Assessment of the Nutritional Composition, Microbiological and Sensory Attributes of Maize-based fortified food with Peanut and Carrot Blends

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KEYWORDS

Fortified Food, Functional, Maize, Nutrient, Peanut and Carrot.

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ABSTRACT

This research assessed the nutritional composition, microbiological and sensory attributes of maize-based fortified food with peanut and carrot blends. A total of six composite flour samples were formulated using varying ratios of maize, peanut, and carrot: (MPC1) 100% maize flour (control), (MPC2) 90% maize, 5% peanut, and 5% carrot, (MPC3) 80% maize, 15% peanut, and 5% carrot, (MPC4) 70% maize, 20% peanut, and 10% carrot, (MPC5) 60% maize, 25% peanut, and 15% carrot, and (MPC6) 50% maize, 30% peanut, and 20% carrot. The proximate, mineral, vitamin, antinutrient, and functional properties of these fortified food samples were assessed using established methodologies. The proximate analysis revealed a significant increase ($p<0.05$) in moisture, crude protein, fat, crude fibre, ash, and energy content of the fortified samples, with values ranging from 1.63% to 3.80%; 3.08% to 44.43%; 2.39% to 15.16%; 3.58% to 7.04%; 2.34% to 3.80%; and 381.75 to 432.52 KJ/100g, respectively, as the supplementation of peanut and carrot flours increased. Conversely, the carbohydrate content decreased from 86.98% to 27.64%. The mineral content of the fortified samples also showed a significant increase ($p<0.05$) with higher levels of peanut and carrot flour supplementation. The findings of this study indicated a statistically reduction ($p<0.05$) in the antinutrient profiles of the fortified food samples. Additionally, the vitamin content significantly increased ($p<0.05$) with the addition of peanut and carrot flours. The overall viable counts were significantly low, and there were no detectable coliform or fungal counts. Although, the result of sensory evaluation indicated that the control sample was more organoleptically acceptable than the substituted samples, incorporating these nutrient-rich and functional ingredients in the production of maize-based cereals may broaden the application of peanut and carrot flours in the creation of various cereal types and other cereal-based food items.

INTRODUCTION

Protein-energy malnutrition represents a significant challenge in developing nations, often linked to caloric deficiencies that result in widespread protein malnutrition, particularly affecting children (WHO, 2009). In rural settings, deficiencies in micronutrients, including essential vitamins and minerals, are among the primary contributors to health issues (Black *et al*., 2013). The availability of micronutrients in sufficient quantities is not only a vital aspect of nutrition but also their bioavailability, which is essential for fulfilling human dietary requirements. The lower bioavailability of minerals in unprocessed food items diminishes their nutritional efficacy, potentially leading to metabolic health disorders. Nevertheless, the nutritional status of a population can be enhanced by improving the bioavailability of food nutrients, a process that can be achieved through food fortification. This practice involves the incorporation of micronutrients into foods that did not originally contain them prior to processing (Nwadi *et al*., 2019). Oyeyinka and Oyeyinka (2018) suggested that food fortification can effectively elevate the micronutrient levels within a population at a reasonable expense, provided that the fortified foods are adequately consumed by a significant portion of the target demographic.

Cereal serves as a significant energy source for various demographic groups, although it lacks certain vitamins and contains some antinutritional factors. Consequently, it is essential to supplement cereals with pulses, legumes, or animal-derived products such as milk, meat, fish, and eggs. Maize, a crucial cereal, is utilized in the preparation of maize gruel, commonly referred to as Akamu among the Igbo people in Nigeria. The protein content in typical maize varieties ranges from 8% to 11% of the kernel weight (FAO, 2012). This protein contains moderate levels of sulfur-containing amino acids, specifically methionine and cystine, but is deficient in lysine and very low in tryptophan (FAO, 2012). In contrast, the crude protein content of various legumes spans from 16% in bambara groundnut to 35% in peanuts. While peanut protein is limited in essential sulfur-containing amino acids, it is abundant in lysine and tryptophan. Therefore, peanuts can serve as an effective complement to maize, which is low in tryptophan (Barber *et al*., 2017). Carrot roots are also an excellent component for creating fortified foods, offering higher energy content compared to other root vegetables (Amagloh *et al*., 2013). The starch found in carrots is easily digestible, making it a valuable ingredient for infant food preparation (Gibson *et al*., 2010). Thus, the development of fortified foods using these locally sourced ingredients presents an opportunity to utilize underappreciated food products for both infant ad adult nutrition. Furthermore, incorporating these nutrient-dense local ingredients into the formulation of infant foods will enhance the nutritional quality of homemade products in the developing communities around the World especially Ekowe Community of Southern Ijaw, Bayelsa State, Nigeria.

MATERIALS AND METHODS

Materials

The yellow maize variety (Zea mays), groundnut (Arachis hypogea), and carrot (Daucus carota L.) utilized in this study were acquired from Swalli Market in Yenagoa, Bayelsa State, Nigeria. All chemical reagents and equipment employed were of analytical grade.

Sample Preparation

Preparation of Maize Flour

The preparation of maize flour was conducted following the procedure outlined by Abasiekong *et al*. (2010). Initially, one kilogram of maize grains, which were free from impurities and foreign materials, was meticulously cleaned and soaked in three liters of potable water within a plastic bowl at room temperature (30±2 °C) for a duration of 24 hours. The water was changed every six hours to inhibit fermentation. After soaking, the grains were drained, rinsed, and treated with a 2% Sodium hypochlorite solution for ten minutes to ensure sterilization. Subsequently, the grains were rinsed five times with ample water, spread out on trays, and dried in a tray dryer (Model EU 850D, UK) at 50 °C for 24 hours, with periodic stirring every 30 minutes to promote even drying. The dried maize grains were then processed in a locally constructed hammer mill and sifted through a 500-micron mesh sieve. The resulting flour was stored in an airtight plastic container, appropriately labeled, and kept in a refrigerator until required for further use.

