African Journal of Agriculture and Food Science
ISSN: 2689-5331
Volume 7, Issue 2, 2024 (pp. 199-218)
www.abjournals.org

CHEMICAL COMPOSITION, MICROBIOLOGICAL AND SENSORY QUALITIES OF BANANA BASED COMPLEMENTARY DIETS FORTIFIED WITH AFRICAN BREADFRUIT SEED AND CARROT FLOURS

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Cite this article:

Edima-Nyah A. P., Effiong B. N., Ndah L. S., Ntukidem V. E., Ekanem M. C., Ogbonna C. A. (2024), Chemical Composition, Microbiological and Sensory Qualities of Banana Based Complementary Diets Fortified with African Breadfruit Seed and Carrot Flours. African Journal of Agriculture and Food Science 7(2), 199-218. DOI: 10.52589/AJAFS-PO1ZG9QP

Manuscript History

Received: 11 Mar 2024

Accepted: 17 May 2024

Published: 17 Jun 2024

ABSTRACT: *About the age of six months, an infant requires more nutrients and energy than those provided by the breast milk, and complementary diets are therefore introduced to meet those needs. The objective of this study was therefore to develop and evaluate complementary diets from cooking banana, African breadfruit seeds and carrot flour blends. Ratios of cooking banana, African breadfruit seed and carrot flour blends in 90:0:10 as Diet 1, 85:5:10 as Diet 2, 80:10:10 as Diet 3, 75:15:10 as Diet 4 and 70:20:10 as Diet 5, were used for formulation of complementary diets. The flour blends for diet production showed bulk density and gelatinization temperature decreased from 0.98 to 0.65 g/ml and 85.67 to 78.10°C respectively, while swelling and water absorption capacity increased from 268.33 to 295.00% and 208.33 to 243.33% respectively, with increase in African breadfruit seed flour in the composite blends. Phytate (1.25 – 11.03 mg/100g) and trypsin inhibitor activities (1.05 – 1.17 TIU/100g) increased with increasing African breadfruit flour supplementations. Proximate composition of diets showed increased protein (2.16 – 18.47%), fat (1.81 – 2.23%), ash (2.42 – 2.96 %) and decreased carbohydrate (73.14 – 89.80%). Iron and calcium content of Diets increased from 14.11 – 19.23mg/100g and 28.24 – 43.23 mg/100g, while magnesium decreased from 6.24 – 8.25mg/100g respectively with increasing African breadfruit flour. Vitamin A and C decreased from 13.09 to 9.16 and 0.98 – 0.75mg/100g respectively. Microbial quality of all Diets developed were within the acceptable limit of 10^3 cfu/g for both total bacterial (TBC) and total fungal count (TFC). Diet 3 (80:10:10) was most accepted in sensory qualities. Complementary diets produced with 80% cooking banana, 10% African breadfruit seed and 10% carrot flour blends could help fill the gaps, when transitioning from breast milk to family diet, to provide the essential nutrients and energy required for infant's activity, optimum growth and development.*

KEYWORDS: Complementary diets, Cooking banana, African breadfruit seed, Carrot, Sensory qualities, Formulation.

Article DOI: 10.52589/AJAFS-PO1ZG9QP
DOI URL: https://doi.org/10.52589/AJAFS-PO1ZG9QP

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INTRODUCTION

All the nourishments needed for growth and development of a baby in the first six months are provided by breast milk. However, once an infant reaches six months, there is a need to introduce semi-solid or solid foods into the diet of the infant to improve the nutrition for growth and development. Complementary foods are those foods given to older infants and young children once breast milk alone is no longer adequate to meet their nutritional needs after the exclusive period of breastfeeding (Okeye *et al.*, 2018). Most infants suffer from malnutrition not mainly because of economic status, but also due to inability to utilize the locally available raw materials to formulate infant foods that will meet their daily requirements (Ojinnaka *et al.*, 2013).

Complementary feeding is the period when malnutrition starts in many infants contributing significantly to the high prevalence of malnutrition in children that are less than five years of age all over the world (Okeye *et al.*, 2018). Infant feeding and rearing practices have a major effect on short term and long-term nutritional status of children as most undernutrition is associated with faltering practices that occur in weaning period. Faulty feeding practices as well as lack of suitable complementary foods are responsible for undernutrition in older infants and young children (Daelmans & Saadeh, 2003). As in Nigeria and most other developing countries of the world, the high cost of fortified, nutritious and proprietary complementary foods is always beyond the reach of most Nigerian families. Such families often depend on inadequately processed traditional foods consisting mainly of un-supplemented cereal-based porridges made from maize, sorghum or millet which are grossly inadequate in some macro and micronutrients (Nnam, 2001). However, there is a need for low-cost complementary foods that can be easily prepared at home and community kitchens from locally available food crops using the simple processing techniques that are within the reach of the general public. In developing countries such foods can be more nutritious than most of the commercial brands that abound in major markets. To provide nutritionally adequate and balanced complementary foods, it is important to have mixtures of a variety of foods that fulfill macro- and micro-nutrient needs of the infants. The young infant has a small stomach and can only consume small amounts of food at a time. Thus, it is important to feed the child with energy and nutrient dense meals (Adenuga, 2010).

