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Quality Evaluation and Sensory Acceptability of Complementary Foods made from Pearl Millet (*Pennisetum glaucum*), African Yam Bean (*Sphenostylis stenocarpa*) and Carrot (*Daucus carrota*) Flour Blends

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Abstract
Nutrient-dense and energy foods are increasingly in demand as complementary foods to ensure sufficient nutrients intake for infants. The studies was carried out to evaluate the proximate composition of flours from fermented pearl millet, fermented African yam bean and carrot fruit, and determine the effect of supplementation of the pearl millet flour with African yam bean and carrot flours on the chemical and sensory properties of complementary foods prepared from the blends. Pearl millet, African yam bean and carrot flours were blended in the ratios of 100:0:0, 90:5:5, 80:15:5 and 70:20:10, designated as M100, $MAC_{1,}$ MAC_2 and MAC_3 respectively. Standard analytical methods were employed to determine the proximate composition, energy values, mineral content, vitamin content and sensory attributes of the blends. Significant differences ($p<0.05$) existed in the proximate, energy, mineral, vitamin and sensory properties of the blends with increased inclusion of African yam bean and carrot flours into pearl millet flour. The proximate composition results indicated significant ($p<0.05$) increase in protein (10.80 – 19.72%), ash (0.70 – 3.70%), crude fibre (1.62 – 3.86%), and decease in fat (3.70 – 3.00%), carbohydrate (76.12 – 62.61%) and energy values (380.98 – 356.32 kcal/100 g) with increased addition of African yam bean and carrot flours into pearl millet flour. Increasing percent of African yam bean and carrot flours into pearl millet flour had increase effect on the beta-carotene, ascorbic acid, thiamin, riboflavin and niacin. The magnesium content ranged from (140.11 – 166.20 mg/100g), potassium (301.0 – 535.50 mg/100g),calcium (41.10 – 340.82 mg/100g),iron (6.56 – 11.65 mg/100g) and zinc (6.48 – 8.86 mg/100g).The sensory evaluation results showed that the formulated complementary foods were acceptable judging from the sensory scores, although the blend (MAC_3) containing 70% pearl millet, 20% African yam bean and 10 % carrot flours was the most preferred, and the blend had the highest nutrient density and satisfied the recommended dietary allowance (RDA) for infants.

Keywords: Complementary foods, pearl millet, African yam bean, carrot, nutrient-dense, recommended dietary allowance

Introduction

Complementary foods can be described as those foods fed to infants after six months of age when the mothers breast milk are no longer adequate to meet the infants' nutritional needs. According to WHO (2020), complementary feeding is that process that starts when breast milk alone is no longer sufficient to meet infants' nutritional requirements, and consequently, along with breast milk, other foods and liquids are essential. Complementary foods are introduced from 6 months of age to 2 years as it is the most critical growth period for a child, and nutrition deficiencies may result to health problems such as kwashiorkor, iron deficiency anaemia, stroke, cancer, and coronary heart disease among others (Haimi and Lerner, 2014). In Nigeria, complementary foods are prepared mainly from cereals such as maize, millet, sorghum among others, which are grossly inadequate in some macronutrients and micronutrients (Nnam, 2000). Protein, energy and micronutrients malnutrition of infants and children are some of the major nutritional challenges prevalent in Nigeria and other developing countries. Many families are poor in

Nigeria and cannot afford commercial complementary foods to wean their infants and so resort to use of cereal gruels which are low in nutrients. However, the low nutrients can be improved by supplementing the cereals with grain legumes.

Pearl millet (*Pennisetum glaucum*) is a cereal crop produced in large quantity in Nigeria. Nigeria produces 21% of the world's total millet (FAO, 2002). Pearl millet is used primarily for human food, as an important source of calories and food security in Nigeria. Pearl millet contains high amount of carbohydrate and moderate protein. It is rich in calcium, iron, zinc, B vitamins and dietary fibre (Malik *et al*., 2002). Qureshi *et al*. (2000) noted that millets are nutritionally superior to major cereals in terms of energy value, proteins, fat and minerals. It can be used to produce household breakfast gruel (akamu'dawa'), dough (fura), cookie, cake and beer.

African yam bean (*Sphenostylis stenocarpa*) is an edible underutilized legume widely cultivated in Africa and used for human and animal nutrition (Eke, 2002). It contains protein (19.5 – 22.30%), carbohydrate (57.78 - 62.6%), fat (2.5 – 3.0%), vitamins and minerals (Iwuoha and Eke, 1996; Arukwe *et al*., 2021). Its protein contains over 32% essential amino acids, with lysine and leucine being dominant (Onyenekwe *et al*., 2000). It is also a good source of antioxidants and free radical scavengers. Complementing underutilized pearl millet and African yam bean will serve as a potential source of the much needed protein that can be used to curb the wide spread of protein, energy, and micronutrient malnutrition in Nigeria and other developing countries. Carrot was added to the blends to improve the micronutrient content of the porridge. Carrot contains beta-carotene, a precursor of vitamin A. Carotenoids widely distributed in orange carrots are potent antioxidants which neutralize the effect of free radicals (Vilchez *et al*., 2011), anticarcinogens, and immune-enhancers. Consumption of dietary carotenoids supplies the body with vitamin A which aid in vision and maintenance of normal function of the immune system, normal skin and mucosal membrane (Soltoft *et al*., 2011).

