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# Knowledge, Attitudes, Practices, and Barriers to Iron-Biofortified Bean Consumption among Caregivers of Under-Five Children in Butezi Health District, Burundi: A Mixed-Methods Study

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## Abstract

**Background:** Iron deficiency is a major cause of childhood anemia in sub-Saharan Africa, affecting 71% of children under five in Ruyigi province, Burundi. Since 2015, iron-fortified beans have been promoted locally, but little is known about household awareness, attitudes, and consumption of these beans. **Objective:** To document caregivers' knowledge, attitudes, and practices, and to identify barriers to children aged 24 - 59 months consuming iron-biofortified beans in the Butezi health district, Burundi. **Methods:** This community-based, mixed-methods cross-sectional study was conducted from November to December 2023. It involved a structured survey of 602 children and caregivers, as well as 66 semi-structured qualitative interviews. **Results:** Only 17 respondents (2.82%) reported hearing about and knowing about iron-biofortified beans. 96.01% of participants expressed a preference for beans among children, and 51.66% had consumed beans the previous day. 88.87% of household seeds came from local markets. Among those aware of biofortified beans, acceptance was high at 88.2%, primarily due to their favorable taste. Qualitative findings suggest that limited awareness and challenges in seed distribution, rather than taste preferences, are the main barriers. **Conclusion:** Iron-biofortified beans in Butezi remain limited, with low awareness and limited access. To improve adoption and combat childhood anemia in rural Burundi,

it is recommended to bolster community nutrition education and increase the availability of certified seeds.

## Keywords

Iron-Biofortified Beans, Childhood Anemia, Knowledge, Attitudes, and Practices, Mixed Methods, Burundi.

## 1. Introduction

Childhood micronutrient deficiencies remain a significant global public health concern, particularly in sub-Saharan Africa [1]-[3]. The prevalence is 56% worldwide and 62% in sub-Saharan Africa among children aged 6 - 59 months [4]. Iron deficiency is among the most prevalent micronutrient deficiencies in children [5]. During early childhood, a critical period of rapid growth and brain development, inadequate iron intake can lead to severe outcomes, including cognitive developmental disorders, diminished immunity, impaired physical growth, and heightened susceptibility to disease [6]-[8].

Prolonged iron deficiency leads to iron deficiency anemia (IDA), which is among the most common nutritional problems in children under five [9] [10], and accounts for nearly half of childhood anemia cases [11].

Dietary factors are a leading cause of iron deficiency in young children [12]. In many rural regions, children's diets lack diversity and are low in foods rich in iron. Research in sub-Saharan Africa indicates that inadequate complementary feeding practices play a significant role in the persistent problem of childhood anemia [13]. Therefore, improving access to nutrient-dense foods is essential within strategies aimed at decreasing iron deficiency.

One way to bridge this gap is to promote iron-biofortified beans [14]. These beans have been developed through conventional breeding to increase their iron content while preserving traits valued by farmers and consumers [15] [16]. Nonetheless, implementing intensified biofortification as a sustainable public health solution still faces many agronomic, commercial, and political obstacles that must be addressed alongside its nutritional advantages [17].

Considering the extensive consumption of common beans in Eastern and Central Africa, biofortified varieties offer a practical way to increase iron intake without requiring major changes to the diet [18]. Research from multiple African countries has demonstrated the positive effects of consuming iron-biofortified beans on iron levels and other health markers [19] [20].

In Burundi, anemia affects 61% of children under five, according to the 2017 Demographic and Health Surveys (DHS). Data on iron deficiency are limited. However, the DHS reports that only 25% of children aged 6 to 23 months consumed iron-rich foods in the 24 hours before the survey [21].

Food fortification in Burundi is regulated by Presidential Decree No. 100/68,

dated March 18, 2015. The National Institute of Agronomy's bean iron fortification program began in 2015. Beans are among the most widely consumed foods in the country [22].

Anemia affects 60% of children under 5 nationwide, with rates rising to 71% in Ruyigi former province [21]. Among the province's four health districts, Butezi has the highest rate of chronic childhood malnutrition [23].

Although biofortified bean varieties suited to local conditions are available, there are limited data on how households use them and on their effects on child nutrition. Because beans are a staple of the local diet, these varieties could be an effective, accessible way to increase young children's iron intake.

The success of biofortification initiatives depends not only on providing improved seed varieties but also on increasing community awareness and acceptance [24] [25]. Households' awareness of iron-biofortified beans and their ability to distinguish them from traditional types influence their consumption decisions [26] [27].