Banana is a major staple food; it is starchy, rich in carbohydrate, calcium, phosphorus, iron and other food nutrients (Onwuka *et al.*, 2015). Cooking banana is a species of banana that is shorter, fatter and heavier than plantain and because of this, it is common in the market and less attractive to consumers, hence attracts low price in the market (Strosse *et al*., 2006). Most producers of cooking bananas are small-scale farmers either for home consumption or local markets. Cooking bananas produce fruit all year-round, they provide an extremely valuable food source during the hunger season (when the food from annual/semi-annual harvest has been consumed and the next is still to come). Cooking bananas is therefore critical to global food security. The shelf life of cooking bananas is relatively short and at the ripe stage becomes too soft and difficult to pound, slice or fry. In order to avert these problems encountered during processing, it may be necessary to convert fresh bunches of cooking bananas into flour to increase its utilization and improve its market potential which will be of good advantage to food processors (Onwuka *et al.*, 2015). Cooking banana flour is potential flour, which could be used for various food formulations.

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The African breadfruit (*Treculia africana*) is a neglected and under-exploited tropical tree belonging to the taxonomic family *Moracceae* (Osuji & Owei, 2010). According to Edima-Nyah *et al*. (2019a), it is a common forest tree known by various tribal names in Nigeria, such as *Ukwa* (Igbo), *afon* (Yoruba), *barafuta* (Hausa), *Ize* (Benin), *eyo* (Igala) and *(*Efik/Ibibio). The tree crop is widely grown in the Southern States of Nigeria where it serves as a low-cost meat substitute for poor populace (Badifu & Akubor, 2001). The plant produces large, usually round, compound fruits covered with pointed outgrowths and the seeds are buried in spongy pulp of the fruits. There is an increased interest in African breadfruit seed, which is an important food item among the Igbo tribal group of South-Eastern Nigeria. The seeds are seldom eaten raw but can be baked, boiled, roasted and fried before consumption. Ijeh *et al.* (2010) also reported that the seeds of *Treculia africana* are eaten as a delicacy in the South-Eastern part of Nigeria. Diverse food forms could be produced from the seeds on the basis of custom, tradition and ethnic background. The seeds are highly nutritious and constitute a cheap source of vitamins, minerals, proteins, carbohydrate and fats. The seeds contain 17-23 % crude protein, 11 % crude fat and other essential vitamins and minerals (Akubor *et al*., 2000).

Carrot (*Daucus carota. L*) is one of the important nutritious root vegetables grown throughout the world. It is an excellent source of phyto-nutrients such as phenolics, polyacetylenes and carotenoids (Hansen *et al.*, 2003). The main physiological function of carotenoids is as a precursor of vitamin A (Nocolle *et al.*, 2003). Carotenoids are potent antioxidants present in carrots which help to neutralize the effect of free radicals. Reports have shown that they have inhibitory mutagenesis activity thus, contributing to decreased risk of some cancers (Dias, 2012). In recent times, consumption of carrot and its products has gained wide acceptance as a result of its natural antioxidants properties coupled with the anticancer activities of β-carotene in it which is a precursor of vitamin A (Ibidapo *et al.*, 2017). Consequently, consumption of carrot and its products would be very useful in alleviating vitamin A deficiency particularly, among children below six years and adults. Vitamin A deficiency (VAD) has been reported to be one of the major public health problems in developing countries in which Nigeria is one, hence the need to incorporate it in food formulations.

The increase in infant malnutrition in West Africa during the weaning period has been attributed to inappropriate feeding practices and is responsible for half of the child mortality cases. Weaning is the most important transitional phase for a baby as he starts tasting and eating foods that add nutrients to his body. The need to wean babies generally starts from the age of 6 months and can go on till that of 12 months to 2 years depending on the baby’s intake and type of weaning food and portions. In view of the high price of commercial baby foods and low level of locally made complementary foods, the search for locally available, cheap and high carbohydrate sources for complementary food formulation becomes imperative. Thus, the use of African breadfruit (*Treculia africana*) which is one of the principal sources of energy, protein, vitamins and mineral content is comparable and, in some cases, superior to some cereals or food grains (Adebowale *et al.*, 2008). This present study will lead to encouraging the use of cooking banana which is a local food crop which is quite cheap and easily accessible and also highly nutritious in the production of weaning food and fortified with carrot flour to boost the vitamin and mineral content thereby reducing malnutrition due to inappropriate complementary feeding practices.

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Therefore, the objective of this study is to formulate and evaluate the chemical composition, microbiological and sensory qualities of complementary diets from cooking banana, African breadfruit seeds and carrot flour blends that would meet infant nutritional requirements.

MATERIALS AND METHODS

Materials Procurement/Collection

African breadfruit seeds (*Treculia africana*), cooking banana (*Musa cardaba*) and carrot (*Daucus carota*) were purchased from Itam market in Uyo. The chemicals and other reagents used in this research work were of analytical grade and were obtained from the Department of Food Science and Technology, University of Uyo, Nigeria.

Preparation of African Breadfruit Seed Flour

The African breadfruit seed flour was prepared according to the method described by Giami *et al*. (2004) as shown in Figure 1.

