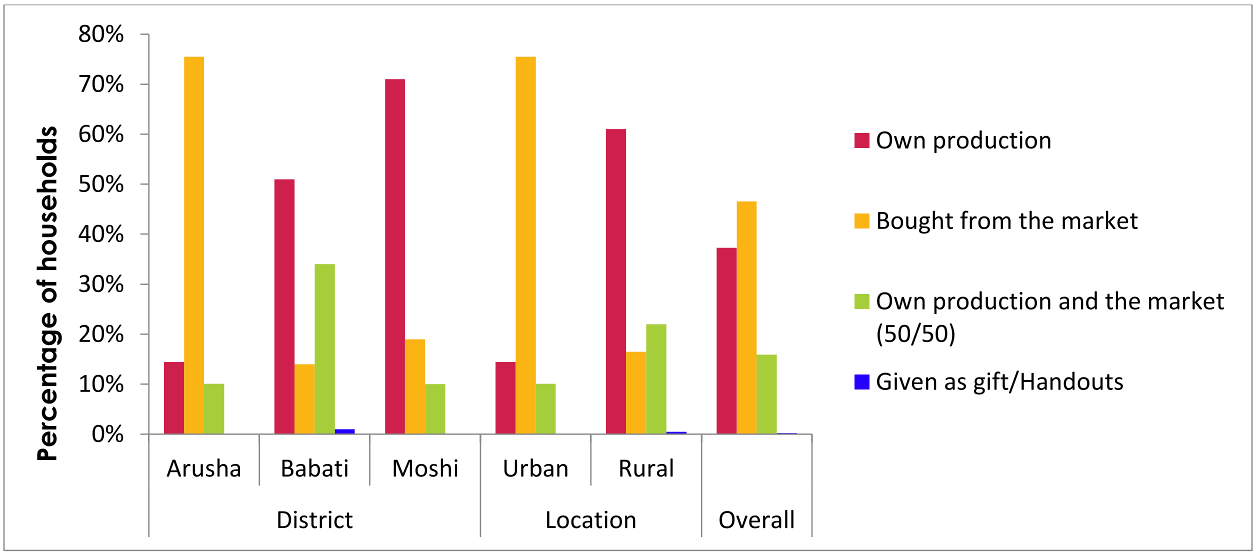


Figure 10: Main source of beans for home consumption

There was variation in the proportion of households that purchase beans across the districts and localities (Table 10). Overall, 70% of the households buy beans. This is more pronounced in Arusha (89%) than Moshi (54%) and Babati (48%). Among the proportion that buys beans, a household purchases an average of 88 kg of beans per year, with Arusha recording the highest mean of 105 kg, Moshi 76 kg and Babati 63 kg per year.

Women are more (68%) involved in decisions on whether to purchase beans than men (33%) and children (5%). This is particularly pronounced among urban (82%) than rural (53%) households. However, the cost of purchased beans is majorly met by men (49%) than women (33%) and least by children (1%).