Community health workers, often the primary link between health systems and rural communities, could be vital in closing this awareness gap. However, their support for nutrition-focused programs varies across Sub-Saharan Africa [28].

Data on caregivers' understanding, attitudes, and behaviors regarding iron-biofortified beans are scarce, particularly for children under five. This study aims to provide evidence to support nutrition policies and programs aimed at reducing childhood anemia in Burundi.

## 2. Methods

### 2.1. Study Design, Setting, and Population

We conducted a community-based cross-sectional study using mixed methods in the Butezi health district, former Ruyigi Province, eastern Burundi. Among the four districts in Ruyigi, Butezi has the highest rates of chronic malnutrition among children. The district, which comprises two communes, Butezi and Nyabitsinda, is predominantly rural and relies mainly on subsistence and small-scale livestock farming for income. The map below shows the district's location within Ruyigi Province (**Figure 1**).

The source population included all children aged 24 to 59 months residing in the Butezi health district. For the quantitative part of the study, we selected children within this age group whose mothers or primary caregivers lived in the designated hills and agreed to take part. Children whose caregivers could not be contacted despite several attempts or who were ill during the interview were excluded.

### 2.2. Sample Size Considerations

We determined the sample size using the proportion formula $n = p(1 - p)Z\alpha^2/i^2$, where $Z = 1.96$ (95% confidence level), with an estimated prevalence of iron-fortified bean consumption ($p$) of 50% and a margin of error ($i$) of 0.03. This yielded a total of 544 children. Adding 10% to account for potential non-response

