Journal of Food Technology Research
2025 Vol. 12, No. 1, pp. 1-10
ISSN(e): 2312-3796
ISSN(p): 2312-6426
DOI: 10.18488/jftr.v12i1.4148

Knowledge, attitudes, and practices of farmers on production and consumption of the biofortified NUA 45 sugar beans in Makoni District, Zimbabwe

Ropafadzo Chirimubwe[1+]
Rudo Natasha Mugadza[2]
Victor Tatenda Nyanhete[3]
Phyllis Nyamande[4]
Amiel Mugari[5]
Ruth Nyoka[6]

[1,2,3,4,5,6]*Food Science and Nutrition Department- Midlands State University, Private Bag 9055, Gweru, Midlands Province, Zimbabwe.*
[1]*Email: chirimubwer@staff.msu.ac.zw*
[2]*Email: mugadzar@staff.msu.ac.zw*
[3]*Email: nyanhetevt@staff.msu.ac.zw*
[4]*Email: pnyamande@staff.msu.ac.zw*
[5]*Email: mugaria@staff.msu.ac.zw*
[6]*Email: nyokar@staff.msu.ac.zw*

(+ Corresponding author)

Article History
Received: 18 September 2024
Revised: 20 February 2025
Accepted: 7 March 2025
Published: 27 March 2025

Keywords
Attitudes
Biofortification
Hidden hunger
Knowledge
NUA 45 sugar beans
Practices.

ABSTRACT

This study examines the knowledge, attitudes, and practices of farmers regarding the production and consumption of the biofortified NUA 54 sugar beans in Makoni district, Zimbabwe. Staple food crops typically have low micronutrient levels, leading to potential deficiencies among individuals whose diets lack diversity. Biofortification is a scientific strategy that enhances the micronutrient content of staple crops through selective breeding. A notable example is the development of iron-biofortified beans, which address nutritional deficiencies and improve dietary iron intake. This study aimed to evaluate farmers' knowledge, attitudes, and practices in the Makoni district of Zimbabwe concerning the production and consumption of biofortified NUA 45 sugar beans. A total of 299 respondents were interviewed through household surveys, and four focus group discussions were conducted to gather comprehensive data on these aspects. The findings demonstrate that farmers in the Makoni district possess a high level of knowledge regarding biofortified crops. Moreover, there is significant acceptance, extensive production, and notable consumption of NUA 45 sugar beans among these farmers. The growing recognition and popularity of biofortified crops, such as NUA 45 sugar beans, potentially contribute to enhanced nutrition and food security in the region. Understanding what farmers know, how they feel, and what they do about NUA 45 sugar beans can help fill in gaps in our knowledge, encourage the use of biofortified beans as a way to combat malnutrition, and assist Extension Services in creating training and support programs that are specific to the needs of farmers.

Contribution/Originality: This study uniquely explores the farmers' knowledge, attitudes, and practices regarding both the production and consumption of biofortified NUA 45 sugar beans in Makoni District, Zimbabwe. It provides localized insights into biofortification adoption, filling a gap in understanding behavioral patterns that influence sustainable nutrition and food security strategies.

1. INTRODUCTION

Hidden hunger, which is defined as a deficiency in essential micronutrients (vitamins and minerals) such as vitamin A, iron, iodine, and zinc, remains a public health challenge in Sub-Saharan Africa (FAO, IFAD, UNICEF, WFP, & WHO, 2020). Ohanenye et al. (2021) highlighted that 80% of the global cases of iron, zinc, and vitamin A deficiencies were recorded in Sub-Saharan Africa. These micronutrient deficiencies are more prevalent in populations where there is poor dietary diversity and cereal grains constitute a large proportion of the diet (Allen, De Benoist, Dary, & Hurrell, 2006). Iron deficiency is among the three leading risk factors included in the 2019 Global Burden of Disease report (Vos et al., 2020) and is responsible for approximately 137 million cases of anemia in children under the age of 5 (Sundararajan & Rabe, 2021). Iron deficiency may present symptoms such as anemia and fatigue; however, iron deficiency may also be asymptomatic (Pasricha, Tye-Din, Muckenthaler, & Swinkels, 2021). The global prevalence of anemia has been reported to be high in children aged 6-59 months and women of reproductive age (WHO, 2015). Anemia has been associated with preterm delivery in pregnant women, low birth weight in infants, poor cognitive development, impaired physical activity, and a reduced quality of life in adults (Black et al., 2013).