Preparation of Defatted Peanut Flour

The procedure outlined by Mukesh *et al*. (2015) was employed to produce peanut flour. A total of 700 grams (0.7 kg) of shelled peanuts, which were free from contaminants and foreign materials, underwent thorough cleaning. Subsequently, 500 grams of in-shell peanuts were shelled to collect the nuts. These nuts were then dried in an oven until a constant weight was achieved and subsequently milled into flour. To decrease the oil content of the milled peanut flour to approximately 15%, a cold-pressing oil extraction method was initially applied. This involved dispersing the milled peanut meal in a receptacle containing n-hexane at a ratio of 1:5 (w/v) and stirring the mixture for 2 hours at room temperature (30±2 °C) before decantation. The partially defatted flour underwent further defatting using a Soxhlet extraction apparatus with hexane (boiling point: 60 ±2 °C) for 3 hours at room temperature. The resulting defatted flour was dried in a fume cupboard to eliminate any residual organic solvent, then triturated, sieved through a 500 µm sieve, packaged in an airtight plastic container, labeled, and stored in a refrigerator prior to analysis.

Preparation of Carrot flour

The analytical method outlined by Bahadur *et al*. (2006) was employed in this study. A total of six kilograms (6 kg) of carrot tubers were carefully sorted to eliminate any foreign materials and damaged roots. Subsequently, the carrots were washed thoroughly in water, peeled with a knife to reveal the flesh, sliced, and blanched in a water bath (Griffis and George water bath BJL-410-110F, Germany) containing 0.2% potassium metabisulphite and 1% salt at a temperature of 80ºC for three minutes to enhance the retention of β-carotene. The diced carrot pieces were then dried in a blast-air electric oven (NAAFCO B5, model OVH 102, Germany) set at 50ºC for a duration of 24 hours. Following the drying process, the carrot was dry-milled using a Binatone Grinder (BL 1500 PRO, China) and subsequently sieved through a 500 µm mesh. The final product was packaged in an airtight plastic container and stored in a refrigerator until required for food formulation and laboratory analysis.

Formulation of the fortified maize-based cereal Samples

Maize, peanut and carrot flours was mixed thoroughly in the ratios of 90:5:5, 80:15:5, 70:20:10, 60:25:15 and 50:30:20 in a rotary mixer (Philips, type HR 1500/A Holland) to produce homogenous samples of fortified food. The formulated fortified foods formulated were separately packaged in airtight plastic containers, labelled and preserved in a refrigerator until needed for analyses. The maize flour without any supplementation with peanut and carrot flours (100% maize flour) was used as control.

Evaluation of Nutrient Composition of the fortified maize-based cereal Samples

The moisture content, ash, crude fibre, crude protein, and fat content of the fortified maize-based cereal samples derived from maize, peanut, and carrot were analyzed according to the AOAC (2010) methodology. Total carbohydrates were computed by difference. The caloric value was assessed using the Atwater factors for protein (4), fat (9), and carbohydrates (4). The vitamins, including B-complex, A, C, and E, along with certain mineral elements such as calcium, potassium, iron, zinc, and phosphorus, were quantified using the AOAC (2010) method with the Atomic Absorption Spectrophotometer (AA 800 Perkin-Elmer Germany).

Evaluation of Antinutrient Composition of the fortified maize-based cereal Samples

The concentrations of antinutritional factors, including haemagglutinin, trypsin inhibitor, and phytate, in the fortified maize-based cereal samples were assessed utilizing the spectrophotometric technique outlined by Onwuka (2005). The measurement of phytate was conducted through the solvent extraction gravimetric method as specified by AOAC (2006).

Microbial Analysis of The fortified maize-based cereal Samples

The total counts of viable organisms, coliforms, and fungi in the fortified maize-based cereal samples were assessed in duplicate utilizing the pour plate technique outlined by James (2003).

Sensory Evaluation of fortified maize-based cereal Samples

The control and formulated cereal samples were each prepared into separate gruels. A total of fifty grams (50g) from each sample was combined with 150mL of potable water in a small plastic container. Following this, 80mL of boiling water was added to each mixture while continuously stirring to achieve a custard-like consistency. To improve the flavor, three grams (3g) of granulated sugar were incorporated into each gruel. Each resulting gruel was assigned a unique code and presented to a panel of twenty (20) semi-trained judges, consisting of staff and students from the Federal Polytechnic Ekowe, Bayelsa State, at the Entrepreneurship Centre (Food Tech Unit). The samples were served on uniform white ceramic plates, accompanied by white plastic spoons, at an ambient temperature of 30±2°C for evaluation based on attributes such as color, flavor, texture, taste, and overall acceptability. Clean drinking water was provided to the judges for rinsing their mouths between tastings to eliminate any residual flavors. The judges were instructed to taste, assess, and score each fortified cereal gruel sample according to their preferences and acceptance, using a nine-point Hedonic scale where 1 represented extreme dislike and 9 represented extreme like. Expectoration cups with lids were available for those panelists who chose not to swallow the samples.

