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# The potential of Amaranth Grain-Based Flour in Complementary Feeding: *A Community-Based Approach in Kongwa District, Tanzania.*

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**Abstract**

Complementary feeding is critical for child development, yet inadequate nutrient intake remains a significant challenge in low-income countries, including Tanzania. The selection of appropriate complementary foods that meet dietary diversity is key to child growth and development. This study was done to unleash the potential of amaranth grain in complementary feeding in the Kongwa district, to provide an alternative to maize-based complementary feeding that is low in nutrients and highly susceptible to mycotoxins contamination. Amaranth grain-based flour for complementary feeding was formulated from a mixture of amaranth grain, millet, and pumpkin seeds at 4:1:1 (w/w/w). Kjeldahl method and atomic absorption spectrometry were used to quantify nutrients, while High-Performance Liquid Chromatography was used to determine aflatoxin contamination. Recipe trials involved focus group discussions with 48 mothers of children 6-24 months. Furthermore, sensory evaluation using a 9 hedonic scale technique was adopted to assess the acceptability of the Porridge made from Amaranth grain-based flour. Amaranth grain-based flour presented high nutritive value: Energy 485.50 kcal/100g, protein 14.76 g/100g, Lipids 14.22 g/100g, and iron 15.36 g/100g, zinc 16.8 mg/100g, calcium 301.19 mg/100g, and vitamin A 402.34 ug/100g portion of flour. The nutritive composition of five nutrients met the WHO-RNI recommendation except lipid and calcium,

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that was low, 30 and 32% below RNI, despite the statistical insignificance (p = 0.815). The maximum aflatoxin contamination of the flour was 0.5 µg/kg, which was below the maximum tolerable limit of 10 µg/kg for total aflatoxin in food, harmonized by the East African Community and adopted by the Tanzania Bureau of Standards. Porridge made from flour was highly accepted by mothers, with a 9 hedonic scale result of 9.3 out of 10. Amaranth grain-based flour is a nutrient-dense, safe, and culturally acceptable option for complementary feeding in the Kongwa District. Its adoption may address nutritional deficiencies in children.

**Abbreviations**

| | |
|---|---|
| MMT | Mycotoxin Mitigation Trial |
| AF | Aflatoxin |
| KNCHREC | Northern Tanzania Health Research Ethics Committee |
| NIMR | National Institute of Medical Research |
| MNAPP | Multisectoral Nutrition Action Plan Programme |
| WHO | World Health Organization |
| FGD | Focus Group Discussion |
| IYC | Infant and Young Children |
| IYCF | Infant and Young Child Feeding |
| CF | Complementary Feeding |
| RNI | Recommended Nutrient Intake |
| MOS | Months |
| AGP | Amaranth Grain-Based Product |

## Introduction

Appropriate complementary feeding is important for the nutrition and development of young children during the transition from breastfeeding to family diets. However, complementary feeding practices in many low-income countries are inadequate to fulfil children's daily nutritional requirements. In Tanzania, for example, only 10% of children consume diets that meet the minimum acceptable standards as per World Health Organization (WHO) indicators for infant and young child feeding (IYCF) practices.[1] According to Bégin and Aguayo (2017),[2] the lack of adequate quality and quantity of nutritious complementary foods contributes to the prevalence of stunting and malnutrition in children. Similarly, incidences of undernutrition among infants and young children (IYC) in Tanzania have been associated with inappropriate complementary feeding practices and are extremely linked to high mortality rates.[3] Relatively recent reports show that 32% of children under the Age of 5 in Tanzania are stunted, while 14% are underweight due to poor child feeding habits.[4] According to Sanghvi *et al.* (2016),[5] there are multiple causes of poor child-feeding practices in Tanzania, and solutions require an in-depth examination of complementary feeding practices in specific contexts and how IYCF practices can be improved in a culturally sensitive manner.