According to Lockyer, White, and Buttriss (2018) and Ohanenye et al. (2021), food fortification strategies such as mass, targeted, household fortification, biofortification, and microbial fortification are employed as mitigatory measures against life-threatening conditions caused by micronutrient deficiencies. On the other hand, Bamji, Murty, and Sudhir (2021) emphasized nutrition-sensitive agriculture as a sustainable measure against poor plant growth and productivity due to climate change-associated stresses on the environment, pressure on natural resources, and arable land (Roriz, Carvalho, Castro, & Vasconcelos, 2020).

This commonly reduces the nutritional value of harvested food crops, posing a major challenge to the ever-growing population fighting malnutrition problems, particularly micronutrient deficiencies. To reduce the public health problem of hidden hunger, it is important to use nutrition-based agricultural interventions like biofortification. Biofortification refers to the enhancement of the nutritional value of a crop through transgenic techniques and agronomic practices (Kumar & Pandey, 2020). This way of intervening in nutrition might help people who aren't getting enough micronutrients while also providing them with a wider range of foods to eat, which will lead to better health outcomes related to their diet (Khush, Cho, & Jeon, 2012). To date, some of the biofortified crops include maize, iron-enriched beans, cowpeas, sweet potatoes, and rice (Dhaliwal et al., 2022). Humans worldwide consume the common bean (*Phaseolus vulgaris*), which is a grain legume that has the potential for iron and zinc biofortification (Ibrahim & Ramadan, 2015; Petry, Boy, Wirth, & Hurrell, 2015). Nutrient Andean 45 sugar beans (NUA 45 sugar beans) is a red mottle-colored cultivar that was among the first generation of biofortified bean cultivars enriched with iron (Fe) and zinc (Zn) (Maereka et al., 2024). Vaiknoras and Larochelle (2021) indicated that the adoption of biofortified bean crops improves iron intake compared to the non-biofortified varieties.

The adoption of biofortified crops faces challenges that affect their demand among consumers, which in turn influences farmers' cultivation decisions. In Zimbabwe, a study by Muvhuringi and Chigede (2021) highlighted low rates of production and consumption of biofortified crops due to the limited availability of biofortified seeds and the distance to seed supply markets. This data suggests that establishing sustainable markets for biofortified seeds and products is crucial for the effectiveness of biofortification initiatives (Kiran et al., 2022). Research by Muthini, Nzuma, and Nyikal (2019) found that farmers who were familiar with certain crop varieties but lacked knowledge about their nutritional benefits were less likely to adopt biofortified options.

Therefore, the success of biofortification depends on the people who are supposed to benefit from it accepting and consuming these foods (Meenakshi et al., 2012). Understanding the knowledge, attitudes, and practices (KAPs) of communities regarding the production and use of biofortified crops is essential to address public concerns. This study specifically aims to explore the knowledge, attitudes, and practices related to biofortified NUA 45 sugar beans among communities in the Makoni district, Zimbabwe.

2. METHODOLOGY

2.1. Study Area

The research was carried out in Makoni District, which is located in Manicaland Province, in northeastern Zimbabwe. Makoni District was selected for the study on the basis of having participated in the biofortification program under the Livelihoods, Food and Security Program (LFSP) that was funded by the UK government (Livelihoods and Food Security Programme (LFSP), 2019). In addition, the district has moderate food insecurity and high stunting levels (FNC, 2022), and there is potential for market development. The research was conducted from January to August 2022.