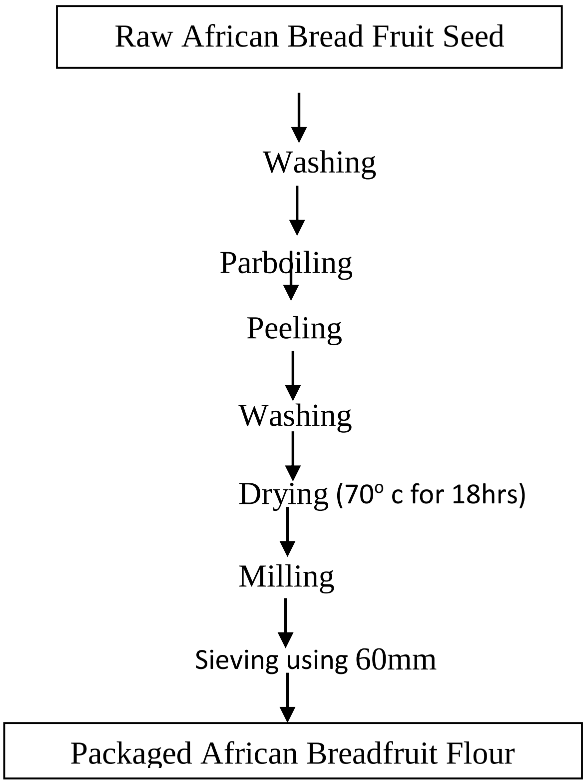

Fig. 1: Flow chart for the preparation of African Breadfruit Flour

Source: *Giami et al. (2004)*

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Preparation of Cooking Banana (*Musa cardaba*)

Cooking banana flour was prepared according to the method described by Edima-Nyah *et al.* (2019b) as shown in Figure 2.

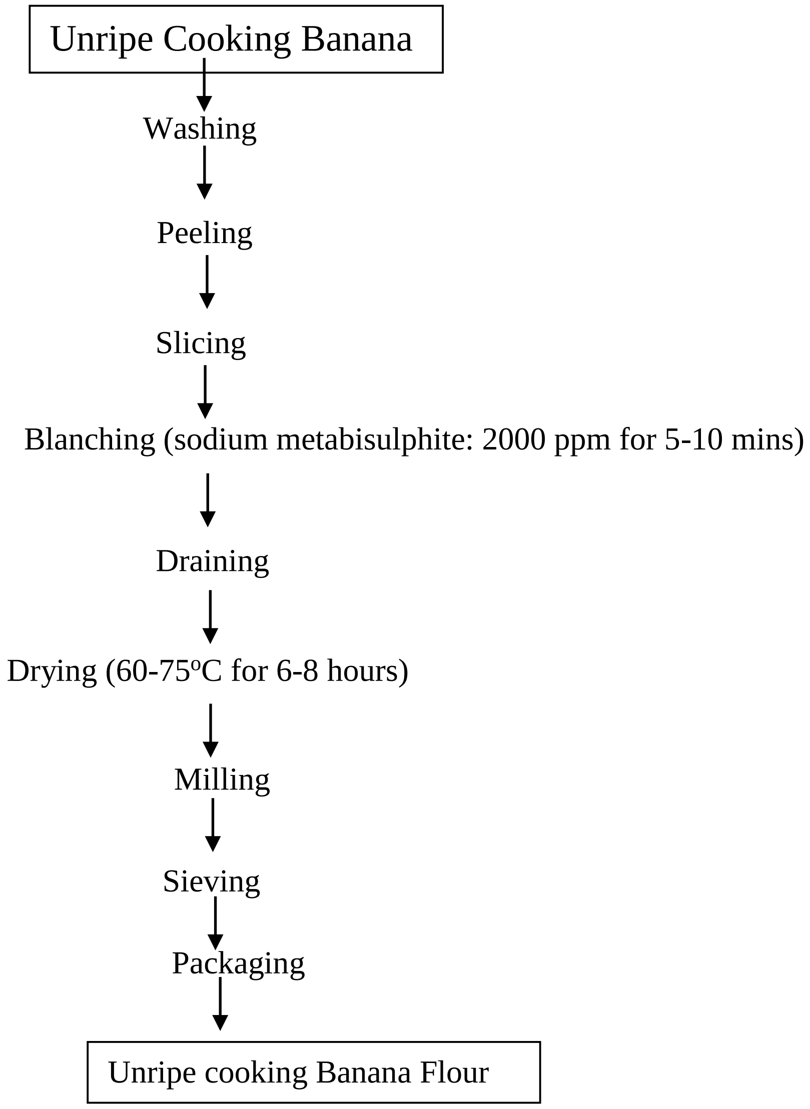

Fig. 2: Flow chart for preparation of unripe banana flour.

Source: *Edima-Nyah et al. (2019b).*

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African Journal of Agriculture and Food Science
ISSN: 2689-5331
Volume 7, Issue 2, 2024 (pp. 199-218)

Preparation of Carrot Flour

The carrot flour was prepared according to the method described by Phebean *et al*, (2017) as shown in Figure 3.

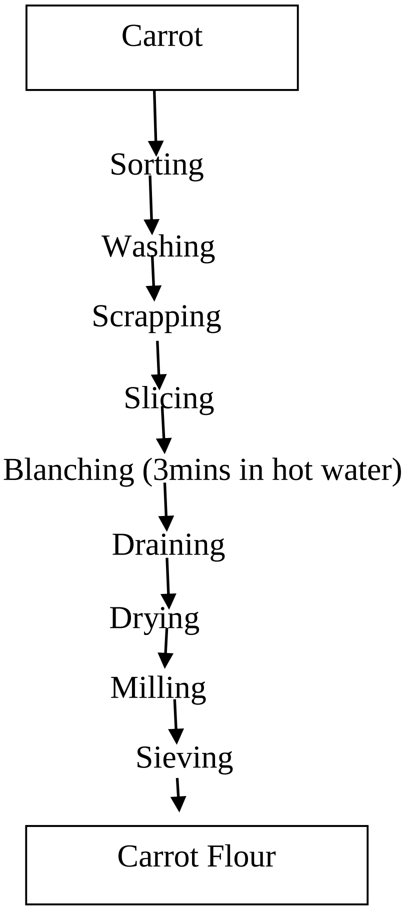

Fig. 3: Flow chart for the production of carrot Flour

Source: *Phebean et al. (2017)*

PRODUCT FORMULATION

The composite flours of the three raw materials were blended to form five (5) food formulations as in Table 1.