Reports show that contamination of complementary foods with aflatoxin may significantly contribute to poor child growth.[6,7] This is particularly notable given that maize and groundnuts, commonly used in complementary foods across many parts of Tanzania, are frequently contaminated with aflatoxins.[8-10] In the Chamwino district in Dodoma, aflatoxins were detected in 42.5% of complementary food ingredients, including maize and groundnuts.[11] Besides contamination with mycotoxins, maize and groundnut porridge have relatively low nutrients.[11-13] Cognizant of this, other options for nutritious complementary food ingredients are necessary to improve IYC nutrient intake, health, and development.

Amaranth grain can be an important nutritious ingredient in complementary foods. It is classified as a pseudo-cereal,[14] meaning that it is not technically a cereal grain like wheat or oats but shares a comparable set of nutrients and is used similarly. While Amaranth grain is common in other parts of sub-Saharan Africa,[15] including Kenya.[16] In Tanzania, the leaf is mostly used as a leafy vegetable and not the grain.[17,18] Although its popularity is increasing at a slow pace, Amaranth grain can be a key solution to malnutrition and food insecurity problems in many parts of the country since they have a unique composition of proteins, carbohydrates, lipids, and several micronutrients.[19,20] According to Soriano-García and Aguirre-Díaz (2019)[21] the grain is richer in protein than any other cereal and has a higher lysine content. The grain can be especially beneficial in meeting the nutritional demand during dry seasons when vegetables cannot grow. Therefore, the Amaranth grain can alleviate the nutritional inadequacy of complementary foods in areas with high food shortages due to unreliable rainfall patterns and prolonged droughts.

Nutritional inadequacy and mycotoxin contamination of the traditional maize-based complementary feeding observed during the implementation of the Mycotoxins Mitigation Trial (MMT) has triggered our interest in formulating Amaranth grain-based complementary flour as an alternative to maize and groundnut.[3] The objective of the present study was to introduce Amaranth grain-based flour for complementary food in the Kongwa District and assess its nutritive value, safety, and acceptability of the porridge made from the flour through a recipe trial. Specifically, we aimed to answer these questions.

a) What is the nutritive value of the Amaranth grain-based flour?
b) Is the Amaranth grain-based flour aflatoxin safe?
c) Is the porridge made from Amaranth grain-based flour acceptable to mothers/guardians?

## Materials and Methods

### Study Design and Site

This research was designed to complement the gap reported by a large-scale intervention project, the Mycotoxin Mitigation Trial (MMT) in Kongwa (Figure 1). The MMT found high reliance on maize and groundnuts for infant feeding and detected high aflatoxin contamination of 82.14% of all samples in the range of 0.27 to 317 µg/kg.[9,21] The study further reported low micronutrient intake, mostly Iron and Zinc, while macronutrients and other micronutrients were felt below the recommended nutrient intake.[22]