2.2. Study Design

A mixed research approach was used to conduct the study, adapted from Muvhuringi and Chigede (2021). A quantitative research method was employed to quantify the knowledge, attitudes, and practice patterns, while a qualitative research approach was utilized to identify trends in the knowledge, attitudes, and practices, which helped to illuminate the quantitative research findings.

2.3. Sampling

Four wards, namely 10, 19, 20, and 32, were randomly selected for focus group discussions and household surveys. Purposive sampling was utilized to select 10 participants for each focus group discussion within the designated wards. Additionally, a comprehensive list of community members was compiled, from which simple random sampling was applied to select 299 households for the household surveys.

2.4. Data Collection

2.4.1. Household Surveys

The researchers conducted household surveys across four wards, employing a semi-structured questionnaire in the local language, Shona. This approach aimed to gather information on household demographics, farmers' knowledge, seed sources, and produce consumption. In total, 299 respondents were interviewed from the four wards.

2.4.2. Focus Group Discussions

A total of four Focus Group Discussions (FGDs) were held in wards 10, 19, 20, and 32. The purpose of these discussions was to gather insights into farmers' attitudes, knowledge, and practices regarding the production and consumption of the biofortified NUA 45 sugar beans. Additionally, the FGDs aimed to identify challenges faced during the production of biofortified sugar beans and to explore the factors that limit their consumption within the community. To ensure effective communication, the discussions were conducted in the local language, allowing all respondents to participate fully. The researchers developed a discussion guide, which was pretested and refined to address any ambiguities in the questions.

2.5. Data Analysis

The data obtained from household surveys was analyzed using the Statistical Package for the Social Sciences (SPSS) version 24, developed by IBM in Delhi, India. A descriptive analysis was conducted for the qualitative data gathered from focus group discussions (FGDs), leading to a comprehensive presentation of the findings.

2.6. Ethical Considerations

Ethical clearance for the study was granted by the Midlands State University's Research Ethics Committee. Participants voluntarily consented to take part in the study, and their responses were used solely for that purpose. The study adhered to research principles concerning privacy, confidentiality, and anonymity.

3. RESULTS

3.1. Socio-Economic and Demographic Characteristics

In the survey, 45.2% of respondents were aged 36–50 years, while the 18-35 years age group had the least representation at 20.7%. Females comprised the majority at 64.9%, with males making up 35.1%. Most respondents (68.6%) had completed secondary education, 6% had reached tertiary education, and only 1% had no formal education (Table 1).

Table 1. Socio-demographic characteristics.

Variable	Subgroups	Number of respondents	Percentage (%)
Age	18 to 35 years	62	20.7
	36 to 50 years	135	45.2
	50 + years	102	34.1
Sex	Male	105	35.1
	Female	194	64.9
Level of education	No formal education	3	1.0
	Primary	73	24.4
	Secondary	205	68.6
	Tertiary	18	6.0
Wards	10	71	23.7
	19	80	26.8
	20	74	24.7
	32	74	24.7
Household size	1	5	1.7
	2	20	6.7
	3	57	19.1
	4	74	24.7
	5	56	18.7
	6	50	16.7
	7	20	6.7
	8	7	2.3
	9	7	2.3
	10	2	0.7
	11	1	0.3

3.2. Knowledge of Biofortified Beans

All the respondents were knowledgeable about the biofortified NUA 45 sugar beans (Table 2). A larger proportion (41.1%) of the respondents had a knowledge timeline about NUA 45 sugar beans of more than five years. Biofortified seeds were found to be readily available, as indicated by 92.6% of the respondents.

Table 2. Knowledge of biofortified beans.