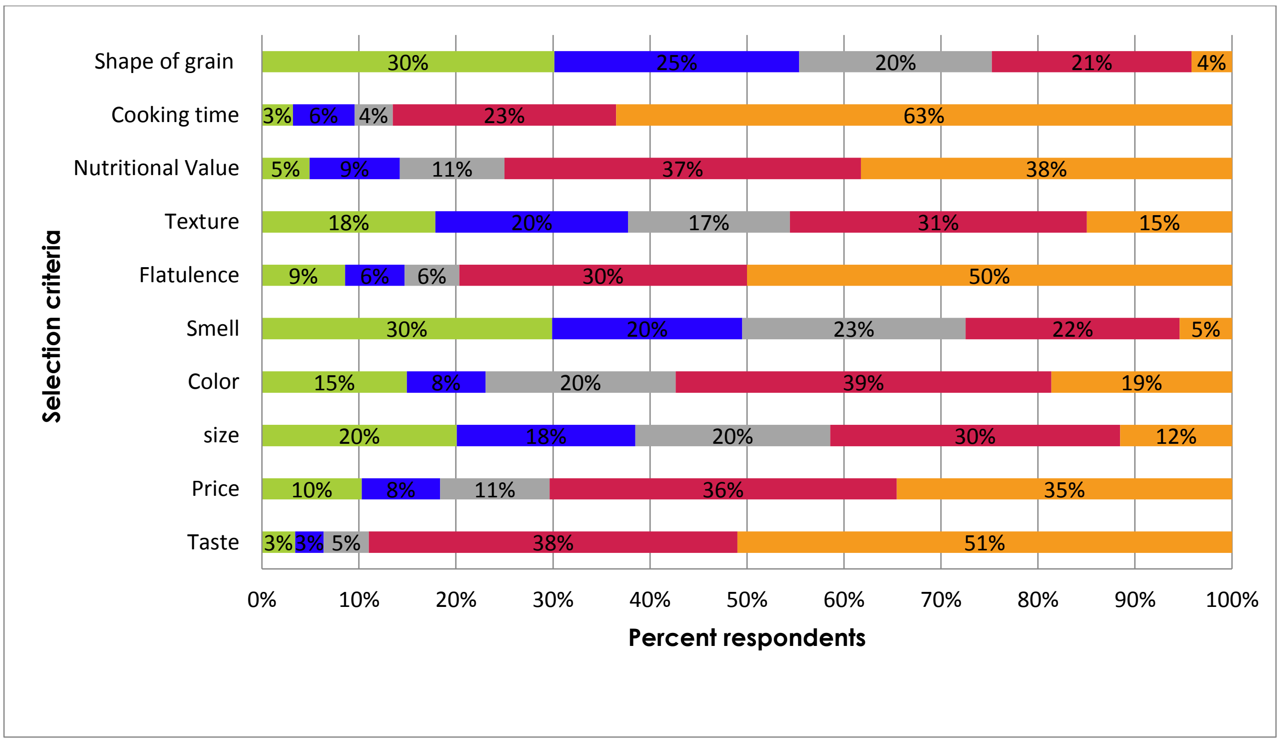
Overall, 45% of the households felt that the beans they purchased from the market were of fairly good quality, good quality: 39%, very good quality: 9% and fairly poor quality: 7%. More (12%) urban households felt that they purchased very good quality beans from the market than rural households (4%). A good proportion of households in urban settings (43%) exclusively buy beans for consumption while this category is less in rural settings (13%). Similarly, more (38%) rural households exclusively consume the beans they produce in their farms than urban households (10%).

Table 2: Distribution of households by purchase behavior and bean quality assessment, 2017

Variable	Category	District			Location		Overall
		Arusha	Babati	Moshi	Urban	Rural	
Household buys beans (%)	-	89	48	54	89	51	70
Quantity of beans bought (mean kg/year)		105	63	76	105	70	88
Buying price (mean TZS/kg)	-	2,202	1,784	2,024	2,202	1,911	2,099
Distance to market (mean Km)	-	1.37	2.82	3.88	1.37	3.38	2.15
Share of bean consumption met through own production	None	43	11	14	43	13	28
	25%	25	11	22	25	17	21
	25 – 50%	7	13	10	7	12	9
	50 – 75%	6	16	7	6	12	9
	75 – 99%	8	8	12	8	10	9
	100%	10	41	35	10	38	24
Who makes decision to buy beans (%?)?	Man	27	43	34	27	39	33
	Woman	82	40	65	82	53	68
	Children	9	1	0	9	1	5
Who goes to buy beans (%?)?	Man	9	7	15	9	11	10
	Woman	70	41	46	70	44	57
	Children	30	20	1	30	11	21
Who pays for beans (%?)?	Man	60	36	40	60	38	49
	Woman	38	21	34	38	28	33
	Children	1	1	0	1	1	1
Perception on quality of purchased beans (%)	Fairly poor	9	4	4	9	4	7
	Good	34	54	43	34	48	39
	Fairly good	45	42	46	45	44	45
	Very good	12	0	7	12	4	9

Criteria for selecting beans for consumption

To obtain optimal satisfaction from bean consumption, households select the beans for consumption based on certain criteria as shown in Figure 11. The most important criteria include cooking time (63%), taste (51%), flatulence (50%), nutritional value (38%) and price (35%). Cooking time is critical because it determines how much fuel would be used to have the beans ready for eating – the longer the cooking time the more the fuel required and the higher the cost of preparing bean meal. Longer cooking time also means less time left for other home chores. Therefore households would prefer bean types that can be cooked within the shortest time period. Bean taste has to do with palatability and is critical in increasing bean consumption levels and therefore enhanced nutrition status, especially with increased awareness about the health benefits of beans (Audu *et al.,* 2014; Olaofe *et al*., 2010; Katungi *et al*., 2009). Bean price is critical as an indicator of marketability. Although many households grow beans for subsistence (Katungi *et al*., 2009), marketability is important because the crop is steadily transforming into market oriented one (Buruchara *et al*., 2011). This is motivating farmers to sell part of their produce for extra income (PABRA, 2014) and also to meet other household cash needs.



