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NUTRIENT COMPOSITION, FUNCTIONAL, SENSORY AND MICROBIAL STATUS OF POPCORN-BASED (*Zea may everta*) COMPLEMENTARY FOODS ENRICHED WITH CASHEW NUT (*Anacardiumoccidentale L.*) FLOUR

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ABSTRACT

Protein-energy malnutrition among Nigerian children is a major health challenge. This nutrition problem is attributed to the inappropriate complementary feeding practices, low nutritional quality of traditional complementary foods and high cost of quality protein-based complementary foods. Therefore, the aim of this study was to formulate complementary foods from popcorn flour and cashew nut. A quantity (500g) of each popcorn and cashew nut seeds (500g) was processed into fermented, germinated and roasted flours. The blends (40% popcorn, 60% cashew nut) were bio-chemically evaluated for proximate, minerals and amino acids profile. The microbiological properties and sensory attributes were determined using standard methods. For Protein, the results were 22.48% for germinated popcorn-cashew nut (GPC),20.76% for roasted popcorn-cashew nut (RPC) and 21.82% for fermented popcorn-cashew nut (FPC); values for ogi and Nutrend were 12.60% and 16.27% respectively. With respect to energy value, FPC, GPC, RPC, ogi and Nutrend had 533.85, 516.65, 530.49, 389.88 and 397.68 kcal, respectively. The percentages of total essential amino acids in the composition of the blends were36.9%, 40.7% and 38.9%for FPC, GPC and RPC, respectively; non-essential amino acids contents were 63.1%, 59.3% and 61.1% for FPC, GPC and RPC, respectively. The mineral content, that is, potassium, zinc and magnesium, of formulated samples were higher than those obtained for ogi and Nutrend. The antinutrient composition of FPC was lower than that of GPC and RPC. For the functional properties, water absorption capacity was between 1.83 – 1.93 g/ml, least gelation concentration 12.67 – 14.00 g/ml, swelling capacity 0.40 – 0.74 g/ml, loose bulk density 0.43 – 0.49 g/ml and packed bulk density 0.69 – 0.83 g/ml for the formulated samples. The overall acceptability of FPC was rated higher than GPC, RPC and ogi, but lower than Nutrend. For the microbial status, bacteria count was between 1.00–39.00 x 10^4cfu/g, mould1.00–4.00 x 10^4cfu/g and yeast 1.00–4.33 x 10^5cfu/g. The study concluded that the FPC sample was better than ogi in terms of protein and mineral compositions and comparable in overall acceptance to Nutrend. Therefore, the FPC may be used as a complementary food.

Keywords: Popcorn-cashew, microbial, nutrient composition, functional properties

Note:

INTRODUCTION

Cashew is one of the most important plantation crops in India, Brazil, Nigeria and Vietnam[1]. Nigeria produces between 5,000-7,000 MT annually as an export crop [2]. Apart from the economic value of cashew nuts, italso serves as food [3, 4]. Several investigations have been carried out on the chemical composition and effects of different processing methods on the proximate, amino acids and fatty acid composition of cashew nut [3, 5]. It is well documented that cashew nuts contain essential nutrients such as protein, fat and appreciable amounts of minerals [3]. Cashew nut is rich in essential unsaturated fatty acidthat is beneficial to both the heart and arteries; and hence, prevents arteriosclerosis formation and hypertension [3].

Popcorns are cereal grains and the seeds are the only type of corn that can be popped and sometimes consumed byhumans as a nutritious snack. Popcorn contains substantial amounts of carbohydrates, fibre, B vitamins, potassium, phosphorus, magnesium, iron, zinc, pantothenic acid, copper, manganese, linoleic acid and essential amino acids that promote growth and good health status [6].

Despite the nutritional benefits of cashew nut and popcorn, their utilization as a food is limited to snacks. In view of this, the present study aimed at incorporating cashew nut flour into popcorn flour to formulate complementary foods of high nutritive values. Complementary food can be defined as any food, liquid, semi-liquid or solid given to an infant [7]. The complementary process may be gradual, lasting for months until the infant is finally introduced to the family diet. The major traditional complementary food in southern Nigeria is "Ogi" made from fermented corn or other cereals. A previous work has shown that Ogi, which is the common complementary food for Nigerian children has low protein quality and other vital nutrients [8]. This poor traditional complementary food (ogi) has made many children prone to nutritional problems, such as protein-energy malnutrition; hence stunted growth and poor cognitive development are common among Nigerian children [8].

Commercial complementary foods are energy-dense and rich in high quality protein to meet the nutritional requirements of infants in both developed and developing countries. However, the products as marketed are too expensive for the target groups in developing countries. It is therefore, desirable to study ways and means of developing less costly but equally nutritious complementary foods that may be within the reach of the wider population. Hence, cashew nut and popcorn flour were utilized in this study to formulate complementary food.

MATERIALS AND METHODS

Sources of raw material: The materials, that is, popcorn seeds were purchased from Erekesan market in Akure Township and the cashew nut was obtained from JOF Company, Owo, Ondo State, Nigeria.

Samples preparation: The cashew nuts and popcorn kernels were subjected to three processing methods, that is, roasting, fermentation and germination.