Adequate nutrition is crucial for proper growth and development of a child in the first two years of life because such diet promote its health and wellbeing. The use of blends of pearl millet, African yam bean and carrot flours for the production of complementary foods for infants will help in solving the problems of protein, energy and micronutrients malnutrition common in Nigeria and other developing countries. A good quality complementary food should have high nutrient density, made from local raw materials, and affordable to the low income people. Supplementation of pearl millet flour with African yam bean and carrot flours will improve the nutrient density of the blends and make the products within reach of the poor. The study aimed to produce nutrient-dense complementary foods from blends of pearl millet, African yam bean and carrot flours, and evaluate the proximate composition, mineral content, vitamin content and sensory properties.

Materials and Methods

Raw materials collection

Pearl millet grains, African yam bean seeds and carrot fruits were purchased from Ubani Main Market in Umuahia North Local Government Area, Abia State.

Sample Preparation

Production of Fermented Pearl Millet and African Yam Bean Flours

One kilogram (1 kg) each of pearl millet and African yam beanseeds were sorted to remove dirt and extraneous materials. The grains were washed, steeped in water and left to ferment for 48 h with intermittent changing of water. The water was drained and the seeds were dehulled manually. The grains were dried in an oven at 60 ˚C for 7 h (Gallenkemp, 300 Plus, England). The dried grains were milled into flour using disc attrition mill (Asiko A11, Addis Nigeria), sieved with standard sieve (0.25 mm mesh size) and packaged in polyethylene bag for further studies.

Production of Carrot Flour

Carrot flour was prepared according to the method described by Marvin (2009) with slight modification. Five hundred grams of carrot fruit was properly washed, scraped and sliced for easy drying. Hot water (95 ˚C) containing 0.1% sodium metabisulphite was used for blanching for about 3 m to prevent browning and discolouration. Then, the carrot was cooled by exposing it to air, and dried in a cabinet drier at 50 ˚C for 12 h. The dried carrot was milled into powder and sieved (0.25 mm mesh size) before packaging in polyethylene bag for further studies.

Formulation of Complementary Foods

Pearl millet flour was supplemented with different proportions of African yam bean and carrot flours and designated as follows: 100:0:0 (M100), 90:5:5 (MAC_1). 80:15:5 (MAC_2), 70:20:10 (MAC_3), where sample M100 served as control. To obtain homogenous flour, the different blends were individually homogenized in a Kenwood mixer, and stored in airtight polyethylene bags for further studies.

Determination of Proximate Composition and Energy Value

Determination of moisture content

Moisture content of the samples was determined according to the method of AOAC (2012). Two grams of each of the samples were weighed into different moisture cans. They were then placed in an oven at 150 ˚C for 3 h, drying was stopped after obtaining two consecutive values differing by 0.001. The samples were cooled in a desiccator and weighed. Moisture content of the samples was then calculated as follows:

$$\% \text{ Moisture} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

where: W_1 = initial weight of empty can,

W_2 = weight of empty can + sample before

drying,
W_3 = final weight of empty can + sample after drying.

Determination of ash content

The method described by AOAC (2012) was used to determine the ash content of the samples. Porcelain crucible were dried and cooled in desiccators before weighing. Two grams of the each of the samples were weighed into the crucible and the weight taken. The crucible containing the samples were placed into the muffle furnace and ignited at 550 ˚C. This temperature was maintained for 3 h. The muffle furnace was then allowed to cool; the crucibles were then brought out, cooled and weighed. The ash content was calculated as follows:

$$\% \text{ Ash} = \frac{W_2 - W_1}{\text{Weight of sample}} \times 100$$

Where: W_2 = weight of crucible + ash,
W_1 = weight of empty crucible.

Determination of fat content

The fat content of the samples was determined using solvent extraction in a soxhlet apparatus as described by AOAC (2012). Two grams of each of the samples were wrapped in a filter paper and placed in a soxhlet reflux flask which is connected to a condenser on the upper side and to a weighed oil extraction flask full with two hundred milliliters of petroleum ether. The ether was brought to its boiling point, the vapour condensed into the reflux flask immersing the samples completely for extraction to take place on filling up the reflux flask siphons over carrying the oil extract back to the boiling solvent in the flask. The process of boiling, condensation, and reflux was allowed to go on for four hours before the deffated samples were removed. The oil extract in the flux was dried in the oven at 60 ˚C for thirty minutes and then weighed.