Variable	Subgroups	Number of respondents	Percentage (%)
Knowledge of biofortified beans	Yes	299	100
	No	0	0
Knowledge timeline	1 year ago	15	5.0
	2 years back	44	14.7
	3 years ago	72	24.1
	4 years ago	45	15.1
	More than 5 years ago	123	41.1
Availability	Readily available	277	92.6
	Scarce	20	6.7
Variety of biofortified beans	NUA45	100	100

3.3. Sources of Information on Biofortification

Only 1.3% of the respondents received knowledge through pamphlets (Table 3); the majority (66.1%) relied on health facilities as a source of information on biofortification.

Table 3. Sources of information on biofortification.

Source	Number of respondents	Percentage (%)
Neighbour/Farmer group	24	8.1
Community-based volunteers	19	6.4
NGOs, seed companies	44	14.8
Pamphlet	4	1.3
Health facilities	197	66.1
Radio messages / Mobile farming application	10	3.3
School children	0	0
Other	0	0
None	0	0

3.4. Preferred Sources of Information on Biofortified Products

Health facilities/Department of Agricultural, Technical and Extension Services (AGRITEX) were the most preferred sources of information on biofortification, as highlighted by 52.1% of the respondents (Table 4), whereas social media and pamphlets were the least preferred sources of information, as indicated by 0.6% of the respondents.

Table 4. Distribution of the participants' preferred sources of information about biofortified products.

Sources of information	Frequency	%	Ranking
Community-based volunteers	13	4.1	5th
Health facilities/AGRITEX	168	52.1	1st
Neighbour/Farmer group	26	8.1	4th
NGOs, seed companies	39	12.1	3rd
Pamphlet	2	0.6	6th
Radio messages/Mobile farming application	72	22.4	2nd
Social media	2	0.6	6th

3.5. Consumption and Preparation Habits of Biofortified Beans

65.9% of the respondents indicated that they consumed NUA 45 sugar beans, while 20.7% consumed both NUA 45 sugar beans and the non-biofortified beans, and 13.4% consumed the non-biofortified beans only (Table 5). A greater proportion of the respondents (59.5%) indicated that they did not soak beans before cooking, and 53.8% discarded the water in which the beans were soaked. Most farmers consumed the biofortified beans that they produced (97.7%), with only 2% indicating gifts as their source of NUA 45 sugar beans.

Table 5. Consumption and preparation habits of biofortified beans.

Variable	Subgroups	Number of respondents	Percentage (%)
Type of consumed beans	High iron biofortified beans	197	65.9
	Normal, traditional beans	40	13.4
	Both high-iron beans and normal traditional beans	62	20.7
	Don't know	0	0
Soaking beans before cooking	No	178	59.5
	Yes	121	40.5
Sources of biofortified beans for consumption	Home grown	225	75.3
	Local open market	12	4.0
	Directly from farmer	39	13.0
	Retail shop	7	2.3
	Food aid	10	3.3
	Gift	6	2.0
Consumption of water in which the beans are soaked	No	161	53.8
	Yes	138	46.2
Consumption of biofortified beans that you produce	No	7	2.3
	Yes	292	97.7

3.6. Farming and Marketing of Biofortified Beans

Most respondents (91.6%) produced biofortified beans, with 34.9% using retained seed for cultivation. Among those, 75.9% grew biofortified beans for their nutritive value, while only 3.3% cited agronomic benefits as a reason (Table 6).

Regarding the cost comparison, 29.8% of respondents found the price of NUA 45 sugar bean seed to be similar to that of non-biofortified sugar bean seed, whereas 59.5% considered NUA 45 sugar beans to be more expensive. Recycling NUA 45 sugar beans for planting was prevalent, as 95% reported reusing beans. The primary reason for using recycled seed was a lack of income to purchase inputs, noted by 59.4% of respondents. The main source of retained seed was from previous harvests, according to 90% of respondents.

Table 6. Farming and marketing of biofortified beans.