Roasted cashew nut/popcorn seeds:

The cashew nuts (500g) were sorted and cleaned manually with distilled water. The seeds were roasted using the local method, that is, in hot fine sand for 30 minutes. The roasted seeds were dehulled manually using cashew nut crackers, cleaned by winnowing, milled using a Philips laboratory blender (HR2811 model) and sieved to obtain fine roasted cashew nut flour using a 60 mm mesh sieve (British Standard).

The popcorn seeds (500g) were sorted, winnowed, manually washed with distilled water and drained. The drained popcorn seeds were toasted at 85^{o}C in an oven for 3 hours, cooled to room temperature (27^{o}C) and milled using a Philips laboratory blender (HR2811 model), sieved through 60mm wire mesh (British Standard), packed

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in a plastic container seal with an aluminum foil and stored at room temperature (~27^{o}C) until required for use.

Fermented cashew nut/popcorn seeds

The cashew nuts (500g) were shelled manually, manually cleaned with distilled water and boiled at 100^{o}C for 1 hour. The boiled seeds were tightly wrapped in plantain leaf for 72 hours to ferment. Fermentation was performed using the microorganisms naturally present on the seed surface. The fermented seeds were oven-dried at 60°C(Plus11 Sanyo Gallenkamp PLC, UK)for 48 hours, milled using a Philips laboratory blender (HR2811 model) and sieved through 60mm wire mesh (British Standard).

For the popcorn, the seeds (500g) were cleaned manually with distilled water and soaked in clean water. The seeds were then left in water for 72 hours to ferment using the microorganisms naturally present on the grain surface. The fermented seeds were washed again with distilled water manually, drained and oven-dried (Plus11 Sanyo Gallenkamp PLC, UK)at 60°Cfor 48 hours. The dried seeds were milled using a Philips laboratory blender (HR2811 model), sieved through 60mmwire mesh (British Standard) and stored in a sealed plastic container at room temperature (~27^{o}C).

Germinated cashew nut/popcorn seeds: The raw cashew seeds (500g) were freed from foreign matter manually and sorted to pick the viable ones. The selected cashew nuts were planted in a basket containing wood sawdust as the soil/medium/substrate for growth. The planted cashew seeds were watered daily, and after 7 days the cashew seeds were fully germinated. The seeds were washed, drained and dried in a hot air oven at 60^{0}C for 24 hours. The dried germinated seeds were milled and sieved through a 60 mm wire mesh screen to give the finished product of germinated cashew nut flour. The popcorn kernels (500g) were sorted and soaked overnight for 12 hours and then drained using sieves and allowed to germinate (4 days). The germinated seeds were oven dried at 60^{0}C for 20 hours, milled using an attrition mill, sieved and the resultant flour sealed in a plastic container that was stored at room temperature (~27^{o}C).

Diet formulations

The food samples were formulated with reference to protein requirement of infants (18 g/day) using Nutrisurvey linear programming (2004) software in a ratio of 40:60 of popcorn flours (fermented, germinated and roasted) and cashew nut (fermented, germinated and roasted) respectively. The ogi (corn gruel and a traditional complementary food) and Nutrend (a commercial complementary formula) were used as the control.

Chemical analyses

Macronutrient analysis: Nutrient composition of the food sample was determined using the standard procedures of Association of Official Analytical Chemists [9]. Triplicate samples were used for moisture content in a hot-air circulating oven (Galenkamp). Ash was determined by incineration (550°C) of known weights of the samples in a muffle furnace (Gallenkamp, size 3) (Method No 930.05) [9]. Crude fat was determined by exhaustively extracting a known weight of sample in petroleum ether (boiling point, 40 to 60°C) in a soxhlet extractor (Method No 930.09) [9]. Protein (N × 6.25) was determined by the Kjeldahl method (Method No 978.04) [9]. Crude fiber was determined after digesting a known weight of fat-free sample in refluxing 1.25% sulfuric acid and 1.25% sodium hydroxide (Method No 930.10) [9]. The carbohydrate content was determined by subtracting the total of crude protein, crude fiber, ash and fat from the total dry weight (100 g) of the food sample differences. The gross energy was determined with a Gallenkamp ballistic bomb calorimeter (Gallenkamp ccb-330-010L, UK).

Mineral composition: Mineral content (sodium, potassium, calcium, magnesium, iron, copper, zinc, manganese and selenium) of the flour samples was determined using an AOAC method [9]. Flour was digested with a mixture of concentrated nitric acid, sulfuric acid and perchloric acid (10:0.5:2, v/v) and analyzed using an atomic absorption spectrophotometer (GBC 904AA; Germany). The total phosphorus was determined as orthophosphate by the ascorbic acid method after acid digestion and neutralization using phenolphthalein indicator and combined reagent [10]. The absorbance was read at 880 nm (Spectronic 21 D, Miltonroy, New York, USA) and KH_2PO_4 (Merck, Mumbai, India) served as a standard.

