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Production and quality evaluation of complementary food produced from millet, soybean, cashew nuts and carrot flour blends

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Abstract
Protein-energy malnutrition remains a significant public health issue among children under five in developing countries, primarily due to the reliance on low-protein, cereal-based complementary foods. This study focused on the production and nutritional evaluation of complementary food formulated from finger millet, soybean, cashew nuts, and carrot flours. The ingredients were processed using standard methods and blended into four formulations: A (100% millet – control), B (70:15:10:5), C (60:20:15:5), and D (50:25:20:5), representing varying proportions of millet, soybean, cashew nut, and carrot flours, respectively. The samples were used to prepare pap and analyzed for proximate composition, mineral and vitamin contents, and anti-nutritional factors using standard AOAC methods. The results showed a progressive increase in protein (from 8.52% to 12.52%) and fat (from 1.72% to 10.22%) as the inclusion of soybean and cashew increased. Carbohydrate content declined from 73.57% in the control to 59.62% in Sample D. Ash content increased from 2.22% to 3.13%, while fibre slightly decreased but remained within safe levels for infants. Anti-nutritional factors including phytate, tannin, and oxalate were significantly reduced across the formulations, with Sample D recording the lowest values. Mineral analysis showed marked increases in potassium (342.42 mg/100g), magnesium (110.92 mg/100g), and calcium (270.52 mg/100g) in Sample D. Vitamin content also improved, with Sample D having the highest values for vitamin A (26.32 µg), C (13.22 mg), and D (2.32 µg). Sensory evaluation results showed no significant differences in flavour, aroma, taste, texture, and overall acceptability among the samples. However, Sample A had slightly higher scores in appearance and overall acceptability. Sample D was the most nutrient-dense and showed highest acceptability, indicating its potential for combating malnutrition using locally available ingredients.

Keywords: Complementary food, finger millet, cashew nut, soybean, infant nutrition

Introduction

Protein energy malnutrition among children under five in developing countries is largely attributed to the consumption of unfortified cereal-based complementary foods, such as finger millet or maize, which are low in both protein content and quality. Recent demographic and health surveys indicate that these foods are the primary weaning diet, contributing to high rates of stunting (26%) and a child mortality rate of 39 deaths per 1,000 live births (KNBS, 2014). Introducing a combination of cereals and legumes is seen as a sustainable and effective approach to enhance the nutritional quality of complementary foods and hence combat protein-energy malnutrition. Complementary foods are solid or semi-solid foods introduced to infants alongside continued breastfeeding from six months of age, as breast milk alone becomes inadequate to meet the increasing energy and nutrient demands required for healthy growth (PAHO & WHO, 2003; Yaseen *et al*., 2014). The World Health Organization (2003) [34] recommends exclusive breastfeeding for the first six months, after which appropriate, safe, and nutrient-dense complementary foods should be introduced. These foods should be soft, easy to digest, free from choking hazards, and given frequently due to the small stomach capacity of infants (USAID, 2011). Processed cereal-based complementary foods, made from cereals, legumes, nuts, and oilseeds, are commonly used as weaning foods and must be produced under hygienic conditions with clean, high-quality ingredients (BIS, 2006). Appropriate feeding practices during this phase are crucial for meeting the nutritional needs of growing children while maintaining breast milk intake (Ikujenlola & Adurotoye, 2014).

In settings where commercial fortified foods are unaffordable or unavailable, home-prepared complementary foods using locally sourced, nutrient-rich ingredients are essential to address malnutrition and support healthy development (Akinola *et al*., 2014; Bala *et al*., 2014). Traditional weaning diets often rely on cereals, which are energy-rich but typically low in certain essential amino acids like lysine and tryptophan (Acharya & Shah, 1998). Legumes, rich in lysine but low in sulphur-containing amino acids, complement cereals nutritionally (Pawar & Dhanvijay, 2007). Finger millet (Eleusine coracana), cashew nuts (Anacardium occidentale), carrots (Daucus carota), and soybeans are examples of such local foods with high nutritional value (Osagie & Eka, 1998; Kenneth, 1996). Under-nutrition during infancy causes irreversible damage and threatens global efforts to reduce stunting among under-five children. Improving nutrient bioavailability, not just adequacy, is key to addressing this issue. Continued research on sustainable strategies for enhancing complementary feeding remains essential (Adenuga, 2010; Oyarekua, 2013; Ige, 2017). Therefore, this research focuses on production and nutritional evaluation of complementary foods made from millet, soybeans, cashew nuts and carrot flour blends.