Knowledge of diet diversity and beans

Over 95% of the consumers agreed that beans are an important food in the diet and that consuming beans is important for a diverse diet. However, when it comes to the importance of iron as a nutrient, there is a lower level of concurrence with 36% of the respondents being indifferent. This shows a strong level of knowledge on the importance of beans both for nutrition and dietary diversity but not so much on beans as a source of iron. On the other hand, only 15% of the consumers were aware of iron biofortified beans and 28% aware of other biofortified crops in the market. This alludes to a low level of knowledge on iron biofortification among the bean consumers in the study area.

Table 3: Knowledge of diet diversity, beans and improved beans (perceived benefits)

Statement	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Beans are an important food in the diet	0	0	1	37	61
Beans consumption is important for a diverse diet	0	0	4	48	48
Beans are an important source of iron in the diet	4	3	36	43	14
I am aware of iron biofortified beans	13	25	47	14	1
I am aware of other biofortified crops where iron is an invisible trait	11	22	38	18	10
I know of foods where iron is an invisible trait	7	15	27	31	19

Behavioural beliefs and evaluation of behavioural outcome

Based on behavioral beliefs, 86% believed that what they eat affects their nutrition status and 83% believed that eating beans can make children stronger. With regards to iron as nutrient, 76% believed that eating foods rich in iron can make children stronger yet a much lower proportion of 55% were in agreement with the statement that eating iron biofortified beans rather than ordinary beans can make children stronger (Figure 15). A higher level of indifference (41%) was observed when a statement which compares bio fortified beans to ordinary beans in making children stronger was presented to the bean consumers than when they are presented with a statement on the importance of eating iron rich foods. This is in agreement with the opinions expressed earlier concerning biofortified bean iron as an invisible trait where the level of knowledge and acceptance is lower than that of iron as a nutrient.

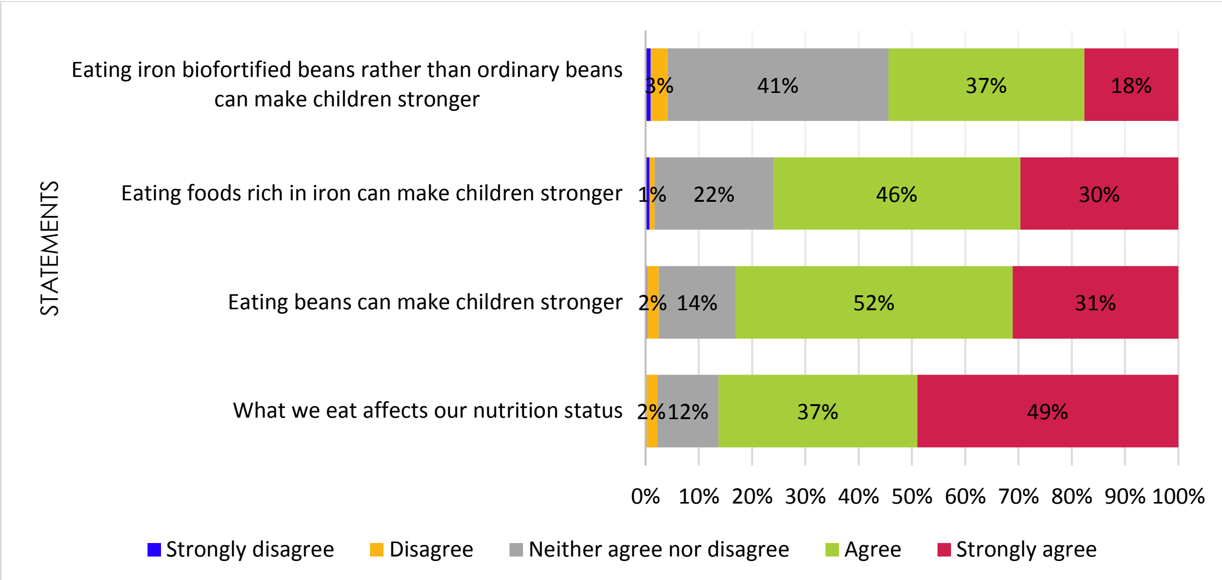


Figure 15: Behavioural beliefs

Barriers to consumption of biofortified beans

A majority of the consumers disagreed with most of the statements that sought to get an understanding of their opinion regarding perceived barriers to the consumption of iron biofortified beans. Close to a third of the consumers were afraid that buying iron biofortified beans will be expensive (29%) while 28% feared that they may not be able to differentiate between iron biofortified beans and ordinary beans when they become available in the market (Figure 17). These proportions are in tandem with the opinion regarding buying nutritious foods where 32% are afraid that buying such foods is expensive.