Variable	Subgroups	Number of respondents	Percentage (%)
Production of biofortified beans	No	25	8.4
	Yes	274	91.6
Sources of biofortified seed	Purchase from another farmer	60	21.6
	Purchase from shops	31	11.2
	Free test packs/Donation	79	28.4
	Retained seed	97	34.9
	Gift	11	3.9
Purpose of production	Because of its nutritive value	227	75.9
	Palatability-taste, color, texture	51	17.1
	Agronomic benefits-yield	10	3.3
	Trying out the new variety	11	3.7
	Free input	0	0
Sale of biofortified produce	No	161	53.8
	Yes	138	46.2
Market	Vendors	47	19.9
	Neighbors	101	42.8
	Local shops/Market	41	17.4
	GMB	41	17.4
	Other	6	2.5
Cost of Nua45 bean seed compared to normal seed	The same	89	29.8
	More	178	59.5
	Less	5	1.7
	Don't know	27	9.0
Recycling NUA45 seed	No	15	5.0
	Yes	284	95.0
Purpose of retaining seed	Lack of income to purchase enough inputs	177	59.4
	Bad season forecast	2	0.7
	Unavailability of certified seed on the market	26	8.7
	Do not have access to the market	1	0.3
	Recycled seed performs fairly well for a few seasons	92	30.9
Sources of retained seed	Previous harvest	269	90.0
	From neighbor	9	3.0
	Open market	8	2.7
	No response	13	4.3

4. DISCUSSION

The study showed that the majority of the farmers were middle-aged (Table 1), and this could be attributed to the fact that this age group is actively involved in agricultural activities and decision-making about food consumption in the household (Table 1). Females dominate the number of respondents in this study. This finding aligns with

previous research by Oladejo, Olawuyi, and Anjorin (2011), which indicated that women demonstrate higher engagement levels in agricultural activities. Consequently, this heightened level of engagement may contribute to the amplified responses observed in women.

In this study, health facilities and AGRITEX workers were the most preferred sources of information for farmers on biofortification (Table 3). The degree of relationship that farmers in Makoni District have with health facilities and AGRITEX personnel may explain this. Earlier research has shown that agricultural extension services are very important for teaching people about biofortification (Nchanji et al., 2023; Okello, Kwikiriza, Muoki, Wambaya, & Heck, 2019). This preference could also be attributed to the fact that agricultural extension services are reliable sources of information on crops. The majority of farmers in the study had a positive attitude towards biofortified NUA 45 sugar beans, probably because of their high knowledge of the nutritional value of the variety as well as its other desirable qualities, such as good taste. FGD participants also agreed that they accepted and valued the introduction of the biofortified variety in their area because of the good taste, shorter cooking time, and perceived nutritional value compared to the non-biofortified beans that they normally grew in their community. These findings are similar to those reported by Mwangwela, Mwachumu, and Banda (2021). The study also noted that most respondents indicated that they soaked their beans before cooking (Table 5). Soaking is mostly associated with a reduction in the cooking time of beans, as acknowledged by Munthali et al. (2022). Rehman, Salariya, and Zafar (2001) also suggested that soaking beans reduces anti-nutrients and improves cooking quality.

The study also noted that all the respondents were knowledgeable about the biofortified NUA 45 sugar beans. The participants acquired knowledge about this variety from the Livelihood and Food Security Program, which was implemented in the Makoni district (Livelihoods and Food Security Programme (LFSP), 2019). All the focus group discussions with the community members also supported the findings from household surveys that most farmers knew about the variety and were growing biofortified crops. According to the Zimbabwe 2021 crop and livestock survey report, the area planted with biofortified crops in the 2020/21 season was 11,990 ha (7,662 ha in vitamin A maize (0.4% of total maize area) and 4,328 ha in iron beans (12% of total bean area)). Furthermore, Katungi, Kalemera, Mutua, and Maereka (2020) revealed that the most adopted bean varieties included Cherry and Gloria as well as NUA 45, and that the adoption rate of the biofortified NUA 45 variety in Zimbabwe increased from less than 2% in 2016 to 12% in 2018.

