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Research Article
Effect of Processing Method of Millet on Proximate Composition and Sensory Evaluation of Complementary Food Produced from Blends of Millet, Cowpea and Unripe Plantain Flours

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Abstract
Objective: This research aimed to produce nutritionally dense supplementary food from millet, cowpea, and unripe plantains. **Materials and Methods:** Complementary foods were produced from blends of millet, cowpea and unripe plantain. Millet was processed using fermentation, germination and roasting methods, to obtain flours. The blends were formulated and designated as MCF_a (70% untreated millet flour, 20% cowpea flour and unripe plantain flour 10%), MCF_b (70% fermented millet flour, 20% cowpea flour and unripe plantain flour 10%), MCF_c (70% germinated millet flour, 20% cowpea flour and unripe plantain flour 10%) and MCF_d (70% roasted millet flour, 20% cowpea flour and unripe plantain flour 10%). The flour samples were subjected to proximate analysis. The gruel obtained was subjected to sensory evaluation using standard methods. A completely randomized design (CRD) was used for the experiment. Data was subjected to one-way analysis of variance (ANOVA). **Results:** Proximate composition showed that there were no significant ($p>0.05$) differences in protein, fat and ash contents. The Crude fibre, moisture, carbohydrate and Calorific values were determined. Samples were significantly ($p<0.05$) different from each other. Sensory scores showed that the samples were acceptable to the panelists and there were significant ($p<0.05$) differences between samples in all accessed parameters. **Conclusion:** Fermentation and germination are the best methods for processing of millet for complementary foods, but fermentation recorded greater potentials. Addition of cowpea improved the protein-energy balance. Panelists recorded preference for the fermented sample (MCF_b) over other samples.

Key words: Cowpea, millet, unripe plantain, infant nutrition, complementary foods

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The infancy phase, which lasts from 0 to 2 years, is crucial to a child's development. Their growth, health, and behavioral development are at their best during this time[1]. For a child to grow and develop normally into a healthy adult, adequate nutrition is crucial throughout this time[2]. For the first six months of life, newborns should only be breastfed, according to World Health Organization[3]. This is so because after six months of life, breast milk alone can no longer meet an infant's or young children entire nutritional needs as they develop and become more active. As infants and young children grow, this difference widens. To close these gaps, complementary nutrition becomes essential and complementary foods can be introduced.

According to the World Health Organization (WHO), complementary feeding begins when breast milk is no longer enough to meet an infant's nutritional needs and other foods and liquids are needed instead. Complementary foods, or infant formula, should subsequently be introduced to infants in order to provide them extra nutrients[4].

Weaning is the gradual process of adding other foods to breast milk to meet the needs of the growing child. This is the process of gradually substituting breast milk with other meals in the diet of a baby in order to complement nutritional value. The reliance of a child on breast milk gradually decreases as the amount of supplementary (weaning) food provided increases, this decrease continues until the child can meet all of his or her nutritional needs with adult diet. The weaning process varies depending on the socioeconomic status and can begin as early as four to six months. Gradually introducing the baby to the family diet may take several months, or it may happen suddenly, in which case the baby is immediately served family meals. Problems arise from abrupt weaning since the child might not be able to consume enough adult food to meet their nutritional needs[5].

Protein-energy malnutrition has been recognized as a major issue in Africa, which has been exacerbated by population growth. Conventional supplementary diets made from millet, maize, or sorghum are lacking in other essential nutrients and protein. Low-income families in underdeveloped countries cannot pay the extortionate cost of commercial supplemental foods. Majority of people in Nigeria, a developing country, rely on plants for their food. As the main sources of protein, calories, vitamins, and minerals, cereals and legumes are staple food for many people, including children. Many countries have developed weaning diets using inexpensive, locally available plant components derived from cereals and legumes[5]. In poor countries, complementary foods made from locally sourced and nutrient-dense crops can help prevent malnutrition in babies and related health problems. Therefore, the goal of this research was to use millet, cowpea, and unripe plantain to create inexpensive supplementary food that is high in nutrients.

Millet (*Pennisetum glaucum*) lacks the lysine, which must be added to the diet to obtain the full range of amino acids found in foods such as cowpeas. Plants in the Leguminosae family are excellent sources protein for diets. They can be eaten raw as juvenile seeds, mature seeds, dry seeds, or green pods that contain the immature seeds. Cowpea, soy bean, peanut, pigeon pea, and bambara nut are a few examples.