Table 1: Formulation of Flour Blends for Development of Complementary Diets

Food Sample	Cooking banana	African breadfruit	Carrot	Total
Diet 1	90	0	10	100
Diet 2	85	5	10	100
Diet 3	80	10	10	100
Diet 4	75	15	10	100
Diet 5	70	20	10	100

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Evaluation of Functional Properties of Formulated Flours Blends

Absorption Capacity (WAC)

Water absorption capacity was determined by the method of the (AACC 1995). A 2g of each diet was dispersed in 200 ml of distilled water. The contents were mixed for 30 seconds every 10 minutes using a glass rod and after mixing five times, it was centrifuged at 4000 g for 20 min. The supernatant was carefully decanted and then contents of the tube were allowed to drain at a 450 angle for 10 min before it was weighed. The water absorption capacity was expressed as a percentage increase of the sample weight.

Swelling Capacity (SC)

Swelling capacity was determined by the method described by Adepeju *et al.* (2014). 3-5g of the diets were weighed into a tarred 50 ml centrifuge tube. About 30 ml distilled water was added and mixed gently. The slurry was heated in a water bath at 95^{o}C for 30 min. During heating, the slurry was stirred gently to prevent clumping of the sample. On completion of the 30 min, the tube containing the paste was centrifuged at 3000 g for 10 minutes. The supernatant was decanted immediately after centrifugation. The tubes were dried at 50^{o}C for 30 min, cooled and then weighed (W2). Centrifuge tubes containing samples alone were weighed prior to adding distilled water (W1). Swelling capacity was calculated as follows:

$$\text{Swelling Index} = \frac{\text{volume occupied by sample after swelling} \quad \text{volume occupied by sample after swelling}}{\text{volume occupied by sample before swellingvolume occupied by sample before swelling}}$$

Bulk Density

The bulk density was determined by the method of Adepeju *et al.* (2014). A 10 ml graduated cylinder, previously tarred, was gently filled with the complementary diet. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was no further diminution of the sample level after filling to the 10 ml mark. Bulk density was calculated as: Weight of sample per unit volume of sample (g/ml).

$$\text{Bulk Density} = \frac{\text{Weight differenceWeight difference}}{\text{Initial Volume} \quad \text{Initial Volume}}$$

Gelatinization Temperature (GT)

This was determined using the procedure of Onwuka (2005). Ten grams (10g) of the sample was suspended in distilled water in a 250ml beaker and made up to 100 ml sample suspension. The aqueous suspension was heated in a boiling water bath with continuous stirring using a stirrer. A thermometer was then clamped on the retort stand with its bulb submerged in the suspension. The heating and stirring continued until the suspension began to gel and the corresponding temperature was recorded.

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Development of Complementary Diets

One hundred grams of each blend was mixed in 880 mL of water and stirred to obtain consistent slurry. One gram of salt and 25 g of sugar were added to the slurry before boiling for 6-8 min into cooked porridges. Plate 3.1 shows the gruel prepared from the diet formulations.

Plate 1: Prepared Complementary Foods

DIET 1= 90:0:10, DIET 2= 85:5:10, DIET 3= 80:10:10, DIET 4= 75:15:10 and DIET 5= 70:20:10 of cooking banana, African breadfruit and carrot flour blends respectively.

Determination of Anti-nutrients

Determination of Phytic Acid:

This was determined using the method described by Onwuka (2005). The sample was first extracted with 0.2N HCL, 0.5ml of the extract solution was pipette into a test tube fatted with a round glass stopper. Ferric acid solution (1 ml) was added and the tube was covered well. The tube was later heated in a boiling water bath for 30 min. After heating, the tube was cooled in ice water for 15 min and allowed to adjust to room temperature. The tube was then mixed and centrifuged for 30 min at 3000 rpm. The supernatant (1ml) was transferred to another tube and 1.5ml of 2, 2, Bipyridine solution and the absorbance were measured at 519 nm against distilled water.

Calculation:

Phytic Acid (mg/g) = $\left(\frac{VF}{VX} \times \frac{100}{W} \times \frac{1}{100}\right)\left(\frac{VF}{VX} \times \frac{100}{W} \times \frac{1}{100}\right)$

Where:

Vf = Total volume of extract

Vx = Volume of extract used

w = weight of sample used

x = ppm of curve.

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Determination of Trypsin Inhibitor

Trypsin inhibitor activity was determined according to standard procedures of AOAC (2005).

Determination of Proximate Composition

Moisture content, protein, fat, ash, fiber, and carbohydrate were determined using the standard method of AOAC - Association of Official Analytical Chemists (2005).

Determination of Total Energy: The total energy value of the food formulation was calculated according to the method of Mahgoub (1999) using the formula as shown in the following equation.