$$\% \text{ Fat} = \frac{\text{Weight of fat}}{\text{Weight of sample}} \times 100$$

Determination of crude fibre

The crude fibre of the samples was determined according to the AOAC (2012) method. Two grams of each of the samples were boiled under reflux for 30 min with 200 ml of solution containing 1.25 g of tetraoxosulphate (vi) acid (H_2SO_4) per 100 ml of solution. The solution was filtered through linen on a flaunted funnel and washed with water until the washing is no longer acidic. The residue was then transferred to a beaker and boiled for thirty minutes with 100 ml of solution. The final residue was filtered through a thin but closer pad of washed and ignited asbestos in a Gosh crucible. The residue was then dried in an electric oven and weighed. The residue was incinerated, cooled and weighed. Crude fibre content of the sample was then calculated as follows:

$$\% \text{ Crude fibre} = \frac{W_2 - W_3}{W_1}$$

Where: W_1 = weight of sample used,
W_2 = weight of crucible plus sample,
W_3 = weight of sample crucible

Determination of crude protein

Crude protein of the samples was determined using the Kjedahl method as described by AOAC (2012). One gram of the sample was introduced into the digestion flask. Kjedahl catalyst (Selenium tablets) was added to the sample. Twenty milliliters of concentrated sulphuric acid was added to the sample and fixed to the digester for eight hours until a clear solution was obtained. The cooled digest was transferred into 100 ml volumetric flask and made up to the mark with distilled water. The distillation apparatus was set and rinsed for ten minutes after boiling. Twenty milliliters of 4 % boric acid was pipetted into conical flask. Five drops of methyl red was added to the flask as indicator and the sample was diluted with 75 ml distilled water. Ten milliliters of the digest was made alkaline with 20 ml of sodium hydroxide (NaOH) (20 %) and distilled. The steam exit of the distillatory was closed and the change of color of boric acid solution to green was timed. The mixture was distilled for 15 min. The filtrate was then titrated against 0.1 N Hydrochloric acid (HCl).
The total percentage of protein was calculated:
% protein = % nitrogen x conversion factor (6.25).

Determination of carbohydrate

Carbohydrate content of the samples was determined using the formula described by AOAC (2012).

% carbohydrate =100 − % (protein + fat + fibre + ash +moisture) content.

Determination of energy value

The energy value was estimated using Atwater factors as described by AOAC (2012). The energy value was calculated by multiplying the proportion of protein, fat and carbohydrate by their respective physiological fuel value of 4, 9, and 4 kcal/g respectively and taking the sum of their products.
The energy value was calculated thus:

$$F_e = (\% CP \times 4) + (\% CF \times 9) + (\% CHO \times 4)$$

Where: F_e = Food energy (in grain calories), CP= Crude protein
CF= Crude fat, CHO= Carbohydrate

Determination of Minerals

The Onwuka (2018) method was employed for the determination of minerals. The samples were ashed and digested and the digests were used for mineral element determination. The EDTA complexiometric titration method as described by Udoh and Ogunwale (1986) was used to measure calcium and magnesium. The flame photometric method of AOAC (2012) was used to analyze potassium. The zinc and iron were analyzed by atomic absorption spectrophotometer, model AAS, Hitachi 26100, Tokyo Japan (AOAC, 2012).

Determination of Vitamins

The photometric method as described by Okwu (2004) was used to determine thiamin (vitamin B_1) and riboflavin (vitamin B_2) respectively. The Barakat titrimetric method as outlined by Okwu and Ndu (2006) was adopted for ascorbic acid (vitamin C) determination. The photometric method of Onwuka (2018) was used for the determination of niacin (vitamin B_3), while the method by Klimes and Jedlicka (2002) was used in beta-carotene (provitamin A) determination.

Preparation of the Complementary Porridge

Hundred grams (100 g) of each of the formulated samples from pearl millet, African yam bean and carrot flours were dissolved with 200 ml of water to form slurry. Three hundred milliliters (300 ml) of water was placed to boil in a pot and the slurry was poured into the boiling water and ceaselessly stirred with a spatula until a thick paste (porridge) was formed. The porridge obtained was used for sensory evaluation.

Sensory Evaluation

Sensory evaluation of the porridge samples made from pearl millet, African yam bean and carrot flour blends was carried out using the 9-point Hedonic scale (where 9 = like very much and 1 = dislike very much) as described by Iwe (2014). Twenty semi-trained panelists made up of nursing mothers were involved in the evaluation of flavor, taste, texture, appearance and overall acceptability.

Statistical Analysis

The data obtained was subjected to Analysis of Variance using the Statistical Product for Service Solution version 23.0, while treatment means were separated using Duncan's Multiple Range Test at 95% confidence level ($p<0.05$).

