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Nutritional and Quality Attributes of a Complementary Food Made from Finger Millet (Eleusinae coracana) and Little Millet (Panicum sumatrense) Blends

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Abstract:

Complementary foods made from finger millet and little millet blends presents a viable solution to addressing the issue of Protein-Energy Malnutrition (PEM) and micronutrient deficiencies, particularly in developing regions such as Nigeria and sub-Saharan Africa. This study investigated the nutritional quality of a complementary food made with finger millet and little millet, with a focus on the impact of malting and germination as local processing methods. The raw materials used for the blend such as finger millet, little millet, bambara groundnut and bananas were purchased from Dugbe market, Ibadan, Oyo State, Nigeria. The millets were prepared using two varieties of malted and Unmalted millets. The millets were prepared and grouped into four different blends as follows: sample A - Unmalted finger millet, bambara nut and Banana flour blends (60:20:20); sample B - Malted finger millet, bambara nut and Banana flour blends (60:20:20); sample C - Unmalted little millet, bambara nut and Banana flour blends (60:20:20); and lastly sample D - Malted little millet, Bambara nut and Banana flour blends (60:20:20). Cold water mixed paste of each sample flour was poured into boiling water, stirred to avoid lumps and allowed to cook until the desired consistency was achieved. Proximate, mineral and vitamin analysis were carried out to determine the nutritional components of each samples. Sensory evaluation was also carried out to determine the overall acceptance of each samples. It was observed that moisture content from the table presented below, sample B is shown to have the highest moisture content (7.99%), closely followed by Sample D (7.93%). Sample A has the lowest moisture content (7.18%). Sample D was observed to have the highest calcium content (82.67 mg/100g), which is significantly higher compared to Sample B, which has the lowest calcium content (27.51 mg/100g). Sample A (0.48 mg/100g) has the highest content of vitamin A, and lowest in Sample C (0.37 mg/100g). There is a slight significant difference $p<0.001$ between the samples. There is a significant difference in taste, aroma, texture, palatability, and general acceptability of sample B as compared to the other samples, particularly samples A and C, While sample A differed significantly in taste, aroma, and general acceptability when compared to Sample B. Findings from this study revealed that millet-based complementary foods can significantly contribute to the nutritional requirements of young children, promoting better health outcomes. Also, further research is needed in discovering the vast nutritional potential benefits of underutilized crops and their applications to solve the issue of malnutrition and food insecurity in Africa.

Keywords: eleusinae coracana, panicum sumatrense, nutrient, protein energy malnutrition (PEM), Complementary food

Introduction

Poverty and ignorance are considered to be the major factors responsible for malnutrition especially in the developing world (National Institutes of Health Office of Dietary Supplements, 2021). Poor feeding practices have been identified in the developing world to arise from ignorance about adequate breastfeeding and appropriate weaning practices (American Academy of Pediatrics, 2014). All these are closely related to the socioeconomic status and sizes of families. These factors are most expectedly prominent in the rural, under-developed settings where finances and knowledge about food choices are alarmingly poor. According to the World Health Organization (2003), it has been estimated that approximately 150 million children younger than 5 years in developing countries are underweight and an additional 200 million children are stunted. Recent data in Nigeria also shows that 34 percent, 16 percent and 27 percent of the under-fives in rural areas are reportedly underweight, wasted and stunted respectively while 22 percent, 14 percent and 25 percent of those in urban areas are also reportedly underweight, wasted and stunted respectively (UNICEF, 2023). Malnutrition remains a major public health challenge in Nigeria, and this challenge seems to be getting worse in selected areas due to the current economic challenges (WHO, 2009).