Amino acid analysis: Amino acid composition of samples was measured on hydrolysates using aminoacid analyzer (Sykam-S7130) based on high performance liquid chromatography technique. Sample hydrolysates were prepared following the method of Moore and Stein [11]. Two hundred milligrams of sample were taken in hydrolysis tube. Then 5 mL 6 N HCl were added to sample into the tube, tightly closed and incubated at 110°C for 24 hours. After incubation period, the solution was filtered and 200 mL of the filtrate were evaporated to dryness at 140°C for an hour. Each hydrolysate after dryness was diluted with one milliliter of 0.12 N, pH 2.2 citrate buffers, the same as the amino acid standards. Aliquot of 150 µL of sample hydrolysate was injected into a cation separation column at 130°C. Ninhydrin solution and an eluent buffer (The buffer system contained solvent A, pH 3.45 and solvent B, pH 10.85) were delivered simultaneously into a high temperature reactor coil (16 m length) at a flow rate of 0.7 ml/min. The buffer/ninhydrin mixture was heated in the reactor at 130°C for 2 minutes to accelerate chemical reaction of amino acids with ninhydrin. The products of the reaction mixture were detected at wavelengths of 570 nm and 440 nm on a dual channel photometer. The amino acid composition was calculated from the areas of standards obtained from the integrator and expressed as percentages of the total protein.

Anti-nutrient analysis: The estimation of phytin-phosphorus (phytin-P) was by the colorimetric procedure of Wheeler and Ferrel[12] as modified by Reddy *et al*. [13]. Phytic acid was calculated by multiplying phytin-P by a factor of 3.55 as described by Enujiugha and Olagundoye [14]. Oxalate content was determined according to the procedure of Day and Underwood [15].

Tannin contents were determined by the modified vanillin-HCl methods [16]. A 2 g sample was extracted with 50 ml 99.9% methanol for 20 minutes at room temperature with constant agitation. After centrifugation for 10 min at 653 x g, 5 ml of vanillin-HCl (2% vanillin and 1% HCl) reagent was added to 1 ml aliquots, and the colour developed after 20 min at room temperature was read at 500nm. A standard curve was prepared using catechin (Sigma Chemical, St. Louis, MO) after correcting for blank, and tannin concentration was expressed in g/100g.

The trypsin inhibition activity (TIA) was assayed in terms of the extent to which an extract of the defatted flour inhibited the action of bovine trypsin (EC 3.4.21.4) on the substrate benzoyl-DL-arginine-p-nitrianilide (BAPNA) hydrochloric [17], as modified by Smith*et al*. [18]. The samples (1g each) were extracted continuously at ambient temperature for 3 hours with 50mL, 10 mMNaOH using a mechanical shaker (GallenKamp orbital shaken Surrey, UL). The resulting slurry was adjusted to pH 9.4 -9.6 with 1M NaOH. After extraction, the suspension was shaken and diluted with distilled water such that 1 ml of the extract produced trypsin inhibition of 40-60% at 37^{o}C. The respective dilutions were noted. Consequently, TIA was calculated in terms of mg pure trypsin (Sigma type lll, lot 20H0868).

$$TIA = \frac{2.632DA}{S} \text{ mg pure trypsin inhibited g}^{-1} \text{ sample}$$

Where D is the dilution factor, A is the change in absorbance at 410mm due to trypsin inhibition per ml diluted sample extract and S is the weight of the sample.

Functional property determinations:

Water absorption capacity was determined using the method of Sathe and Salunkhe [19] by adding 10 ml of distilled water to 1.0 g of the sample in a beaker. The suspension was stirred using magnetic stirrer for 5 min followed by centrifugation (3500 rpm for 30 min) and the supernatant was measured into a 10 ml graduated cylinder. Water absorbed was calculated as the difference between the initial volume of water added to the sample and the volume of the supernatant.

Least gelation property was determined using the method described by Coffman and Garcia [20]. Sample suspensions of 2 – 16% were prepared in distilled water. An aliquot (10 ml) of each dispersion was transferred into a test tube and heated in a boiling water bath for 1hour, cooled rapidly in a cold water bath, and allowed to cool further at 4^{0}C for 2 hours. The least gelation concentration was determined when the sample from the inverted test tube did not slip or fall.

Swelling capacity was determined by weighing 20 g of the food sample into a cleaned, dried graduated cylinder. The cylinder was tapped 3 times on the table and then 80 ml of distilled water was poured into the cylinder. The cylinder was allowed to stand for 1hour after which the final volume of the food sample was noted. The ratio of the final volume to initial volume gave the swelling capacity. The supernatant was descanted and the weight of food sample and the cylinder was obtained, and the ratio of final weight to initial weight of the food sample gave the swelling capacity on weight basis.

The bulk density (Packed Bulk density and Loose Bulk density) was determined using the procedure of Fagbemi [5]. A specified quantity of the flour mixes was put into an already weighed 5ml measuring cylinder (W_1). For packed bulk density (PBD), it was gently tapped to eliminate air spaces between the flour mixes in the measuring cylinder and the volume was noted to be the volume of the sample used. The new mass of the sample and the measuring cylinder recorded as (W_2). The Bulk density was expressed as:

$$B.D = \frac{W_2 - W_1}{\text{Vol. of sample used}} \times 100$$

For loose bulk density (LBD), space was not eliminated by tapping.