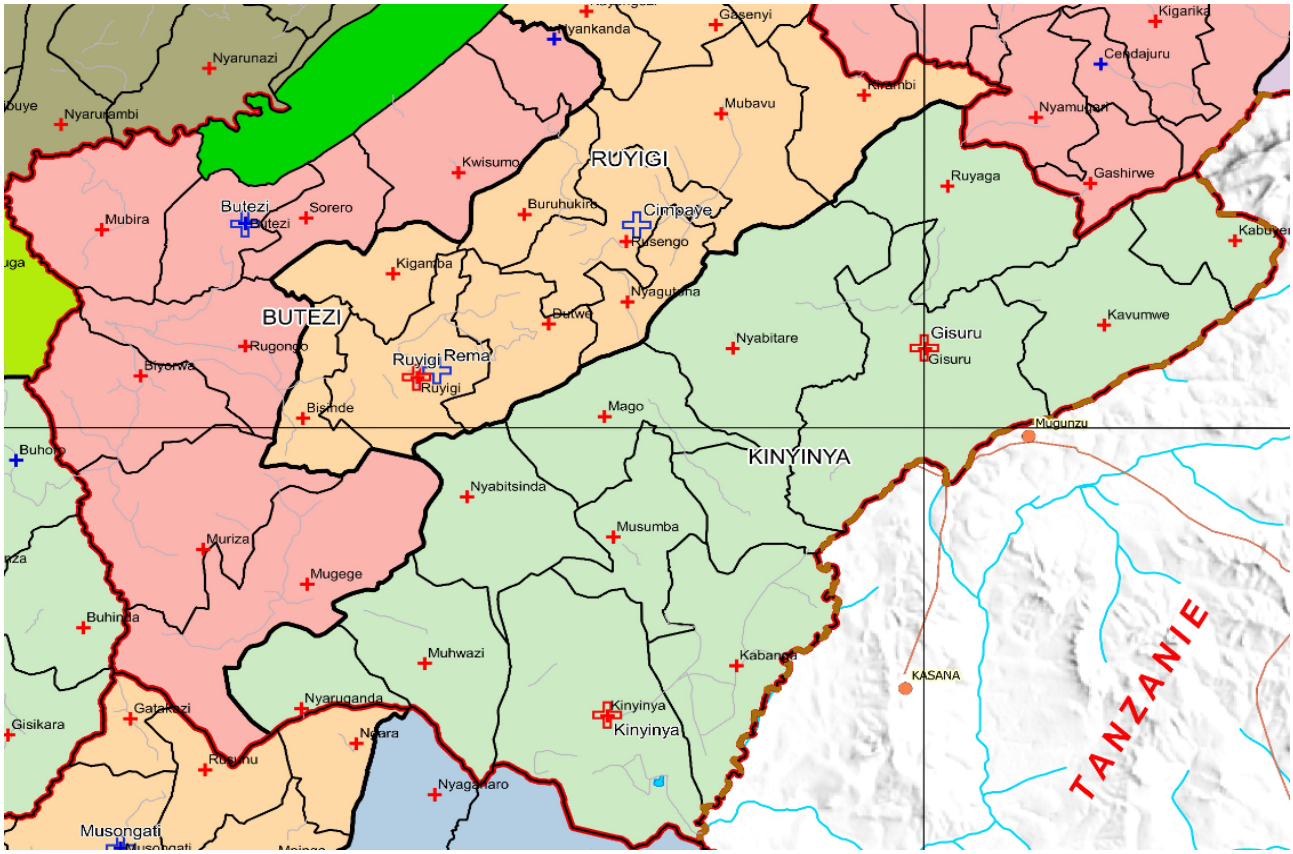


**Figure 1.** Butezi health district. From the Burundian sanitary health Card, 2016.

increased this to 598, which we rounded up to a final target of 602.

This total was then allocated proportionally across the hills in both communes, based on the estimated number of eligible children in each hill, ensuring that no hill would be under- or overrepresented relative to its population.

## 2.3. Sampling Method

We randomly selected 14 of the 54 hills in the 2 communes of the Butezi health district: 4 from Butezi commune and 10 from Butaganzwa commune. Within each selected hill, eligible households were identified using household lists compiled by community health workers, and children were selected through simple random sampling until the hill's quota was reached. In households with more than 1 child under 5, we randomly selected one child.

This two-stage approach, consisting of proportional allocation across the hills followed by random selection of children within each hill, ensured that the sample was representative of the study area and made the selection process transparent and easy to replicate.

## 2.4. Data Collection Tool and Procedures

We designed a structured questionnaire, informed by a literature review of similar studies, covering sociodemographic characteristics, household and child infor-

mation, and knowledge, attitudes, and practices regarding iron-fortified beans. A supplementary semi-structured interview guide was developed for the qualitative component to explore perceptions of anemia as a health problem, the perceived role of iron-fortified beans in its prevention, and the availability and accessibility of these beans in the community.

Nutrition experts validated both tools and pilot-tested them in the Ruyigi Health District, adjacent to Butezi but outside the study area, to ensure that their wording was clearly understood before fieldwork began and to avoid influencing the population that would later be recruited for the main survey.

The interviewers were trained in data collection tools, the study's objectives, and procedures to ensure data quality; daily supervision sessions were held throughout the fieldwork. Before each interview, the study's objective was explained to participants, and those who agreed to participate signed a consent form. Quantitative interviews were conducted with mothers or primary caregivers, randomly selected from the list of eligible children in the study areas; each interview lasted approximately 20 minutes and was conducted in Kirundi, the local language.

For the qualitative component, key informants were purposively selected from seven categories of actors involved at different levels in the production, distribution, promotion, or consumption of iron-biofortified beans in the Butezi health district: caregivers of children aged 24 - 59 months (n = 28), community health workers (n = 14), agricultural extension officers (n = 14), health facility staff, including health center heads and hospital-based providers (n = 6), the district's Chief Medical Officer (n = 1), the provincial Director of Agriculture and Livestock (n = 1), and bean seed multipliers (n = 2). This resulted in 66 semi-structured interviews, one per participant.

This targeted, multi-category sampling approach was designed to gather insights from all key stakeholders involved in adopting iron-biofortified beans. It included provincial agricultural authorities and seed multipliers at the upstream level, along with community health workers, agricultural extension agents, and caregivers as end users. The goal was to capture diverse viewpoints across and within these groups, rather than focusing on a single perspective.

Within each category, interviews continued until no new themes emerged, indicating saturation. This was most evident among the groups of mothers, community health workers, and agricultural extension officers, which had the highest respondent counts. Single-informant groups were included to capture unique institutional perspectives, as only one individual holds each role in the study area. The two seed multipliers interviewed represent nearly all seed multipliers active in the study communes. Interviews were conducted in Kirundi.

Data were collected over 10 days: quantitative data from November 23 to 28, 2023, and qualitative data from November 30 to December 5, 2023.

## 2.5. Variables of the Study

For the "knowledge, attitudes, and practices" (KAP) aspects of our study, we used

the following variables: knowledge of the type of iron-fortified beans, source of information about iron-fortified beans, perceived importance of consuming iron-fortified beans, types of iron-fortified beans consumed, frequency of bean consumption, taste of iron-fortified beans, and side effects of iron-fortified beans. The type of iron-biofortified beans reported as known and consumed was caregiver-reported; biofortification status was not independently verified.

For the qualitative component, the questions and topics were designed to understand the factors limiting the consumption of iron-fortified beans.