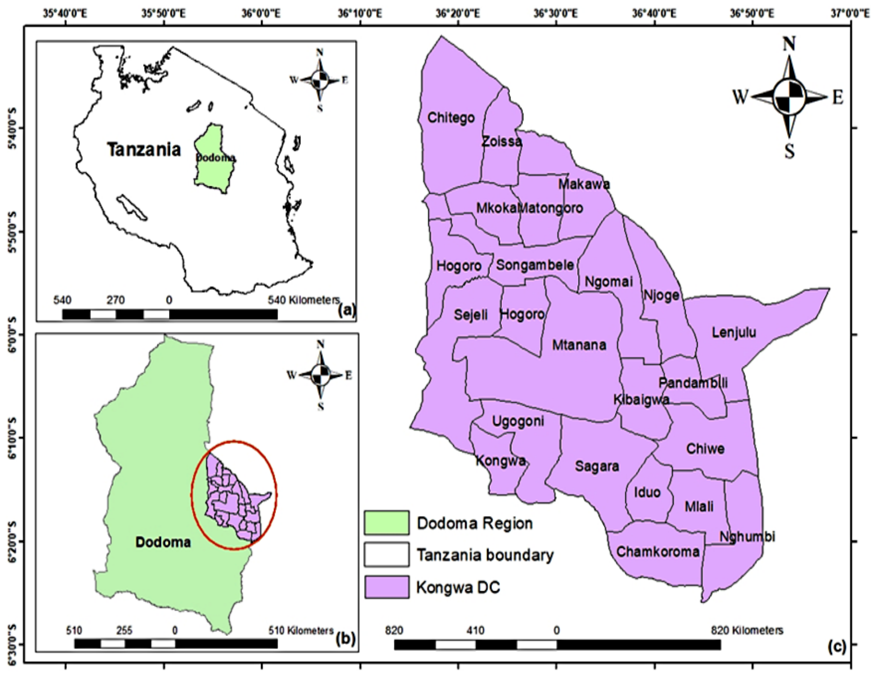


**Fig. 1: A map of Kongwa DC showing MMT sites.**

Additionally, Kongwa district was chosen because of the availability of Amaranth grain, previously introduced in 11 villages (Tubugwe, Kibaoni Tubugwe Juu, Mseta A, Mseta B, Manghweta, Banyibanyi, Songambele, Chamae, Nghumbi, Hogoro villages) by The World Vegetable Center Eastern and Southern Africa (WorldVeg) - Arusha office. Other ingredients of the Amaranth grain-based flour, such as millet and pumpkin seeds, are also locally produced in Kongwa. Four out of the 10 villages, namely, Hogoro, Songambele, Nghumbi, and Chamae, were purposely selected for the recipe trial due to the presence of active farmers' groups who produce Amaranth grain, increasing access to this ingredient.

### Participants Selection

Through the help of community health workers, 10-12 mothers of children between 6 and 24 months who produce Amaranth grain were identified. From those households, mother dyads were screened, selected, and consented based on a variation of ages of mothers and children and education level. For maternal ages' we wanted to observe experience in child feeding; for elder mothers get the experience and ability to feed babies as they had more other babies; for young mothers, we want to know their feeding experience, having few babies and still anxious to feed the baby, with education we need to know mothers exposure towards a variety of food their feeding babies, time for feeding and ability to catch up advises from the clinic and peers. The amount of time that mothers spend away from their children was also considered since it could influence the frequency of feeding, types of food preparation, and responsibility for child feeding.

### Amaranth Grain Flour Preparation

Amaranth grain porridge flour was prepared by mixing Amaranth grain, millet, and pumpkin seeds in a ratio of 4:1:1 (1000g, 250g, 250g), respectively. This ratio was adopted with slight modification from a previous study, which reported a median use of a 4:1 ratio of pre-blended maize to groundnut porridge flour.[3,23] A grinder (DXF 20D Pulverizer, Volt 220V, Power 2000W, Rotational Speed 25,000 rpm, finished product fineness 80-250 mm, Capacity 1 kg) was used to grind the ingredients into flour at the Nelson Mandela African Institution of Science and Technology (NM-AIST) food processing hub.

### Analysis of Nutrient Contents of Amaranth Grain-Based Flour

Analysis of macro- and micro-nutrient contents of amaranth grain-based flour was performed at Arusha Technical College (ATC) Laboratories as described.

### Protein Content

The total protein content was determined using the Kjeldahl method,[24] a widely accepted procedure. The flour sample was digested in concentrated sulfuric acid, converting organic nitrogen into ammonium sulphate. After neutralization, ammonia was distilled and quantified. The nitrogen content was then used to estimate the protein content using a conversion factor of 6.[25]

### Lipid (Fatty Acid) Content

The Fatty acid profile was determined using the method described by Jenkins (2010). This method involves saponifying fats in the flour sample using an alkaline solution, followed by titration with a standard acid. The amount of acid required to neutralize the free fatty acids was measured, providing an estimate of the total lipid content in the flour.[25]

### Energy Content

The energy content of the amaranth flour was calculated using Atwater factors.[26] These factors assign specific caloric values to each macronutrient (4 kcal/g for protein, 9 kcal/g for fat, and 4 kcal/g for carbohydrates). The energy contribution of each macronutrient was determined based on its concentration in the flour, and the total energy was calculated by summing the individual contributions.