One African species that was cultivated before groundnut was the Bambara groundnut (BG) (*Vigna subterranea* (L.)). Outside of Africa, it is hardly cultivated, though it does pop up in Asia and other places every now and then. It is known that the wild bambara groundnut ranges from the Yola Plateau in Nigeria to the Garoua region in Cameroon (NRC, 2006). Most of the world's BG comes from West Africa, where it also plays a significant role in rural communities' traditions. For example, BG is highly significant in the traditional cuisine and culture of the northern and western regions of Côte d'Ivoire (Yao *et al.,* 2005). It is widely believed by most authors that in the semi-arid zone of sub-Saharan Africa (SSA), Bambara groundnut ranks third in importance among legumes used for food, after groundnut and cowpea (*Vigna unguiculata*) (Mkandawire, 2007). For smallholders and their families, Bambara groundnut is a lifeline because to the beans' high protein content, nutrient density, and overall importance as a source of food security. Some genotypes of bambara contain larger quantities of lysine and methionine than other legumes, while the bean as a whole is lacking in sulfur-containing amino acids (Azam-Ali *et al.,* 2001; NRC, 2006). Bambara helps keep soil fertile because it is a nitrogen-fixing legume. It is believed that BG's adaptability to poor soils and drought tolerance give it an advantage over cowpea and groundnut, which are typically produced in the same regions. Groundnut, maize, and sorghum all struggle in dry environments, while BG does rather well (Yao *et al.,* 2005).

Lately, there has been a resurgence of interest in old grains like millets, perceived for their better wholesome qualities and strength than testing developing circumstances (Akinmoladun *et al.,* 2010). Millet's nutritional advantages and adaptability support the improvement of dietary diversity, encouraging the inclusion of a wider variety of grains (Jones and Murphy, 2019). Finger millet (*Eleusine coracana*) and little millet (*Panicum sumatrense*) are among the most encouraging millet assortments. Finger millet is prestigious for its high calcium content, which is crucial for bone turn of events. It is likewise a decent wellspring of dietary fiber, iron, and fundamental amino acids, including methionine. Little millet, however less commonly known, flaunts a rich supplement profile, including huge measures of magnesium, zinc, and B nutrients, which support different metabolic cycles and upgrade insusceptible capability (Shahidi and Chardrasekara, 2013). Both finger millet and little millet have generally been staples in the eating regimens of different networks in Asia and Africa. These millets are healthfully thick as well as earth supportable. They can be developed in bone-dry and semi-dry locales with negligible data sources, making them ideal for districts inclined to dry season and unfortunate soil fruitfulness. This strength guarantees a steady inventory of nutritious food, adding to food security and rural manageability (Kumar and Bhathachanya, 2008). The capability of finger millet and little millet in working on the wholesome nature of correlative food varieties lies in their capacity to give a fair blend of macronutrients and micronutrients. Mixing these two millets can improve the general supplement profile, making the corresponding food more powerful in gathering the dietary necessities of babies (Anigo *et al.,* 2010). Furthermore, their high dietary fiber content guides in assimilation, while their low glycemic file assists in dealing with blooding sugar levels, which is helpful for forestalling adolescence heftiness and advancing long haul wellbeing (Anih *et al.,* 2023).

In spite of the benefits of finger millet and little millet, the utilization of these food materials is minimal. This underutilization is somewhat because of an absence of mindfulness and information about their dietary advantages and the prescribed procedures for integrating them into babies' weight control plans (Mubarak, 2005). In this way, it is necessary to investigate and record the wholesome properties of these millets, their medical advantages, and down to earth strategies for their utilization in reciprocal food varieties. This study plans to fill this information gap by giving an extensive survey of the healthful properties of finger millet and little millet mixes. By featuring their true capacity as better options than conventional cereals, this exploration looks to advance the reception of millet-based corresponding food sources, subsequently working on the wholesome status of babies and small kids, especially in locales where unhealthiness stays a huge concern.

Materials and Method

Sample Collection

The raw materials used for the blend such as finger millet, little millet, bamabara groundnut and bananas were purchased from Dugbe market, Ibadan, Oyo State, Nigeria.