Total energy= (% available carbohydrate×4) + (% protein ×4) + (% fat × 9)

Determination of Minerals: Mineral content (iron, calcium, magnesium and potassium) was determined using Atomic Absorption Spectrophotometer (UNICAM – Model: 939, UK) as described by Association of Official Analytical Chemists - AOAC (2005). All determinations were done in triplicates.

Determination of Vitamins

Determination Vitamin A (Beta-carotene)

This method involved chromatographic separation and quantitative determination at 325 nm as described by AOAC (2010). 5g of the samples were weighed and placed in 100 Ml volumetric flasks and homogenized. The samples were saponified with ethanolic KOH (antioxidant added) for 30 min and transferred into the separator funnel, rinsed usingH_2O/ETOH and repeatedly extracted with hexane. The samples were separated and determined by HPLC using MEOH/H_2O, 95/5(v/v) as the mobile phase. A UV detector set at325 nm was used to detect the amount of retinol content of the samples.

Determination of Ascorbic Acid (Vitamin C)

The method described by Okwu and Josiah (2006) was used. Exactly 10g of the sample was extracted with 50 ml EDTA/TCA (50g in 50ml of water) extracting Solution for I hour and filtered through a Whatman filter paper into a 50ml volumetric flask and made up to the mark with the extracting solution. Twenty (20ml) of the-extract was pipette into a 250ml conical flask and 10ml of 30% K.I was added and also 50 ml of distilled water added. This was followed by 2 ml of 1% starch indicator. This was titrated against 0.0ml $CuSO_4$ solution to a dark end point.

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Microbiological Analysis of Samples

The total heterotrophic bacteria and fungi count was carried out using standard microbiological technique. Pour plate method was used as described by Prescott *et al.* (2005); the samples were first serially diluted to 5-fold dilution. One ml (1ml) of each aliquot (stock) sample were aseptically transferred into sterile 9ml blank in a test tube to give a dilution of 10^{-2} for all the samples.1 ml from the 3rd dilution of each sample was transferred into sterile petri dishes. About 20 ml of sterile nutrient agar, macconkey agar, mannitol salt agar, salmonella shigella agar, eosin methylene blue agar, thiosulphate citrate bile salt sucrose agar, were aseptically poured into the seeded plates and swirled to mix with the inoculums. The plates were incubated at 28 degrees for 24-48 hrs using the Gallenkamp incubator, and fungi plates were incubated at 28 degrees for 5-7 days. After incubation, plates that developed were counted and recorded as colony forming units per ml.

Bacteria load (cfu/ml) = N x 1/v x D

Where: N = Number of colonies counted; V =Volume of inoculums; D = Dilution factors Discrete bacteria colonies in culture plates were selected using sterilized wire loop and sub-cultured from the mixed cultures on freshly prepared agar plates and were incubated at $28^{o}C$ for 24 hours. The discrete colonies were further sub-cultured on SDA plates and were incubated at $37^{o}C$ for another 24 hours for each isolate respectively (Adelekan *et al*., 2013).

Sensory Evaluation of the diets

The complimentary food samples including the control sample were coded randomly and served hot in transparent dessert plates. Sensory evaluation was carried out by 15 panelists. The panelists were given water to rinse their mouth after each sampling and a 9-point hedonic scale, where 9 is “like extremely” and 1 is “dislike extremely”, was used to express the degree of liking and disliking based on taste, appearance, aroma, texture/consistency and overall acceptability.

Statistical Analysis

Data obtained from sensory, proximate, functional, vitamins and minerals determinations were analyzed with SPSS (Statistical Package for Social Sciences) Version 16.0 to determine their mean values and standard deviations. Analysis of variance (ANOVA) was carried out to test the level of significance and also compare and separate treatment means using New Duncan Multiple Range Test. Significance was accepted at 95% confidence interval.

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RESULTS AND DISCUSSION

Functional properties of flour blends

Table 2 shows the results of the functional properties of the various samples of the formulated complementary foods from cooking banana, African breadfruit and carrot. There were significant differences ($p<0.05$) among the samples. The bulk density ranged from 0.65 to 0.98 with Diet1 having the highest value. All the diets were significantly different ($p<0.05$). The results obtained for the swelling capacity were generally high with the values ranging from 268.33 to 295.00. The water absorption capacity ranged from 208.33 to 243.33 with diet 1 having the lowest value, there was no significant difference ($p>0.05$) observed in the sample. The gelation temperatures ranged from 85.67 to 78.10 and significant differences ($p<0.05$) existed among the samples.

Table 2: Functional Properties of Formulated Flour Blends for Development of Complementary Foods from Cooking Banana, African Breadfruit and Carrot Flour Blends

Samples	Bulk density (g/ml)	Swelling Capacity (%)	Water Absorption capacity (%)	Gelation Temperature (°C)
Diet 1	$0.98^{a}\pm0.01$	$268.33^{d}\pm2.89$	$208.33^{b}\pm2.87$	$85.67^{a}\pm0.58$
Diet 2	$0.96^{b}\pm0.01$	$270.67^{cd}\pm1.17$	$216.67^{b}\pm5.77$	$80.33^{b}\pm0.58$
Diet 3	$0.79^{c}\pm0.01$	$286.67^{ab}\pm5.77$	$220.00^{b}\pm1.00$	$78.67^{c}\pm0.58$
Diet 4	$0.67^{d}\pm0.01$	$280.20^{bc}\pm0.80$	$218.33^{b}\pm2.89$	$78.33^{c}\pm0.58$
Diet 5	$0.65^{e}\pm0.01$	$295.00^{a}\pm5.00$	$243.33^{a}\pm11.54$	$78.10^{c}\pm0.17$

Values are means ±SD of triplicate determinations. Means differently superscripted along the vertical columns are significantly different. Diet 1:90:0:10, Diet 2: 85:5:10, Diet 3:80:10:10, Diet 4:75:15:10, Diet 5:70:20:10 of Cooking banana: African breadfruit: Carrot flour blends.