Results and Discussion

Proximate Composition and Energy Values of Pearl Millet, African Yam Bean and Carrot Flours

Table 1 presents the proximate composition and energy values of the ingredients (pearl millet, African yam bean and carrot flours) used for the complementary foods formulations for this study. There was no significant difference ($p>0.05$) in the moisture content of the flour samples which ranged from 7.02 – 7.50%. Pearl millet flour had the lowest (7.02%) moisture content followed by African yam bean flour (7.20%), while carrot flour had the highest value (7.50%). The moisture content recorded for the flour samples were within the range (<10%) recommended for safe storage of flour (SON, 2007). The protein content varied significantly ($p<0.05$) and ranged between 1.01% and 20.05%. African yam bean flour sample had the highest (20.05%) protein content followed by pearl millet flour (10.73%), while carrot flour had the least value (1.01%). This result obtained was expected because African yam bean is a legume, and legumes are good protein sources. This is in consonance with the report of Arukwe *et al*. (2021) during the production of cookies from wheat-sorghum-African yam bean flours. The ash contents of the samples varied significantly ($p<0.05$) and was highest in African yam bean flour sample (3.60%) followed by carrot flour sample (1.20%) and lowest for pearl millet flour (0.67%). This result suggests that African yam bean is richer in minerals compared to the other samples since ash content depicts mineral content of a food material. The fat content indicated significant differences ($p<0.05$) with pearl millet flour recording the highest value (3.66%) followed by African yam bean flour (2.73%), while the least value was recorded for carrot flour (0.35%). This suggests that pearl millet is a better source of fat than African yam bean and carrot.

The crude fibre content which varied significantly ($p<0.05$) ranging from 1.58 – 5.30%. African yam bean flour had the highest value (5.30%) followed by carrot flour (2.20%), whereas pearl millet flour had the lowest value (1.58%). This implies that African yam bean is richer crude fibre than the other samples. This also agrees with the findings of Arukwe *et al*. (2021). There were significant differences ($p<0.05$) in the carbohydrate content of the flour samples which ranged between 61.22% and 87.74%. The highest value of carbohydrate was recorded for carrot flour (87.74%) followed by pearl millet flour (76.77%), while the lowest was recorded for African yam bean flour (61.22%). This implies that carrot flour and pearl millet flour are better sources of carbohydrate than African yam bean flour. The energy value of the flour samples varied significantly ($p<0.05$) and ranged between 349.65% and 382.94%. Pearl millet flour had the highest energy value (382.94%), followed by carrot flour (358.15%), while the lowest energy value (349.65%) was recorded for African yam bean flour. This result is expected since cereals are energy giving foods. The carrot flour though having the highest carbohydrate content did not record the highest energy value. This could be attributed to the fact that carrot being a fruit, has little protein and fat, and these values are used in calculating the energy value, hence the lower energy value than that of pearl millet. The blend of these flours was therefore expected to give complementary foods with enhanced and balanced nutrients, with respect to both macronutrients and micronutrients.

Proximate Composition and Energy Values of the Formulated Complementary Foods

Table 2 shows the proximate composition and energy values of complementary foods prepared from blends of pearl millet, African yam bean and carrot flours. The moisture content ranged from 7.06 – 7.11% with the control sample (100% pearl millet flour) recording the least value which showed slight increment with increasing addition of African yam bean and carrot flours to the blend, though of no significant difference ($p>0.05$). The slight increase may be due to carrot flour which had more moisture content (Table 1). The moisture contents of the blends were within the acceptable limit of not more than 10% for long term storage of flour (Akubor and Eze, 2012). The low moisture content of the blends would enhance storage stability by preventing the growth of mould and reduce moisture dependent chemical reactions (Onimawo and Akubor, 2012). The moisture contents recorded in this study are within the range (6.05-8.0%) reported by Oyegoke *et al*.(2021) who produced complementary foodsfrom yellow maize, soybean, millet and carrot composite flours. The recommended dietary allowance (RDA) for moisture in foods is $\leq$ 7% (FAO/WHO, 1998) and all the blends moisture content are within this range.

The protein content of the samples varied significantly ($p<0.05$) ranging from 10.80 – 19.72% with the control sample recording the lowest value and sample MAC_3(blend containing 70% pearl millet, 20% African yam bean and 10% carrot flours) recording the highest value. The protein content of the blends recorded consistent increment with increase in percent inclusion of African yam bean and carrot flours. This could be attributed to the high protein content of African yam bean (Table 1). Reportshave shown that protein is synergistically enhanced in cereal-legume blends due to the contribution of lysine by legume and methionine by cereal (Wakil and Kazeem, 2012; Arukwe *et al*.(2021). The result is in consonance with that of Obinna-Echem *et al*. (2018) who produced complementary foods from maize, soybean and carrot flours. The formulated blends had more protein content than the control, but only sample MAC_3 protein content (19.72%) met the recommended dietary allowance (RDA) for protein in foods which is $\geq$16.0 mg/100g (FAO/WHO, 1998). Protein is necessary for tissue replacement, growth and development.