Materials and Methods

Millet, soybean, cashew nuts, and carrots were procured from Sayedero Market in Ilaro, Ogun State, and thoroughly cleaned to eliminate foreign materials. Finger millet flour was prepared based on the method described by Ndife *et al*. (2011) [18]. The millet grains were sorted, washed, soaked for six hours, sun-dried for five hours, then milled and sieved using a 500-micron mesh. The fine flour obtained was sealed in airtight nylon bags and labeled for storage.

Soybean flour was produced using the procedure by Henry *et al*. (2010) [9] with slight modification. The soybeans were cleaned, soaked for eight hours, boiled for 30 minutes, dehulled, roasted for 30 minutes, and oven-dried at 60°C for 15 minutes. They were then milled and sieved into fine flour, which was stored in an airtight plastic container at ambient temperature.

Cashew nuts were sorted to remove unwanted particles and defective nuts. After soaking in water for five minutes and sun-drying for five hours, the nuts were roasted using an open-pan method for 20 minutes. Shelling was done manually with a wooden hammer. The kernels were oven-dried, peeled, and winnowed to obtain clean, cream-colored nuts, which were milled, sieved, and stored in polyethylene bags at 5ºC.

Carrot flour was prepared as outlined by Krishan *et al*. (2012). Fresh carrots were washed, peeled, grated, soaked for 20 minutes, and dried in an oven at 50°C for 10 hours. The dried product was milled, sieved, and stored in high-density polyethylene bags.

The resulting flours were blended in the following ratios: 100:0:0:0 (Sample A – control), 70:15:10:5 (Sample B), 60:20:15:5 (Sample C), and 50:25:20:5 (Sample D) for millet, soybean, cashew nuts, and carrot respectively. These formulations were used to produce pap, which was analyzed for proximate composition, micronutrients, and anti-nutritional factors using standard AOAC (2005) [3] methods.

Result

Proximate Composition

The proximate composition is shown in table 1. The highest protein content was observed in sample D with a value of 12.52%, while the lowest was found in sample A at 8.52%. Fat content also peaked in sample D at 10.22%, compared to the lowest value of 1.72% in sample A. This reflects the high-fat and high-protein contributions of cashew nut and carrot. Moisture content was highest in sample A at 10.27% and lowest in sample D at 8.62%, suggesting that the fortified blends may have improved shelf-stability. Ash content increased from 2.22 % in sample A to 3.13% in sample D, making sample D the most mineral-dense. Crude fibre was highest in sample A at 3.82% and lowest in sample D at 3.22%, with a small but significant reduction observed. Carbohydrate content decreased significantly across the samples, with sample A having the highest value at 73.57% and sample D having the lowest at 59.62 There was a statistically significant difference across all the samples in terms of the proximate composition.

Table 1: Proximate Composition of the samples

Sample	Moisture (%)	Protein (%)	Fat (%)	Fibre (%)	Ash (%)	Carbohydrate (%)
A	10.27±0.03^a	8.52±0.03^d	1.72±0.03^d	3.82±0.03^a	2.22±0.03^d	73.57±0.03^a
B	9.17±0.03^b	10.32±0.03^c	6.92±0.03^c	3.62±0.03^b	2.52±0.03^c	64.67±0.03^b
C	8.92±0.03^c	11.22±0.03^b	8.52±0.03^b	3.47±0.03^c	2.77±0.03^b	62.22±0.03^c
D	8.62±0.03^d	12.52±0.03^a	10.22±0.03^a	3.22±0.03^d	3.13±0.03^a	59.62±0.03^d

Value of triplicate mean± standard deviation determination). Sample with different superscripts within the same column were significantly different ($p<0.05$)

Mineral Composition of the samples

Table 2 shows the mineral composition of the samples: The mineral content of the samples improved significantly with Sample D having the highest in the potassium (342.42), magnesium (110.92), and calcium (270.52). Conversely, sample A had the lowest values in terms of potassium (315.52), magnesium (95.22), and calcium (240.32). These results demonstrate that increasing the levels of cashew nut and carrot enriched the complementary food with essential minerals, enhancing its nutritional value.

