

Research Article

Nutritional evaluation of complementary food developed from Unmalted Millet, Malted Malt, Sweet Potato, Breadfruit, and Soybean flour blends

M. Bello* & T. T. Adebowale

Department of Home Economics, Adeyemi Federal University of Education, Ondo, Nigeria.

Abstract

Poor weaning practices are a major cause of malnutrition in infants between the ages of 6 and 24 months. This may be due to ignorance, poverty, or the expense of commercial weaning foods. Thus, the formulated complementary food is to provide a practical solution with the aim of bridging the gap. This study developed and evaluated the nutritional quality of complementary food made from unmalted millet and malted millet flour, breadfruit flour, soybean flour, and sweet potato flour blends in the ratios of (0:50:20:20:10); (0:40:30:20:10); (0:30:40:20:10); (0:20:50:20:10); (100:0:0:0:0), respectively. They were evaluated for proximate composition and sensory qualities using established methods. There are significant differences ($p < 0.05$) among the formulated samples in all the measured parameters. The result of the analysis on proximate composition shows moisture content (10.65-13.57%), Protein (5.68-7.37%), fats and oil (2.14-2.45%), fibre (0.54-0.82%), carbohydrate (77.34-77.93%), and energy (3.53-4.21%). Generally, significant differences ($p < 0.05$) were observed in most of the sensory attributes evaluated. The sensory quality rating of the different complementary foods was higher than that produced from only millet flour, with the most acceptable sample being sample A (50% malted millet, 20% breadfruit, 20% soybean, and 10% sweet potato flour blends). The findings of this study are an indication that an acceptable, low-cost, and nutritionally dense complementary food that can serve as a better alternative to the traditional cereal-based weaning food can be developed from malted millet, breadfruit, soybean, and sweet potato flour blends.

Keywords: Complementary food, Composite flour blends, Malnutrition, Nutritional evaluation, Weaning food

1. Introduction

Complementary foods are the solid or weaning foods that are given to infants aged 6 months to complement breast milk or formula, providing additional nutrients and helping the baby transition to family foods (World Health Organization, 2023). Complementary feeding is a key developmental phase when infants move from exclusive breast milk or formula to gradually consuming solid and semi-solid foods. This period typically begins around 6 months of age, as recommended by the World Health Organization (WHO), and continues until the child is approximately 2 years old. Furthermore, poor weaning practices contribute significantly to the global burden of undernutrition, affecting 45 million children below five years of age (Alristina et al., 2025). Developing and promoting nutrient-dense complementary foods enriched with vitamins and minerals is essential for addressing these challenges. Incorporating locally available food materials can enhance

the acceptability and affordability of such foods, making them sustainable interventions in vulnerable populations (Oladiran & Emmambux, 2022).

Millet grains contain phytochemicals that benefit human health by helping to lower blood cholesterol levels (Hassan et al., 2021). Millets contain anti-nutrients, which hinder the availability of nutrients present in the food for maximum absorption and body utilization. Malting, a simple traditional process of sprouting whole grains, enhances nutrient availability. It significantly increases hydrolytic enzyme activity in the grain, which improves the bioavailability of vitamins, carbohydrates, minerals, and proteins. Malting millet (or finger/pearl millet) improves digestibility and nutrient bioavailability. Malted cereals have been used in various complementary foods (Okoye and Egbujie, 2018; Syeunda et al., 2021). According to Yousaf et al. (2021) millet contributes substantial carbohydrates with moderate

*Corresponding author: M. Bello

Email address: bellomonsurat01@gmail.com (M. Bello)

ORCID: <https://orcid.org/0000-0002-7366-978X>

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protein, and when malted, may improve functional properties desirable for infant foods.

Breadfruit (*Artocarpus altilis*), is referred to as largely underutilized. It is commonly called “Gbeere or Gbefu” in Youba, “Ukwa” in Igbo, and “Gurjiya” in Hausa all in Nigeria. In developing countries, utilization is constrained by poor post-harvest storage, with fresh fruits deteriorating within 3–5 days of harvest (Zainol et al., 2022). Breadfruit is important because of the presence of antioxidant and pro-vitamin A carotenoid content, high energy value of 3870 kcal/kg, low crude fat of 3.94 g/100 g, substantial dietary fiber, and good-quality protein containing essential amino acids such as lysine and leucine rich in micronutrients, that is, potassium, which supports cardiovascular health, while vitamin C boosts immunity and acts as an antioxidant (Calix-Rivera et al., 2025). Breadfruit is also considered easily digestible, as it lacks anti-nutrients and other compounds that may trigger intolerance (Calix-Rivera et al., 2025). Breadfruit has been used in various research studies involving the development of complementary feeds (Okwunodulu et al., 2022; Abasiokong et al., 2023)