### 2.6. Data Management and Analysis

The completeness and accuracy of the data were verified daily. In Stata, quantitative data were recorded and analyzed; categorical variables were summarized as proportions, and continuous variables were described using measures of central tendency and spread.

The interviews were transcribed in Kirundi, translated into English for analysis, and a manual thematic analysis was conducted in Excel to identify recurring sub-themes across the informant categories. The interviews were coded by five encoders using a hybrid thematic approach that combined deductive and inductive elements. For each main theme derived from the interview guide, sub-themes were identified through a thorough reading of the transcripts. For each sub-theme, recurring keywords were extracted from the corpus to build a hierarchical coding grid (theme, sub-theme, keywords). The five encoders worked independently before comparing their respective grids to assess coding consistency. Disagreements were resolved through collective discussion until consensus was reached. The final categories were validated by the entire team before the qualitative results were integrated with the quantitative results.

The abbreviations are defined as follows: ASC for community health worker; MCD for head of the medical district; DPAE for provincial director of agriculture and livestock; and ISABU for the Institute of Agricultural Sciences in Burundi. In the results, citations are followed by an anonymized participant code that indicates the informant's category, interview number, and source hill (e.g., mother, community health worker, agricultural extension officer). These codes were assigned during data encoding to protect participant privacy.

### 2.7. Ethical Considerations

The National Ethics Committee of Burundi (CNE/14/2023) approved the study protocol. Before fieldwork began, we met with local administrative and health authorities in the study area to present the project and obtain their support.

Before any data were collected, participants received a consent form and an explanation of the research's benefits. Only participants who consented to the study were invited to participate in data collection. In data management, we assigned a code to each participant to ensure anonymity and protect personal data.

Written informed consent was obtained from the mother or primary caregiver

for each participating child before data collection. Participants were informed of the study's purpose, procedures, and their right to withdraw at any time without penalty. For the qualitative component, verbal consent to record interviews was also obtained from key informants.

## 3. Results

### 3.1. Quantitative Results

#### 3.1.1. Description of the Sample

The study population consisted of 602 children aged 24 to 59 months. Table 1 below describes the sociodemographic characteristics:

Table 1. Distribution of respondents by sociodemographic and economic characteristics (N = 602).

| Characteristics | Frequency (n) | Percent (%) |
|---|---|---|
| **Age of child in months** | | |
| 24 - 35 | 251 | 41.69 |
| 36 - 47 | 203 | 33.72 |
| 48 - 59 | 148 | 24.58 |
| **Sex of child** | | |
| Female | 298 | 49.50 |
| Male | 304 | 50.50 |
| **Birth order** | | |
| Oldest | 126 | 20.93 |
| Youngest | 110 | 18.27 |
| 3rd and above | 366 | 60.80 |
| **Child under five** | | |
| One child | 259 | 43.02 |
| 2 children and above | 343 | 56.98 |
| **Mother's level of education** | | |
| None | 148 | 24.58 |
| Primary | 376 | 62.46 |
| Secondary and above | 78 | 12.96 |
| **Profession of mother** | | |
| Cultivator | 593 | 98.50 |
| Civil servant and other professions | 9 | 1.50 |
| **Mother's marital status** | | |
| Single | 10 | 1.66 |
| Married | 578 | 96.01 |

**Continued**

| | | |
|---|---|---|
| Cohabitation | 8 | 1.33 |
| Widow | 6 | 1.00 |
| **Mother's age range (years)** | | |
| 15 - 19 | 4 | 0.66 |
| 20 - 34 | 372 | 61.79 |
| 35 - 49 | 226 | 37.54 |
| **Profession of father** | | |
| None | 7 | 1.16 |
| Cultivator | 568 | 94.35 |
| Civil servants and others | 27 | 4.49 |
| **Head of household** | | |
| Female | 35 | 5.81 |
| Male | 567 | 94.19 |

In our sample of 602 children, 251 (41.69%) were between 24 and 35 months old, and more than half were male (50.50%). The majority (60.80%) were the third child in their family.

Based on the characteristics of the children's families, 343 children came from families with two or more children under 5, representing 56.98% of our sample.

Most mothers were farmers (98.50%), had a primary school education (62.46%), and were married (96.01%). The 20 - 34 age group was the largest among mothers, accounting for 61.79% of cases. The majority of the fathers of the surveyed children were farmers (94.35% of cases), and the head of the household was male in 94.19% of cases.