### Micronutrient Content

The concentrations of essential minerals such as Iron, Zinc, and calcium were quantified using Atomic Absorption Spectrometry (AAS).[27] This technique allows for the precise measurement of trace metals. After digesting the flour sample with a mixture of acids, the resulting solution was analyzed by AAS, which provided accurate values for the micronutrient content.

### Vitamin A Content

The Vitamin A content was determined using High-Performance Liquid Chromatography (HPLC). This highly sensitive technique allows for the accurate quantification of fat-soluble vitamins.[28] The flour sample was extracted with a solvent mixture of hexane, ethanol, and water (2:1:1, v/v/v), purified, and analyzed by HPLC. The results were expressed as micrograms of retinol equivalents (RE) per 100g of sample.

**Analysis of Aflatoxins**

To assess aflatoxin contamination in both amaranth grain and amaranth-based flour, we used High-Performance Liquid Chromatography (HPLC), following a method previously reported by Klaus *et al.* (2004), with slight modifications to accommodate the sample matrix.[29-31]

Briefly, about 10g of each sample was weighed, and grain samples were carefully ground before extraction. The samples were then extracted using a mixture of 60:40 methanol and water or 60:40 (v/v). After extraction, the sample mixture was filtered through the Whatman No. 1 filter paper. To clean up the extract and isolate the aflatoxins, we passed the filtered solution through an immunoaffinity column (Aflacolumn, VICAM, USA).

The purified aflatoxins were then eluted using HPLC-grade acetonitrile before being injected into the HPLC system. A Shimadzu HPLC system with a reverse-phase C18 column was coupled with a fluorescence detector (FLD) set at 360 nm (excitation) and 440 nm (emission).

To ensure the reliability of our results, we validated the method using aflatoxin standards (AFB1, AFB2, AFG1, AFG2) (Sigma-Aldrich) at a concentration of 0.5 µg/kg, 1.0 µg/kg, and 2.0 µg/kg. The method showed excellent accuracy, with recovery rates of 102.0%, 94.4%, and 118.4% for the respective concentrations. The limits of detection (LOD) and quantification (LOQ) were found to be 0.1 µg/kg and 0.2 µg/kg, respectively, ensuring accurate detection.

**Cooking Demonstration and Sensory Evaluation**

Participants in each site were gathered at a convenient location, such as a school or healthcare facility, for the Focus Group Discussion (FGD). The FGD of 10-12 mothers was conducted by a trained and experienced researcher to establish the types of complementary foods that a mother usually feeds their baby and cooking methods. In total, 48 mothers were asked about what recipes they frequently prepared for their children, the age at which certain foods are fed to the children, and barriers and facilitators to feeding children with diversified complementary foods. Then, mothers were introduced to Amaranth grain-based flour. During the discussions, notetakers documented group interactions and interpersonal communications such as disagreements and jokes. All discussions were conducted in Kiswahili, audio-recorded, and one trained data collector took detailed notes of the discussion, activities performed, and mothers' responses to different activities.

A participatory recipe trial was done for all 48 participants to assess the acceptability of Amaranth grain-based flour. Mothers were asked to engage in porridge cooking and testing through the FGDs actively. In each FGD, mothers were split into two smaller subgroups, and the facilitators asked a few volunteers to cook porridge from the Amaranth grain flour. Mothers used firewood to cook the porridge and feeding utensils used at home, including pots, bowls, cups, and spoons. Mothers mixed one cup of 350 ml to 5 spoons (100g) of flour for 6 - 9 months old children, and the amount of water to flour increased slightly depending on the Age of the baby. Mothers who were not cooking were encouraged to participate by commenting on the viscosity of the Porridge. After cooking, the mothers tasted the Porridge and served it to their children. The facilitators asked the mothers for their opinions on the porridge's taste, acceptability, ease of preparation, and willingness to continue preparing the same porridge and feeding their babies at home. A note-taker recorded detailed responses from the mothers.