The cowpea (*Vigna sinensis*) variety used in this study also called locally as *Apama*, is a member of the *Fabaceae* family and varies in size, shape, and seed coat colour. Similar to other suitable sources of dietary protein, cowpeas have a good bioavailability and low percentage of anti-nutritional components. It is high in dietary fiber (both soluble and insoluble), minerals, and vitamins, in addition to being a good source of protein[6].

However, a few fruits, such as staples like plantains and bananas, are recommended as foods to combat hunger and infant malnutrition due to their nutrient makeup and usefulness. According to Hasanah *et al.*[7], unripe plantains (*Musa paradisiaca*) are high in calcium, iron, potassium, B complex vitamins among other nutrients. Osteoporosis and anemia can be treated by eating them. It is also high in dietary fibre.

Millet seeds (*Pennisetum glaucum*), cowpeas (*Vigna sinensis*) and unripe plantains (*Musa paradisiaca*) are easily accessible local resources with exceptionally high yields. Post-harvest losses can be reduced as well as human benefits can be achieved by using these raw materials in various ways.

MATERIALS AND METHODS

Procurement of raw materials: Millet (*Pennisetum glaucum*), cowpea (*Vigina sinensis*) and unripe plantain (*Musa paradisiaca*) were purchased from Ogige market in Nsukka, Enugu State, Nigeria. All chemicals and reagents were of analytical grade and were obtained from the chemistry laboratory of Department of Food Science and Technology. University of Nigeria, Nsukka.

Sample preparation

Processing of untreated millet flour: To obtain millet flour, whole millet seeds were sorted to remove unnecessary components, washed, and oven-dried at 60°C for 9 hrs. Then, the seeds were milled in an attrition mill, and sieved through a 250 µm pore-size sieve. Before being used, the flour was kept in enclosed plastic bucket in low density polyethylene bags[8] stored at room temperature.

Processing of germinated millet flour: In order to get rid of unnecessary components, whole millet seeds were cleaned. Soaked in water for eighteen hours, and then drained. After being drained, the grains were spread out on a jute bag and allowed to germinate for 48 hrs at room temperature (30°C), with water sprinkled every 12 hrs. The germinated seeds were oven dried at 60°C for 12 hrs. The oven-dried millet grains were allowed to cool, then rubbed between palms to eliminate the sprouts, winnowed, milled into flour, using an attrition mill, then sieved through a 250 µm aperture sieve size to extract flour. Before being used, the flour was kept in enclosed plastic buckets within low-density polyethylene bags stored at room temperature[9].

Processing of fermented millet flour: Whole millet seeds were sorted and carefully washed before being soaked using tap water at a ratio of 1:3 (w/v) seed: water and allowed to ferment for 48 hrs at 28°C. After fermentation, the grains were oven dried at 60°C for 12 hrs and milled into flour using an attrition mill. After that, the grains were sieved through a 250 µm-opening sieve size. They were then stored in covered plastic buckets within low density polyethylene bags stored at room temperature until they were needed[10].

Processing of roasted millet flour: Foreign contaminants were eliminated, from the millet grains. They were washed and allowed to drain. After wards oven dried at 60°C for 6 hrs. The millets were roasted in batches, 1 kg each was roasted for 30 minutes at 130°C in a grain locally fabricated grain roaster. The seeds were allowed to cool then milled into flour, using an attrition mill and sieved through a 250 µm aperture size sieve[11]. Before being packaged in low density polyethylene bags and kept under closed plastic buckets until needed stored at room temperature.

Processing of cowpea flour: To get rid of unnecessary elements, cowpea seeds were sorted and cleaned. Precooked at 100°C for 20 min, water was drained, and oven dried for 10 hrs at 65°C. They were allowed to cool down a beat. They were dehulled, by manually rubbing them between the palms then winnowed. Afterwards, milled using an attrition mill and sieved to obtain the flour using a 250 µm aperture size sieve. Before being used, the cowpea flour was kept in covered plastic bucket in low-density polyethylene bags stored at room temperature.

Production of unripe plantain flour: The techniques described by Nwakalor and Obi[12] With a few modification was used. The unripe plantain fingers were manually peeled, cut into chips that were about the same thickness (5 mm), and then dried for 7 hrs at 100°C in the oven. The dehydrated chips were milled into fine flour using an attrition mill, passed through a 250 µm aperture size sieve to obtain the flour. The flour was stored at room temperature in a low-density polyethylene bag in a covered bucket until required.