The ash content of the complementary foods varied significantly ($p<0.05$) ranging between 0.70% and 3.70% with the control sample recording the lowest value (0.70%). The ash content increased steadily with corresponding increase in addition of African yam bean and carrot flours in the blends. The sample MAC_3 had the highest ash content and this could be due to its high content of African yam bean (Table 1) and the report that African yam bean is rich in ash (Arukwe and Arukwe, 2021). All the samples had ash content are within the range of recommended dietary allowance (RDA) for ash in foods which is $\leq$ 5.0 mg/100g (FAO/WHO, 1998). Ash content of a food material is an indication of its mineral content and high ash content implies that the food material is rich in minerals. The fat content of the complementary foods varied significantly ($p<0.05$) with the control sample (100% pearl millet flour) recording the highest value (3.70%).

The fat content decreased with increase in supplementation with African yam bean and carrot flours. The least value of fat content (3.00%) was recorded for sample MAC_3. This result is not surprising since pearl millet had the highest fat content as seen in Table 1. The values for fat obtained in this study are lower than the values (9.92-12.39%) reported for complementary foods from yellow maize, soybean, millet and carrot composite flours (Oyegoke *et al*., 2021). The fat content of all the blends met the recommended dietary allowance (RDA) for fat in foods which is $\geq$ 2.0 mg/100g (FAO/WHO, 1998). Fat in the diet of infants and young children is necessary for the supply of essential fatty acids, eases the absorption of fat soluble vitamins, and improves dietary energy density and sensory quality.

The crude fibre content of the complementary foods ranged from 1.62 – 3.86% with the control sample recording the least value. The values for crude fibre significantly ($p<0.05$) increased with increased percent incorporation of African yam bean and carrot flours into pearl millet flour. This increase might be due to the factthat African yam bean is a good source of fibre (Arukwe and Arukwe, 2021; Arukwe *et al*., 2021). Earlier researcher, Oyegoke *et al*. (2021) obtained higher crude fibre values (4.93-6.02%) for complementary foods made from yellow maize, soybean, millet and carrot composite flours. The crude fibre values obtained in this study (1.62 – 3.86%) are below the recommended dietary allowance (4.0 mg/100g) for crude fibre in foods (FAO/WHO, 1998) except sample MAC_3(3.86%) which approximately met the recommended allowance of crude fibre for infants. The low crude fibre content of the blends is in line with the work of Michaelsen *et al*. (2010) who noted that complementary foods should contain low fibre because high fibre can lead to high water absorption and displacement of nutrients and important energy needed for growth of children less than 24 months. Fibre plays important role in greater use of nitrogen and absorption of some other micronutrients.

The carbohydrate content of the formulated blends ranged from 76.12 – 62.61%. The control sample (100% pearl millet) had the highest carbohydrate content. The carbohydrate content of the samples significantly ($p<0.05$) decreased with increase in the addition of African yam bean and carrot flours. Pearl millet is a carbohydrate food, consequently the highest carbohydrate values in sample M100 (76.12%) and sample MAC_1 (74.15%) which contain 100% and 90% proportion of pearl millet respectively. The decrease in carbohydrate due to inclusion of African yam bean is in consonance with the report that addition of legumes decreases the carbohydrate content of cereal-based foods (Mbata *et al*., 2009; Arukwe *et al*., 2021). The values for carbohydrate obtained in this study are higher compared to the values (50.27-57.51%) reported by Oyegoke*et al*. (2021) for complementary foods prepared from yellow maize, soybean, millet and carrot composite flours. The recommended dietary allowance (RDA) for carbohydrate in foods is $\geq$ 60 mg/100g (FAO/WHO, 1998) and all the blends carbohydrate contents are above this requirement.

The energy value of the complementary foods ranged between 380.98 kcal/100g and 356.32 kcal/100g with the control sample having the highest value. The energy value significantly ($p<0.05$) decreased with increased addition of African yam bean and carrot flours. This could be attributed to the low carbohydrate content observed in pearl millet, African yam bean and carrot flour blends. The energy content obtained in this study is relatively higher than that recommended for infants in developing countries which is 200 kcal for the 6 – 8 months old and 300 kcal for the 9 – 11 months of age. However, the values for energy are lower than 500 kcal per day for 12 – 23 months of age (FAO/WHO, 1998).

Overall, the inclusion of African yam bean and carrot flours to pearl millet increased the nutrient content of the blends, particularly sample MAC_3 is nutrient-dense and met the recommended dietary allowance for protein, fat, ash, energy among others and could serve the purpose of alleviating protein, energy and micronutrient malnutrition in Nigeria and other developing countries when used in place of the traditional cereal-based diets for infants.