The FGD and recipe trials were selected as data collection methods in the study because they are useful methodologies to collect in-depth data on participants' experiences, practices, and interactions. Besides, the methods involved small samples; they are innovative and relatively rapid ways of exploring the acceptability of complementary feeding recommendations.[32] The techniques were also preferred over the in-depth interviews or surveys because they facilitated discussion of different perspectives as well as observation of the actual preparation of usual and modified recipes and the women's perception of the recipes. The methods thus promoted discussions on experiences with cooking and practices relevant to complementary feeding rather than personal views. Sensory quality in terms of aroma, appearance, taste, mouth feel, and overall acceptability of the Amaranth grain-based product was assessed using 48 mothers through a 9-point Hedonic scale with 1 being ‘like extremely’ and 9 being ‘dislike extremely.[33]

**Qualitative Data Analysis for Recipe Trials**

Audio recordings of the FGDs were transcribed and translated into English, along with the summary notes. The interview notes and observations from the recipe trials were compiled into one detailed summary for each session. A codebook was developed using Atlas t1(Version 7), and the transcripts from the four FGDs were qualitatively coded using the constant comparative method to identify attitudes towards Amaranth grain porridge and barriers or facilitators to feeding infants the new product. The FGD analysis focused on emergent themes, current feeding practices, and perceptions of the acceptability and feasibility of changing the type of porridge ingredients to Amaranth grain porridge to improve dietary diversity and nutritional value. Data from all sources were compiled in tables and analyzed thematically to identify the participants' reactions to recipe modifications while summarizing results across sites.

## Results

**Participant Demographics**

The demographic information of mothers, including their ages, professions, and education levels, is provided in Table 1. In total, 48 women (12 at each site) participated in the study. Most participants (88%) had attained primary school, whereas 3% had no formal education, and 9% had completed secondary school. Most participants (97%) were small-scale farmers, 2% had small informal businesses, and 1% were homemakers. Of the 48 mothers, three were no longer breastfeeding their children.

**Table 1: Participant Demographics**

| Demographic Variables | Category | Percentage |
|---|---|---|
| Mother’s Age (years) | Mean: 29.7 (SD = 9.2, range: 18-48) | |
| Child’s Age (months) | Mean: 6.9 (SD = 0.5, range: 6-23) | |
| Breastfeeding | Continue breastfeeding | 96 |
| | No longer breastfeeding | 4 |
| Education Level | Primary | 88 |
| | Secondary | 9 |
| | No school | 3 |
| Economic Activities | Farmers | 97 |
| | Small business | 2 |
| | No work/housewife | 1 |
| Age of Child’s First Solid Food | Mean: 6.0 (SD=0.5, range: 6-9 months) | |
| Hours Spent Outside Home (mothers) | 2-3 hours | 89 |
| | 4-6 hours | 11 |

**Nutritional Value of Amaranth Grain-Based Flour**

The Amaranth grain-based flour had high nutritional value, both macronutrients and micronutrients (Table 2).

**Aflatoxin Contamination of Amaranth Grain and Flour**

The analysis showed that both Amaranth grain and the processed Amaranth grain-based flour had low levels of total aflatoxin contamination. Aflatoxin levels in the raw Amaranth grain ranged from 0.1 to 0.5 µg/kg, with a mean concentration of 0.3 ± 0.2 µg/kg. For the Amaranth grain-based flour, the contamination levels ranged from 0.8 to 1.7 µg/kg, with a mean of 1.17 ± 0.4 µg/kg. All measured values were below the national maximum limit of 10 µg/kg for total aflatoxins in complementary foods. All measured values were captured because they were within the detectable limit.