Formulation of the complementary food: Table 1 shows the blends of flours prepared from millet, cowpea and unripe plantain.

Proximate analysis: Proximate analysis was carried out using the Association of Official Analytical Chemist (AOAC)[13] procedures. Energy value was calculated using the Atwater factor as described by AOAC[13].

Preparation of gruel from the formulated complementary food: A total of 100 mls of clean water were used to reconstitute 50 g of the sample. The reconstituted complementary formula was added to 150 mls of boiling water in a pot, stirred constantly, and cooked for 5 min, to make a smooth gruel. Milk and sugar were added to improve taste.

Sensory evaluation: Sensory evaluation was conducted at the sensory evaluation laboratory, Department of Food Science and Technology, University of Nigeria, Nsukka. A panel of nursing mothers made up of staff and students assessed the complementary food (gruel) sensory quality of the Department of Food Science and Technology, University of Nigeria, Nsukka, who reviewed the products according to the

Table 1: Blends of flours prepared from millet, cowpen and unripe plantain

Sample	Untreated miller	Fermented millet	Roasted millet	Germinated millet	Cowpea	Unripe plantain
MCF_a	70	0	0	0	20	10
MCF_b	0	70	0	0	20	10
MCF_c	0	0	0	70	20	10
MCF_d	0	0	70	0	20	10

MCF_a: 70% untreated millet flour, 20% cowpea flour and unripe plantain flour 10%, MCF_b: 70% fermented millet flour, 20% cowpea flour and unripe plantain flour 10%, MCF_c: 70% germinated millet flour, 20% cowpea flour and unripe plantain flour 10%, MCF_d: 70% roasted millet flour, 20% cowpea flour and unripe plantain flour 10%

procedure described by Ihekoronye and Ngoddy[14]. The panelists scored the samples on a nine-point Hedonic scale, with 9 representing "like extremely" and I representing "dislike extremely". Samples were coded before presenting to panelists. Samples were evaluated for appearance, taste, mouth-feel, flavour, consistency, aftertaste, and overall acceptability. To prevent prejudice, each panelist received a cup of water, to rinse the mouth during evaluation.

Experimental design and data analysis: One-way analysis of variance (ANOVA) was used to analyze generated data with a Complete Randomized Design (CRD). Statistical Product for Service Solution (SPSS) software version 25.0 was used. Duncan's New Multiple Range Test (DNMRT) was utilized to compare treatment means. At $p<0.05$, significance was deemed acceptable[15].

RESULTS AND DISCUSSION

Proximate composition of blends of millet, cowpea and unripe plantain flours: Table 2 shows the proximate composition of blends of millet, cowpea, and unripe plantain. The protein contents ranging from 6.57 to 9.98% for sample MCF_d and MCF_a, respectively. Generally, the different treatments given to the millet component of the formulation did not cause a significant ($p>0.05$) difference in mean values of protein contents of the complementary food. Sample MCF_a and MCF_b had slightly higher protein contents than samples MCF_c and MCF_d. Sample MCF_b (fermented millet) showed slightly higher values, possibly because microorganisms hydrolyzed and metabolized carbohydrates and fat as energy sources and lower values in the germinated sample could be attributed to the degradation by proteases during the germination process of millet[16]. The values obtained from the formulation were lower than those reported by Mbaeyi Nwaoha and Obetta[17] for complementary food produced from millet, pigeon pea and breadfruit.

Crude fat content ranged from 2.81-5.41%. Even though there were no significant ($p>0.05$) differences in the fat content across the samples. Sample MCF_d containing roasted millet recorded the highest value for fat. This can be attributed to concentration of fat and other nutrients as a result of removal of moisture. The decrease in the germinated sample could be due to the increased activities of the lipolytic enzymes during germination. Fat values in the sample was an indication of its potential to be stable during storage due to reduced rancidity of fats. The current result is similar to the result (1.21-4.85%) of a previous study of Nwaoha and Obetta[17] complementary food made from breadfruit, pigeon pea, and millet.

The amount of ash in the blends is a sign that minerals are present. According to the findings, the ash level of samples MCF_b and MCF_a varied from 4.90-6.05%, respectively. Between the samples, no significant ($p>0.05$) differences were found. A high ash content is crucial for complementary food formulations because the minerals in a food can affect its physiochemical characteristics and inhibit the growth of microbes[18].