Table 2: Mineral Composition of the Complementary Food Sample

Sample	Potassium (mg/100g)	Magnesium (mg/100g)	Calcium (mg/100g)
A	315.52±0.03^d	95.22±0.03^d	240.32±0.03^d
B	328.02±0.03^c	102.62±0.03^c	250.12±0.03^c
C	335.62±0.03^b	106.82±0.03^b	260.72±0.03^b
D	342.42±0.03^a	110.92±0.03^a	270.52±0.03^a

Value of triplicate mean± standard deviation determination with the significant different in ($p<0.05$). Sample with different superscripts within the same column were significantly different ($p<0.05$).

Vitamin Composition of the samples

Vitamin composition of the sample is shown in table 3. Vitamins A, C, and D all increased significantly as cashew nut and carrot content increased. Sample D had the highest levels of vitamins: vitamin A (26.32), vitamin C (13.22), and vitamin D (2.32), while sample A had the lowest with values of 12.52, 3.82, and 0.92 respectively. These results highlight the nutritional benefits of blending finger millet with carrot and cashew nut, especially in boosting the micronutrient quality of the food.

Table 3: Vitamins Composition of the Complementary Food Sample Produced

Sample	Vitamin a	Vitamin c	Vitamin d
A	12.52±0.03^d	3.82±0.03^d	0.92±0.03^d
B	18.62±0.03^c	8.42±0.03^c	1.52±0.03^c
C	22.42±0.03^b	10.82±0.03^b	1.92±0.03^b
D	26.32±0.03^a	13.22±0.03^a	2.32±0.03^a

Value of triplicate mean± standard deviation determination with the significant different in ($p<0.05$). Sample with different superscripts within the same column were significantly different ($p<0.05$).

Anti-nutrients Composition of the Samples

Table 4 shows the anti-nutrients composition of the samples. All anti-nutritional components decreased significantly across the samples. Sample A had the highest levels in terms of oxalate (5.70), tannin (2.60), and phytate (80.02), while sample D had the lowest values: oxalate (4.42), tannin (1.84), and phytate (15.22). These reductions indicate that the addition of cashew nut and carrot to finger millet effectively lowered anti-nutrient content, which in turn may improve the bioavailability of important nutrients like iron, zinc, and calcium.

Table 4: Anti-nutrients Composition of the Complementary Food Samples Produced

Sample	Oxalate	Tannin	Phytate
A	5.70±0.01[a]	2.60±0.01[a]	80.02±0.03[a]
B	5.21±0.02[b]	2.34±0.01[b]	45.33±0.04[b]
C	4.89±0.01[c]	2.11±0.01[c]	30.60±0.01[c]
D	4.42±0.01[d]	1.84±0.01[d]	15.22±0.02[d]

Value of triplicate mean± standard deviation determination with the significant different in ($p<0.05$). Sample with different superscripts within the same column were significantly different ($p<0.05$).

Sensory attributes of the complementary food samples

Table 5 shows the sensory attributes of the food samples. The sensory scores showed no significant differences among the samples in most parameters, including flavour, aroma, taste, texture, and overall acceptability. Overall acceptability ranged from 7.40 in sample D to 7.72 in sample A, with all samples rated well. However, in terms of colour, a significant difference was observed: sample A had the highest score at 7.92, while sample B had the lowest at 7.20. This slight difference suggests that while nutrient fortification did not affect the sensory quality overall, colour perception may have varied slightly depending on ingredient proportions.