Mineral Contents of Formulated Complementary Foods

Table 3 shows the mineral content of the complementary foods formulated from blends of pearl millet, African yam bean and carrot flours. The levels of magnesium, potassium, calcium, iron and zinc significantly ($p<0.05$) increased as the proportion of African yam bean and carrot flours increased in the blends. This increase confirms the beneficial effect of supplementation (Lutter and Dewey, 2003). A significant difference ($p<0.05$) was obtained in the magnesium content which ranged between 140 mg/100g and 166 mg/100g. The control sample (100% pearl millet flour) had the lowest value (140 mg/100g) while sample MAC_3 had the highest magnesium content (166 mg/100g).The increased magnesium content can be attributed to the inclusion of African yam bean and carrot flours. This is in consonance with the report that African yam bean is rich in magnesium (Obatolu *et al*., 2007; Arukwe and Arukwe, 2021). Silva Dias (2014) noted that carrot is a good source of magnesium. The recommended magnesium intake for infants of 7 – 12 months is 54 mg/day (WHO/FAO, 2004) and all the blends met this requirement. Magnesium helps in proper functioning of muscles, provides bone strength, aids enzyme, nerve and heart functions (Osaloni*et al*., 2019). The potassium content of the complementary foods varied significantly ($p<0.05$) and ranged from 301-535.50 mg/100g. The lowest value was recorded for the control sample while the sample MAC_3 had the highest value (535.50 mg/100g) of potassium. The increases in potassium could be attributed to the incorporation of African yam bean and carrot flours to the blends. The potassium contents of the formulated complementary sample MAC_3met the recommended dietary allowance of potassium for infants less than one year which is 500mg/100 g (Ukegbu and Anyika, 2012) while the other samples were less than the recommended requirement. Potassium is an electrolyte essential in the homeostatic balance of body fluids. It plays an important role in the treatment of high blood pressure.

The calcium content of the blends increased significantly ($p<0.05$) from 41.10 mg/100g in the control sample (100% pearl millet flour) to 340.82 mg/100g in sample MAC_3(70% pearl millet flour, 20% African yam bean flour and 10% carrot flour). The observed increase in calcium contents is an indication that African yam bean and carrot flours are rich in calcium. The values for calcium obtained in this study for sample MAC_3 (340.82 mg/100g) met the recommended calcium intake (295mg/100 g) for infants (Oyarekua, 2009) while the other samples did not meet the requirement. Calcium is an important micronutrient in infants and young children for building bones and teeth, functioning of muscles and nerves, blood clotting and immune defense, regulation of the tone and contractility of heart and acts as an antidote to the depressant action of potassium (Pravina *et al*., 2013). Calcium helps rennin in the coagulation of milk in the stomach. The iron content varied significantly ($p<0.05$) ranging from 7.56-11.65 mg/100g. The lowest iron content was recorded for the control sample which gradually increased with the substitution of pearl millet flour with African yam bean and carrot flours. The sample MAC_3 had the highest (11.65 mg/100g) iron content. The iron contents of the formulated blend MAC_3met the recommended iron intake (11.6 mg/day) for infants of 7 – 12 months (WHO/FAO, 2004). Iron is an important component of the red blood cells (Agbon *et al*., 2009) and is essential for prevention of anaemia in infants and children. The zinc content ranged from 6.48-8.86 mg/100g. The zinc content of the samples significantly ($p<0.05$) increased with increase in supplementation of pearl millet flour with African yam bean and carrot flours. The recommended zinc intake is 8.6 mg/day for infants of 7 – 12 months (WHO/FAO, 2004) and the blend MAC_3met this requirement. Zinc is an integral component of enzymes, and plays important role in all the major metabolic pathways.

Vitamin Content of Formulated Complementary Foods

Vitamins are needed for normal functioning of the body. The vitamin contents of the complementary foods made from blends of pearl millet, African yam bean and carrot flours are presented in Table 4. Significant ($p<0.05$) differences existed in the beta carotene, ascorbic acid, thiamin, riboflavin and niacin contents of the blends. The beta-carotene (provitamin A) content of the samples varied significantly ($p<0.05$) ranging from 5010.10 – 8022.50 ug/100 g, with the control sample (100% pearl millet flour) recording the lowest value and sample MAC_3 having the highest value. The increase observed in the values of beta-carotene with increased addition of African yam bean and carrot flours is expected because carrot is a good source of beta-carotene, a precursor of vitamin A. The increased content of beta-carotene in the blends will help to check the prevalence of vitamin A deficiency diseases (VAD) in the population. The recommended daily intake for infants of 6-24 months for vitamin A is 400 ug RE/day (FAO/WHO, 2002) and all the blends met this requirement. Vitamin A is required for normal vision, gene expression, reproduction, development of embryo, growth and immune functions. Vitamin A also acts as free-radical scavenger (Bramley, 2000).