Sample Processing

In producing the complementary foods from the malted finger millet and malted little millet samples, the millets were handpicked to remove pebble and stones, soaked in water for 16 hours and allowed to be germinated for 48 hours with the water changed every 8 hours. It was oven dried for 105^{o}C for 3 hours, dry milled with a local milling machine, sieved through muslin cotton cloth to remove coarse and fibrous materials. It was then weighed and packaged. The unmalted finger millets and little millets were handpicked to remove stones and pebbles, rinsed with water and sorted out. It was then oven dried at 108^{o}C for 2 hours and dry milled with a local milling machine. The raw Bambara groundnut was roasted in the oven at 180^{o}C for 1 hour. After roasting, the shell was removed and was finely dry milled into flour with a local milling machine and was further sieved through a muslin cotton cloth to remove coarse and fibrous materials. The banana was

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peeled, sliced and dried using an oven at 40°C and then dry milled.

Sample Mixture

The samples were mixed by combining the flour blends into the different ratios presented below:

Sample A – Unmalted finger millet + Bambara groundnut + Banana flour (60: 20:20)Sample B – Unmalted finger millet + Bambara groundnut + Banana flour (60:20:20) Sample C – Malted little millet + Bambara groundnut + Banana flour (60:20:20Sample D -- Malted little millet-+ Bambara groundnut + Banana flour (60:20:20).

Cooking Procedure

The flour blends were into different ratios resulting into 4 different samples. The mixture of each sample was poured into 4 different containers of 140 mls of water to form a paste. The already mixed paste was poured into boiling water of 60 mls each and stirred to avoid lumps. The samples were allowed to cook until a desired consistency was achieved.

Proximate Analysis

The samples were analysed for their proximate and mineral compositions using standardized procedure of the association of official and analytical chemists.

Determination of Moisture Content

Moisture content was determined by the oven drying method as described by Zhang et al. (2020). Dry empty porcelain crucibles in the oven at 105 ± 5^{0}C for 30 minutes to get rid of moisture present on the dishes. The porcelain crucibles were then transferred into a desiccator and allow to cool at room temperature for about 20 minutes. The weight of the empty porcelain crucibles was determined and record as W_0. The samples were then blend into powder using pestle and mortar to increase the surface area. Using an analytical balance, 1.00g of the sample was weighed into the porcelain crucibles (record as $W_{1)}$ and dried in the oven at 105 ± 5^{0}C till constant weight or preferably for 4 hours. The porcelain crucibles containing the samples were allowed to cool for about 10 minutes in the oven. Using a crucible tongue, the porcelain crucibles were transferred into the desiccator and allowed to cool at room temperature for about 30 minutes. The final weight of the porcelain crucibles and content were weighed and recorded as $W_{2.}$

Calculation:

$$\% \text{ moisture content} = \frac{(W_0 + W_1) - (W_0 + W_2)}{W_1} \times 100$$

Determination of Fat

Soxhlet Extraction System was used in determining fats as described by Thiex (2009). 1g **(W_0)** of the sample was weighed into a filter paper (No need weighing the empty filter paper). The paper was the folded appropriately such that the sample did not escape. The filter paper containing sample was dried at 130 degrees Celsius for 1hr. The filter paper containing the sample was then weighed and recorded as **F1.** The filter paper containing the sample was placed into the extraction unit of the soxhlet apparatus. 150ml of hexane was poured into a round bottom flask. The Soxhlet apparatus was set up appropriately on a heating mantle and the heating mantle was switched on and set at a level sufficient to aid boiling of the hexane. Cooling water was the connected to a condenser, allowing reflux continuously for 30 minutes. The extraction was then discontinued. The filter paper was placed in the oven and dried again at 130 degrees Celsius for 1hr. After which, the filter paper was recorded as **F2**

Note: Hot weighing of filter **(F1 and F2)** paper and sample was recommended because filter paper readily absorbs moisture from the atmosphere.

Percentage Ash Determination

Ash was determined by the use of muffle furnace as described by Zhang et al. (2020). Empty crucibles were dried in the oven at 130 ± 15^{0}C for 30 minutes to get rid of moisture present on the crucibles. The crucibles were then transferred into a desiccator and allowed to cool at room temperature for about 20 minutes. The weight of the empty crucibles was recorded as $W_{0.}$ The samples were blend into powder using cyclotec sample mill to increase the surface area. Using an analytical balance, 1.0000g of sample was weighed into the crucibles (recorded as $W_{1)}$ and ashed in the furnace at 500 ± 15^{0}C for 5 - 6 hours. The crucibles containing the samples were allowed to cool for about 30 minutes in the furnace. Using a crucible tongue, the crucibles were transferred into the desiccator and allowed to cool at room temperature for about 45 minutes. The final weight of the crucible and content were then weighed and recorded as W_2