Sensory evaluation: The formulated samples were made into light gruels, using about 20 g sample and 60 ml of water. The reconstituted blends were evaluated along with a traditional complementary food (ogi) and commercial complementary food (Nutrend). Sensory evaluation was conducted on the reconstituted samples which were coded and presented to 10 trained panelists that were familiar with the products. The sensory evaluation was conducted in a standard sensory laboratory, where each of the panelists was positioned in a separate cubicle to avoid interference. The samples were rated on the following attributes of colour, aroma, taste, mouth feel and overall acceptability using a 9 point hedonic scale as follows:

9 = like extremely
8 = like very much
7 = like moderately
6 = like slightly
5= neither like nor dislike
4 = dislike slightly
3 = dislike moderately
2 = dislike very much
1 = dislike extremely

Microbial evaluation: The microbial analysis was carried out on the sample as described by Olutiola [21]. The media were prepared according to manufacturer's specifications. One gram of each sample was aseptically transferred into a sterile beaker and mixed with a sterile glass rod for 5 min. The samples were thoroughly mixed to form a homogenous solution. An aliquot (20ml) of sterile distilled water was added and mixing continued for another 5 min until the sample formed a paste. A 1ml aliquot of each samples was pipetted into sterile 20cm^3 test tubes and serially diluted in another six sets of test tubes each containing 9 ml of sterile distilled water to a dilution ratio of 10^{-6}. Aliquots of 1ml portion of the diluents from the forth (10^{-4}) and second (10^{-2}) dilution factors were aseptically transferred into different sterile Petri dishes. Sterile molten agar media (45^{o}C) was added, swirled gently for even distribution of the inoculums, allowed to set (solidify) and incubated at 37^{o}C for 24 hours. To isolate the mold and yeast from the sample, a 1ml aliquot of the sample which has been serially diluted was pipetted into sterile petri – dishes and sterilized molten malt extract agar was added to form gel, and then incubated at room temperature (27±2^{o}C) for 48 hours. At the end of incubation period, microbial colonies were counted and recorded appropriately.

Coliform Test: A 35g MacConkey lactose broth was dispersed in 1litre of sterile distilled water and 10 ml was dispensed into each MacCartry bottles. Each bottle (contained an inverted Durham tube to collect gas if produced) was autoclaved at 121^{o}C for 15 min and allowed to cool. The prepared samples were discharged using sterile pipettes into the medium as follows. Five 1ml samples were discharged into 5ml single strength medium and another set of five 0.1ml samples were equally discharged into 5ml single strength medium. The bottles were incubated at 37^{o}C and examined after 24 – 48hrs, respectively for acid and gas production.

Statistical analysis: The data were analyzed using SPSS (Statistical Package for Social Scientist) version 15.0. The mean and standard error of means (SEM) of the triplicate analyses were calculated. The analysis of variance (ANOVA) was performed to determine the level of significant differences between the means of formulated food samples using Duncan Multiple Range Test.

Ethical approval

The study protocol was approved by the Ethical Committee of School of Agriculture and Agricultural Technology, Federal University of Technology, Akure, Ondo State, Nigeria

RESULTS

Macronutrient composition: The macronutrient compositions (g/100g) of the formulated and control samples are presented in Table 1. The 22.4% protein content of germinated popcorn-cashew nut mixes (GPC) was the highest, while that of roasted popcorn-cashew (RPC) (20.7 %) was the lowest. The 533.85 kcal energy value of fermented popcorn-cashew (FPC) mixes was the highest while the germinated popcorn-cashew (GPC) mixes (516.65 kcal) had the lowest value. The 1.51% fiber content of GPC was the highest while that of roasted popcorn-cashew mixes (RPC) was the lowest at 0.62 %. Statistically, the protein content and energy values of the formulated samples were significantly higher than the Nutrend and that of ogi(corn gruel, a traditional complementary food) ($p<0.05$), respectively. Also, the fiber content of formulated samples was lower than the Nutrend, but higher when compared with that of ogi ($p<0.05$).

Mineral composition: The mineral compositions of formulated food samples and controls (ogi and nutrend) are presented in Table 2. The potassium, zinc and magnesium contents of formulated food samples were higher when compared with values obtained for popcorn, ogi and Nutrend. However, the Ca, Fe, Na, and P of the Nutrend were higher than the formulated food samples. Understandably, the higher mineral contents of Nutrend product could be attributed to fortification practices (i.e., addition of micronutrient) normally carried out on such products.

Amino acids composition: The amino acid compositions of the raw and processed samples are shown in Table 3. The total essential amino acid (EAAs) of the raw cashew nut flour (41.6%) was higher when compared with the raw popcorn flour (41.3%) and that of popcorn-cashew nut mixes (36.9 – 40.7%). However, the essential amino acid composition of germinated popcorn-cashew nut flour (40.7%) mixes was significantly higher when compared with fermented (36.9%) and roasted popcorn-cashew nut (38.9%) flour mixes respectively ($p<0.05$). Also, the non-essential amino acid composition of the raw cashew nut (58.4%) flour was lower when compared with that of raw popcorn (58.7%) and the formulated food samples (59.1-63.1%). The present study also showed that the amino acid compositions of the formulated food samples were better than the popcorn flour alone, but lower than that of cashew nut flour alone. Comparatively, the essential amino acids of the formulated food samples were lower when compared with the FAO recommended daily allowance (RDA) (Table 3b).

Anti-nutrient composition of the food samples: The anti-nutrient composition of the formulated food samples is shown in Table 4. The oxalate and phytate contents of fermented popcorn-cashew nut flour mixes were significantly lower than those of germinated popcorn-cashew nut and roasted popcorn-cashew nut flour mixes, respectively ($p<0.05$). The tannin and trypsin inhibitor contents of fermented popcorn-cashew nut flour mixes were insignificantly low when compared with those of germinated and roasted popcorn-cashew nut flour mixes respectively ($p>0.05$).