Anti-nutrient Content of Complementary Foods

Phytate and trypsin inhibitor activity content of complementary foods formulated with cooking banana, African breadfruit seed and carrot flour bends are shown in Table 4.4. Phytate content of samples ranged from 1.25 to 11.03 mg/100g. Phytate composition increased significantly with increased proportion of African breadfruit seed flour in the blend formulation. Values of phytate content were higher than the values reported for raw *Treculia africana* seeds (2.16 mg/100g) by Osabor *et al. (*2009). This could be due to the processing technique, time and method used.

Trypsin inhibitor content of the diet samples ranged from 1.05 to 1.17 mg/100g, with Diet 5 having the highest value of 1.17, while Diet 1 had the least value of 1.05. These values were lower than values obtained in African breadfruit seed flour (3.00mg/100g) by Nwaigwe and Adejumo (2015). This may possibly be due to the processing techniques being used.

Article DOI: 10.52589/AJAFS-PO1ZG9QP
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Table 3: Anti-nutrient Content of Formulated Complementary Foods from Cooking Banana, African Breadfruit Seed and Carrot Flour Blends

Samples	Phytate (mg/100g)	Trypsin inhibitor activity (mg/100g)
Diet 1	$1.25^{e}\pm0.01$	$1.05^{b}\pm0.01$
Diet 2	$6.37^{d}\pm00.01$	$1.07^{b}\pm0.01$
Diet 3	$8.45^{c}\pm0.02$	$1.07^{b}\pm0.06$
Diet 4	$8.98^{b}\pm0.01$	$1.15^{a}\pm0.01$
Diet 5	$11.03^{a}\pm0.02$	$1.17^{a}\pm0.01$

Values are means ± SD of triplicate determinations. Means are differently superscripted along the vertical columns and are significantly different ($p<0.05$). Diet 1:90:0:10, Diet 2:85:5:10, Diet 3:80:10:10, Diet 4:75:15:10, Diet 5:70:20:10 of Cooking banana: African breadfruit: Carrot flour blends.

Proximate Composition of Formulated Diets

Results of the proximate composition of the formulated complementary foods are shown in Table 4. Moisture content ranged from 76.17 to 78.52 %, with Diet 6 (control) with the highest value while the lowest value was recorded for Diet 3. Protein contents ranged from 2.16 to 18.47 %, with Diet 1 with the lowest value while Diet 5 had the highest value. Fat value varied from 1.81 to 5.10, with Diet 1 with the lowest value while Diet 6 had the highest value. The highest value of ash content was recorded in Diet 4 and the lowest value was recorded in Diet 6. Fiber content values ranged from 2.08 to 3.11 %, with Diet 6 having the highest value and Diet 5 the lowest value. Carbohydrate values of the samples were generally high ranging from 73.14 to 89.80 %, Diet 1 had the highest value while Diet 5 had the lowest value. Energy values varied slightly amongst the samples ranging from 383.06 to 409.86 kcal/100g, the highest value was recorded in Diet 1 while the lowest value was recorded in Diet 4.

Table 4: Proximate Composition of Formulated Weaning Food from Cooking Banana, African Breadfruit Seed and Carrot Flour Blends

Sample	Moisture (%)	Dry weight basis					Energy value (kcal/100g)
		Protein (%)	Fat (%)	Ash (%)	Fiber (%)	CHO (%)	
Diet 1	$77.69^{c}\pm0.01$	$2.16^{d}\pm0.02$	$1.81^{f}\pm0.01$	$2.42^{e}\pm0.01$	$3.81^{a}\pm0.01$	$89.80^{a}\pm0.02$	$384.13^{b}\pm0.05$
Diet 2	$78.03^{b}\pm0.02$	$6.64^{c}\pm0.02$	$2.12^{e}\pm0.01$	$2.48^{d}\pm0.01$	$3.62^{b}\pm0.02$	$85.15^{b}\pm0.03$	$386.20^{b}\pm0.15$
Diet 3	$76.17^{f}\pm0.02$	$11.92^{b}\pm0.02$	$2.18^{d}\pm0.01$	$2.74^{c}\pm0.01$	$3.31^{c}\pm0.02$	$79.84^{c}\pm0.01$	$386.69^{b}\pm0.06$
Diet 4	$76.94^{e}\pm0.02$	$13.14^{b}\pm1.73$	$2.25^{c}\pm0.02$	$2.87^{b}\pm0.01$	$3.17^{d}\pm0.02$	$77.58^{d}\pm0.02$	$383.06^{b}\pm6.94$

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Diet 5	77.21[d]±0.01	18.47[a]±0.02	2.32[b]±0.01	2.96[a]±0.02	3.11[e]±0.01	73.14[e]±0.03	387.36[b]±0.03
Diet 6 (control)	78.52[a]±0.01	11.42[b]±0.02	5.10[a]±0.01	1.82[f]±0.02	2.08[f]±0.01	79.86[c]±0.04	409.86[a]±0.15

Values are means ± SD of triplicate determinations. Means on the row with different superscripts are significantly different at p<0.05. Diet 1=90:0:10, Diet 2= 85:5:10, Diet 3=80:10:10, Diet 4=75:15:10, Diet 5=70:20:10 of Cooking banana: African breadfruit: Carrot flour blends. Diet 6= Control (Cerelac).