Soybean Glycine max is an annual legume cultivated for human consumption, animal feed, and industrial raw materials. Soybeans are well-recognised as a high-protein legume. A Nigerian study of soybean flour found the order of proximate composition as: protein > carbohydrate > crude fat > moisture > fibre > ash, affirming its protein richness. The high protein and fat content make soybeans a strong candidate for enriching cereal-based complementary foods to improve protein quality and energy density (Kassem et al., 2021). Soybeans are an excellent protein source, which contributes to their popularity in West Africa. Soybean flour contains thiamine, folate, riboflavin, and vitamins D, E, and K, along with minerals.

Sweet potato ranks as the sixth most important food crop globally, with an annual production of about 90 million tonnes and an important role in food availability. Sweet potato has been identified as a viable ingredient for complementary foods to meet the nutritional needs of infants in developing countries, while also improving crop utilization (Eid et al. 2025). However, infant diets in low-income countries are predominantly based on starchy staples such as maize, millet, and sorghum, which are deficient in the vitamins and minerals essential for healthy growth and development (Omosuli et al., 2019; Ijeomah et al., 2025).

Poor weaning practices have been reported to characterize feeding practices of infants in developing and underdeveloped countries, most especially among low-income families (West et al., 2022). This may be due to ignorance, the high cost of commercial complementary foods, the mother's lack of nutrition education, socio-economic factors, among others. Likewise, inability to properly utilize

the available low-cost, nutrient-dense, adequate, and indigenous food crops to satisfy the nutritional needs of infants may result in infant malnutrition. This research addressed these gaps by developing and evaluating the nutritional value of improved complementary foods, and assessing the acceptability of complementary foods produced, ensuring they meet the dietary needs of infants and young children while aligning with local food habits and economic constraints.

2. Materials and Methods

2.1. Materials

Fresh samples of whole millet grains, sweet potatoes, breadfruit, and soybean were obtained from a central market in Ondo town, South West, Nigeria in a single batch to minimize batch-to-batch variation. Chemicals used for the analysis were of analytical grade.

2.2. Methods

2.2.1. Preparation of raw materials-Malted Millet Flour

Malted millet flour (Figure 1) production was adapted from Okpalanma et al. (2021) with modifications. Millet grains (2kg) were sorted to remove foreign materials, washed, and soaked in water for 24 hours before being drained. The drained grains were spread on a jute bag and placed in a dark cupboard at an ambient temperature of 30°C, where they were watered periodically for 48 hours to promote germination. The germinated millet grains were dried in a cabinet dryer at 60°C for 8 hours. After drying, the sprouts were removed by rubbing the grains between the palms, followed by dry cleaning using air blowing. The grains were then milled into flour and sieved to obtain fine flour. The resulting malted millet flour was packaged in low-density polyethylene bags and stored at room temperature before further use.

2.2.2. Preparation of Sweet Potatoes Flour

Sweet potato flour (Figure 2) was produced using the method adapted from Eid et al, (2025) with modifications. Fresh sweet potatoes were sorted and washed thoroughly to remove dirt, soil, and debris. The sweet potatoes were peeled using a knife or a vegetable peeler to ensure the skins were completely removed and sliced into thin, uniform pieces. The sliced sweet potatoes were then oven-dried at 60°C for 5 hours. The dried sweet potato slices were milled into flour and sieved to obtain fine flour. It was packaged in an airtight container and stored at atmospheric temperature before further use.

2.2.3. Preparation of Breadfruit Flour

Breadfruit flour (Figure 3) was produced using Olaoye et al (2015) with modifications. Freshly harvested mature breadfruits were sorted and cleaned from extraneous materials and dirt, peeled and cut into quarters to remove the core, then sliced into thin, uniform pieces. The breadfruit

was then oven-dried at 135°F (57°C) for 8 hours. The dried breadfruit was milled into a fine powder and then cooled. It was sieved using a 250µm aperture sieve and packaged in an airtight container before further use.