Researchers have found that providing free seed test packs to farmers in certain wards makes people much more aware of and open to biofortified NUA 45 sugar beans. Participants in focus group discussions (FGDs) reported receiving these test packets through the Livelihoods and Food Security Programme (LFSP). Furthermore, engagement in nutrition awareness initiatives, such as food fairs and cooking demonstrations, has been instrumental in promoting not just the production but also the consumption of biofortified crops.

The Makoni District's accessibility to biofortified seeds boosts local farmers' production of NUA 45 beans. This increased availability can be attributed to the demand generated by the Livelihoods and Food Security Programme (LFSP) (2019), prompting local agro-dealers to stock biofortified seeds. This finding contrasts with the study conducted by Muvhuringi and Chigede (2021), which reported insufficient production and consumption of biofortified crops, primarily due to the unavailability of seeds, alongside low consumption rates of biofortified beans and orange maize.

This study also found that many farmers continued using old seeds from previous crops, mostly because they didn't have enough money to buy certified commercial seeds, which was something that Birachi (2012) had already written about. Additionally, local farmers expressed concerns regarding the potential for price inflation of biofortified products, alongside fears of future seed scarcity. These apprehensions align with the findings of Rehman et al. (2020), articulating that significant challenges to the adoption and production of biofortified crops include seed unavailability and prohibitive seed costs.

Strengthening the seed supply chain emerges as a pivotal strategy for enhancing the widespread adoption of biofortified crop varieties (Sheoran et al., 2022). Moreover, farmers from the Makoni district have recommended that governmental departments amplify nutrition awareness campaigns, including cooking demonstrations and the ongoing distribution of free seed test packets within communities. This recommendation is corroborated by Sharma, Aggarwal, and Kaur (2017), who emphasize the importance of nutrition training in fostering awareness within communities, thus ensuring the successful implementation of biofortification initiatives.

5. CONCLUSIONS AND RECOMMENDATIONS

Based on the findings, it can be concluded that the farmers in Makoni district were highly knowledgeable about biofortified crops and their potential health benefits since the introduction of the NUA 45 sugar bean variety in 2016. Acceptance, production, and consumption of NUA 45 sugar beans in Makoni district were high. Thus, the research recommends further studies on knowledge, attitudes, and practices regarding the production and consumption of other biofortified crops, such as the vitamin A orange maize and orange-fleshed sweet potatoes.

Funding: This study received no specific financial support.
Institutional Review Board Statement: The Ethics Committee of Midlands State University, Zimbabwe has granted approval for this study on 8 January 2022 (Ref. No. 019/01/2022).
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

REFERENCES

Allen, L. H., De Benoist, B., Dary, O., & Hurrell, R. (2006). *Guidelines on food fortification with micronutrients*. Geneva, Switzerland: World Health Organization and Food and Agriculture Organization of the United Nations.

Bamji, M. S., Murty, P., & Sudhir, P. D. (2021). Nutritionally sensitive agriculture—an approach to reducing hidden hunger. *European Journal of Clinical Nutrition, 75*, 1001-1009. https://doi.org/10.1038/s41430-020-00760-x

Birachi, E. A. (2012). Value chain analysis of beans in Eastern and Southern Africa: Building partnerships for impact through research on sustainable intensification of farming systems.

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., De Onis, M., . . . Martorell, R. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet, 382*(9890), 427-451.

Dhaliwal, S. S., Sharma, V., Shukla, A. K., Verma, V., Kaur, M., Shivay, Y. S., . . . Barek, V. (2022). Biofortification—A frontier novel approach to enrich micronutrients in field crops to encounter the nutritional security. *Molecules, 27*(4), 1340. https://doi.org/10.3390/molecules27041340

FAO, IFAD, UNICEF, WFP, & WHO. (2020). *In brief to the state of food security and nutrition in the world 2020 transforming food systems for affordable healthy diets*. Rome: FAO.