**Table 2: Nutritional profile of the Amaranth grain-based porridge flour**

| Nutrients | Amount/100g |
|---|---|
| Energy (Kcal) | 485.50 |
| Protein (g) | 14.76 |
| Lipids (g) | 14.22 |
| Iron (g) | 15.36 |
| Zinc (mg) | 16.83 |
| Calcium (mg) | 301.19 |
| Vitamin A (ug) | 402.34 |

**Table 3: Nutritional difference between the Amaranth grain-based product and the Recommended Nutrient Intake (RNI).**

| Nutrients | RNI/day | Amaranth-based flour/100g | Difference | % Difference |
|---|---|---|---|---|
| Energy (Kcal) | 479 | 485.5 | 6.5 | 1.34 |
| Protein (g) | 10.5 | 14.76 | 4.26 | 28.86 |
| Lipids (g) | 18.6 | 14.22 | -4.38 | -30.80 |
| Iron (g) | 9.3 | 15.36 | 6.06 | 39.45 |
| Zinc (mg) | 4.1 | 16.83 | 12.73 | 75.64 |
| Calcium (mg) | 400 | 301.19 | -98.81 | -32.81 |
| Vitamin A (ug) | 400 | 402.34 | 2.34 | 0.58 |

Note: a two-sample t-test with equal variances calculated p-value = 0.815.

**Sensory Evaluation and Acceptability**

Participants scored well on the cooking methods and texture of the flour. The amaranth grain-based flour was generally accepted by mothers, with high sensory scores of aroma (1.0), mouth feel (1.0), and taste (1.0) and overall acceptability scores of 9.3 out of 10.

**Infant Feeding Practices**

In Table 4, mothers reported the most available and commonly prepared foods and their appropriate nutrition for children ages 6-24 months. The majority mentioned porridge made of maize and groundnuts, while some reported pre-blended porridge made of maize and groundnuts, plus millet and groundnuts. They also mentioned foods they believed were nutritious, such as animal-source foods like chicken, meat, eggs, and milk, though not often used in complementary foods.

The common barriers to feeding certain foods across the sites included cost, availability, and some negative notions, such as that certain foods were not good for children due to difficulties in chewing or swallowing. Mothers generally agreed that animal-source foods like milk, eggs, meat, and fish were healthy for young children; however, costs and availability were barriers to often including them in complementary foods. Farming facilitated the use of other types of food ingredients, such as groundnuts, in complementary foods. When asked about Amaranth grain, most mothers reported knowing and used its leaves as vegetables and often sold the grains.

**Recipe Trials**

The mothers participated in a recipe trial for Amaranth grain-based porridge. They provided comments about learning to use Amaranth in the complementary foods recipe, as follows.

*"…This exercise gave us a chance to learn, we have the Amaranth grain in our farms, it is good to feed children, and now we can cook at our home (Site 2)".*

*"… This has given us a challenge as mothers. I think we were just lacking the awareness, but Amaranth grain porridge is good (Site 1)."*

**Another Mother Said**

*"It is hard to feed the baby the type of food that other family members do not eat, but since we know that amaranth grain can be grounded to get porridge flour, I can now do that (Site 3)".*

Among the ingredients used to prepare the Amaranth grain-based porridge, such as Amaranth grain and pumpkin seeds, were reported as uncommon complementary foods during the FGDs. However, mothers were willing to cook and taste the porridge after observing the colour and texture of the flour. All 48 mothers reported positive perceptions of porridge's taste, color, and cooking methodology. The mothers were also ready to incorporate Amaranth grains and pumpkin seeds in the porridge they would be making for their children. They said they would use this flour to improve complementary feeding for the health of their children. This participatory approach changed mothers' perceptions from only using Amaranth leaves as vegetables, to even using amaranth grains in complementary feeding.