Statistical analysis

The data obtained underwent a one-way analysis of variance (ANOVA) utilizing the Special Package for Social Science (SPSS Version 20) software. To identify significant differences, Duncan's New Multiple Range Test was employed, with a significance level set at $p<0.05$.

RESULTS AND DISCUSSION

Proximate Composition of fortified Maize-based cereal with peanut and carrot flours

The proximate composition of the fortified food samples derived from maize, defatted peanut, and carrot flours is detailed in Table 1. The moisture content of these samples varied between 1.63% and 3.80%. The sample with the lowest moisture content was the one composed entirely of maize, while the highest moisture content was observed in the composite blend consisting of 50% maize, 30% peanut, and 20% carrot flour. The findings of this study indicated a significant difference ($p<0.05$) in the moisture content among the composite blends. An increase in the proportions of peanut and carrot in the samples corresponded with an increase in moisture content, attributable to the inherent moisture levels in the supplemented peanut and carrot. The moisture values recorded in this study were lower than those reported by Barber *et al*. (2017), which ranged from 10.03% to 12.59% for complementary foods made from fermented maize, soybean, and carrot flours. Nevertheless, these results remain within the acceptable moisture limits established by the WHO for fortified foods, which is essential for maintaining the stability of flour blends (Nasir *et al*., 2003). Elevated moisture levels can enhance proteolytic activity (Nasir *et al*., 2003). The crude protein content of the samples ranged from 3.08% to 45.19%.

The sample consisting entirely of maize exhibited the lowest protein content, whereas the highest protein content was observed in the composite blend comprising 50% maize, 30% peanut, and 20% carrot flour. The findings of this study indicated a significant difference ($p<0.05$) in the crude protein content of the composite blends, demonstrating that an increase in peanut supplementation corresponded with an increase in crude protein levels. This phenomenon can be attributed to the fact that peanuts are a versatile oilseed/legume known for their high protein content (Nsa and Ukachukwu, 2009). These results align with previous research conducted by Nnam (2002), which evaluated complementary foods made from maize, groundnut, pawpaw, and mango flour. It is important to note that maize is deficient in essential amino acids, particularly lysine and tryptophan. The ash content of the samples varied between 2.34% and 2.88%. The analysis revealed that the sample consisting entirely of maize exhibited the lowest ash content, whereas the composite blend comprising 50% maize, 30% peanut, and 20% carrot flour demonstrated the highest ash content. The study indicated a statistically significant difference ($p<0.05$) in the ash content among the various composite blends. An increase in the proportions of peanut and carrot flour corresponded with a rise in the ash content of the blends when compared to the control sample of 100% maize. This phenomenon can be attributed to the high mineral content found in both peanut and carrot, which enhances the overall ash content of the composite mixtures. The ash content serves as an indicator of the mineral composition within the food product. The ash content recorded in this study, ranging from 2.34% to 2.88%, aligns closely with the ash content of complementary foods formulated from sorghum, groundnut, and crayfish, as reported by Nzeagwu and Nwaejike (2008), which ranged from 1.88% to 3.17%. Additionally, the crude fibre content of the samples varied between 3.58% and 7.04%. The lowest fibre content was observed in the 100% maize sample, while the highest was found in the composite blend of 50% maize, 30% peanut, and 20% carrot flour. The results indicated a significant difference ($p<0.05$) in the crude fibre content among the composite blends. The fat content in the samples varied between 2.39% and 15.16%. The sample with the lowest fat content was the 100% maize, while the highest was observed in the composite blend consisting of 50% maize, 30% peanut, and 20% carrot flour. The study revealed a significant difference ($p<0.05$) in the fat content among the composite blends, with an increase in fat content corresponding to higher levels of peanut and carrot flour supplementation.

As noted by Mohammed *et al.* (2016), elevated fat levels can accelerate spoilage by encouraging rancidity, which may result in the emergence of off-flavours and odours. Fat plays a crucial role in human nutrition as it is a high-energy nutrient, serving as a backup fuel source and providing insulation during colder conditions. The carbohydrate content of the samples ranged from 27.64% to 86.98%, with the highest level found in the 100% maize sample and the lowest in the composite blend of 50% maize, 30% peanut, and 20% carrot flour. The findings of the study indicated a notable difference ($p<0.05$) in the carbohydrate content of the composite blends. The carbohydrate levels exhibited an inverse relationship with the protein content; specifically, as the proportion of peanut flour in the composite blend increased, the carbohydrate content correspondingly decreased. This observation aligns with the research conducted by Ibidapo *et al*. (2017), which noted a reduction in carbohydrate content with the increased incorporation of cowpea into the composite blend. The energy content of the samples varied between 381.75 and 432.52 kJ/100g, with the lowest energy content recorded in the 100% maize sample and the highest in the composite blend consisting of 50% maize, 30% peanut, and 20% carrot flour. The study also revealed a significant difference ($p<0.05$) in the energy content of the composite blends. Since fat serves as a reservoir of energy for the body, an increase in fat content leads to a rise in the energy content of the composite blend. The significant differences ($p<0.05$) observed in the energy levels of the developed complementary food samples can be attributed to the variations in the contents of protein, fat, and carbohydrates within the blends.