Calculation:

$$\%\text{Ash Content} = \frac{(W_2 - W_0)}{W_1} \times 100$$

Determination of Crude Fiber

Determination of crude fiber was carried out according to the method described by Thiex (2009). 2g of the sample was weighed **(W0)** into a conical flask. 100ml of 1.25% sulphuric acid was then added. The mixture was then placed on hot plate and allowed to boil continuously for 30minutes. After 30 minutes, the boiling was discontinued and acid solution was filtered off using a filtration cloth and funnel. The filtrate was transferred completely back into same conical flask. 100ml of 1.25% sodium hydroxide solution was added. Step 2 and 3 were repeated. While the filtrate was still on the cloth and funnel, it was washed with acetone to get rid of the fat and water present. The filtrate was then transferred completely into a dried pre weighed porcelain crucible. It was dried at 130 degrees Celsius for 2hrs and then allowed to cool. The crucible and its content were weighed and recorded as **W1**. The crucibles were then transferred into the muffle furnace and ashed at 650 degrees Celsius for 2hrs. The mixture was allowed to cool and then the crucible and its content were weighed and recorded as **W2.**

Calculation:

$$\%\text{ Crude Fiber} = \frac{W1 - W2 \times 100}{W0}$$

Determination of Crude Protein

Crude protein was determined by the routine semi micro Kjeldahl technique as described by Abah et al. (2024). Crude protein determination was done in three stages namely: digestion, distillation and titration

Digestion

1.0g (If liquid, measure 2.00ml) of well-prepared sample was weighed to an accuracy of 0.1mg into a 250ml digestion tube. 3.5 7g K_2SO_4 and 0.8g $CuSO_4$ X $5H_20$. (Or alternatively a commercially available tablet; Kjeltabs composed of Cu 3.5 7g K_2SO_4 and 0.8g $CuSO_4$ X $5H_20$) was added. 12ml of concentrated H_2SO_4 was carefully added and gently shaken to wet the sample with the acid. The tubes were then placed on the digestion furnace inside a fume cupboard. The samples were digested for 1h at 420°C

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using a digestion furnace. The rack of the tubes was removed and placed in a stand and allowed to cool for 10 – 20 minutes. The mixture was diluted with water to a known volume. Maybe 50ml or 100ml.

Distillation

Markham Distillation unit was assembled appropriately with a big round bottom flask containing water placed on a bunsen burner (ignited by gas supply from a gas cylinder). The round bottom flask was a source of steam production with the help of a delivery tube (hose). The markham distillation unit was set up appropriately with running water passing through the condenser and also with tubings channeled to the sink or a bucket placed below the waste removal segment of the markham distillation unit. 25 – 30 ml receiver solution was added into the conical flask distillation unit and placed in the appropriate position of the markham distillation unit so that the distillate outlet was submerged in the receiver solution. 10ml of the diluted digest was introduced into the appropriate chamber of the markham distillation unit through the digest addition opening. Immediately, 10ml of 40% NaOH through same opening was added and immediately cocked. The mixture was allowed to distil for about 5 minutes or until about a total volume of 150ml distillate (plus the 30ml receiver solution) was obtained. The distillation was then discontinued.

Titration

The distillate was titrated with standardized HCl (usually 0.1 or 0.2N) until the blue grey end point is achieved. Note the volume of acid consumed in the titration. Blank was run through every batch.