## Discussion

This study assessed the potential of Amaranth grain in complementary foods by addressing three research questions. The first question was whether the nutritive value of Amaranth grain outweighs that of traditional maize-based complementary flour, which is known to be low in nutrients. Results from this study showed high nutritional content of Amaranth grain flour in both macronutrients, energy, protein, and lipids, as well as micronutrients, including those that have a direct association with child growth: Iron, Zinc, calcium, and vitamin A (Table 2). This new product showed the highest nutrients compared to those reported by.[34,35] Among the seven nutrients analyzed, five (energy, protein, Iron, Zinc, and Vitamin A were adequate and exceeded the RNI. Lipids and calcium were slightly low and did not meet RNI for 30% and 32%, respectively (Table 3). Despite the observed differences, the p-value shows no significant differences between the two. This means that the product is suitable for children's well-being and can thus improve complementary foods and child growth because it is nutrient-dense and a diversified product by itself. The results from this study are also different from other studies in which nutrient intake does not meet the recommended protein and energy intake.[36,37] Furthermore, results from this study differ from the findings of the lipid-based nutrient supplement study done in central Zimbabwe, which reported low intake of Iron (0% met RNI) and Zinc (16% met RNI).[38]

The second question was whether the newly formulated product is aflatoxin-safe, as the traditional maize-based complementary flour is frequently contaminated with these toxins to unacceptable levels.[39,40] Results further show that Amaranth grain-based flour is low in aflatoxin contamination and, therefore, suitable for complementary feeding. The highest aflatoxin in the Amaranth grains was 0.5 μg/kg, while that of Amaranth grain-based flour was 1.7 μg/kg. These concentrations are low compared to the Maximum Tolerable Limit (MTL) of 10 μg/kg for aflatoxin in Tanzania.[41,42] Amaranth is known for its low susceptibility to aflatoxin contamination; such findings are reported by Alekhina *et al.* (2021)[43] and Bresler *et al.* (1998).[44] On the other hand, the traditional ingredients of complementary food, such as maize and groundnuts or their resultant flour, are highly susceptible to aflatoxins. They are the main contributors to aflatoxin exposure in humans in Sub-Saharan Africa.[45] Mollay *et. al,* (2021),[3] Ngure *et. al,* (2023)[21] and Kassim *et. al,* (2023)[46] reported higher aflatoxin levels in maize and groundnut-based complementary food consumed by children in the Kongwa district, where the current study was implemented.

The third research question referred to the perception of mothers to include the Amaranth grain product in complementary foods. The recipe trial that involved sensory evaluation for the Amaranth grain-based porridge reported high acceptability of the product. Mothers reported that the taste, texture, and colour of the amaranth grain were good. Additionally, cooking methods were simple and common to other types of Porridge they cooked at home. Through this trial, mothers identified ways to use other locally available foods besides maize and groundnuts to improve the nutritional quality of complementary feeding. Recipe trials also allowed exploration of the mothers' decision-making around Amaranth grain-based flour as a complementary food. The results informed the development of specific recommendations to incorporate nutritious, locally available foods into recipes that were adapted from unusual practices and, therefore, more likely to be feasible and culturally acceptable for mothers in central Tanzania. This study is comparable to Okoth *et al.* (2017)[47] who prepared a nutrient-dense complementary food in Kenya by using amaranth-sorghum grain. Similarly, Mburu *et al.* (2012)[48] determined the nutritional and functional properties of Amaranth grain grown in Kenya for the preparation of recommended infant complementary food.

Recipe trials have been implemented around the world to support optimal complementary feeding. In our study, the majority of mothers (93%) accepted the use of amaranth grain mixed with pumpkin seeds and millet for making porridge for their children as complementary food after the recipe trial. This result is comparable to the results in the Philippines. Talavera and Narciso (2014)[49] established that recipe trials improved the nutritional value of complementary foods. Other researchers have also reported that recipe trials can be used for nutrition improvement if done by appropriately trained individuals.[50–52] Recipe trial FGDs are generally essential based on their participatory approach and cooking activities that enable mothers to take part in developing new recipes in their community. Recipe trials were also a proper strategy to explore decision-making by the mothers regarding what foods were prepared for their children and to identify the criteria used to choose appropriate foods for their children. The mothers overcame barriers related to worries that the children could not be given Amaranth grain by directly observing the children eating without difficulty. Hence, the mothers reported positive perspectives of the new recipes.