Table 1: Proximate Composition of Maize fortified with peanut and carrot flours

Composition (%)	MPC 1	MPC 2	MPC 3	MPC 4	MPC 5	MPC 6
Crude Protein	$3.08^{f} \pm 0.00$	$25.57^{e} \pm 0.03$	$28.8^{d} \pm 0.03$	$29.36^{c} \pm 0.00$	$44.43^{b} \pm 0.03$	$45.19^{a} \pm 0.03$
Moisture	$1.63^{f} \pm 0.03$	$2.30^{e} \pm 0.13$	$3.11^{c} \pm 0.01$	$3.40^{b} \pm 0.01$	$2.64^{d} \pm 0.03$	$3.80^{a} \pm 0.00$
Ash	$2.34^{f} \pm 0.01$	$2.68^{c} \pm 0.010$	$2.37^{a} \pm 0.03$	$2.7^{b} \pm 0.00$	$2.44^{d} \pm 0.03$	$2.88^{a} \pm 0.00$
Crude Fibre	$3.58^{f} \pm 0.03$	$4.44^{e} \pm 0.00$	$5.39^{c} \pm 0.03$	$5.3^{d} \pm 0.03$	$6.09^{b} \pm 0.03$	$7.04^{a} \pm 0.03$
Fat	$2.39^{f} \pm 0.05$	$14.2^{e} \pm 0.03$	$14.54^{c} \pm 0.03$	$14.8^{d} \pm 0.03$	$15.14^{b} \pm 0.03$	$15.16^{a} \pm 0.00$
Carbohydrate	$86.98^{a} \pm 0.00$	$50.61^{b} \pm 0.00$	$45.79^{c} \pm 0.00$	$44.42^{d} \pm 0.00$	$27.64^{e} \pm 0.00$	$27.55^{f} \pm 0.00$
Energy (kJ/100g)	$381.75^{f} \pm 0.00$	$424.72^{e} \pm 0.00$	$427.22^{d} \pm 0.00$	$428.32^{c} \pm 0.00$	$429.22^{b} \pm 0.00$	$432.52^{a} \pm 0.00$

Values are mean ± SD of Triplicate determinations. Means within the same row with different letters are significantly different at p<0.05. Sample A = 100% Maize; Sample MPC1 = 100% Maize; Sample MPC2 = Maize 90% + Peanut 5% + Carrot 5%; Sample MPC3 = Maize 80% + Peanut 15% + Carrot 5%; Sample MPC4 = Maize 70% + Peanut 20% + Carrot 10%; Sample MPC 5 = Maize 60% + Peanut 25% + Carrot 15%; Sample MPC 6 = Maize 50% + Peanut 30% + Carrot 20%.

Mineral Composition of fortified Maize-based cereal with peanut and carrot flours.

The mineral composition of the fortified food samples derived from a mixture of maize, peanut, and carrot flours is detailed in Table 2. The calcium levels in these samples varied between 45.11 and 67.30 mg/100g. The sample with the lowest calcium content was the one composed entirely of maize, whereas the highest calcium concentration was observed in the composite blend containing 50% maize, 30% peanut, and 20% carrot flour. The study revealed a significant difference ($p<0.05$) in the calcium content among the composite blends. The observed increase in calcium levels across all formulated samples can be attributed to the enhanced inclusion of soybean flour in the mixtures. According to Nandutu and Howell (2009), legumes are excellent sources of calcium. This mineral is crucial for the proper development of bones in infants and young children. Olomu (2011) noted that calcium plays a vital role in bone formation, blood clotting, and muscle contraction. Additionally, calcium is involved in enzymatic reactions, hormonal signalling, glucose metabolism, neurotransmitter release, and maintaining membrane integrity and excitability. It also helps regulate the acid-base balance of blood, supports hormone secretion, and facilitates cell division. The calcium content in the formulated foods falls within the World Health Organization's recommended levels (50 to 150 mg/100g) for fortified foods, particularly those intended for infants and young children. Therefore, providing infants with these formulated foods will aid in the development of their teeth and bones. The iron content in the samples ranged from 4.98 to 25.19 mg/100g, with the lowest level found in the 100% maize sample and the highest in the composite blend of 50% maize, 30% peanut, and 20% carrot flour. The study also indicated a significant difference ($p<0.05$) in the iron content among the composite blends. A similar increase in iron content with the enhancement of supplementation using African yam bean and soybean flours was documented by Ishiwu and Onyeji (2004) in their study of an instant gruel made from a mixture of maize starch, African yam bean, and soybean flour. The phosphorus levels in the samples varied between 10.45 and 83.90 mg/100g, with the lowest concentration observed in the 100% maize sample and the highest in the composite blend consisting of 50% maize, 30% peanut, and 20% carrot flour. The findings indicated a significant difference ($p<0.05$) in the phosphorus content among the composite blends. Furthermore, the phosphorus levels in the fortified foods developed in this study exceeded those reported by Onoja and Obizoba (2009), which ranged from 3.20 to 5.80 mg/100g for gruel made from blends of fermented cereal, legume, tuber, and root flour. The zinc levels in the samples varied between 1.27 and 2.92 mg/100g, with the lowest concentration detected in the 100% maize sample and the highest found in a composite blend consisting of 50% maize, 30% peanut, and 20% carrot flour. The study revealed a statistically significant difference ($p<0.05$) in the zinc content among the composite blends. It was noted that the zinc concentration in the samples increased as the proportion of peanut flour in the blends rose. Notably, peanuts are recognized as an excellent source of zinc (Plahar *et al*., 2003).