The ascorbic acid (vitamin C) content showed significant differences ($p<0.05$) among the samples with the control sample having 4.01 mg/100 g. The ascorbic acid contents of the samples significantly ($p<0.05$) increased with increased inclusion of African yam bean and carrot flours to the blends, with sample MAC_3 having the highest value (8.50 mg/100 g).The increase obtained in ascorbic acid content might be due to the fact that African yam bean and carrot flours are rich in ascorbic acid. The recommended dietary allowance for ascorbic acid (vitamin C) in infant's is 3.6 mg/100 g (Ukegbu and Anyika, 2012) and all the samples met this requirement. Ascorbic acid (vitamin C) functions as an antioxidant and free-radical scavenger. The thiamin (vitamin B1) content recorded significant ($p<0.05$) increase with increased substitution of African yam bean and carrot flour to pearl millet flour ranging from 0.53 – 1.23 mg/100 g. The increase observed in thiamin content suggests that African yam bean and carrot flours are rich in thiamin. The values obtained for thiamin in this study for sample MAC_3 met the recommended dietary allowance of 1.2 mg/100 g for infants (Okafor *et al*., 2018; Richardson, 1997) whereas the other samples did not meet this requirement. Thiamin acts as co-enzyme in the metabolism of energy. The riboflavin (vitamin B2) content of the samples increased significantly ($p<0.05$) ranging from 0.16 mg/100g in the control sample to 1.30 mg/100 g in sample MAC_3. This result shows that African yam bean and carrot flours are good sources of riboflavin. The recommended dietary allowance for riboflavin in infants is 1.3 mg/100 g (Okafor *et al*., 2018; Richardson, 1997) and only sample MAC_3 met this requirement. Riboflavin is necessary for growth and development of infants and children (Okwu, 2004). The niacin (vitamin B3) content of the samples significantly ($p<0.05$) increased from 10.25 mg/100 g for the control sample to 17.15 mg/100 g for sample MAC_3 with increase in percent addition of African yam bean and carrot flours to pearl millet flour. The observed increase can be attributed to the fact that African yam bean and carrot flours are good sources of niacin. The niacin content obtained for sample MAC_3 met the recommended dietary allowance for infants which is 16 mg/100 g (Okafor *et al*., 2018; Richardson, 1997) while the other samples are less than the requirement. Niacin is part of the respiratory co-enzyme (nicotinamide adenine dinucleotide - NAD) that is necessary for tissue oxidation in the human body.

The increase in the availability of minerals and vitamins in this study can be attributed to the removal of antinutritional factors which interfere with the absorption of nutrients through the processing methods of fermentation and heat treatments.

The result obtained in this study has proved that the incorporation of African yam bean and carrot flours into pearl millet flour in the production of complementary foods yielded nutrient-dense products. This is substantiated by the increased protein, ash, crude fibre, magnesium, potassium, calcium, iron, zinc, and vitamins A, C, thiamin, riboflavin and niacin.

Sensory Acceptability of Formulated Complementary Foods

The sensory evaluation results of the complementary foods are presented in Table 5. There were significant ($p<0.05$) differences among the samples in flavor, texture, appearance and overall acceptability. The result shows that the inclusion of African yam bean and carrot flours into pearl millet flour did not have any significant difference ($p>0.05$) in the taste as observed by the panelists. The control sample (100% pearl millet flour) without any supplementation had significantly ($p<0.05$) the lowest score for all the parameters assessed while sample MAC_3 had the highest. Sample MAC_3had mean scores of 7.80 and 7.80 for appearance and overall acceptability respectively signifying most acceptable. This result shows that as the percent of inclusion of African yam bean and carrot flours increased, the score for appearance and the overall acceptability increased. Therefore, African yam bean and carrot flours improved the appearance of the porridge. Appearance of a product increases its attractiveness and acceptability.

Conclusion

The complementary foods formulated from blends of pearl millet, African yam bean and carrot flours in this study could be useful to mothers in feeding their children during the weaning period. The results showed that protein, crude fibre, ash, fat, carbohydrate, energy and micronutrients met the recommended dietary allowance which is beneficial both for the growth and wellness of the child and the affordability, since the raw materials for the production of the complementary foods are locally available. The addition of African yam bean and carrot flours into pearl millet flour enhanced the quality of the complementary foods both nutritionally and in sensory acceptability.

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Table 1: Proximate Composition and Energy Value of Composite Flours

Flour Sample	Moisture %	Protein %	Ash %	Fat %	Crude Fibre %	Carbohydrate %	Energy Kcal/100g
Pearl millet	$7.02^a \pm 0.01$	$10.73^b \pm 0.0$	$0.67^c \pm 0.02$	$3.66^a \pm 0.01$	$1.58^c \pm 0.0$	$76.77^b \pm 0.01$	$382.94^a \pm 0.0$
African yam bean	$7.10^a \pm 0.02$	$20.05^a \pm 0.01$	$3.60^a \pm 0.0$	$2.73^b \pm 0.01$	$5.30^a \pm 0.01$	$61.22^c \pm 0.02$	$349.65^c \pm 0.01$
Carrot	$7.50^{ab} \pm 0.00$	$1.01^c \pm 0.02$	$1.20^b \pm 0.01$	$0.35^c \pm 0.02$	$2.20^b \pm 0.02$	$87.74^a \pm 0.00$	$358.15^b \pm 0.00$

means with different superscripts down the column are significantly different (p<0.05)