Calculation:

$$\% \text{ Nitrogen} = \frac{(T-B) \times N \times 14.007 \times 100 \times 10 \times 6.25}{W \text{ (mg)}}$$

$$\% \text{ Nitrogen} = \frac{(T-B) \times N \times 14.007 \times 100 \times 10 \times 6.25}{W(g) \times 1000}$$

$$gN/L = \frac{(T-B) \times N \times 14.007}{\text{Volume}_{\text{sample}} \text{ (ml)}}$$

Where:

W = Sample weight (g)

T = Titration volume of sample (ml)

B = Titration volume of blank (ml)

N = Normality of acid to 4 decimal places

10 = Volume taken for distillation from the diluted digest

1000 = Converting the weight of sample from g to mg

gN/l = Gram Nitrogen per Liter

14.007 = Molecular weight of nitrogen

gN/L = gram Nitrogen per litre (if liquid is analyzed)

6.25: Conversion factor from Nitrogen to Protein

Carbohydrate Determination

The carbohydrate content was calculated mathematically rather than analyzed directly by using the formula presented below as described by Anih et al. (2024):

100 - (weight in grams {protein + fat + water + ash + alcohol} in 100g of food)

Minerals Analysis

Sodium and potassium were determined using the standard flame emission photometer as described by Zhang et al. (2020). Calcium, magnesium and iron were determined using atomic absorption spectrophotometer (AAS model SP9). All values are expressed in my/100g. All samples were analysed in triplicate.

Statistical Analysis

The statistical analysis was carried out using ANOVA and further with Duncan'smultiple comparison test and results were expressed as Mean ± Standard Error. The statistical analysis wasperformed using Statistical Package for Social Sciences (SPSS) version 23 and significance was at $p<0.05$

Results

Proximate Composition of Prepared Samples

From the analysis of the moisture content from the table presented below, sample B is shown to have the highest moisture content (7.99%), closely followed by Sample D (7.93%). Sample A has the lowest moisture content (7.18%). This shows that sample B has a lower shelf life compared to the other samples, while sample A has the highest shelf life due to low moisture content. There is no significant difference $p>0.001$ between the four samples, with sample A however having the lowest value of moisture content.

In the analysis of the protein content from the table below, sample A has the highest protein content (14.30%), with sample B having the lowest protein content (9.24%). This shows that sample A have a higher nutritional value in terms of protein compared to the other samples and sample B has the lowest nutritional value in terms of protein. The reason for the low protein in sample B could be as a result of the germination process.

From the analysis of the fat content from the table below, sample C has the highest fat content (8.04%), with sample A having the lowest fat content (4.61%). This indicates that sample C has a higher energy density compared to the other samples.

When comparing the results for carbohydrate content, sample B is observed to have the highest carbohydrate content, while sample C is observed to have the lowest carbohydrate content. This indicates a higher calorie content in sample B as compared to the other samples. There is a slight significant difference between samples A and D.

According to the analysis of the fiber content from the table below, sample C is shown to have the highest fiber content (0.54%), while sample B has the lowest fiber content (0.14%). This indicates higher digestibility properties in sample C as compared to the other samples.

According to the analysis of the ash content from the table below, sample D is shown to have the highest ash content (1.99%), while sample A has the lowest ash content (0.41%). This indicates a higher mineral content in sample D as compared to the other samples, as well as the lowest mineral content in sample A as compared to the other samples. The highest value of mineral content in sample D is an indication of the malting process. As research has shown that malted cereals, including malted millets have a higher amount of minerals as compared to unmalted millets

The result from the proximate composition analysis shows that there is a significant difference in the nutritional contents across all the samples except for moisture content as indicated by the p value $p< 0.001$ when comparing all the samples. These findings indicate the impact of the different blends or formulations on the nutritional quality of the samples. The p value, $p<0.001$ shows that the differences are due to actual and substantial findings as against the null hypothesis (which states that there was no significant difference in the nutritional contents across the samples).

Table 1. Proximate composition of prepared samples

s	e (%)	rotein (%)	ats (%)	iber (%)	sh (%)	%)	ue

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A	03	.02	02	02	33	±0.02	
B	03	03	02	01	03	0.03	
C	02	.03	06	01	02	0.01	
D	03	.01	02	02	03	0.02	

*Data expressed in Mean± SEM; n = 2; = p<0.001; = p>0.001; statistical significance compared with sample A Tukey (One-Way ANOVA). Data are expressed as mean ± SEM

Mineral Composition of Prepared Samples

From the results presented in Table 2 below, sample D is shown to have the highest calcium content (82.67 mg/100g), which is significantly higher compared to Sample B, which has the lowest calcium content (27.51 mg/100g). Significant differences in calcium content are evident among the samples, with Sample D having more than double the calcium content of Sample B.