### 3.1.2. Knowledge of Iron-Biofortified Beans

The following Table 2 shows the results regarding knowledge of iron-fortified beans:

Table 2. Distribution of respondents by knowledge of iron biofortification in beans (N = 602).

| Characteristics | Frequency (n) | Percent (%) |
|---|---|---|
| **Have you heard of iron biofortified beans?** | | |
| No | 585 | 97.18 |
| Yes | 17 | 2.82 |
| **Types of iron biofortified beans known** | | |
| Bagara, yinayina, shushamarike | 1 | 0.17 |
| Kinure | 12 | 1.99 |

Continued

| | | |
|---|---|---|
| Sinamakamwe | 4 | 0.66 |
| No knowledge | 585 | 97.18 |
| **Source of information** | | |
| None | 585 | 97.18 |
| HCW | 3 | 0.50 |
| Radio | 2 | 0.33 |
| Health facilities | 3 | 0.50 |
| Agriculture monitors | 4 | 0.66 |
| Seeds multipliers | 5 | 0.83 |
| **Importance of iron-biofortified beans** | | |
| Rich in protein | 6 | 1.00 |
| Improving childhood growth | 7 | 1.16 |
| Rich in iron | 4 | 0.66 |
| No knowledge | 585 | 97.18 |

Based on knowledge of bean biofortification, only 17 of 602 respondents reported hearing of biofortified beans; all 17 (100%) cited at least one type of biofortified bean they knew. The most frequently cited sources of information on bean biofortification were health care facilities, agriculture monitors, seed multipliers, and community health workers.

### 3.1.3. Consumption of Iron-Biofortified Beans

In terms of practices, they are explained in more detail in Table 3 below.

Table 3. Distribution of respondents according to practices related to beans and biofortified beans (N = 602).

| Characteristics | Frequency (n) | Percent (%) |
|---|---|---|
| **Consumption of beans yesterday** | | |
| No | 291 | 48.34 |
| Yes | 311 | 51.66 |
| **Consumption of iron-biofortified beans yesterday** | | |
| No | 585 | 97.18 |
| Yes | 17 | 2.82 |
| **Weekly frequency of bean consumption** | | |
| At least once | 204 | 33.89 |
| 2 or 3 times | 286 | 47.51 |
| **Characteristics** | | |
| 4 times and above | 112 | 18.60 |
| **Children like to eat beans.** | | |
| No | 24 | 3.99 |

**Continued**

| | | |
|---|---|---|
| Yes | 578 | 96.01 |
| **Sources of bean seeds** | | |
| Personal reserves | 27 | 4.49 |
| Donation/NGO | 33 | 5.48 |
| Market | 535 | 88.87 |
| Multipliers of seeds | 7 | 1.16 |

More than half of the children in our sample (51.66%) had eaten beans the day before the survey. Only 2.82% of caregivers reported that their children had eaten biofortified beans. Nearly half of the children reported eating beans three times a week. Mothers interviewed reported that their children generally like beans (96%). Most bean seeds came from markets.

There is a contrast between common and non-biofortified iron beans: beans, as a food category, are accepted and consumed by children, with 96.01% of respondents saying they like to eat them and more than half having eaten beans the day before; however, biofortified varieties are still rarely seen in diets (2.82%).

#### 3.1.4. Attitudes Related to Iron-Biofortified Beans

The following Table 4 shows the participants' perceptions and attitudes toward iron-biofortified beans:

Table 4. Distribution of respondents by attitudes about biofortification of beans with Iron (N = 602).

| Characteristics | Frequency (n) | Percent (%) |
|---|---|---|
| **Taste** | | |
| Good | 15 | 2.49 |
| Bad | 2 | 0.33 |
| No idea | 585 | 97.18 |
| **Side effects** | | |
| Abdominal pain | 1 | 0.17 |
| No side effects | 16 | 2.66 |
| No idea | 585 | 97.18 |

Based on respondents' attitudes toward biofortification, the vast majority (97.18%) are unaware of both its taste and its side effects.

### 3.2. Qualitative Results

#### 3.2.1. Factors Limiting the Consumption of Iron-Fortified Beans

**1) Perceptions of the prevalence of childhood anemia, its causes, and ways to address it**

Most participants agreed that anemia among children under 5 is a reality in

their area, as one of the interviewed mothers attested:

"Anemia exists in our community. Even my child has had to deal with it. It really does exist here." BMZA1

The causes cited included poverty and inadequate nutrition, as highlighted by a community health worker who took part in the study:

"In my opinion, the main cause is a lack of proper nutrition, which leads to a gradual decrease in the child's blood levels until full-blown anemia sets in." ANBI1

This perception was echoed at the health system level, as follows:

"Infantile anemia is a fact in our health district. So, when children suffer from malaria, their hemoglobin levels decrease, and sometimes we transfuse them. This means that even with this malaria, they had a low rate of hemoglobin, and malaria highlights the already pre-existing low rate." MDB1

For most participants, the foods that help combat anemia are the three major food groups: carbohydrates, fats, and proteins. Only a few specifically mentioned beans as an iron-rich food, as in the following quote:

"I could mention beans, vegetables, and oils as foods that can help reduce anemia." AMRA1

These accounts reveal a generally correct understanding of the link between diet and the occurrence of anemia. Beans were not spontaneously identified as a full-fledged source of iron, but were instead subsumed into a broad and undifferentiated category of foods that help.

This gap between general awareness of anemia related to malnutrition and a lack of specific knowledge about iron-rich foods mirrors the patterns already described in the complementary quantitative survey conducted in the same district, where iron intake from dense foods of animal origin, such as meat and eggs, is low.

This suggests that nutrition education messages in this context may need to go beyond generic dietary advice and adopt more targeted, diet-specific communication about iron sources.

**2) Awareness of iron-biofortified beans among key informants**

Most participants were unfamiliar with this type of bean, including community health workers. One of them put it this way:

"No, I don't know these beans, but I hope that among the beans available in our area, they are included as well." ARTA1.

This mother also emphasized: *"These beans don't exist where we live."* BMGE2

Taken together, these testimonies illustrate a form of "invisibility" of biofortified iron beans in the community's food landscape: even health professionals and community health workers have described these varieties as absent, unknown, or

hypothetical rather than as a concrete option for production or consumption, suggesting that the seed distribution chain has not yet reached the region in a structured or continuous manner.

This is consistent with the low proportion of respondents able to spontaneously name a biofortified variety in the quantitative component (2.82%), and confirms that the barrier at this stage is exposure rather than non-acceptability.

**3) Structural and economic barriers to seed access and cultivation of iron-biofortified beans**

The main reasons cited for the low consumption of biofortified beans were a lack of awareness and limited availability of seeds and manure. As one participant noted: *"People aren't well-informed about this type of bean; the cost of seeds and manure also hinders bean cultivation."* MUNBIC66.

Beyond the lack of information, participants highlighted concrete structural constraints: the cost of quality seed and manure needed to support their cultivation has repeatedly discouraged farmers from adopting new bean varieties, even when interest exists.

This finding aligns with the overall results of the quantitative survey, in which 88.87% of household bean seeds were purchased from regular markets rather than from specialized propagation or distribution channels (1.16%). This indicates that most families lack a readily accessible supply route for biofortified seeds.

The seed multipliers have also reported this point of view: *« One of the challenges we face is the cost related to these beans, and also, once the beans are available, we have difficulties with manure. »* MSN2

### 3.2.2. Stakeholders' Suggestions and Perspectives on Increasing Consumption

The main suggestions from the participants were to increase awareness of iron-biofortified beans and their availability. As one participant said: *"What I can ask for is greater availability of seeds and more awareness sessions to encourage the practice of consuming these beans."* AKGAC1

The provincial director of agriculture and livestock spoke about the need for more awareness among all stakeholders and greater accessibility to these bean varieties: *"Awareness must be raised about this type of bean, not only among farmers, but also among all stakeholders involved in child nutrition. We have platforms where we meet; we need to spread these messages on these beans so that we can speak the same language in the field and raise awareness. And on our side, if we have a partner who wants to get involved in agriculture, we will tell them to mobilize to make available these types of beans that help combat anemia."* DPR1

This call for greater seed availability, coupled with awareness raising, reflects a community that is not resistant to innovation but rather constrained by a lack of practical opportunities to adopt it.

This suggests that demand responsiveness already exists and that the programmatic effort would be more effectively directed toward providing seeds and secondary communications, expanding local access to certified biofortified seeds,

and equipping community health workers and agricultural agents with simple, visual, and repetitive messages.

## 4. Discussion

This study uses a mixed-methods approach to assess caregivers' knowledge, attitudes, practices, and perceived barriers related to children under five consuming iron-biofortified beans in Burundi. By combining quantitative and qualitative data, it provides a detailed understanding of the factors affecting adoption of these beans in a rural area with an existing national biofortification program. The results show that awareness of and intake of iron-biofortified beans remain very low, despite the widespread use of traditional beans. This indicates that the main challenges to their adoption are limited awareness and poor access, rather than issues of acceptability.