Table 5: Sensory Properties of the Complementary Foods

Sample	Appearance	Colour	Flavour	Aroma	Taste	Texture	Overall Acceptability
A	7.76±0.92[a]	7.92±1.07[a]	6.88±1.30[a]	7.00±1.25[a]	7.60±1.04[a]	7.44±1.26[c]	7.72±1.20[a]
B	7.28±1.10[a]	7.20±1.19[b]	6.76±1.42[a]	7.28±1.42[a]	7.12±1.13[a]	6.92±1.18[a]	7.44±0.87[a]
C	7.32±1.14[a]	7.52±1.19[ab]	7.12±1.50[b]	7.16±1.40[a]	7.08±1.38[a]	7.12±1.01[b]	7.48±1.04[a]
D	7.12±1.16[a]	7.56±1.04[ab]	7.16±1.40[b]	7.08±1.28[a]	7.56±1.29[a]	7.44±1.00[c]	7.40±1.47[a]

Value of triplicate mean ± standard deviation determination with the significant different in ($p<0.05$). Samples with different superscripts within the same column were significantly

Discussion

The moisture content of the samples ranged from 10.27% in Sample A to 8.62% in Sample D. Compared to Okoye *et al*. (2008) [22], who found moisture levels of 12–14% in cereal-legume blends, these values are lower, indicating improved shelf-stability in these food samples. Sample D has the lowest moisture level, which makes it ideal for extended storage and lower microbiological activity. This is a little lower compare to the findings of Onabanjo *et al*. (2009) [28] who reported moisture contents of approximately 11.5%. In terms of protein, the protein content ranged from 8.52% in Sample A to 12.52% in Sample D. These are similar to those reported by Omueti *et al*. (2009) [26], who discovered 9.2-11.8% protein in cereal-soybean-crayfish mixtures. Sample D, had the highest protein content, which could be due to increase substitution of soybeans and cashew nuts flours in the formulation's blends, therefore meeting WHO recommendation for protein-dense complementary foods (WHO, 2003).

The inclusion of high-fat cashew nuts flour could possibly result to the increase in fat content across the samples, with Sample D having the highest fat content (10.22%), and this is higher than the fat content (5-8%) of a legume based complementary food blends reported by Fasoyiro *et al*. (2010) [7]. This showed that the complementary food samples were energy-dense, and therefore could help in combating severe acute malnutrition under five children. Also, in terms of crude fiber content, the fibre content varied from 3.22% to 3.82%, which is slightly higher than the fibre content (2.5 and 3.0%) of sorghum and legume-based meals reported by Ijarotimi and Aroge (2005) [13]. The fibre content of the complementary foods are within the acceptable limit for infant food.

The Ash content of the samples which shows the total mineral content, was found to be highest in Sample D (3.13%), and lowest in Sample A (2.22%). These findings are consistent with the report of Oladiran and Emmambux (2020) [23]. The increased level of ash in the samples could result from inclusion of millet and carrots which are rich sources of minerals, making the formulations helpful in addressing micronutrient deficiencies.

In terms of carbohydrate, there is gradual reduction from Sample A (73.57%) to Sample D (59.62%). This could be due increased substitution with other flour. Also, Muhammad *et al*. (2020) [17] discovered that combining cereals with legumes or nuts reduces carbohydrate density while increasing protein quality.

The mineral content of the complementary food samples revealed a gradual increase from Sample A to D. the Potassium content varied from 315.52 mg/100g in Sample A to 342.42 mg/100g in Sample D. This high potassium content of the samples is in line with the findings of Ukwuru *et al*. (2020) [32], who discovered that inclusion of potassium-rich foods such as legumes could drastically increase the potassium content of weaning diets. Accord to WHO report, Potassium is important in ensuring fluid balance and nerve transmission in infants and young children, and its inclusion in complementary foods can support their development (WHO, 2021). In the same vein, Magnesium levels increase from 95.22 mg/100g in Sample A to 110.92 mg/100g in Sample D. the increase level, could result from cashew nuts and millet. This is consistent with findings from Oyarekua and Eleyinmi (2014) [29], who reported that composite flours containing nuts and cereals could improve the magnesium content of infant's meals. Also, the calcium level increases from 240.32 mg/100g in sample A to 270.52 mg/100g in Sample D. Calcium is important for bones and teeth formation in children. These results support the findings of Nnam (2001) [19], who observed that calcium-rich foods significantly enhance the calcium content of complementary foods. According to FAO/WHO (2004) [6] guidelines, calcium-rich formulations are essential for populations susceptible to dietary calcium deficiency, particularly children in low socio-economic settings.