Table 2: Mineral Composition of fortified Maize-based cereal with peanut and carrot flours

Parameter (mg)	MPC 1	MPC 2	MPC 3	MPC 4	MPC 5	MPC 6
Calcium	45.11^{f} ±0.00	47.05^{e} ±0.03	50.10^{d}±0.03	51.84^{c} ±0.03	54.21^{b} ±0.03	67.30^{a} ±0.03
Iron	4.98^{f} ±0.02	5.08^{e} ±0.03	5.18^{d} ±0.01	20.05^{c} ±0.01	20.76^{b}±0.01	25.19^{a} ±0.00
Phosphorus	10.45^{f} ±0.01	20.1^{e} ±0.01	47.23^{d} ±0.02	67.36^{c} ±0.00	70.60^{b}±0.00	83.90^{a} ±0.01
Zinc	1.27^{f} ±0.04	2.13^{e} ±0.00	2.43^{d} ±0.00	2.46^{c} ±0.02	2.71^{b} ±0.00	2.92^{a} ±0.06

Values are mean ± SD of Triplicate determinations. Means within the same row with different letters are significantly different at p<0.05. Sample MPC1 = 100% Maize; Sample MPC2 = Maize 90% + Peanut 5% + Carrot 5%; Sample MPC3 = Maize 80% + Peanut 15% + Carrot 5%; Sample MPC4 = Maize 70% + Peanut 20% + Carrot 10%; Sample MPC 5 = Maize 60% + Peanut 25% + Carrot 15%; Sample MPC 6 = Maize 50% + Peanut 30% + Carrot 20%.

Vitamin Composition of fortified Maize-based cereal with peanut and carrot flours.

The vitamin composition of the fortified food samples derived from a mixture of maize, peanut, and carrot flours is detailed in Table 3. The pro-vitamin A levels in the samples varied between 4.51 and 28.88 IU, with the lowest concentration observed in the 100% maize sample and the highest in the composite blend consisting of 50% maize, 30% peanut, and 20% carrot flour. The study revealed a statistically significant difference ($p<0.05$) in the pro-vitamin A content among the composite blends.

The thiamine content across the samples ranged from 40.9 to 55.67 mg/100g, with the lowest level found in the 100% maize sample and the highest in the composite blend of 50% maize, 30% peanut, and 20% carrot flour. The findings indicated a significant difference ($p<0.05$) in thiamine content among the composite blends.

Riboflavin levels in the samples ranged from 76.30 to 90.23 mg/100g, with the lowest concentration in the 100% maize sample and the highest in the composite blend of 50% maize, 30% peanut, and 20% carrot flour. The results demonstrated a significant difference ($p<0.05$) in riboflavin content among the composite blends. The niacin levels in the samples varied between 63.26 and 93.23 mg/100g, with the lowest concentration observed in the 100% maize sample and the highest in the composite blend consisting of 50% maize, 30% peanut, and 20% carrot flour. The study revealed a significant difference ($p<0.05$) in the niacin content among the composite blends. The folic acid content in the samples ranged from 12.35 to 31.25 mg/100g, with the lowest level found in the 100% maize sample and the highest in the same composite blend. The results indicated a significant difference ($p<0.05$) in the niacin content of the composite blends. The ascorbic acid levels in the samples varied between 1.51 and 35.20 mg/100g. The lowest concentration was observed in the 100% maize sample, whereas the highest ascorbic acid level was recorded in the composite blend consisting of 50% maize, 30% peanut, and 20% carrot flour. The study revealed a significant difference ($p<0.05$) in ascorbic acid content among the composite blends. The α-tocopherol levels in the samples ranged from 1.51 to 35.20 mg/100g, with the lowest found in the 100% maize sample and the highest in the composite blend of 50% maize, 30% peanut, and 20% carrot flour. The findings indicated a significant difference ($p<0.05$) in α-tocopherol content among the composite blends.

Antinutrient Composition of the fortified Maize-based cereal with peanut and carrot flours

The antinutrient profiles of the fortified food samples derived from a mixture of maize, peanut, and carrot flours are detailed in Table 4. The haemagglutinin levels in the samples varied between 0.86 and 2.65 Hui/100g. The sample containing 90% maize, 5% peanut, and 5% carrot flour exhibited the lowest haemagglutinin content, whereas the highest levels were observed in the composite blend consisting of 50% maize, 30% peanut, and 20% carrot flour. The findings of this study indicated a statistically significant difference ($p<0.05$) in the haemagglutinin content among the various composite blends. Haemagglutinin is known to induce the agglutination of red blood cells through a mechanism referred to as haemagglutination, with common examples including antibodies and lectins (Dorland's Medical Dictionary, 2001). The haemagglutinin values recorded in this study fall within the acceptable range (0.44-2.10 mg/100g) for fortified foods as established by the WHO (2010). Additionally, the trypsin inhibitor levels in the samples ranged from 0.64 to 3.45 Tui/100g, with the lowest content again found in the sample comprising 90% maize, 5% peanut, and 5% carrot flour, while the highest was noted in the composite blend of 50% maize, 30%

peanut, and 20% carrot flour. The results also revealed a significant difference ($p<0.05$) in the trypsin inhibitor content among the composite blends. The elevated levels of trypsin inhibitors present in certain foods tend to bind with proteins, rendering these proteins bio-unavailable within the food product. The trypsin inhibitor values identified in this study fall within the acceptable range (0.51-2.65 mg/100g) for fortified foods as outlined by the WHO (2010). Consequently, the fortified food samples analyzed in this study are deemed safe for human consumption and do not present any health risks. The phytate content in the samples varied from 1.46 to 4.21 mg/100g, with the lowest concentration observed in the 100% maize sample and the highest in the composite blend consisting of 50% maize, 30% peanut, and 20% carrot flour. The study revealed a significant reduction in the antinutrient contents of the composite blends. Therefore, the fortified food samples from this study are considered safe for human consumption.