Functional properties: The functional properties of formulated samples and controls are presented in Table 5. The loose bulk density was lower in the formulated food samples than the Nutrend, but higher in the ogi. Also, the packed bulk density of the formulated food samples was higher than the control samples. The loose bulk density of formulated food samples and that of ogi were lower when compared with the Nutrend ($p<0.05$). Also, the packed bulk density of the formulated samples was higher than for the ogi and Nutrend. The water absorption capacity (WAC) of the formulated food samples was lower than that of commercial complementary formula (Nutrend).The least gelation of formulated food samples was higher than the control samples. The swelling capacities of the formulated food samples were higher when compared with those of the control (Nutrend and ogi) samples.

Sensory properties: The sensory attributes of formulated ogi and Nutrend samples are presented in Table 6. The sensory properties of Nutrend food samples in term of colour, aroma, taste, mouth feel and overall acceptability were significantly higher than the formulated food samples ($p<0.05$). However, the fermented blend (FPC) was rated better than other formulated food samples and ogi except nutrend.

Microbial status: Results of the microbial evaluation of popcorn and cashew nut samples are shown Table 7. The result shows that total viable count (TVC) of micro organisms in the food materials used for formulation ranged between $9.33x10^4$ for fermented cashew nut and $39.00x10^4$Cfu/g for fermented popcorn. Mould was detected in some of the food samples except in roasted cashew nuts, germinated cashew nuts and fermented cashew nuts flour. The mould count ranged between $4x10^3$ - $1x10^4$ cfu/g. Other microorganisms like staphylococci species, salmonella species and Enterococci species were not detected in any of the food samples either in raw, roasted, germinated, fermented popcorn and cashew nut flour. The yeast count ranged between $4.33x10^3$ -$1.00x10^5$cfu/g. The highest yeast count was found in the germinated cashew nut flour while the least count was observed in roasted popcorn.

DISCUSSION

It is well known that the traditional complementary foods in developing countries, Nigeria included, are devoid of essential nutrients like proteins but are energy-dense[8]. Therefore, the present study formulated and evaluated nutritional status of complementary foods from locally available food materials.

The protein content and energy values of the formulated samples were significantly higher when compared with the values obtained for Nutrend (a commercial complementary formula) and ogi (corn gruel, a traditional complementary food) ($p<0.05$), which may be attributed to the high oil and protein contents of cashew nut. This finding was similar to the study of Ijarotimi and keshinro [22], who reported that the protein and energy content of popcorn-African locust-bambara groundnut based complementary food were higher than those of ogiand Cerelac. Also, the fiber content of formulated samples was lower than the Nutrend, but higher when compared with that of ogi ($p<0.05$).Stransky *et al*. [23] recommended low level of fiber content in complementary foods; and that low fiber content in complementary food reduces bulkiness of the food and encourages high digestibility and absorption of nutrients such as proteins and minerals. Similarly, the present study showed that the nutrient compositions of the popcorn, such as protein and energy value, were increased when cashew nut flour was added. This increase in protein content and energy value of the mixes could be attributed to high protein and fat contents of cashew nut that had been reported by Aremu*et al*. [24]. Studies have shown that a single plant-based food, such as ogi (corn gruel), is low in protein content and is energy dense [25]; when combined with protein-rich food materials like legume or crayfish, the protein content of the mixes usually improved [26]. Intake of corn gruel (ogi) has been implicated in the etiology of protein–energy malnutrition among children in the areas where it is being used as the sole complementary food for infants[27]. Protein-energy-malnutrition (PEM) has continued to pose challenges in Nigeria and other developing countries, due to poor child feeding practices, low quality protein commonly associated with plant-based single diets and nutrient losses during processing [28].

The potassium, zinc and magnesium contents of formulated food samples were higher when compared with popcorn, ogi and Nutrend. However, the minerals like Ca, Fe, Na, and P of the Nutrend were higher than the formulated food samples. This could be attributed to the enrichment of Nutrend with these micronutrients. Comparing the mineral composition of the formulated food samples, the mineral composition of germinated popcorn-cashew nut blends was the highest when compared with the roasted and fermented samples. Fagbemi [5] reported that germination technique improved bioavailability of some minerals in food products when compared with other processing techniques.

The total essential amino acid (EAAs) profile of the germinated popcorn-cashew nut flour mixes was significantly higher when compared with the fermented and roasted popcorn-cashew nut flour mixes ($p<0.05$). Also, the total essential amino acid compositions of the formulated food samples were higher than the popcorn flour alone, but lower than that of cashew nut flour alone. Fashakin and Ogunsola[27] reported that combinations of two or more plant based food materials usually improved the overall nutrient composition and quality of the food products. Besides, it is well documented that processing methods such as heating, germination, soaking, fermentation and cooking can reduce the level of antinutritional factors. Besides, processing methods such as germination and fermentation also increase the contents and bioavailability of the nutrients in food products [29].Comparatively, the essential amino acids of the formulated food samples were virtually lower when compared with the FAO recommended daily allowance (RDA) (Table 4). However, intake of 150g of the formulated food sample per day would provide the essential amino acids requirement of the children aged (2-5 years).

The oxalate and phytate content of fermented popcorn-cashew nut flour mixes were significantly lower than those of germinated popcorn-cashew nut and roasted popcorn-cashew nut flour mixes, respectively ($p<0.05$). The tannin and trypsin inhibitor contents of fermented popcorn-cashew nut flour mixes were not significantly different when compared with those of germinated and roasted popcorn-cashew nut flour mixes respectively ($p>0.05$). It is well documented that processing methods, such as soaking, cooking, germination, fermentation and roasting, reduce the level of antinutritional factors in food [30]; thereby bioavailability of nutrients in food products is enhanced [31].