The vitamin content of the complementary food samples increased considerably across the formulations, with sample D recording the highest levels of vitamin A (26.32 µg/100 g), vitamin C (13.22 mg/100 g), and vitamin D (2.32 µg/100 g). This aligns with the findings of Onabanjo and Oguntona (2003) [], who reported a high vitamin composition in cereal-legume blends for infant feeding. This increase could be attributed to high proportion of carrot and cashew nut, which are rich sources of retinol and vitamin C respectively (Okorie *et al*., 2015) [21].

The anti-nutritional contents (oxalate, tannin, and phytate) varied significantly between the samples (A-D). Sample A had the highest content and Sample D had the lowest. Oxalate levels in the samples are lower than those reported by Akande *et al*. (2010) [1], who discovered oxalate levels in various legumes and leafy vegetables as high as 12-25 mg/100g. This shows that the formulations contain minimal anti-nutritional contents which could be attributed to processing techniques adopted. The results are also consistent with Chai and Liebman (2005) [5], who found that boiling reduced oxalate content in vegetables by more than 30%.

Meanwhile, Tannin levels, which decreased from 2.60 mg/100g in Sample A to 1.84 mg/100g in Sample D, are somewhat similar to the report (1.0-6.0 mg/100g) of Makkar (2003) [16] in low-tannin legume and grain formulations. These findings are lower than the increased level of tannins in unprocessed pulses, indicating that the food processing techniques may have effectively reduced tannin levels (Kakade *et al*., 1974) [15]. In the same vein, Phytate levels ranged from 80.02 mg/100g in Sample A to 15.22 mg/100g in Sample D. These levels are lower than those found in raw legumes and cereals, which typically range from 100 to 600 mg/100g (Hurrell, 2003) [11].

The sensory evaluation results of the samples showed that all of the samples had high acceptability. Sample A was rated highest in terms of appearance (7.76), color (7.92), taste (7.60), texture (7.44), and overall acceptability (7.72). These findings show that Sample A had highest acceptability. This support the findings of Olapade and Aworh (2012) [24], who found that consumer preference for complementary foods, is highly impacted by colourl and flavor, especially when known ingredients are used in acceptable quantities. According to Olorunfemi *et al*. (2020) [25], color and flavour are important drivers of food choice among caregivers for their children.

Obatolu *et al*. (2007) [20], reported that flavour could be improved by mild roasting, which significantly improved the palatability of the blended complementary foods. This further confirms that with appropriate ingredient combinations and processing techniques, it is possible to develop multiple formulations of complementary foods that meet acceptable sensory standards. Ijarotimi and Aroge (2005) [13] also noted that varying the proportions of local cereals and legumes without compromising nutritional quality can maintain or improve the sensory appeal of the food.

Conclusion

This study demonstrated that the nutritional quality of finger millet-based complementary foods can be significantly enhanced through the incorporation of soybean, cashew nut, and carrot flours. The formulated sample D (50% finger millet, 25% soybean, 20% cashew nut, and 5% carrot) showed the highest levels of protein, fat, essential minerals (potassium, magnesium, calcium), and vitamins (A, C, and D), while also recording the lowest levels of anti-nutritional factors such as oxalate, tannin, and phytate. These improvements contribute to better nutrient bioavailability and overall dietary quality, crucial for addressing protein-energy malnutrition in infants. Importantly, all formulations were sensorially acceptable, indicating potential for practical use at the household or community level. Thus, leveraging locally available, nutrient-rich ingredients through appropriate processing and blending can offer an affordable and sustainable solution to improve infant nutrition, particularly in resource-limited settings.

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