Similar results were reported by Nwaoha and Obetta[17] for complementary foods made of millet, pigeon pea, and breadfruit, also these results reinforce the results of a study by Orekoya *et al.*[19] for a supplemental diet made of unripe plantain and pigeon pea blends.

Crude fibre content ranged from 3.50-7.98% for sample MCF_c and sample MCF_a, respectively. Significant ($p<0.05$)

Table 2: Proximate composition and energy value of blends of milet, cowpea and unripe plantain flours

Sample	Protein	Fats (%)	Ash (%)	Crude fibre (%)	Moisture (%)	Carbohydrates (%)	Energy (kcal)
MCF_a	9.85 ± 0.62^a	2.92 ± 0.33^a	6.05 ± 1.20^a	7.98 ± 0.21^b	7.28 ± 0.71^{ab}	65.92 ± 1.83^a	305.72 ± 6.89^a
MCF_b	9.98 ± 0.62^a	3.94 ± 0.68^a	4.90 ± 0.99^a	6.02 ± 0.64^{ab}	7.62 ± 1.89^b	67.55 ± 2.84^a	321.62 ± 2.74^a
MCF_c	7.66 ± 0.62^a	2.81 ± 0.69^a	5.50 ± 0.28^a	3.50 ± 0.21^a	7.38 ± 0.54^{ab}	73.15 ± 0.40^a	330.16 ± 5.36^a
MCF_d	6.57 ± 0.00^a	5.41 ± 1.65^a	5.95 ± 0.78^a	7.00 ± 0.71^{ab}	7.08 ± 0.47^a	68.00 ± 2.67^a	331.19 ± 4.20^b

Values are Maans ± standard deviation of duplicate determinations. Means with the same superscripts in a column are not significantly ($p>0.05$) different, MCF_a: 70% untreated millet flour, 20% cowpea flour and unripe plantain flour 10%, MCF_b: 70% fermented millet flour, 20% cowpea flour and unripe plantain flour 10%, MCFc: 70% germinated millet flour, 20% cowpea flour and unripe plantain flour 10%, MCF_d:70% roasted millet flour, 20% cowpea flour and unripe plantain flour 10%

Table 3: Sensory scores of complementary foods from blends of unripe plantain, cowpea and millet flours

Sample	Appearance	Taste	Mouth-feel	Flavour	Consistence	AT	OA
MCF_a	6.80 ± 1.01^b	6.70 ± 1.34^{ab}	6.70 ± 1.30^a	6.60 ± 1.27^b	6.60 ± 0.50^a	5.95 ± 1.36^a	6.75 ± 1.29^b
MCF_b	7.85 ± 1.04^c	8.40 ± 1.00^c	7.90 ± 1.33^b	7.85 ± 0.99^c	7.20 ± 0.83^b	7.75 ± 0.72^c	8.25 ± 0.97^c
MCF_c	6.10 ± 0.64^a	6.15 ± 1.31^a	6.20 ± 0.95^a	5.85 ± 0.93^a	6.05 ± 0.95^c	5.95 ± 0.83^a	6.05 ± 1.00^a
MCf_d	6.80 ± 1.15^b	7.20 ± 0.83^b	6.80 ± 0.95^a	7.35 ± 1.18^c	7.10 ± 0.64^c	7.05 ± 0.61^b	7.15 ± 0.75^b

Values are means ± standard deviation of duplicate determinations. Means with the same superscripts in a column are not significantly ($p>0.05$) different, MCF_a: 70% untreated millet flour, 20% cowpea flour and unripe plantain flour 10%, MCF_b: 70% fermented millet flour, 20% cowpea flour and unripe plantain flour 10%, MCF_c: 70% germinated millet flour, 20% cowpea flour and unripe plantain flour 10%, MCF_d: 70% roasted millet flour, 20% cowpea flour and unripe plantain flour 10%, AT: After taste and OA: Overall acceptability differences were observed between sample MCF_a and MCF_c but samples MCF_b and MCF_d did not differ significantly from any of these samples. Samples containing germinated millet had the lowest fibre content and this can be attributed to the fact that after germination, seed coats were removed along with rootlets. A similar trend was observed by Jood *et al.*[20] in germinated sorghum based food product and germinated samples had significantly lower fibre values than non-germinated samples.

Moisture content of the complementary food ranged from 7.08-7.62% for sample MCF_d and MCF_b, respectively. The moisture content of the fermented sample was significantly ($p<0.05$) higher than the moisture content of the roasted sample. There was no significant difference in moisture content of the germinated sample and the other samples.