2.2.4. Preparation of Soybean Flour

Soybean flour (Figure 4) was produced according to the method described by Iwayemi and Ikujenlola, (2025) with modifications. The soybeans (2kg) were sorted to remove pebbles, stones, and other extraneous materials. It was wet cleaned and steeped for 10 hours. The steeped soybeans were drained and precooked for 20 minutes at 100°C, after which it was dehulled (by rubbing in between the palms), and the hulls were removed by rinsing with clean water. The dehulled soybeans were dried in the cabinet drier at 60°C for 7 hours and dry milled into fine flour. The soybean flour was sieved using a sieve to obtain smooth flour. The soybean flour was packaged in a low-density polyethylene bag before further use.



Figure 1. Flow Chart for the Production of Malted Millet Flour (modified from: Okpalanma et al. (2021))



Figure 2. Flow Chart for the Production of Sweet Potato Flour (Modified from Eid et al., (2025))



Figure 3. Flow Chart for the Production of Breadfruit Flour (Source: Olaoye, et al (2015))



Figure 4. Flow Chart for the Production of Soybean Flour (modified Iwayemi & Ikujenlola (2025))

2.2.5. Blended Formulation

Four blends were produced by mixing breadfruit flour, sweet potato flour, malted millet flour, and soybean flour in the percentage proportions as shown in Table 1, using a machine food processor (Kenwood HM 430, England).

Table 1: Percent composition of complementary food formulation representing blends of malted millet flour, breadfruit flour, sweet potato flour, and soybean flour

Parameters/ Formulations	Unmalted Millet Flour (%)	Malted Millet Flour (%)	Breadfruit Flour (%)	Soybean Flour (%)	Sweet Potato Flour (%)
A (0:50:20:20:10)	0	50	20	20	10
B (0:40:30:20:10)	0	40	30	20	10
C (0:30:40:20:10)	0	30	40	20	10
D (0:20:50:20:10)	0	20	50	20	10
E (100:0:0:0:0)	100	0	0	0	0

A- Malted Millet flour 50% + breadfruit flour 20% + Soybeans flour 20% + Sweet Potato flour 10% + B-malted millet flour 40% + Breadfruit flour 30% + Soybean flour 20% + Sweet Potato flour 10%, C- Malted millet flour 30% + Breadfruit flour 40% + Soybean flour 20% + Sweet Potato flour 10%, D- Malted Millet flour 20% + Breadfruit flour 50% + Soybean flour 20% + Sweet Potato flour 10%, E- Ordinary Millet flour 100% (control).

2.3. Analyses

2.3.1. Proximate Analyses

Moisture, crude fibre, fat, ash, and crude protein were determined according to (AOAC, 2023). Carbohydrate content was determined by difference using the Arithmetic difference method described by AOAC (2023). Energy was calculated according to Mullan (2006) using energy substrates

The carbohydrate content will be determined by difference. The carbohydrate content will be given by the expression below.

$$\% \text{ CHO} = 100 - (\% \text{ A} + \% \text{ CP} + \% \text{ F} + \% \text{ CF} + \% \text{ M}) \quad (6)$$

Where, CHO-Carbohydrate, A-Ash, CP-Crude Protein, F-Fats, CF-Crude Fibre.

2.3.2. Calorie content determination

The calories were estimated using the Atwater conversion factors: 4 kcal/g for protein, 4 kcal/g for carbohydrate, and 9 kcal/g for lipids (Merrill and Watt, 1973).

2.3.3. Sensory Quality Evaluation

The sensory quality of the complementary foods was carried out by 9-point Hedonic scale, where 9 and 1 represented liked extremely and disliked extremely. Twenty (20) semi-trained panelists among students of Adeyemi Federal University of Education, Ondo, Ondo State. The sensory qualities evaluated include colour, taste, flavour, texture, sweetness, smoothness, mouth feel, appearance, and overall acceptability. They were instructed to rinse their mouth before and after each test.

2.3.4. Statistical Analysis

The experimental results were expressed as mean $\pm$ standard error (SE) of three replicates. Data obtained were statistically analyzed using Analysis of Variance (ANOVA), a tool in Statistical packages for Social Science (SPSS 14.0).

The level of significance was set at $p < 0.05$. Means were separated with Duncan's New Multiple Range Test (DNMRT).

3. Results and Discussion

Proximate composition results of the formulated samples are presented in Table 1.

Moisture content (MC) of the formulated samples (10.65-12.02%) was lower than that of the control (13.57%), and they were significantly ($p < 0.05$) different from each other. Moisture content is a measure of the water availability of the sample to microbial infestation and chemical changes, hence a determinant of sample shelf-life. The MCs of samples B, C, and D, which were below 10%, and hence their shelf stability, will not be affected once stored in airtight containers.