FNC. (2022). *Second round crop and livestock assessment report*. Retrieved from https://fscluster.org/sites/default/files/documents/2nd_round_assessment_report_2021_23_april_2021.pdf

Ibrahim, E. A., & Ramadan, W. A. (2015). Effect of zinc foliar spray alone and combined with humic acid or/and chitosan on growth, nutrient elements content and yield of dry bean (Phaseolus vulgaris L.) plants sown at different dates. *Scientia Horticulturae, 184*, 101-105. https://doi.org/10.1016/j.scienta.2014.11.010

Katungi, E., Kalemera, S., Mutua, M., & Maereka, E. (2020). *Bean technology adoption and its impact on smallholder farmers' productivity, bean consumption; and food security: Evidence from Zimbabwe*. The Alliance of Bioversity International and CIAT. Report. pp. 28.

Khush, G. S., Cho, J. I., & Jeon, J. S. (2012). Biofortification of crops for reducing malnutrition. *Plant Biotechnology Reports, 6*, 195-202. https://doi.org/10.1007/s11816-012-0216-5

Kiran, A., Wakeel, A., Mahmood, K., Mubaraka, R., Hafsa, & Haefele, S. M. (2022). Biofortification of staple crops to alleviate human malnutrition: Contributions and potential in developing countries. *Agronomy, 12*(2), 452.

Kumar, S., & Pandey, G. (2020). Biofortification of pulses and legumes to enhance nutrition. *Heliyon, 6*(3), 1-6. https://doi.org/10.1016/j.heliyon.2020.e03682

Livelihoods and Food Security Programme (LFSP). (2019). *Nutrition and biofortification: A training manual for community workers on nutrition and the growing, processing, storage and utilization of Vitamin A orange maize and iron beans.* Harare, Zimbabwe: LFSP.

Lockyer, S., White, A., & Buttriss, J. (2018). Biofortified crops for tackling micronutrient deficiencies–what impact are these having in developing countries and could they be of relevance within Europe? *Nutrition Bulletin, 43*(4), 319-357. https://doi.org/10.1111/nbu.12347

Maereka, E. K., Mutari, B., Kunaka, F., Nchanji, E., Tsekenedza, S., Muthoni-Andriatsitohaina, R., & Chimboza, D. (2024). NUA 45, a dry bean cultivar, builds a subtle brand in Zimbabwe against all odds. *Frontiers in Sustainable Food Systems, 8*, 1-12. https://doi.org/10.3389/fsufs.2024.1260167

Meenakshi, J., Banerji, A., Manyong, V., Tomlins, K., Mittal, N., & Hamukwala, P. (2012). Using a discrete choice experiment to elicit the demand for a nutritious food: Willingness-to-pay for orange maize in rural Zambia. *Journal of Health Economics, 31*(1), 62-71. https://doi.org/10.1016/j.jhealeco.2012.01.002

Munthali, J., Nkhata, S. G., Masamba, K., Mguntha, T., Fungo, R., & Chirwa, R. (2022). Soaking beans for 12 h reduces split percent and cooking time regardless of type of water used for cooking. *Heliyon, 8*(9), 1-11. https://doi.org/10.1016/j.heliyon.2022.e10561

Muthini, D. N., Nzuma, J. M., & Nyikal, R. A. (2019). Variety awareness, nutrition knowledge and adoption of nutritionally enhanced crop varieties: Evidence from Kenya. *African Journal of Agricultural and Resource Economics, 14*(4), 225–237.

Muvhuringi, P. B., & Chigede, N. (2021). Trends in production and consumption of selected biofortified crops by rural communities in Zimbabwe. *Cogent Food & Agriculture, 7*(1), 1894760. https://doi.org/10.1080/23311932.2021.1894760

Mwangwela, A., Mwachumu, M., & Banda, I. (2021). *Cooking characteristics and consumer acceptability of biofortified beans international institute of agriculture and natural resources.*

Nchanji, E., Nduwarugira, E., Ndabashinze, B., Ntukamazina, N., Toywa, J., & Cosmas, L. (2023). Gender dynamics in the biofortified bean value chain in Burundi. *Outlook on Agriculture, 52*(4), 411-423. https://doi.org/10.1177/00307270231193049