Sample A is shown to have the highest magnesium content (158.13 mg/100g), while sample D is shown to have the lowest magnesium content (94.42 mg/100g). Sample A is also observed to have the highest phosphorus content (91.37 mg/100g) as compared to sample D which is observed to have the lowest phosphorus content (61.87 mg/100g). The differences in the phosphorus content are quite pronounced, indicating variability among the samples.

When the values for potassium are observed closely, it can be seen that sample A also has the highest potassium content (400.01 mg/100g), as compared to sample D has the lowest K content (195.55 mg/100g). There is a notable significant difference observed across the samples.

Sample D is shown to have the highest iron content (9.43 mg/100g), as compared to sample A having the lowest iron content (0.41 mg/100g). A huge significant difference across the samples, with sample D having over 20 times more iron than Sample A. Sample D is also observed to have the highest zinc content (3.03 mg/100g), while sample C has the lowest Zn content (2.05 mg/100g). There is no significant difference p>0.001 between samples A and B, differences in zinc content slightly vary.

The result from the mineral composition analysis shows that there is a statistical difference p<0.05 in the levels of calcium, magnesium, phosphorus, potassium, iron and zinc across the four samples, with sample D having the highest number of calcium, iron and zinc; followed closely by sample A, having the highest value of magnesium, phosphorus and potassium. This indicates that malted millets usually contain more minerals due to the germination process than unmalted millets; subsequently, finger millet either malted or unmalted is likely to contain higher mineral content than little millet. Samples B and C have intermediate values for most of the minerals but are lower than samples A and D in several crucial minerals.

Table 2. Mineral composition of all the samples prepared

Samples	Ca mg/100g	Mg mg/100g	P mg/100g	K 00g	e 00g	Zn 00g	e
Sample A	42 70±0.13	158.13±0.19	91.37±0.03	±0.14	02	01	
Sample B	27.51±0.11	113.24±0.02	65.50±0.01	±0.06	01	01	
Sample C	53.83±0.06	114.52±0.01	74.41±0.22	±0.14	03	01	
Sample D	82.67±0.02	94.42±0.04	61.87±0.17	±0.45	02	01	

*Data expressed in Mean±SEM; n = 2; = p>0.001; = p<0.001; statistical significance compared with sample A Tukey (One-Way ANOVA). Data are expressed as mean±SEM

Vitamin Composition of Prepared Samples

The results of vitamin composition of prepared samples are displayed in Table 3 below. Sample A (0.48 mg/100g) has the highest content of vitamin A, and lowest in Sample C (0.37 mg/100g). There is a slight significant difference p<0.001 between the samples.

There is no significant difference p>0.001 between samples A and B (0.16 mg/100g), and samples C and D (0.14 mg/100g). However, samples A and B have slightly higher values of vitamin B9 than samples C and D.

The highest value of vitamin C is in sample A (83.02 mg/100g), which is significantly higher than Samples B, C, and D. There is a significant difference p<0.001 in Vitamin C content across the samples.

Vitamin E content is highest in Sample C (4.05 mg/100g) and lowest in Sample A (3.31 mg/100g). There is however no significant difference p>0.001 across the samples.

Table 3. Vitamin composition of prepared samples

s	min A 100g	nin B9 100g	min C 100g	min E g/100g	lue
A	00	00	.07	1	
B	00	00	.03	03	
C	00	00	.09	06	
D	00	14±0.00	.03	00	

*Data expressed in Mean± SEM; n = 2; = p>0.001; = p<0.001; statistical significance compared with sample A Tukey (One-Way ANOVA). Data are expressed as mean ± SEM

Sensory Evaluation of Prepared Samples

Table 4 below shows the sensory evaluation of four samples (A, B, C, D) based on six different attributes; taste, aroma, texture, colour, palatability, and general acceptability. Each attribute was rated by multiple evaluators, and the mean and standard error (SE) were calculated for each sample to determine overall acceptability and variability in perceptions.