Protein content of the formulated samples increased significantly ($p < 0.05$) with an increase in the level of breadfruit inclusion. The protein content of the formulated samples and that of the control was lower than >15% recommended for infant complementary foods (FAO/WHO, 1991). Proteins are one of the essential food components required for growth and development; they are major components of cells in infants. There is a need to increase the soybean content of the formulated foods to increase the protein content to an acceptable recommended level.

Crude fibre (CF) content of the formulated samples (0.54-0.67%) was significantly lower than that of the control (0.82%), this may be because the millet for the formulated samples has been malted, unlike that of the control, in which whole millet is used (Studocu, 2022). The CF content of the formulated samples increased significantly ($p < 0.05$) with an increase in breadfruit. The values were lower than those reported by Okwulodulu et al. (2020 & Okoye et al. (2021), The CF values obtained in this study were within the range (<5%) recommended by FAO/WHO (1991) for complementary foods. Low fibre content is desirable for infant food formulation. Hence, the CF values obtained were

indicative that the formulated samples will be good complementary foods. The CF are responsible for normalizing an infant's bowel movement, preventing constipation, and helping control blood pressure (Bello et al., 2017; Okwulodulu et al., 2020).

The fat content of the formulated samples ranged from 2.17% to 2.45%, while that of the control was 2.45%. There was a significant difference ($p < 0.05$) in the fat content of all the formulated Samples. It was observed that the fat content increased with increasing breadfruit addition. This concurs with the findings of Okwulodulu et al. (2020), who reported an increase in the fat content of a formulated food from the combination of plantain, soybean, and breadfruit flours as a result of increased breadfruit inclusion levels. The fat content of the samples meets the recommendation (10-25%) for fat by FAO/WHO (1991) for complementary foods. As fat is a major energy substrate, lower fat values of the formulated samples will affect their energy values, flavour, texture, acceptability, and swallowing as fat enhances them (Okwulodulu et al., 2020). Therefore, there is a need to increase the soybean content of the sample to increase the fat

content of the formulated foods.

The carbohydrate content of all the formulated samples (70.27-74.60%) was significantly lower than that of the control (70.93%). The lowered carbohydrate content of the formulated samples, when compared to that of the control, may apparently be due to the malting of the millet (Murungweni et al., 2023).

Carbohydrates are one of the macromolecules that can supply energy to infants. The high content of carbohydrates in the samples is of great advantage since they are active in nature, and it is in line with the FAO/WHO (1985) recommendation that foods fed to infants should be energy-dense and adequate in protein (Okwulodulu et al., 2020).

Energy values of the formulated blends increased significantly ($p > 0.05$) with an increase in breadfruit and soybean inclusion in the blends. The energy values of the formulated samples (353.99-421.17 kcal) will meet the recommended energy RDA range of 200-550 kcal per day for infants aged 6-23 months, as recommended by the WHO (2002). All the samples are therefore good sources of energy needed by the infants for their daily activities.

Table 1: Proximate Composition (% (Kcal/100g) and Energy Value of Complementary Food Formulations

Parameters	Moisture Content	Crude Protein	Crude Fat	Crude Fibre	Total Ash	Carbohydrate	Energy Value
A	12.02 $\pm 0.08^b$	5.88 $\pm 0.02^d$	2.17 $\pm 0.06^d$	0.54 $\pm 0.01^c$	1.76 $\pm 0.03^a$	77.63 $\pm 0.05^c$	353.54 ± 0.78
B	11.74 $\pm 0.09^d$	6.07 $\pm 0.05^c$	2.14 $\pm 0.05^c$	0.58 $\pm 0.01^d$	1.62 $\pm 0.02^d$	77.8 5 ± 0.35^b	421.17 ± 0.85
C	11.75 $\pm 0.18^c$	6.29 $\pm 0.07^b$	2.21 $\pm 0.00^c$	0.62 $\pm 0.01^c$	1.71 $\pm 0.01^b$	77.42 $\pm 0.23^d$	356.57 ± 1.24
D	10.65 $\pm 0.01^c$	7.37 $\pm 0.01^a$	2.45 $\pm 0.01^a$	0.67 $\pm 0.02^b$	1.52 $\pm 0.00^c$	77.34 $\pm 0.01^c$	353.99 ± 0.13
E	13.57 $\pm 0.05^a$	5.68 $\pm 0.02^c$	2.31 $\pm 0.05^b$	0.82 $\pm 0.01^a$	1.69 $\pm 0.01^c$	75.93 $\pm 0.11^a$	353.38 ± 0.03

The mean $\pm$ standard deviation of triplicate determinations means values with different superscripts in a row are significantly different ($P < 0.05$).