Mineral Composition of Formulated Diets from Cooking Banana, African Breadfruit and Carrot Flour Blends

Results of the mineral composition of formulated complementary diets are shown in Table 5. Mineral elements play a vital role in metabolic processes. This includes regulation of muscle contractions, transmitting of impulses, bone formation, maintenance of osmotic pressure acid-base balance, absorption of glucose among others (Weaver & Heaney, 2006).

Iron content ranged from 14.11 – 19.23 mg/100g. Significant (P<0.05) differences existed amongst the samples. Fe content increased with increase in African breadfruit and decrease in cooking bananas. Obasi *et al.* (2018) reported higher values (20.42-20.88) in formulated weaning foods using sprouted brown rice flour, sprouted African yam bean flour and pawpaw flour blends. When foods with iron, potassium are eaten, it is absorbed into proteins and help these proteins take in, carry and release oxygen throughout the body, iron deficiency "anemia" is very common among children developing nations such symptoms of deficiency included fatigue weakness and shortness of breath (Nnorom *et al.*, 2015).

Calcium content of the complementary diets increased significantly (P<0.05) with an increase in the proportion of African breadfruit flour from 28.24 – 43.23 mg/100g. The result is in line with the findings of Kukwa *et al. (*2018) for Ca content (23.92-35.94 mg/100g) of African yam bean-carrot flour based complementary foods. Calcium content of this research is lower than those reported (155-170 mg/100g) for sprouted brown rice flour, sprouted African yam bean four and pawpaw flour based weaning foods (Obasi *et al*., 2018). This difference may be due to differences in food crops, processing methods and blending ratios used. Calcium is essential in bone and teeth formation and a deficiency of it causes rickets and osteoporosis (Hunt *et al.*, 1980). Although all the samples were below the codex standard for Ca (170 - 400 mg/100g) as reported by Obasi *et al.* (2018), they could be beneficial in child's bone and teeth development.

Magnesium content of the diets ranged from 6.24 – 8.25 mg/100g, decreasing significantly with increase in African breadfruit and decrease in cooking banana flour addition. The result is very low when compared to 56.1 of Ijarotimi (2005) on evaluation of the nutritional composition, sensory and physical properties of a potential weaning food from locally available food material breadfruit and soybean. This may perhaps be due to the variations and proportions of the flour compositions. In terms of the African breadfruit and carrot which are high in magnesium, their proportions could be increased in subsequent formulations for better improvement of the mg content. Magnesium is an activator of many enzyme systems and maintains the electrical potential in the nerves (Adeyeye & Agesin, 2007). It works with Ca to

Article DOI: 10.52589/AJAFS-PO1ZG9QP
DOI URL: https://doi.org/10.52589/AJAFS-PO1ZG9QP

assist in muscle contraction, blood clothing and the regulation of blood pressure and lung functions (Mir-marques *et al.*, 2012).

Values recorded for potassium content of complementary diets ranged from 32.01 to 39.29 mg/100g. Diet 6 had the highest value of 44.12mg/100g, while Diet 1 had the lowest value of 32.01mg/100g. Significant differences (P<0.05) existed among the samples with respect to potassium content. Potassium content increased with increase in African breadfruit, and with decrease in cooking bananas. This slight variation could be attributed to African breadfruit flour inclusion as reported by Wang *et al.* (2011), that African breadfruit is rich in Ca, P, Fe, K, Carotene and Vit. B. Okoye and Egbujie (2018) reported lower values of potassium (4.55-6.32 mg/100g) in maize-based complementary foods fortified with soybean and sweet potatoes. Potassium is a macro element required for the maintenance of cellular water balance, acid-base balance and nerve transmission, and is required in large amounts in the body (Worthyington-Roberts, 2007).

Table 5: Mineral Composition of Formulated Complementary Foods from Cooking Banana, African Breadfruit and Carrot and Commercial Weaning Food (Cerelac)

Samples (mg/100g)	Fe	Ca	Mg	K
Diet 1	$14.11^{f}\pm0.01$	$28.24^{f}\pm0.01$	$8.25^{a}\pm0.01$	$32.01^{f}\pm0.01$
Diet 2	$14.54^{e}\pm0.01$	$34.05^{c}\pm0.01$	$7.42^{b}\pm0.02$	$33.24^{e}\pm0.01$
Diet 3	$14.88^{c}\pm0.01$	$36.01^{d}\pm0.01$	$7.17^{c}\pm00.01$	$33.88^{d}\pm0.01$
Diet 4	$17.15^{a}\pm0.01$	$38.40^{c}\pm0.01$	$7.01^{d}\pm0.01$	$34.21^{c}\pm0.01$
Diet 5	$19.23^{a}\pm00.01$	$43.23^{b}\pm0.01$	$6.24^{e}\pm0.01$	$39.29^{b}\pm0.06$

Values are means ±SD of triplicate determinations. Means differently superscripted along the vertical columns are significantly different (p<0.05). Diet 1 = 90:0:10, Diet 2 = 85:5:10, Diet 3= 80:10:10, Diet 475:15:10, Diet 5:70:20:10 of Cooking banana: African breadfruit: Carrot flour blends. Diet 6: Control (Cerelac).