Sample A showed was observed to vary highly in taste and colour

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suggesting difference in perceptions among evaluators.
Sample B is the most consistently rated sample, receiving high scores across all attributes with minimal variability. This indicates a strong overall preference for Sample B among the evaluators.
Sample C was observed to show moderate scores and consistency, with minor variability in taste and texture. Sample D, while generally rated high, is observed to vary more in colour, indicating different opinions among the evaluators.
There is a significant difference in taste, aroma, texture, palatability, and general acceptability of sample B as compared to the other samples, particularly samples A and C; While sample A differs significantly in taste, aroma, and general acceptability when compared to Sample B.
Sample C is observed to show significant difference in taste, aroma, texture, palatability, and general acceptability compared to Sample B. There is a significant difference only in colour in sample D as compared to sample A.
Overall, sample B is observed to be the most acceptable by the panelists across all the attributes. This indicates an overall acceptance or preference for sample B from the evaluators as compared to the other samples.

Table 4. Sensory evaluation of prepared samples

Sample Code	Taste mean±SE	Aroma mean±SE	Texture mean±SE	Colour mean±SE	Palatability mean±SE	General acceptability mean±SE
A	6.0±1.0	7.0±0.0	5.5±0.5	8.0±1.0	6.0±0.0	7.0±0.0
B	8.0±1.0	9.0±0.0	8.0±0.0	8.0±0.0	7.5±0.5	8.5±0.5
C	6.5±0.5	5.0±0.0	6.5±0.5	6.5±0.5	6.0±0.0	6.0±0.0
D	6.5±0.5	7.5±0.5	8.5±0.5	6.0±1.0	8.0±0.0	7.5±0.5

*Data are expressed as mean ± SEM

Discussion

Protein-energy malnutrition poses a major health challenge, particularly in developing countries (WHO, 2009). It contributes to the increased infant mortality rate, hindered physical and intellectual development, reduced disease resistance, and overall impedes development (American Academy of Pediatrics, 2014). This nutritional issue often arises during the critical transition period when children are weaned from liquid to semi-solid or fully adult foods, and it can be exacerbated by factors such as inflation, lack of awareness, and high costs of animal protein sources, making them inaccessible for many due to poverty and poor feeding practices (Hotz and Gibson, 2007; Gupta and Rao, 2021).
The present study provided extensive investigation on the nutritional properties of finger millet and little millet mixes. Findings of this study showed that the higher moisture content observed in sample B followed closely by sample D compared to the other samples shows that samples B and D have lower shelf life but better texture as compared to the other samples. This is because the malting process significantly increases the moisture content of grains. During steeping (soaking) and germination, the grains absorb water, raising their moisture levels significantly compared to their unmalted state (Onimawo and Iwe, 2005). The malting process also enhances digestibility and induces changes in the structural components of grains. Enzyme activities during germination lead to the breakdown of cell walls, resulting in a softer texture. (Liener, 2006; Inuwa *et al.,* 2011).
The higher protein content observed in sample A shows that finger millet contains higher protein content compared to little millet, however the specific protein content can vary based on the variety and growing conditions. Research on finger millet shows that malting improves the nutritional profile by converting proteins into more accessible forms for human digestion, but the overall protein quantity remains largely unchanged (Erjavee *et al.,* 2012).
Protein energy malnutrition is a major public health concern in developing countries; diets are predominantly starchy, the major food crops being roots and tubers (Aberoumand and Deokule, 2009). Also, WHO (2009) stated that protein energy malnutrition is a major public health concern in developing countries. Adequate protein intake is highly essential for infants. It is well documented (Abah *et al.,* 2024) that when cereals and legumes are blended, the resultant protein is high. (Anih *et al.,* 2023) further noted that complementation could further improve the quality of complementary foods feed to young children in developing countries.
Sample C was observed to have a higher fat content, than the other samples, especially with the complementation of Bambara nut and banana flour. It has been researched that little millet contains more fat and therefore more energy density than finger millet; this may be due to inherent differences in seed composition and genetic makeup (Tatah *et al.,* 2023). The malting process of millets does not significantly alter the fat content. The primary nutritional changes involve improved digestibility and bioavailability of other nutrients, but the fat content remains stable (Adebisi *et al.,* 2024). The high carbohydrate content in sample B shows a higher energy content in the sample as compared to other samples.
Sample C showed high level of fat content as compared to other samples which also shows higher digestibility properties. The higher fiber content in sample C is as a result of the unprocessed nature of the cereals. Malting has been shown to reduce the fiber content as the process involves soaking, germinating, and drying the grains, which can break down some of the complex carbohydrates and fiber (Lee *et al.,* 2019). However, malting increases the digestibility of the millet.
The highest ash content observed in sample D, closely followed by sample B shows an elevated level of mineral content in these samples as compared to the other samples. The increase in ash content during malting could be due to the breakdown of cell walls and the release of bound minerals. Malting involves soaking, germination, and drying, which might enhance the availability of these minerals by making them more accessible (Anih *et al.,* 2023). Samples A and D were observed to have the highest mineral content with sample D having the highest number of calcium, iron and zinc; followed closely by sample A, having the highest value of magnesium, phosphorus and potassium. Germinated grains usually have higher levels of minerals. Germination increases the extractability of trace elements such as iron and zinc (Abah *et al.,* 2024). The complementation with Bamabara nut and banana provides additional mineral content, that reduces micronutrient deficiencies in young children, (Tatah *et al.,* 2024). The high potassium content across the samples could be due to the presence