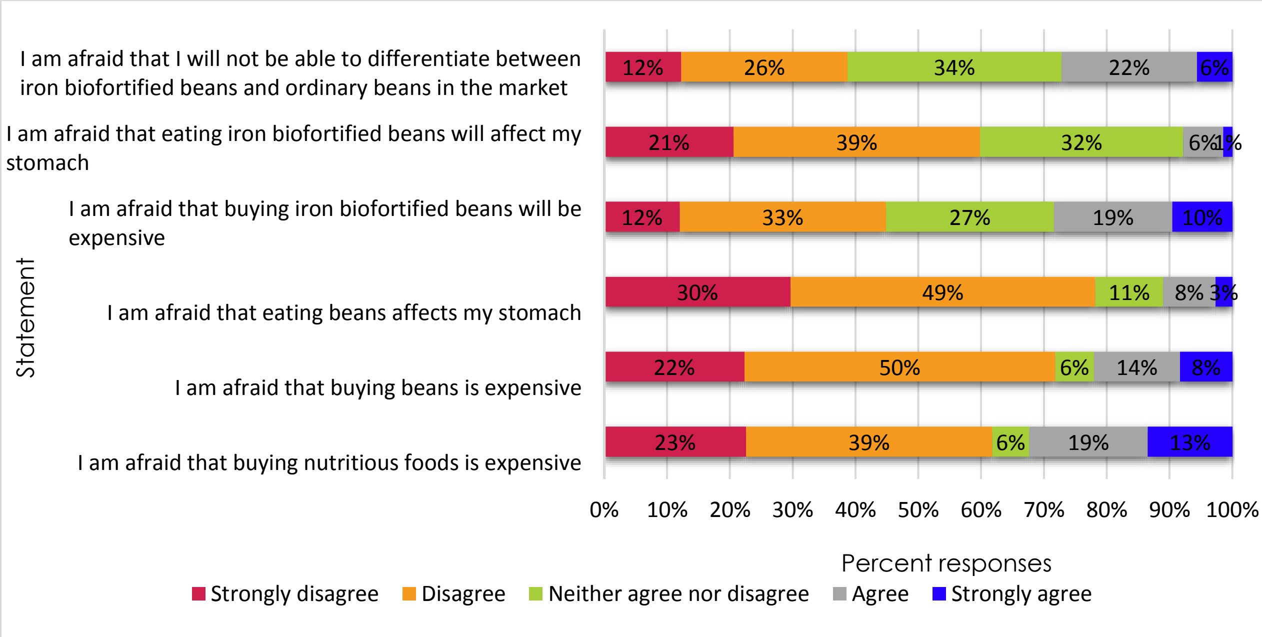


Figure 17: Barriers to consumption of biofortified beans

Average price of beans

The average price of beans is TZS 2,099 per kg across all locations, but varies across the districts. In Arusha, the average price is TZS 2,202 per kg while in Moshi and Babati the prices are lower with a mean of TZS 2,024 and TZS 1,784 respectively.

Willingness to pay for biofortified beans

To elicit the willingness to pay for biofortified beans a choice experiment and contingent valuation experiment were conducted. Respondents were presented with information about two types of beans: improved non-biofortified beans which are already in the market in all of Tanzania; and biofortified beans which are not yet available in the market. Results from choice experiment show that 95% of the consumers are willing to purchase iron bio fortified beans. This presents a good opportunity for the uptake of biofortified beans in Tanzania when they become available in market. Results are disaggregated by district, location of the household and gender of the respondent as well as sex of the household head (Figure 19).