The functional properties of complementary foods (gelation, bulk density, swelling index, emulsifying capacity, water binding capacity) are very important for the appropriateness of the diet to the growing children [28]. The consistency of energy density (energy per unit volume) of the complementary food and the frequency of feeding are also important in determining the extent to which an infant can meet his or her energy and nutrient requirements [28].

The results of functional properties of the formulated food samples showed that the loose bulk density was lower in the formulated food samples than the Nutrend, but higher with the ogi. Also, the packed bulk density of the formulated food samples was higher than the control samples. The bulk density value is of importance in packaging [32]. The lower loose bulk density implies that less quantity of the food samples would be packaged in constant volume thereby ensuring an economical packaging. However, the packed bulk densities would ensure more quantities of the food samples packed in a packaging material, but less economical to the producer of the food products. The loose bulk density of formulated food samples and that of ogi were lower when compared with that of Nutrend ($p<0.05$). Also, the packed bulk density of the formulated samples was higher than that of ogi and Nutrend. Nutritionally, loose bulk density promotes easy digestibility of food products, particularly among children with immature digestive system [33].

Water absorption capacity (WAC) of the formulated food samples was lower than that of the commercial complementary formula (Nutrend). WAC is an index of the maximum amount of water that a food product can absorb and retain [34]. With respect to water absorption capacity, Giami and Bekeham [35] reported that the microbial activities of food products with low WAC would be reduced. Hence the shelf-life of such product would be extended.

The least gelation of formulated food samples was higher than the control samples. This showed that the formulated samples would be digestible when consumed. Scientific studies have shown that foods that form gels at low concentrations are not ideal for complementary foods, because they would require a lot of dilution in an attempt to improve digestibility in relation to volume [36].

The swelling capacity is an important factor used in determining the amount of water that diets would absorb and the degree of swelling within a given time. The present study showed that the swelling capacities of the formulated food samples were higher when compared with the control (Nutrend and ogi) samples. The high values of swelling capacity imply that more of the formulated food samples would be needed for reconstitution when compared with the control food samples (i.e. Nutrend and ogi). Ebrahim [37] reported that food samples with low gelling properties when constituted into gruel have higher nutrient density than food sample with high gelling properties.

It is evident that in developing countries most complementary diets are starch and cereal based [28]. Starch is often the principal source of energy, but when heated with water, starch granules gelatinize to produce a bulky, thick (viscous) porridge. These complementary foods tend to be of low energy density and protein content. Although their liquid consistency makes them easy to consume, the volumes needed to meet infant energy and nutrient requirements often exceed the maximum volume the infant can ingest; and this may lead to inadequate nutrient intakes; hence, protein-energy malnutrition.

Furthermore, the low energy and nutrient density means that large volumes of food have to be consumed to meet the infant's requirements. This is not usually possible, owing to the infant's limited gastric capacity and to the limited number of meals offered per day. According to **S**vanberg [38], a good quality complementary diet must have high nutrient density, low bulk density, viscosity and appropriate texture. Also, complementary foods should be rich in energy, protein and micronutrients, and have a consistency that allows easy consumption.

The sensory properties of Nutrend food samples in terms of colour, aroma, taste, mouth feel and overall acceptability were significantly higher than the formulated food samples ($p<0.05$). This observation could be as a result of the enrichment of Nutrend formula with sweetening and flavouring agents that gave it better sensory attributes over the formulated food samples. However, the fermented popcorn-cashew nut flour mixes was rated higher than the remaining formulated samples and ogi in terms of overall acceptability.

It was observed in this present study that the micro organisms were low in cashew nut flour when compared with the fermented popcorn. This observation could be attributed to the involvement of micro-organisms in fermentation processing. A study has reported on high microorganism counts in fermented foods products when compared with food products produced from other processing methods [39]. Mould was detected in some of the food samples except in roasted cashew nuts, germinated cashew nuts and fermented cashew nuts flour; however, staphylococci, salmonella and Enterococci species were not detected in any of the food samples either in raw, roasted, germinated, fermented popcorn and cashew nut flour. The value of yeast count was highest in the germinated cashew nut flour while that of roasted popcorn was the least. This observation could be attributed to the presence of micro-organisms that play vital roles in fermentation process. Also, the low microbial level in oven dried samples of raw and roasted cashew and popcorn could be due to low moisture content of the food samples [8]; and also destruction of the microorganisms during the oven drying of the food sample. The study also found that Escherichia coli were not present in any of the food samples.

The nutritive values, coupled with the low microbial level of the formulated samples showed that the food samples are suitable for human consumption. For instance, the energy values and protein contents of the food samples were adequate to support the energy demand for physical activities, normal growth and cognitive development of children, particularly the complementary age children. This implies that the formulated food samples are better in terms of protein contents than the traditional complementary food (ogi). Several studies have reported that the traditional complementary food (ogi) is the major factor responsible for the increase in prevalence of protein-energy malnutrition among the children in developing countries, particularly in West Africa where ogi is used as the sole complementary food for the children [40]. However, evidence has shown that consumption of popcorn by children under the age of 5 years may lead to choking, hence death [41]. Therefore, there is a need for the biological evaluation of this formulated complementary formula to further ascertain the effect of processing methods on this antinutritional factor and before its suitability as a complementary formula.