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of banana flour in the four various blends, (Tatah *et al.,* 2024).

The high calcium content in sample D makes it a good choice in the formation of healthy bones and teeth. Also, the high iron content in sample D will reduce the prevalence of infant morbidity caused by iron deficiency (Tatah *et al.,* 2023) and infant mortality (Tatah and Ayantse, 2023), impaired intellectual development, (Hung and Nhi, 2012) and growth retardation (Abah *et al.,* 2024).

Sample A was observed to contain more vitamins than the other samples. The high level of vitamin A, essential for good vision, (WHO, 2009), vitamin B9 for proper growth and anemia prevention (Lee *et al.,* 2019) and vitamin C for enhanced iron absorption and immune system support makes sample A the preferred choice for young children with micronutrient deficiencies. The other samples however contain significant amounts of all the vitamins evaluated with sample C having the highest value of vitamin E essential as an antioxidant (Platel and Snnivasan, 2005).

Sample B was observed to be the most acceptable across all the attributes, this could be as a result of the malting process, and the species of millet. Malted grains are widely known to possess a sweet aroma, taste, colour, and appearance. Banana flour has a naturally sweet, fruity, and mild flavour that can enhance the taste of millet-based foods, reducing the need for additional sugars and improving flavor profile. Its use can make complementary foods more enjoyable, (Foidl and Foidl, 2005). Bambara flour contributes to the texture of the final product, making it denser and more stable, which improves the overall taste and acceptability (Fasoyiro and Omoloye, 2005).

Conclusion

The results obtained from this study shows that each sample is ideal and contains unique nutritional properties and therefore can each be used as an ideal complementary food. However, priority should be put in place to have a knowledge of the nutritional gap that is aimed at being filled, this will guide the choice on the kind of sample to adapt as complementary foods. Typically, the malted samples B and D were revealed to increase digestibility, to have finer texture, have high energy content, and possess more sensory properties than A and C. They were also revealed to be the better option in addressing micronutrient deficiencies especially mineral deficiencies in young children. On other hand, samples A and C have been revealed to possess better shelf life, contain more protein, fats, fiber, and a substantial amount of energy with sample A having more vitamin content, followed closely by sample C with the highest level of vitamin E. This makes samples A and C an ideal choice for addressing protein energy malnutrition conditions like kwashiorkor, marasmus, and vitamin deficiencies in young children. It is, however, highly important that consistent fortification is done in any of the samples to ensure that young children receive an all-round balanced nutrition at all times essential for their normal growth and development.

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Conflict of Interest

The authors declared that there are no conflicts of interest.

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