Table 3: Vitamin Composition of fortified Maize-based cereal with peanut and carrot flours

PARAMETER	MPC 1	MPC 2	MPC 3	MPC 4	MPC 5	MPC 6
Pro-Vit A (IU)	$4.51^{f}\pm0.03$	$5.26^{e}\pm0.02$	$8.2^{d}\pm0.03$	$27.42^{b}\pm0.03$	$26.59^{c}\pm0.03$	$28.88^{a}\pm0.03$
VIT B$_1$	$40.9^{f}\pm0.00$	$43.4^{e}\pm0.01$	$44.3^{d}\pm0.01$	$47.76^{c}\pm0.00$	$50.1^{b}\pm0.01$	$55.67^{a}\pm0.03$
VIT B$_2$	$76.30^{e}\pm0.03$	$79.1^{d}\pm0.02$	$83.0^{c}\pm0.03$	$83.0^{c}\pm0.01$	$86.55^{b}\pm0.03$	$90.23^{a}\pm0.00$
VIT B$_3$	$63.26^{f}\pm0.00$	$70.9^{e}\pm0.01$	$72.6^{d}\pm0.00$	$84.1^{c}\pm0.01$	$88.24^{b}\pm0.00$	$93.23^{a}\pm0.01$
FOLIC ACID	$12.35^{f}\pm0.03$	$17.4^{e}\pm0.00$	$22.84^{d}\pm0.03$	$25.16^{c}\pm0.00$	$27.62^{b}\pm0.00$	$31.25^{a}\pm0.03$
VIT C	$1.51^{f}\pm0.00$	$1.96^{e}\pm0.03$	$16.25^{d}\pm0.02$	$2.28^{c}\pm0.00$	$28.75^{b}\pm0.01$	$35.20^{a}\pm0.01$
Vitamin E	$0.08^{f}\pm0.01$	$0.19^{e}\pm0.03$	$0.43^{d}\pm0.02$	$0.57^{c}\pm0.00$	$0.69^{b}\pm0.03$	$0.8^{a}\pm0.03$

Values are mean ± SD of Triplicate determinations. Means within the same row with different letters are significantly different at p<0.05. Sample MPC1 = 100% Maize; Sample MPC2 = Maize 90% + Peanut 5% + Carrot 5%; Sample MPC3 = Maize 80% + Peanut 15% + Carrot 5%; Sample MPC4 = Maize 70% + Peanut 20% + Carrot 10%; Sample MPC 5 = Maize 60% + Peanut 25% + Carrot 15%; Sample MPC 6 = Maize 50% + Peanut 30% + Carrot 20%.

Microbial Counts of fortified Maize-based cereal with peanut and carrot flours

The microbial counts of the fortified maize-based cereal, which includes blends of peanut and carrot flour, are detailed in Table 5. The total viable count for the samples varied between 0.41 x 10^4 and 1.04 x 10^4 cfu/g. The control sample exhibited the lowest total viable count at 0.41 x 10^4 cfu/g, whereas the formulation containing 50% maize, 30% peanut, and 20% carrot flours recorded the highest total viable count of 1.20 x 10^4 cfu/g. The relatively low total viable counts across all samples may be attributed to the preparation of the fortified maize-based cereal being conducted in a clean and hygienic environment. Furthermore, it was ensured that clean containers were utilized for packaging the flour samples post-processing. In terms of coliform and fungal counts, none of the blended samples exhibited growth of microorganisms such as coliforms or fungi. The absence of these microorganisms in all fortified food samples suggests that they are safe for human consumption and can be stored for extended periods without negative effects. The total viable count of microorganisms in the food samples was within acceptable limits according to the microbiological quality guidelines for ready-to-eat foods (Anon, 2001), which classify counts of 10^4 cfu/g as satisfactory, 10^4 to 10^5 cfu/g as acceptable, and counts exceeding 10^5 cfu/g as unsatisfactory. The total bacterial and fungal counts in food products may reflect the hygiene levels maintained during post-processing, preservation, and storage, as well as the formulation process. Microorganisms significantly influence the shelf-life of food products and are often responsible for spoilage (FDA, 2013).

Table 4: Antinutritional Contents of fortified Maize-based cereal with peanut and carrot flours

Parameter	MPC 1	MPC 2	MPC 3	MPC 4	MPC 5	MPC 6
Haemaglutinin (HUI)	$0.12^{f}\pm0.01$	$0.43^{e}\pm0.03$	$0.86^{d}\pm0.00$	$1.68^{c}\pm0.03$	$2.1^{b}\pm0.02$	$2.65^{a}\pm0.04$
Trypsin inhibitor (TUI)	$0.30^{f}\pm0.01$	$0.64^{e}\pm0.03$	$1.52^{d}\pm0.03$	$2.22^{c}\pm0.03$	$2.53^{b}\pm0.03$	$3.45^{a}\pm0.03$
Phytate (mg/100g)	$1.46^{f}\pm0.03$	$1.76^{e}\pm0.03$	$1.8^{d}\pm0.03$	$2.67^{c}\pm0.03$	$3.72^{b}\pm0.03$	$4.21^{a}\pm0.03$

Values are mean ± SD of Triplicate determinations. Means within the same row with different letters are significantly different at p<0.05. Sample MPC1 = 100% Maize; Sample MPC2 = Maize 90% + Peanut 5% + Carrot 5%; Sample MPC3 = Maize 80% + Peanut 15% + Carrot 5%; Sample MPC4 = Maize 70% + Peanut 20% + Carrot 10%; Sample MPC 5 = Maize 60% + Peanut 25% + Carrot 15%; Sample MPC 6 = Maize 50% + Peanut 30% + Carrot 20%.