The quantitative finding that only 2.82% of caregivers had heard of biofortified beans was reinforced by qualitative interviews, in which mothers, community health workers, and health professionals consistently reported little or no awareness of these varieties. Together, these findings strengthen confidence that inadequate community awareness is a major challenge. The proportion of respondents who had ever heard of biofortified beans was very low. Similar results have been reported by other studies, which found that awareness of biofortified crops remained limited [29] [30]. In our study, this low level of awareness may be linked to a lack of targeted communication strategies on biofortification. Qualitative interviews indicate that nutrition education activities conducted in health facilities and at the community level address this topic little or not at all.

However, because this study did not directly assess the implementation of the national biofortification program, caution is warranted in attributing the observed knowledge gap solely to program performance. Other factors, such as limited farmer-level exposure to certified biofortified seed, inconsistent local terminology for these varieties, or genuine difficulty distinguishing biofortified from conventional beans by sight, may also have contributed to the very low level of reported awareness.

Despite this low level of knowledge, beans play an important role in children's diets. This observation aligns with available data from the Great Lakes region, where beans are a staple food and contribute significantly to protein and micronutrient intake [31] [32]. The adoption of biofortified varieties could thus build on already established dietary habits.

In this regard, the very high acceptability of common beans documented here (96.01%) is an asset for the adoption of biofortified iron varieties. Promoting biofortified beans requires replacing a staple food consumed regularly.

Regarding attitudes, the majority of participants did not express an opinion about biofortified beans because they were unfamiliar with these varieties. This lack of opinion appears to reflect limited exposure rather than reluctance to use them.

Of the 17 participants who reported familiarity with biofortified beans, 15 said they tasted good, and only one reported experiencing abdominal pain after eating them. Other studies have found little difference in taste between biofortified beans and commonly consumed beans, which facilitates their acceptance and consumption [33].

Similarly, composite dishes made with biofortified iron beans have been well rated by consumers in other studies [34], and studies assessing willingness to pay for iron-rich beans in East Africa have reported comparable acceptance once barriers to awareness are overcome [35].

Although this sub-sample is too small to support firm conclusions, it offers a positive signal for program planners, given that concerns about acceptability are a commonly cited barrier to the expansion of biofortified crops elsewhere in the sub-region [25] [36].

Larger, purpose-designed sensory and acceptability studies, adequately powered to evaluate consumer perceptions of iron-biofortified beans specifically, would be needed before definitive conclusions about their palatability and tolerability can be drawn.

The findings suggest that limited awareness may contribute to the low uptake of biofortified beans. Other constraints were also noted, including limited seed availability, supply challenges, and economic constraints. These findings align with those reported in several African studies on the adoption of biofortified crops [37] [38].

Persistent constraints related to seed multiplication and distribution have also been documented in other multi-stakeholder seed systems initiatives in the region, including in Burundi, highlighting that partnerships among research institutions, seed producers, and extension services remain essential to improving the availability of certified biofortified seeds [39] [40]. These findings suggest that promotion strategies should combine nutritional education with improved access to seeds.

Our qualitative data also specify at which level of the value chain these constraints apply: not at the household level of will, but at the levels of seed multiplication, seed distribution in markets, and the affordability of complementary agricultural inputs such as manure. Thus, in addition to interventions on nutritional messaging in health facilities and at the community level, strengthening the seed supply chain can increase consumption of these biofortified iron varieties.

Finally, participants frequently linked childhood anemia to inadequate nutrition, poverty, and recurrent illnesses. Previous research in Burundi on factors associated with childhood anemia has found that nutritional, infectious, and socioeconomic factors are among the causes of the condition [41]. In this context, incorporating biofortified beans into nutrition interventions could help strengthen strategies for preventing anemia in young children.

Notably, although most participants readily recognized childhood anemia as a health problem linked to poor nutrition, relatively few spontaneously identified

iron-rich foods, particularly iron-biofortified beans, as a specific preventive strategy. This suggests that existing nutrition education messages may emphasize general healthy eating while providing insufficient guidance on specific dietary sources of iron. Counseling messages delivered through health facilities and community platforms should be refined accordingly.

### 4.1. Implications for Policies and Practices

Our results suggest that a single intervention will not be sufficient to increase the consumption of biofortified iron beans in the Butezi district. Given that rural farm households in the region are heterogeneous in terms of food and agricultural decision-making structures and modes [42], these interventions should be designed to reach not only mothers but also other household members who influence food and seed choices.