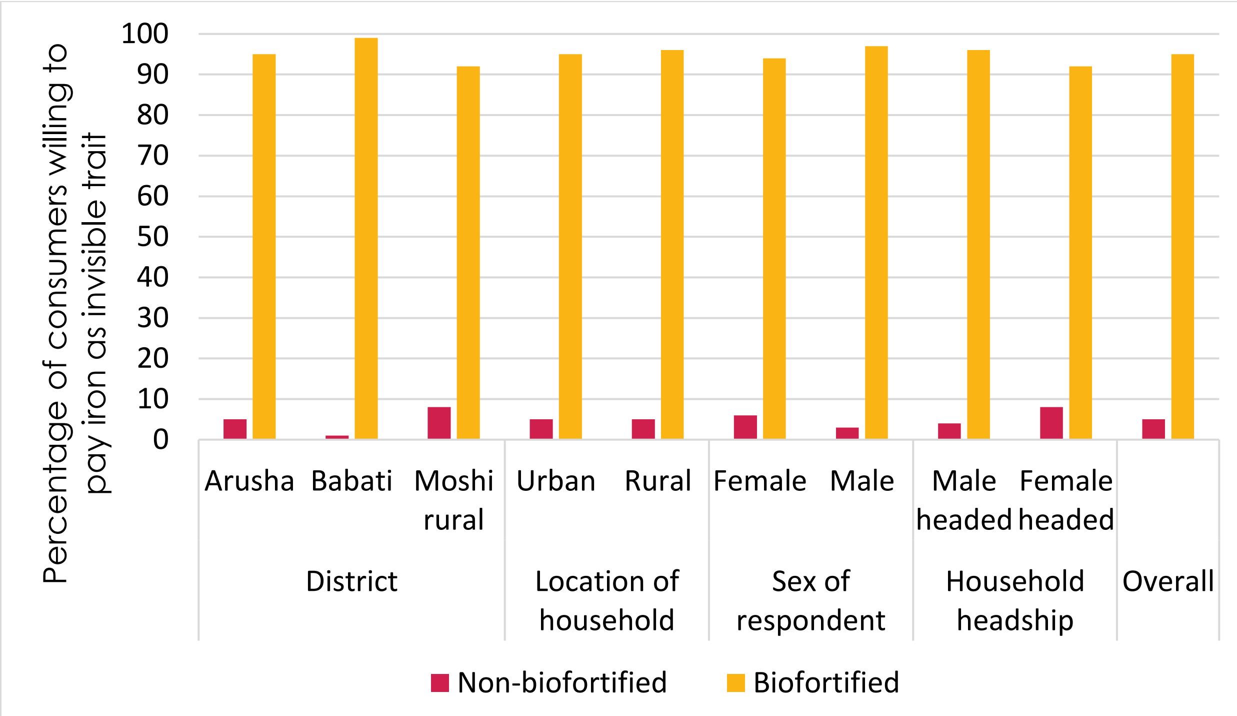


Figure 19. Consumer willingness to pay for iron biofortified beans

In the contingent valuation experiment, the respondents were asked whether they would buy each of the two types of beans (non-biofortified and biofortified) at a pre-determined price which represented the average market price of such beans in Tanzania at the time of the study. The average prices were TZS 2100 and TZS 2500 per kg for conventional non-biofortified and biofortified beans respectively. For those who responded to the affirmative, the price was adjusted upwards and the process repeated up to the point when they indicated that they would not be willing to pay. Conversely, when a respondent indicated that they were not willing to buy the beans at the average market price, the price was adjusted downwards till the point they indicated that they were willing to pay. If at a price TZS 1100 and 1300 for non-biofortified and biofortified beans respectively, the respondent was still not willing to pay; the process was concluded by asking for the reasons why they were not willing to pay for the respective type of beans.

Table 4: Consumer willingness to pay for conventional non-biofortified beans

	District			**Location**			
Price willing to pay (TZS/kg)	**Arusha**	**Babati**	**Moshi rural**	**Urban**	**Rural**	**Overall**	**Cumulative percent**
None*	0	0	2	0	1	1	100
1500	0	0	4	0	2	1	99

1700	0	3	1	0	2	1	98
1900	1	12	3	1	8	4	97
2100**	6	13	3	6	8	7	93
2300	36	30	2	36	16	26	86
2500	27	27	5	27	16	22	60
2700	9	3	4	9	4	6	38
2900	6	3	7	6	5	6	32
3100	4	5	1	4	3	3	26
3600	10	4	68	10	36	23	23

*The lowest price presented to the respondents was TZS 1100 per kg of conventional common beans. One percent indicated that the reason they were not willing to pay for these beans at the lowest price of TZS 1100 kilogram is because they have sufficient beans from their own farm production.
*Average market price