Table 2: Proximate composition and Energy Value of Formulated Complementary Foods

Sample	Moisture %	Protein %	Ash %	Fat %	Crude Fibre %	Carbohydrate %	Energy Kcal/100g
M100	$7.06^a \pm 0.01$	$10.80^d \pm 0.02$	$0.70^d \pm 0.02$	$3.70^a \pm 0.00$	$1.62^d \pm 0.01$	$76.12^a \pm 0.10$	$380.98^a \pm 0.00$
MAC_1	$7.07^a \pm 0.10$	$12.13^c \pm 0.01$	$1.33^c \pm 0.00$	$3.30^b \pm 0.01$	$2.02^c \pm 0.01$	$74.15^b \pm 0.00$	$374.82^b \pm 0.01$
MAC_2	$7.10^a \pm 0.00$	$15.70^b \pm 0.10$	$2.42^b \pm 0.01$	$3.10^c \pm 0.02$	$3.11^b \pm 0.02$	$68.57^c \pm 0.02$	$364.98^c \pm 0.00$
MAC_3	$7.11^a \pm 0.00$	$19.72^a \pm 0.01$	$3.70^a \pm 0.00$	$3.00^d \pm 0.00$	$3.86^a \pm 0.00$	$62.61^d \pm 0.01$	$356.32^d \pm 0.10$

means with different superscripts down the column are significantly different (p<0.05)

Key: M100 = 100% pearl millet flour, MAC_1 = 90% pearl millet flour, 5% African yam bean flour and 5% carrot flour, MAC_2 = 80% pearl millet flour, 15% African yam bean flour and 5% carrot flo ur, MAC_3 = 70% pearl millet flour, 20% African yam bean flour and 10% carrot flour

Table 3: Mineral Contents of Formulated Complementary Foods (mg/100g)

	Magnesium	Potassium	Calcium	Iron	Zinc
M100	$140.11^d \pm 0.01$ Sample	$301.00^d \pm 0.0$	$41.10^d \pm 0.0$	$6.56^d \pm 0.02$	$6.48^d \pm 0.02$
MAC_1	$148.50^c \pm 0.02$	$387.50^c \pm 0.01$	$78.50^c \pm 0.0$	$7.80^c \pm 0.00$	$6.85^c \pm 0.01$
MAC_2	$153.00^b \pm 0.02$	$460.10^b \pm 0.0$	$156.10^b \pm 0.0$	$9.11^b \pm 0.01$	$7.88^b \pm 0.00$
MAC_3	$166.20^a \pm 0.01$	$535.50^a \pm 0.02$	$340.82^a \pm 0.0$	$11.65^a \pm 0.02$	$8.86^a \pm 0.02$

Table 4: Vitamin Content of Formulated Complementary Foods

Sample	Beta-carotene (ug/100 g)	Ascorbic acid (mg/100 g)	Thiamin (mg/100 g)	Riboflavin (mg/100 g)	Niacin (mg/100 g)
M100	$5010.10^d \pm 0.01$	$4.01^d \pm 0.0$	$0.53^d \pm 0.02$	$0.16^d \pm 0.03$	$10.25^d \pm 0.00$
MAC_1	$6021.00^c \pm 0.02$	$5.0^c \pm 0.01$	$0.80^c \pm 0.0$	$0.60^c \pm 0.01$	$12.10^c \pm 0.00$
MAC_2	$7100.15^b \pm 0.00$	$6.90^b \pm 0.02$	$1.02^b \pm 0.01$	$1.22^b \pm 0.02$	$14.63^b \pm 0.00$
MAC_3	$8022.50^a \pm 0.01$	$8.50^a \pm 0.01$	$1.23^a \pm 0.0$	$1.30^a \pm 0.04$	$17.15^a \pm 0.00$

Table 5: Sensory Properties of Formulated Complementary Foods

Sample	Flavour	Texture	Taste	Appearance	Overall Acceptability
M100	$6.00^d \pm 0.0$	$6.10^d \pm 0.0$	$6.00^a \pm 0.0$	$6.00^d \pm 0.0$	$6.00^d \pm 0.0$
MAC_1	$6.20^c \pm 0.0$	$6.30^c \pm 0.0$	$6.01^a \pm 0.0$	$6.50^c \pm 0.0$	$6.30^c \pm 0.0$
MAC_2	$7.50^b \pm 0.0$	$7.30^b \pm 0.0$	$6.01^a \pm 0.0$	$7.40^b \pm 0.0$	$7.50^b \pm 0.0$
MAC_3	$7.80^a \pm 0.0$	$7.50^a \pm 0.0$	$6.02^a \pm 0.0$	$7.80^a \pm 0.0$	$7.80^a \pm 0.0$