Sensory Properties of fortified Maize-based cereal with peanut and carrot flours

The sensory characteristics of the fortified maize-based cereal incorporating peanut and carrot flours are detailed in Table 6. The sensory evaluations of the maize-based cereal, enhanced with peanut and carrot flours from both the control and substituted samples, revealed significant differences ($p<0.05$) in aspects such as colour, taste, flavour, texture, and overall acceptability. The control sample received the highest scores across all evaluated parameters, significantly outperforming the test samples ($p<0.05$). Both the maize-based cereals made entirely from maize flour (control) and those with 15% and 10% substitutions of peanut and carrot flours were generally deemed acceptable. The increased substitution of peanut and carrot flours did not adversely affect the acceptability of the fortified maize-based cereals. The minor colour change observed may be attributed to the higher levels of peanut and carrot flour, resulting in a slightly darker appearance. Panelists rated the maize-based cereals with 15% peanut and 5% carrot flour as having superior taste, colour, flavour, and overall acceptability compared to the other test samples. Consequently, substituting maize flour with peanut and carrot flours at levels not exceeding 15% can effectively yield nutrient-dense and organoleptically acceptable maize-based cereals.

Table 5: Microbial Count (cfu/g) of Microbial Counts of fortified Maize-based cereal with peanut and carrot flours

Samples	Total Viable Count (cfu/g)	Coliform Count (cfu/g)	Fungal Count (cfu/g)
MPC 1	0.41×10^4	Nil	Nil
MPC 2	0.57×10^4	Nil	Nil
MPC 3	0.72×10^4	Nil	Nil
MPC 4	0.98×10^4	Nil	Nil
MPC 5	1.10×10^4	Nil	Nil
MPC 6	1.20×10^4	Nil	Nil

Values are mean ± SD of Triplicate determinations. Means within the same row with different letters are significantly different at p<0.05. Sample A = 100% Maize; Sample MPC1 = 100% Maize; Sample MPC2 = Maize 90% + Peanut 5% + Carrot 5%; Sample MPC3 = Maize 80% + Peanut 15% + Carrot 5%; Sample MPC4 = Maize 70% + Peanut 20% + Carrot 10%; Sample MPC 5 = Maize 60% + Peanut 25% + Carrot 15%; Sample MPC 6 = Maize 50% + Peanut 30% + Carrot 20%.

Table 6: Sensory properties of fortified Maize-based cereal with peanut and carrot flours

Samples	Colour	Flavour	Taste	Texture	Overall Acceptability
MPC 1	$7.90^a±0.10$	$7.45^a±1.32$	$7.60^a±1.39$	$7.30^a±1.13$	$7.55^a±1.39$
MPC 2	$6.75^b±1.25$	$6.85^b±1.19$	$6.80^b±1.47$	$6.45^b±1.19$	$6.70^b±1.32$
MPC 3	$6.40^c±1.28$	$6.75^c±1.33$	$6.80^c±1.24$	$6.45^c±1.45$	$6.65^c±1.07$
MPC 4	$6.40^d±1.27$	$6.65^d±1.23$	$6.60^d±1.43$	$6.30^d±1.45$	$6.50^d±1.31$
MPC 5	$6.20^e±1.07$	$6.10^e±1.33$	$6.45^e±1.23$	$5.90^e±1.46$	$6.25^e±1.14$
MPC 6	$6.05^f±1.05$	$5.90^f±1.41$	$6.40^f±1.28$	$5.85^f±1.44$	$6.05^f±1.28$

Values are mean ± SD of Triplicate determinations. Means within the same column with different letters are significantly different at p<0.05. Sample MPC1 = 100% Maize; Sample MPC2 = Maize 90% + Peanut 5% + Carrot 5%; Sample MPC3 = Maize 80% + Peanut 15% + Carrot 5%; Sample MPC4 = Maize 70% + Peanut 20% + Carrot 10%; Sample MPC 5 = Maize 60% + Peanut 25% + Carrot 15%; Sample MPC 6 = Maize 50% + Peanut 30% + Carrot 20%.

CONCLUSION

The research assessed the nutritional and antinutritional profiles, microbiological characteristics, and sensory attributes of fortified food samples created from blends of maize, defatted peanut, and carrot flours. The indicated that the addition of peanut and carrot flours to maize flour in the formulation of fortified food products substantially enhanced nutrient contents and equally diminished the antinutritional factors. The total viable counts were found to be minimal, with no detectable coliform or fungal counts. Sensory evaluation indicated that the control sample was more organoleptically preferred than sample MPC 3 (Maize 80% + Peanut 15% + Carrot 5%). The application of these nutrient-rich and functional ingredients in maize-based cereals could broaden the scope for utilizing peanut and carrot flours in the development of various cereal and cereal-based food products.

REFERENCES

Abasiekong, K.S., Akobundu, E.N. and Oti, E. (2010). Chemical, sensory and biological evaluation of maize-bambara nut based complementary foods. *Nigerian Food Journal*, 28(2): 22-34.

Amagloh, F.K., Mutukumira, A.N., Brough, L., Weber, J.L., Hardacre, A. and Coad, J. (2013) Carbohydrate composition, viscosity, solubility, and sensory acceptance of sweet-potato and maize-based complementary foods. *Food and Nutrition Research*, 57: 187-192.