A successful approach would involve: 1) connecting with the community through existing channels, such as community health workers, agricultural extension agents, and prenatal care programs that already reach most mothers, while also expanding mass communication; 2) improving local seed multiplication and market distribution to ensure biofortified varieties are as accessible as traditional beans; 3) providing support to reduce the cost of agricultural inputs for these varieties; and 4) incorporating specific messages about iron and food into current nutrition education sessions, moving from general 'good nutrition' advice to explicit guidance on iron-rich foods. Leveraging these existing platforms is likely more cost-effective than establishing new communication strategies.

### 4.2. Strengths and Limitations of the Study

The use of a mixed-methods approach enabled the integration of both quantitative and qualitative data, enhancing our understanding of the factors affecting biofortified bean consumption. Participants might have inaccurately reported not consuming biofortified beans due to limited knowledge. Additionally, because the study was conducted in only one health district, the findings may not apply to other regions within the country.

This mixed-methods design is a particular strength of the study: the consistency of findings across markedly different participant groups (caregivers, community health workers, agricultural agents, and health professionals) reinforces confidence in the conclusion that limited awareness and access, rather than poor acceptability, are the principal barriers to adopting iron-biofortified beans. In addition, the cross-sectional design of the quantitative component limits our ability to establish causal relationships between awareness and consumption, and self-reported information on bean consumption may have been subject to recall or social desirability bias.

Furthermore, because knowledge of biofortified beans was low in our sample, the taste and side effect estimates are based on a very small number of respondents (n = 17). They should be interpreted as indicative rather than representative. Fi-

nally, in the qualitative survey, although opinions were received from various key informants (mothers, health workers, and agricultural agents), social desirability may have influenced certain responses, particularly regarding the perceived causes of anemia.

### 4.3. Research Perspectives

Further studies are needed to assess the effect of awareness-raising interventions on household adoption of biofortified beans. Longitudinal or experimental studies would also help examine their impact on iron status and the prevalence of anemia among children under 5 years of age. Research on local names for iron-bean varieties biofortified in the region, also comparing them with the names of those promoted by the Institute of Agronomic Sciences of Burundi, could help create a cartography of the beans available there and contribute to awareness of their consumption. Finally, research into the production, distribution, and marketing systems for biofortified seeds could help identify the constraints that limit their availability and use in rural communities.

Finally, given the low level of knowledge about biofortified iron beans found in our research, a major short-term research priority would be a formative evaluation of community outreach strategies: for example, assessing the effectiveness of messages delivered by community health workers and agricultural monitors, and comparing their effectiveness with that of media campaigns in this specific rural context, before large-scale investments are made.

## 5. Conclusions

This study found that the consumption of iron-biofortified beans among children under five in the Butezi health district is low. Improved seeds remain largely inaccessible in local markets, and community health workers in the study area have received little training.

Existing dietary practices, cultural familiarity with this staple food, and qualitative survey findings indicating increased awareness and information on the subject are assets for nutrition programs aimed at improving children's diets in the study area.

Taken together, these results indicate that the challenge in Butezi is not a matter of demand or cultural acceptability, but rather a gap between awareness and access that persists despite almost ten years of programmatic investment in biofortification.

The findings suggest that multi-sectoral strategies that engage the health and agriculture sectors may improve awareness of and access to iron-biofortified beans. Integrating iron-specific dietary messages into existing high-impact platforms, such as antenatal care and routine nutrition education sessions, could provide a pragmatic and relatively inexpensive entry point to accelerate the adoption of biofortified iron beans and, over time, help reduce childhood anemia in this rural district of Burundi.

Community health workers and agricultural extension agents, who are closest

to the population, could benefit from capacity-building on existing varieties that can be grown in the district, as well as from access to visual aids to raise awareness, which could improve the local population's knowledge of and consumption of this food.

Capacity-building should also be provided to healthcare workers to help them emphasize the importance of this type of food in children's diets. The provincial directorate of agriculture and livestock, along with the province's nutrition-focused development partners, could develop a roadmap to improve the availability of biofortified beans.

Overall, the findings indicate that the principal challenge is not the acceptability of iron-biofortified beans but rather limited awareness and access. Addressing these barriers through integrated agricultural and health-sector interventions may increase adoption and improve iron intake among young children in rural Burundi.

## Authors Contribution

Belyse, M. conceived and designed the study, participated in field data collection, conducted the statistical analysis, interpreted the results, and drafted the manuscript. Mbazi, S., Juma, K., Sayoki, M., Sévérin, S., and Jonathan, N. supervised the study throughout its conduct, including the quality of data collection and analysis, and critically reviewed and revised the manuscript for important intellectual and scientific content. All authors read and approved the final version of the manuscript.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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