Overall, 93% of the respondents were willing to buy non-biofortified beans at the current average market price of TZS 2100 per kilogram or more (Table 14). The majority of the respondents indicated that they were willing to pay up to TZS 2300 (26%) and TZS 2500 (22%) per kilogram for these non-biofortified beans. For biofortified beans, an average market price of TZS 2500 per kg was presented to the bean consumers to solicit their willingness to pay for such beans when they become available in the market. Close to 95% were willing to pay the average market price or more, of which 15% were not willing to pay any money above this amount (Table 15). A similar proportion would pay an additional TZS 300 per kg to total TZS 2,800 per kg, while 19.4% were willing to pay up to TZS 3000 per kg which represents a 20% markup over the average market price.

Table 5: Willingness to pay for biofortified beans

Price willing to pay (TZS/kg)	District			Location		Overall	Cumulative percent
	Arusha	Babati	Moshi	Urban	Rural		
1300	0.0	0.0	1.0	0.0	0.5	0.2	100.0
1500	0.5	0.0	1.0	0.5	0.5	0.5	99.8
1800	0.0	0.0	1.0	0.0	0.5	0.2	99.3
2000	2.9	3.0	1.0	2.9	2.0	2.5	99.0
2300	2.4	3.0	1.0	2.4	2.0	2.2	96.6
2500	17.8	17.0	6.0	17.8	11.5	14.7	94.4
2800	18.8	17.0	4.0	18.8	10.5	14.7	79.7
3000	24.0	27.0	2.0	24.0	14.5	19.4	65.0
3200	10.1	11.0	2.0	10.1	6.5	8.3	45.6
3500	6.7	7.0	6.0	6.7	6.5	6.6	37.3
3700	7.7	3.0	3.0	7.7	3.0	5.4	30.6
4200	9.1	12.0	72.0	9.1	42.0	25.2	25.2

Overall, the mean price per kilogram of non-biofortified beans that the consumers were willing to pay is TZS 2679. This is higher than the current average market price by about 27 percent. In urban areas the price was 2565 TZS per kilogram while in rural areas it is higher by almost 10 percent standing at was TZS 2799 per kilogram. Similarly, the mean price that households were willing to pay for biofortified beans is higher than the average market price for these beans in Tanzania. The mean price in TZS per kilogram is 3233, a figure that is almost 30 percent higher than the average market price of TZS 2500 per kilogram. Further disaggregation of the data shows a significant difference between the amounts that rural and urban consumers were willing to pay as well as between male and female respondents. As in the case of non-biofortified beans, rural consumers were found to be willing to pay more than their urban counterparts for a kilogram of biofortified beans with TZS 3436 for the former and TZS 3038 for the latter. Males were willing to pay an average of TZS 3336 while females would pay TZS 3099 per kilogram.

Given that the mean amount of money that bean consumers were willing to pay for a kilogram of biofortified beans (TZS 3233) is higher than what they are willing to pay for non-biofortified beans (TZS 2679), it follows that the value attached to the hidden trait of biofortification by the consumers is positive. Willingness to pay for biofortification was defined as the difference between the amounts that the bean consumers were willing to pay for biofortified beans over and above what they were willing to pay the conventional non-biofortified common beans. This amount averaged TZS 556 per kilogram overall with a significant difference between urban (TZS 468) and rural (TZS 649) consumers and across the gender divide, with men willing to pay up to TZS 634 for the invisible trait of biofortification of a kilogram beans while women would pay TZS 456. Table 16 gives a summary of the average prices that consumers are willing to pay for conventional non-biofortified beans and biofortified beans as well as the willingness to pay for biofortified bean iron as an invisible trait.