According to Martin *et al.*,(2021)[3] improving complementary feeding practices through strategies that enable caregivers to access, prepare, and feed appropriate foods in the context of cultural values and preferences is essential because mothers are more likely to adopt changes in complementary feeding practices if the recommendation considers factors such as price, ease of preparation, and taste. Thus, research that engages directly with mothers to prepare and test the new Amaranth grain porridge recipe is a critical step in developing feasible and acceptable complementary foods that are nutritious and safe to cater to hunger and child health.

### Contribution of the Study

This study will answer important research questions regarding nutrient intake and adequacy by providing information on the influence of the intervention on Infant and Young Children's Feeding practices, nutrient intake, and risk of exposure to dietary aflatoxins. The study will further contribute to the body of knowledge about the local nutritious food that will improve the complementary foods. Dissemination of study results through publications and conference presentations will help the exchange of ideas, knowledge, and build capacity among nutritionists, scientists, and researchers about the newly formulated product. Recommendations from this research finding may contribute to the improvements of complementary feeding and the current global efforts of developing sustainable food systems for improving nutrition. The study community will benefit from the information on the product developed about the importance of improved IYCF on nutrient intake and risk of exposure to aflatoxin. Findings from this study might stir more research on nutrition and food safety interventions.

### Strengths and Limitations

Despite the higher acceptability of the product (9.3/10), data about child health that includes growth outcomes would be essential; we encourage other scientists to work on biometer studies to explore the potential of the product. There might be potential biases in the selection of villages with pre-existing amaranth grain farming due to the nature of the selection. Still, we remain confident in the sample size used of 48 mothers engaged in the FGD, cooking demonstration, and sensory testing of the product.

### Recommendation and Future Direction

The recommendation is made to engage other stakeholders to conduct longitudinal studies on child health outcomes in relation to the consumption of amaranth grain-based products. Since amaranth grain is among the underutilized crops in Tanzania, we recommend including it in multisectoral nutrition agendas that engage different sectors, such as agriculture, health, and nutrition, to bring out solutions towards the accessibility, utilization of amaranth grain-based products and cost-effective analysis of the product.

## Conclusion

Amaranth grain-based flour can make it a good alternative, complementary food to maize and groundnuts in the Kongwa district and other parts of Tanzania due to its high nutritional value, availability, and less aflatoxin contamination. The product developed in this study would be appropriate for use in complementary feeding. It can be easily adopted at both household and village levels since Amaranth is not new, and its leaves have been used since ancient times. Improved consumption and utilization of Amaranth grain-based products can solve the problems of malnutrition and improve the livelihood of the rural people in terms of nutrition and health in the central region of Tanzania. Proper recommendations and advocacy of this product in the district might be beneficial to the sub-optimal complementary feeding and child health. Apart from the nutrient density, safety, and cultural acceptability, we emphasize stakeholders to increase the amaranth grain production to ensure product availability at a low cost.

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## Conflict of Interest

The authors declare no conflict of interest.

## Data Availability Statement

The data supporting the findings of this study will be gladly provided by the corresponding author upon request.

## Ethics Statement

Ethical approval for conducting this research was obtained from the Northern Tanzania Health Research Ethics Committee (KNCHREC) with registration number KNCHREC00041/02/2021. All methods were carried out by relevant guidelines and regulations. Written informed consent was obtained from all mothers to participate in the study.

## Informed Consent Statement

Mothers signed the consent form to participate in the study on behalf of their children. We did not include any individual details, images, or videos.

## Clinical Trial Registration

This research does not involve any clinical trials.

## Permission to Reproduce Material from Other Sources

Not Applicable.

## Author Contributions

- **Rosemary Kayanda:** Conceptualization, Methodology, Data Collection, Analysis, Writing Original Draft.
- **Neema Kassim:** Visualization, Supervision, Review of manuscript.
- **Nyabasi Makori:** Data collection supervision and reviewing the manuscript.
- **Neema Mogha:** Methodology that includes amaranth grain sites selection, and reviewing manuscripts.

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