Anon (2001). *Microbiological guideline for ready-to-eat food. Recommendations for food safety monitoring*. Elsevier Publishers Hong Kong. Pp.7-18.

AOAC (2010). *Official Methods of Analysis. Association of Analytical Chemists*. 18th Edition, Washington, D.C. USA. 614-621.

Bahadur, S., Panesar, P.S. and Vikas, N. (2006). Utilization of carrot pomace for the preparation of a value-added product. *World Journal of Dairy and Food Science*, 1(1): 22-27.

Barber, L. I., Obinna-Echem, P. C. and Ogburia, E. M. (2017). Proximate composition, micronutrient and sensory properties of fortified food formulated from fermented maize, soybean and carrots. *Sky Journal of Food Science,* 6(3):033-039.

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P. and De Onis, M. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet*, 382(9890): 427–451.

Dorland's Medical Dictionary (2001). Dorland's Gastroenterology Word Book for Medical Transcriptionists. Dorland's Medical Dictionary Press, UK. Pp 721-729.

FAO. (2012). FAOSTAT, Production. Cited February 12, 2014. http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID =567#ancor.

FDA (2013). *Revised guidelines for the assessment of microbiological quality of processed foods. Department of Health, Food and Drug Administration*. Republic of Philippines. Pp. 5-7.

Gibson, R.S., Bailey, K.B., Gibbs, M. and Ferguson, E.L. (2010). A review of phytate, iron, zinc and calcium concentrations in plant-based complementary foods used in low-income countries and implications for bioavailability. *Food and Nutrition Bulletin*, 31(2): 134-146.

Ibidapo, O. P., Ogunji, A., Akinwale, T., Owolabi, F., Akinyele, O. and Efuribe, N. (2017). Development and quality evaluation of carrot powder and cowpea flour enriched biscuits. *International Journal of Food Science and Biotechnology, 2(3): 67-72.*

Ishiwu, C. N. and Onyeji, A. C. (2004). Properties of an instant gruel based on blend of maize (Zea mays L) starch, African yam bean (*Sphenostylis stenocarpa*) flour and soybean (Glycine max) flour. *Nigerian Journal of Nutritional Sciences, 25:16-19.*

James, M.J. (2003). *Modern Food Microbiology, 12th Edition (Food Science Texts Series)*. Van Nostrand Reinhold, Ireland. Pp 01-781.

Mukesh, I.E., Aprikian, O., Busserolles, J., Grolier, P., Rock, E., Demigné, C. (2015). Pragmatic perspective on conservation genetics and demographic history of the last surviving population of Kashmir red deer (Cervus elaphus hanglu) in India. *National Center for Biotechnology Information*, 24: 12-25.

Nandutu, A.M. and Howell, N.K. (2009a). Nutritional and rheological properties of sweet potato based infant food and its preservation using antioxidants. *African Journal of Food, Agriculture, Nutrition and Development, 4(9): 1076-1090.*

Nasir, M., Masood, S., Butt, F. M., Anjum, K. S. and Rashid M. (2003). Effect of Moisture on the Shelf Life of Wheat Flour. *International Journal of Agriculture and Biology*, 4: 458–459.

Nnam, N.M. (2002). Evaluation of the nutrient and sensory properties of porridges from African yam bean (Sphenostylis stenocarpa) and maize (*Zea mays*) flours. *Nigerian Research in Education, 9:49-54.*

Nsa, E. E. and Ukachukwu, S. N. (2009). Effect of thermal processing methods on the proximate composition, gross energy, minerals and ricin content of undecorticated castor oil seed (*Ricinus communis*). *Global Journal of Agricultural Sciences, 8(2): 223 -227.*

Nwadi, O. M.M., Uchegbu, N. and Onyeyika, S. A. (2019). Enrichment of food blends with Bambara groundnut flour; past, present and future trends. *Legume Science*, 2(1):01-10.

Nzeagwu, O. and Nwaejike, N.J. (2008). Nutrient composition, functional and organoleptic properties of complementary foods formulated from sorghum, groundnut and crayfish. *Nigerian Food Journal, 26(1): 4713-4721.*

Olomu, J. M. (2011). *Non-Ruminant Animal Production*. Jachem Publication. Nigeria. Pp150-177

Onoja, U.S., Obizoba, I.C. (2009). Nutrient composition and organoleptic attributes of gruel based on fermented cereal, legume, tuber and root flour. *Journal of Tropical Agriculture, Food, Environment and Extension*, 8(3): 162-168.

Onwuka, G. I. (2005). Food and Instrumentation Analysis: Theory and Practice. Napthali Publishers Ltd, Lagos, Nigeria. Pp. 46-50.

Oyeyinka, S.A. and Oyeyinka, A.T. (2018). A review on Isolation composition physiochemical Properties and Modification of bambara ground nut sstarch. *Food Hydrocolloids* 75: 62-71.

Plahar, W., Okezie, B. and Annan, N.T. (2003). Nutritional quality and storage stability of extruded weaning foods based on peanut, maize and soybean. *Materiae Vegetabiles*, 58: 1-16.

Potter, N. N. and Hotchkiss, J. H. (2006). *Food Science text series*, *5th edition*. CBS Publishers and Distributors, New Delhi, India. Pp. 124-142.

WHO (2009). Proceedings of the WHO UNICEF WEP UNHCR informal consultation on the management of moderate nutrition in under-5 children, Geneva, Oct.2008. *Food and Nutrition Bulletin;* 30(3):464-474.

WHO. (2010). *Global Recommendations on Physical Activity for Health.* Geneva: WHO.