Carbohydrate content ranged from 65.92-73.15% for sample MCF_b and MCF_c, respectively. No significant ($p>0.05$) differences were observed in the carbohydrate contents of the blends. Lower values for the fermented sample could be due to the fact that during fermentation of the millet, glucose which is a preferred substrate for microorganism fermentation was released and could partly explain the decrease in total carbohydrate after the product was produced. Values obtained were lower than those reported by Mbaeyi Nwaoha and Obetta[17] for complementary food produced from millet, pigeon pea and breadfruit.

Energy values ranged from 305.72-331.19 kcal for sample MCF_a to MCF_d, respectively. A significantly higher energy value was observed in sample MCF_d compared to other samples. This could be due to the high fat content of this sample which has a high At water factor in the computation of energy in the food. Lower values in the fermented and germinated samples could be due to the breakdown of starch to provide energy for these two processes, resulting to lower values in the final product[16].

Sensory evaluation scores for complementary foods produced from blends of millet, cowpea and unripe plantain flours: Sensory scores of complementary food produced from blends of millet, cowpea, and unripe plantain flours was presented in Table 3. Scores for appearance ranged from 6.10-7.85 for sample MCF_c and MCF_b, respectively. Generally, all the samples were highly rated by the panelists as having a desirable appearance. Only sample MCF_d and MCF_a showed similar mean score values for appearance, with significant ($p<0.05$) differences occurring between the other samples. Treatment methods for millet had different effects on its appearance and when compared to the other samples, sample MCF_b, which contained fermented millet, received a high rating from the panelists.

In terms of taste, sensory scores ranged from 6.15-8.40 for sample MCF_c and MCF_b, respectively. Sample MCF_b contained fermented millet was significantly ($p<0.05$) higher than the other samples. There was no significant difference between sample MCF_a and MCF_c contained untreated and germinated millet components.

Mouth-feel is the way a food feels in the mouth, as distinct from taste. The scores ranged from 6.20-7.90 for sample MCF_c and MCF_b, respectively. The mouth-feel scores for sample MCF_b was significantly ($p>0.05$) higher than the other samples. No significant ($p>0.05$) differences were observed in mean scores for samples MCF_a (untreated millet), MCF_c (germinated millet), MCF_d (roasted millet).

Scores for flavour ranged from 5.85-7.85 for sample MCF_c and MCF_b, respectively. There was no significant ($p>0.05$) difference between sample MCF_b (fermented millet) and MCF_d (roasted millet). The flavour could be enhanced in sample MCF_b by microbial action, converting sugars to acids and generating flavouring compounds as other by-products[21]. A possible caramelization reaction due to the high temperatures the millet was exposed to during roasting could explain the enhanced flavour of sample MCF_d[22].

Sensory scores for consistency ranged from 6.60-7.10 for sample MCF_a and sample MCF_c, respectively. Significant differences in consistency were observed between sample MCF_a that had untreated millet component and the other samples. Sample MCF_c (germinated millet) and MCF_d (roasted millet) showed no significant differences in their mean values.

The taste that lingers in the tongue after consuming food is referred to as aftertaste. Sensory scores for aftertaste ranged from 5.95-7.75 for sample MCF_c and sample MCF_b, respectively. This result implies that a noticeable after taste was observed for sample MCF_c containing germinated millet compared to the sample MCF_b that was fermented. This could be a possible reason why sensory scores for taste were rated low for sample MCF_c.

For the overall acceptability, sensory scores ranged from 6.05-8.25 for sample MCF_c and MCF_b, respectively. Panellists appreciated sample MCF_b (fermented sample) the most compared to all other samples. Probably the preference was due to the fact that these nursing mothers were conversant with the taste of fermented gruel since that was the most popularly used method. No significant difference was observed between samples MCF_a containing untreated millet and MCF_d containing roasted millet. Generally, the panellist rated all the samples as acceptable. The results were also higher than those reported by Bolarinwa *et al.*[9] for complementary food produced from malted millet, plantain, and soybeans.

CONCLUSION

Fermentation and germination are the best methods for processing of millet for complementary foods. Addition of cowpea improved the protein-energy balance. Sensory evaluation scores also showed that acceptable complementary food could be made from millet, cowpea and unripe plantain using fermentation, germination and roasting processing methods, although panellists preferred the fermented sample (MCF_b) over other samples. It is recommended that nursing mothers should feed babies with gruel made from composite flours from locally available food materials, as this will support good health and growth and general well-being of the child.

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