CONCLUSION

It is concluded that, local food resources have great potentials in the formulation and preparation of complementary foods. This research also showed that the processing methods used improved the nutrient content of the blends. The study also showed that formulated food samples, particularly the fermented sample, could serve as a complementary food, to prevent cases of protein-energy malnutrition (PEM). However, further research, such as biological tests is needed to substantiate the suitability of the product as complementary food.

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Table 1: Macronutrient composition (%) and energy values (kcal) of raw flour and formulated food samples and control samples

Sample	Moisture	Ash	Fat	Fiber	Protein	carbohydrate	Energy
Raw cashew	1.52^{f}	1.95^{d}	45.49^{a}	2.51^{b}	24.19^{a}	24.34^{g}	603.53^{a}
Raw popcorn	8.54^{a}	1.43^{e}	3.14^{e}	1.16^{f}	10.68^{f}	75.05^{b}	371.17^{g}
FPC	3.68^{c}	0.89^{g}	31.56^{c}	1.41^{d}	21.82^{bc}	40.63^{d}	533.85^{b}
GPC	5.31^{b}	3.23^{a}	31.37^{c}	1.51^{c}	22.48^{b}	36.10^{f}	516.65^{d}
RPC	4.56^{c}	2.20^{c}	32.53^{b}	1.28^{e}	20.76^{c}	38.67^{e}	530.49^{c}
Ogi	2.19^{e}	1.11^{f}	1.11^{f}	0.62^{g}	12.60e	82.37^{a}	389.88^{f}
Nutrend	4.80^{c}	2.68^{b}	8.48^{d}	4.49^{a}	16.27^{d}	64.07^{c}	397.68^{e}

*Analysis of the samples were done in triplicates (n=3); Superscript of the same alphabets are not significantly different. Fermented popcorn-cashew (FPC); Germinated popcorn-cashew (GPC); Roasted popcorn-cashew (RPC); Ogi (corn gruel); Nutrend (commercial formula).

Table 2: Mineral composition (mg/100g) of raw flour and formulated food samples and control samples

Sample	Ca	Fe	Na	Mg	K	Zn	P	Al	Cu	Pb	Mn
Raw cashew	52.16^{a}	0.16^{f}	42.33^{a}	61.80^{e}	60.44^{f}	0.34^{f}	88.61^{e}	-	-	-	-
Raw popcorn	0.45^{f}	0.22^{d}	1.15^{g}	279.86^{d}	87.17^{e}	0.39^{e}	143.55^{d}	-	-	-	-
FPC	7.03^{c}	0.60^{b}	9.83^{e}	285.62^{c}	105.27^{d}	1.59^{d}	256.10^{c}	-	-	-	-
GPC	1.81$_{e}$	0.18^{e}	20.44^{c}	334.18^{b}	113.32^{c}	2.31^{b}	277.93^{a}	-	-	-	-
RPC	5.43^{d}	0.36^{c}	9.61^{f}	334.88^{a}	142.39^{a}	1.89^{c}	274.58^{b}	-	-	-	-
Ogi	0.75^{f}	0.07^{g}	14.96^{d}	36.42^{f}	116.21^{b}	0.07^{g}	70.41^{f}	-	-	-	-
Nutrend	39.53^{b}	1.00^{a}	22.00^{b}	-	57.00^{g}	7.00^{a}	22.00^{g}	-	-	-	-

(-) Not detected in the samples
*Analysis of the samples were done in triplicates (n=3); Superscript of the same alphabets are not significantly different. Fermented popcorn-cashew (FPC); Germinated popcorn-cashew (GPC); Roasted popcorn-cashew (RPC); Ogi (corn gruel); Nutrend (commercial formula).

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Table 3a: Amino acids composition (%) of raw flour and formulated food samples

Amino acid composition	R_aC	R_aP	FPC	GPC	RPC
Essential amino acids					
Histidine	2.045^a	0.961^e	1.270^c	1.537^b	1.186^d
Lysine	3.645^a	1.713^e	1.732^d	2.811^a	2.721^b
Isoleucine	3.675^a	1.541^e	1.727^d	2.103^b	1.859^c
Leucine	6.735^a	3.165^e	3.552^d	4.397^c	4.518^b
Valine	4.945^a	2.324^d	2.353^d	3.419^b	2.603^c
Methionine	1.325^a	0.623^e	0.679^d	0.998^b	0.725^c
Phenylalanine	3.670^a	1.725^e	1.999^d	2.275^b	2.165^c
Threomine	3.105^a	1.459^d	1.667^c	2.155^b	0.783^e
Tryptophan	-	-	-	-	-
TOTAL	29.145	13.511	14.979	19.695	16.560
%EAA	41.6	41.3	36.9	40.7	38.9
Non-essential amino acids					
Arginine	8.285^a	3.894^d	2.298^e	4.989^c	5.096^b
Aspartic acid	7.805^a	3.668^e	5.385^d	5.753^b	6.585^c
Serine	1.315^a	0.618^e	1.027^c	1.573^b	0.822^d
Glutamic acid	10.665^a	5.013^e	8.174^b	7.436^c	7.179^d
Proline	1.715^a	0.806^d	1.323^b	1.251^c	0.718^e
Glycine	4.505^a	2.117^e	3.259^d	3.484^c	3.607^b
Alanine	2.385^a	1.121^d	1.699^c	1.895^b	1.917^b
Cystein	1.525^a	0.717^e	0.777^c	0.816^b	0.566^d
Tyrosine	2.665^a	1.253^e	1.641^c	1.541^d	1.959^b
TOTAL	40.865	19.207	25.583	28.738	25.924
%NEAA	58.4	58.7	63.1	59.3	61.1