Keys:- A- Malted Millet flour 50% + breadfruit flour 20% + Soybeans flour 20% + Sweet Potato flour 10% + B-malted millet flour 40% + Breadfruit flour 30% + Soybean flour 20% + Sweet Potato flour 10%, C- Malted millet flour 30% + Breadfruit flour 40% + Soybean flour 20% + Sweet Potato flour 10%, D- Malted Millet flour 20% + Breadfruit flour 50% + Soybean flour 20% + Sweet Potato flour 10%, E- Ordinary

Millet flour 100% (control).

Table 2 shows the result of the sensory evaluation of the studies, and it revealed that there are significant differences. The characteristics evaluated include colour, taste, texture, mouth feel, and overall acceptability. The study shows that sample A had the highest ratings in all the measured parameters, while sample E (control) had the lowest ratings in all the terms measured. The findings show a decrease in the ratings of all measured parameters as there is a reduction in the level of malted millet and an increase in the level of breadfruit flour addition.

Table 2: Sensory Evaluation of Complementary Food Formulations

Parameter	Colour	Taste	Texture	Mouth feel	Overall Acceptance
A	7.80±1.11 ^a	7.45±0.89 ^a	6.90±1.51 ^b	7.45±1.10 ^a	8.00±0.97 ^a
B	7.50±1.36 ^b	6.55±1.61 ^b	6.70±1.53 ^c	6.60±1.76 ^b	6.90±0.85 ^b
C	7.20±1.64 ^d	6.30±1.81 ^c	7.05±1.77 ^a	6.30±1.48 ^c	6.80±1.40 ^c
D	7.30±1.62 ^c	6.15±2.23 ^d	6.35±2.25 ^d	6.05±1.71 ^d	6.75±1.94 ^d
E	4.75±2.17 ^c	3.45±1.76 ^c	4.45±2.37 ^c	3.85±2.20 ^c	4.25±1.88 ^c

The mean $\pm$ standard deviation of triplicate determinations means values with different superscripts in a row are significantly different ($P < 0.05$).

Keys:- A- Malted Millet flour 50% + breadfruit flour 20% + Soybeans flour 20% + Sweet Potato flour 10%, B-malted millet flour 40% + Breadfruit flour 30% + Soybeans flour 20% + Sweet Potato flour 10%, C-malted millet flour 30% + Breadfruit flour 40% + Soybean flour 20% + Sweet potato flour 10%, D- Malted millet flour 20% + Breadfruit flour 50% + Soybean flour 20% + Sweet potato flour 10%, E- Ordinary millet flour 100% (control).

4. Conclusion

Based on the findings of this study, it could be concluded that locally available food materials such as malted millet, soybean, breadfruit, and sweet potato can be used to develop complementary food that enhances nutritional quality and affordability and is a highly acceptable infant weaning food that is nutrient-dense, most especially in terms of the protein content, which would have great potential in the formulation and preparation of infant complementary foods compared to the use of traditional pap produced from millet used as weaning food by caregivers/mothers. Sensory evaluation revealed that all the formulated complementary foods have higher attributed value than that of the control (Unmalted Millet), which has been the traditional complementary food.

The Sample comprising unmalted millet and malted millet flour, breadfruit flour, soybean flour, and sweet potato flour blends in the ratios of (0:50:20:20:10), respectively, had the highest overall acceptability; this indicates their potential for adoption in infant feeding. This research highlights the feasibility of producing affordable, nutritious complementary foods from indigenous crops, thereby contributing to improved child nutrition and food security. Therefore, food processors and small-scale enterprises should explore commercial production, with attention to packaging, shelf-life stability, and fortification where necessary.

Abbreviations

FAO	Food and Agriculture Organization
RDA	Recommended Dietary Allowance
WHO	World Health Organization

Author Contributions

Monsurat Bello: Conceptualization, Investigation, Validation, writing – Writing - original draft, Data Curation, Formal Analysis, Project Administration, Methodology.

Tomiwa Temitope Adebawale: Data Curation, Investigation, Formal Analysis, Review & Editing

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Conflicts of Interest

The author(s) declare that they have no known competing financial interests, professional affiliations or personal relationships that could have appeared to influence the work reported in this paper.

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