Table 6: Consumer willingness to pay for biofortified *bean iron* as an invisible trait

	District			Location		Gender of the respondent		
	Arusha	Babati	Moshi	Urban	Rural	Male	Female	Overall
Price willing to pay for non-biofortified beans (Mean TZS/kg)	2565	2384	3222	2565***	2799***	2707	2643	2679
Price willing to pay for biofortified beans (Mean TZS/kg)	3038	3052	3820	3038***	3436***	3336***	3099***	3233

Additional amount willing to pay for biofortified bean iron as an invisible trait	468	668	630	468***	649***	634***	456***	556
Proportion of price willing to pay for biofortified bean iron as an invisible trait	0.19	0.29	0.23	0.19***	0.26***	0.25***	0.19***	0.23

Significant at ***p<0.01

Comparing additional price consumers are willing to pay for bio fortified beans by socio-economic characteristics

The additional price consumers were willing to pay for biofortified bean iron as an invisible trait was compared using a simple t-tests and presented in Table 17. The sex of the respondent is found to affect the willingness to pay for biofortified bean iron as an invisible trait with male respondents willing to pay more (TZS 634) in comparison to the female respondents (TZS 456). This could also be as a result of the fact that men are more economically empowered and have more control over resources including income use, as opposed to women who are more informed and/or nutrition conscious. This assertion is supported in this analysis where it was observed that women are involved more in the decision to buy beans yet it is the men who mostly pay for it (see also Table 10). Conversely, sex of the household head is not important in determining willingness to pay biofortified bean iron.

Households participating in groups (community, women or farmer groups) are likely to pay more (TZS 613) than when they are not (TZS 520), and similarly when they have been trained on food and nutrition (TZS 743) as opposed to when they have not been trained (TZS 525). This is in tandem with the fact that community groups have been cited as an important avenue and entry point for information dissemination and penetration of new technologies. As such trainings on nutrition and the importance of biofortified beans in diets can leverage on the presence of farmer and community groups already existent in Northern, Tanzania, and where they are not popular with consumers, such groups can be formed for purposes of creating awareness on biofortified beans and passing nutrition information to a wide audience.

With regards to household demographic composition, participants from households that do not have a child under the age of five years are willing to pay more (TZS 633) for biofortified bean iron in relation to those that have a child five years or below (TZS 487). This scenario presents an opportunity to target nutrition messages and information dissemination to these households since they fall in a demographic group that is vulnerable to iron deficiency. Household size and the presence of elderly members from 66 years and over do not affect the willingness to pay for biofortified bean iron.

Surprisingly, bean producers who sold at least 50% of their bean output the previous season to the time of survey, are willing to pay more (TZS 754) in comparison to those who sold a lower proportion of their produce or did not sell at all (TZS 505). Participants from households that meet at least half of their bean consumption needs from own farm production are willing to pay more (TZS 630) than those who rely more on the market for their bean consumption needs (TZS 504). As such it can be concluded that households that produce more beans, either indicated by the presence of a market surplus or by an increased consumption from own production or being more nutrition conscious hence willing to pay more. Conversely, the willingness to pay for biofortified bean iron is lower for participants from households that normally buy beans for consumption in relation to those who do not. With regard to the frequency of bean consumption, participants from households that consume beans more frequently (three or more days in a week) are willing to pay more (TZS 632) than those who consumed beans less than 3 days in a week (TZS 489). These households may be more aware and conscious of the nutritional benefits of beans thus willing to pay more for additional trait. As such this is an indication of a potential demand for iron biofortified beans when they become available in the markets in Northern Tanzania.

Table 7: Mean comparison of additional price consumers' are willing to pay for biofortified bean iron as an invisible trait

Variable	Mean amount willing to pay for biofortified bean iron (TZS/kg)		|t|	p-value
	Female	Male		
Sex of respondent	456***	634***	3.6145	0.0003
Sex of household head	497	574	1.2932	0.1967
	No	Yes		
Membership in groups	520	613*	1.8346	0.0673

Respondent trained on food and nutrition	525	743***	3.1090	0.002
Household has more than 5 people	540	575	0.7123	0.4767
Household has child(ren) under 5 years	633	487***	2.9621	0.0032
Household has member(s) aged 66 and above	562	530	0.4716	0.6375
Allocated at least 50% of cropped land to beans last season	672	564	1.5058	0.1335
Sold at least 50 % of bean output last season	505	754***	3.823	0.0001
Meets 50% or more of consumption needs from own production	504	630**	2.5144	0.0123
Buys beans for consumption	626	527*	1.8174	0.0699
Consumed beans three or more days in 7 days	489	632***	2.9046	0.0039

*p<0.1, **p<0.05, ***p<0.01

Unit 6 - Scaling HIBs

6.1 Objectives

By the end of this unit participants should be able to:

- Outline the strategic goals of biofortification interventions
- Identify potential partner organizations for supporting HIBs over the long term
- Recognize the potential impact of policies, regulations and trade on biofortification initiatives
- Explain the importance of integrating biofortification into international standards

6.2 Synopsis

In this unit we explore long-term strategies for "scaling" and "anchoring" HIBs within national food systems, including the impact of policy, regulations, trade and international standards on the promotion, adoption and sustainability of biofortified crops generally, and HIBs in particular.