Ohanenye, I. C., Emenike, C. U., Mensi, A., Medina-Godoy, S., Jin, J., Ahmed, T., . . . Udenigwe, C. C. (2021). Food fortification technologies: Influence on iron, zinc and vitamin A bioavailability and potential implications on micronutrient deficiency in Sub-Saharan Africa. *Scientific African, 11*, e00667. https://doi.org/10.1016/j.sciaf.2020.e00667

Okello, J. J., Kwikiriza, N., Muoki, P., Wambaya, J., & Heck, S. (2019). Effect of intensive agriculture-nutrition education and extension program adoption and diffusion of biofortified crops. *Journal of Agricultural & Food Information, 20*(3), 254-276. https://doi.org/10.1080/10496505.2018.1515632

Oladejo, J. A., Olawuyi, S. O., & Anjorin, T. (2011). Analysis of women participation in agricultural production in Egbedore local government area of Osun State, Nigeria. *International Journal of Agricultural Economics and Rural Development, 4*(1), 1-11.

Pasricha, S.-R., Tye-Din, J., Muckenthaler, M. U., & Swinkels, D. W. (2021). Iron deficiency. *The Lancet, 397*(10270), 233-248. https://doi.org/10.1016/S0140-6736(20)32594-0

Petry, N., Boy, E., Wirth, J. P., & Hurrell, R. F. (2015). The potential of the common bean (Phaseolus vulgaris) as a vehicle for iron biofortification. *Nutrients, 7*(2), 1144-1173. https://doi.org/10.3390/nu7021144

Rehman, A., Farooq, M., Ullah, A., Nadeem, F., Im, S. Y., Park, S. K., & Lee, D.-J. (2020). Agronomic biofortification of zinc in Pakistan: Status, benefits, and constraints. *Frontiers in Sustainable Food Systems, 4*, 1-10. https://doi.org/10.3389/fsufs.2020.591722

Rehman, Z.-u., Salariya, A. M., & Zafar, S. I. (2001). Effect of processing on available carbohydrate content and starch digestibility of kidney beans (Phaseolus vulgaris L.). *Food Chemistry, 73*(3), 351-355. https://doi.org/10.1016/s0308-8146(00)00311-3

Roriz, M., Carvalho, S. M., Castro, P. M., & Vasconcelos, M. W. (2020). Legume biofortification and the role of plant growth-promoting bacteria in a sustainable agricultural era. *Agronomy, 10*(3), 435. https://doi.org/10.3390/agronomy10030435

Sharma, P., Aggarwal, P., & Kaur, A. (2017). Biofortification: A new approach to eradicate hidden hunger. *Food Reviews International, 33*(1), 1-21. https://doi.org/10.1080/87559129.2015.1137309

Sheoran, S., Kumar, S., Ramtekey, V., Kar, P., Meena, R. S., & Jangir, C. K. (2022). Current status and potential of biofortification to enhance crop nutritional quality: An overview. *Sustainability, 14*(6), 3301.

Sundararajan, S., & Rabe, H. (2021). Prevention of iron deficiency anemia in infants and toddlers. *Pediatric Research, 89*, 63-73. https://doi.org/10.1038/s41390-020-0907-5

Vaiknoras, K., & Larochelle, C. (2021). The impact of iron-biofortified bean adoption on bean productivity, consumption, purchases and sales. *World Development, 139*, 105260. https://doi.org/10.1016/j.worlddev.2020.105260

Vos, T., Lim, S. S., Abbafati, C., Abbas, K. M., Abbasi, M., Abbasifard, M., . . . Abdelalim, A. (2020). Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: A systematic analysis for the global burden of disease study 2019. *The Lancet, 396*(10258), 1204-1222.

WHO. (2015). *World health organization health topic anemia.* Geneva: World Health Organization.