Essential amino acids (EAA); Non-essential amino acids (NEAA)
*Analysis of the samples were done in triplicates (n=3); Superscript of the same alphabets are not significantly different. Fermented popcorn-cashew (FPC); Germinated popcorn-cashew (GPC); Roasted popcorn-cashew (RPC)

Table 3b: Comparison of FAO recommended daily allowances of essential amino acids (mg/kg body weight) with essential amino acids of formulated food samples with reference to children (2-5 years)

Amino acid (mg/100g)	***Children**	FPC	GPC	RPC
Arginine	-	-	-	-
Histidine	19	12.70	15.37	11.86
Isoleucine	28	17.27	21.03	18.59
Leucine	66	35.52	43.97	45.18
Lysine	58	17.32	28.11	27.21
Methionine + Cystein	25	14.56	18.14	12.91
Phenylalanine + Tyrosine	63	36.40	38.16	41.24
Threonine	34	16.67	21.55	7.83
Tryptophan	11	-	-	-
Valine	35	23.53	34.19	26.03

Source: FAO/WHO/UNU, 1985

Fermented popcorn-cashew (FPC); Germinated popcorn-cashew (GPC); Roasted popcorn-cashew (RPC)

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Table 4: Anti-nutrient composition of processed cashew nut flour

Antinutrient composition	Fermented popcorn-cashew nut	Germinated popcorn-cashew nut	Roasted popcorn-cashew nut
Oxalate (mg/100g)	0.65^c	2.17^a	2.04^b
Phytate (mg/100g)	13.97^c	18.0^b	28.55^a
Tannin (mg/100g)	0.30^b	0.35^b	0.41^a
Trypsin (mg/100g)	0.51^b	0.61^b	1.05^a

*Analysis of the samples were done in triplicates (n=3); Superscript of the same alphabets are not significantly different.

Table 5: Functional Properties of the Formulated Diets and Control (Ogi and Nutrend)

Sample	LBD (g/ml)	PBD (g/ml)	WAC (g/ml)	LG (g/ml)	SC (g/ml)
FPC	0.49^b	0.69^b	1.90^b	14.00^a	0.40^c
RPC	0.49^b	0.69^b	1.83^b	14.00^a	0.40^c
GPC	0.43^c	0.83^a	1.93^b	13.33^a	0.74^b
Ogi	0.32^d	0.63^c	1.87^b	12.67^a	0.66^b
Nutrend	0.54^a	0.56^d	3.11^a	8.00^b	3.35^a

*Analysis of the samples were done in triplicates (n=3); Superscript of the same alphabets are not significantly different. Fermented popcorn-cashew (FPC); Germinated popcorn-cashew (GPC); Roasted popcorn-cashew (RPC); Ogi (corn gruel); Nutrend (commercial formula). Least bulk density (LBD); Pack bulk density (PBD); Water absorption capacity (WAC), Least gellation, Swelling capacity (CP).

Table 6: Sensory attribute of formulated food samples and control (ogi and Nutrend)

Samples	Colour	Aroma	Taste	Mouth Feel	Overall Acceptability
FPC	5.75^{b}	6.13^{bc}	6.50^{b}	6.38^{bc}	6.50^{b}
RPC	5.50^{b}	5.13^{bc}	4.71^{c}	5.29^{c}	5.14^{c}
GPC	5.25^{b}	4.63^{c}	6.00^{bc}	5.25^{c}	5.38^{bc}
OGI	6.00^{b}	6.38^{b}	6.38^{b}	7.38^{bc}	6.13^{bc}
Nutrend	8.88^{a}	8.75^{a}	8.88^{a}	8.50^{a}	8.88^{a}

Superscript of the same alphabets are not significantly different. Fermented popcorn-cashew (FPC); Germinated popcorn-cashew (GPC); Roasted popcorn-cashew (RPC); Ogi (corn gruel); Nutrend (commercial formula)

Table 7: Microbial Status of processed food samples for the formulation and Ogi (Control)

Sample	Bacteria (cfu/g)x10^{4}	Mould (cfu/g) x10^{4}	Yeast (cfu/g)x10^{5}
Raw cashew nut	4.00^{b}	1.00^{c}	4.33^{c}
Germinated cashew nut	7.00^{b}	-	2.00^{c}
Fermented cashew nut	9.33^{b}	-	2.33^{c}
Roasted cashew nut	1.00^{b}	-	-
Raw popcorn	2.67^{b}	2.52^{a}	-
Fermented popcorn	39.00^{a}	2.00^{b}	1.62^{b}
Germinated popcorn	1.67^{b}	-	4.00^{c}
Roasted popcorn	-	4.00^{b}	1.00^{c}
Sweet corn (ogi)	45.00^{a}	-	3.62^{a}

*Analysis of the samples were done in triplicates (n=3); Superscript of the same alphabets are not significantly different.

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