6.3 Key Points

- The introductory phase of intensive promotion and support for biofortified crops is not intended to last forever
- Goal is to achieve sustainability and transfer ownership to local stakeholders
- Creating incentives and supports through policy, regulations, trade and international standards can help to ensure that biofortified crops become permanently anchored within local food systems

Unit 7 – Integrating HIBs into a healthy diet

7.1 Objectives

By the end of this unit participants should be able to:

- Review the nutritional benefits of eating HIBs
- Compare different methods of preparing HIBs in terms of nutrition
- Summarize the findings of the Rwandan study of HIBs

7.2 Synopsis

In this unit we discuss different methods for preparing HIBs and the impact of consuming HIBs on human health.

7.3 Key Points

- HIBs can provide an excellent source of iron, though some methods of preparation are more nutritious than others
- Multiple studies indicate significant improvement in iron levels for women of reproductive age after 3-4 months of consuming High-Iron Beans

7.4 Activities

Cooking with HIBs (Breakout Groups)

7.4.1 Recipes

High-Iron Beans Samosas

Ingredients for the dough:

2 cups wheat flour

350 ml cooking oil for frying

1 tsp baking powder

Water

Salt to taste

Method:

- Sieve the flour together with baking powder and rub in a bit of oil.
- Add the salt and mix properly.
- Add water gradually until mixture reaches stiff consistency.
- Roll out dough and cut into the shape of samosas.

-

Ingredients for stuffing:

1 Tomato

1 Onion

100g HIB beans

1 Green pepper

1 tsp curry or spice

Salt to taste

Method:

- Wash and slice all ingredients for the stuffing.
- Mix ingredients with salt and curry or spice.
    - This mixture is not cooked, because most of the vegetable nutrients would be lost.

Making the samosas:

- Put the stuffing into the cut samosa shapes and seal shut.
- Heat cooking oil until smoke point and deep fry the samosas until golden brown.

Beans muffins

Ingredients:

¼ cup mashed cooked HIB beans (MAC44/RWV1129)

1 ¼ cup baking wheat flour

3 Eggs

¼ cup castor sugar

3 tbsp margarine

3 tsp baking powder

½ tsp salt

Method:

- Preheat oven to 220 - 230°C.
- Sieve the flour, baking powder and salt.
- Cream together margarine, sugar and egg in a bowl. (For a light texture, use 2 whole eggs and only the white of the third).

- Combine the dry ingredients, mashed beans and margarine and egg mixture.
- Stir with a wooden spoon until just mixed. Do not over mix. The mixture should be lumpy.
- Grease the baking tins.
- Spoon the batter into the greased tins using a scoop.
- Reduce oven heat to 180°C and bake for 25 to 30 minutes.
- Cool and serve

Beans balls

Ingredients:

2 cups cooked HIB beans

1 tsp curry

1 onion, finely chopped

1/4 cup cassava flour

1 green pepper, finely chopped

Salt to taste

½ cup cooking oil for frying

Method:

- Mash the beans.
- Add the onion, green pepper, curry powder and salt to the beans.
- Add cassava flour for binding.
- Shape mixture into balls and fry in cooking oil until golden brown.
- Serve

High-Iron Beans Stew

Ingredients:

1 cup dried high-iron beans (MAC44 or RWV1129)

1 tbsp cooking oil

1 Onion

1 Tomato

¼ tsp curry powder

¼ tsp salt

Water

Method:

- Put the dried high-iron beans in a bowl and remove any foreign particles
- Wash the beans in cold water
- Soak the beans overnight in cold water (this reduces the cooking time)
- Replace soaking water in the saucepan with fresh water and boil beans until tender
- Drain the stock from beans and set aside
- Heat the oil
- Peel the onions and cut into cubes
- Fry the onions until tender (do not brown them)
- Peel the tomatoes and slice into small pieces
- Add the tomatoes to the onions and stir until tomatoes are tender
- Add the curry powder and stir
- Add the beans and salt and stir with a wooden spoon.
- Add the stock and continue stirring
- Reduce the heat and simmer for 15-20 minutes
- Serve warm or cold with ugali/sima or rice.

Unit 8 - Conclusion

Key Points

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