Vitamin Composition

Results of the Vitamin A and Vitamin C content of complementary diets formulated using cooking banana, African breadfruit and carrot are shown in Table 6. Vitamin A content ranged from 9.08 to 13.09 mg/100g. The values recorded indicated that Diet 1 had the highest value of 13.09 mg/100g while Diet 6 (control) had the lowest value 9.80 mg/100g, this may be attributed to the inclusion of carrot flour. Significant difference (p <0.05) existed amongst the sample. The results were lower than the result (5.25mg/100g) for banana and bean porridges used as complementary foods as reported by Adepeju and Etukumoh (2014). This perhaps may be due to the small proportion of carrot flour because it is particularly rich in carotene (pro-vitamin A) and also probably due to the drying method of processing the flours which might affect the vitamin content.

Values recorded for Vitamin C ranged from 0.77 to 0.98 mg/100g. Diet 1 had the highest Vitamin C content of 0.98mg/100g, while the control (diet 6) had the lowest value of 0.50mg/100g. Significant difference (p >0.05) existed amongst the sample. The result was lower than that of Okoye and Eno (2018) (8.32mg/100g); possibly due to the leaching out of the vitamin during washing processing method as it is a water-soluble vitamin. Based on the result, the formulated complementary diets had higher vitamin C content than the commercial

Article DOI: 10.52589/AJAFS-PO1ZG9QP
DOI URL: https://doi.org/10.52589/AJAFS-PO1ZG9QP

weaning food. This is probably because carrot flour (10%) was added to the diets to increase the vitamin and mineral content.

Table 6: Vitamins A and C content of Formulated Complementary Diets

Samples	Vitamin A (mg/100g)	Vitamin C (mg/100g)
Diet 1	$13.09^{a}\pm0.01$	$0.98^{a}\pm0.01$
Diet 2	$10.27^{b}\pm0.02$	$0.88^{b}\pm0.01$
Diet 3	$9.81^{c}\pm0.02$	$0.85^{c}\pm0.01$
Diet 4	$9.54^{d}\pm0.02$	$0.77^{d}\pm0.02$
Diet 5	$9.16^{e}\pm0.02$	$0.75^{d}\pm0.02$
Diet 6 (Control)	$9.08^{f}\pm0.02$	$0.50^{e}\pm0.01$

Values are means ± SD of triplicate determinations. Means differently superscripted along the vertical columns are significantly different (p<0.05). Diet 1:90:0:10, Diet 2: 85:5:10, Diet 3:80:10:10, Diet 4:75:15:10, Diet 5:70:20:10 of Cooking banana: African breadfruit: Carrot flour blends. Diet 6: Control (Cerelac)

Microbiological Qualities of the Developed Complementary Foods

Results of microbial quality of the formulated complementary diets are shown in Table 7. Nutrient Agar (NA) is a general-purpose medium; there were significant differences amongst the organisms that were present; which ranged from 5.0 x10^2 – 1.7 x10^3 cfu/g. Diet 2 had the highest THBC of 1.7x10^3 while Diet 4 had the lowest (5.0 x10^2cfu/g) THBC. These growths found may be due to the processing materials used or the water used in the preparation of the food product; although the values are of acceptable range and are non-toxic within that range. Macconkey Agar (MCA) is a selective medium. The values of THBC were significantly different (P<0.05) and ranged from 1.0 x10^2 – 6.0 x10^2 cfu/g, with Diet 4 having the highest score of 6.0x10^2 cfu/g, while Diet 3 had the lowest score of 1.0x10^2 cfu/g. Mannitol Salt Agar (MSA), also a selective media, supported THBC values ranging from 1.0 x10^2 - 5.0 x10^2 cfu/g. No bacteria count was found in Diet 1 and 3, which could be as a result of the proportions of the raw material used and the handling processes. There was no growth in Salmonella Shigella Agar (SSA), Eosin Methylene Blue Agar (EMB) and Thiosulphate Citrate Bile Salt sucrose agar (TCBS). This could indicate the absence of those organisms that grow in those media in the formulated diet. Result also showed that there was no fungal growth on the Sabroud Dextrose Agar medium, therefore, THFC (Total heterotrophic fungal count) across all the samples was nill. However, the food is safe for consumption as it falls within the acceptable limit of 10^3-10^4cfu/g according to International Commission on Microbiological Specification of Foods – ICMSF (2009) for formulated foods.

Table 7: Microbial Qualities of Formulated Complementary Foods from Cooking Banana, African Breadfruit and Carrot Flour Blends

Samples (cfu/g)	NA (THBC)	MCA (THBC)	MSA (THBC)	SSA (THBC)	EMB (THBC)	TCBS (THBC)	SDA (THFC)
Diet 1	$1.5^{b}\times10^{3}\pm0.40$	$5.0^{b}\times10^{2}\pm0.10$	Nil	Nil	Nil	Nil	Nil
Diet 2	$1.7^{a}\times10^{3}\pm0.68$	$3.0^{c}\times10^{2}\pm0.24$	$5.0^{a}\times10^{2}\pm0.10$	Nil	Nil	Nil	Nil
Diet 3	$6.0^{d}\times10^{2}\pm0.57$	$1.0^{e}\times10^{2}\pm0.32$	Nil	Nil	Nil	Nil	Nil

Article DOI: 10.52589/AJAFS-PO1ZG9QP
DOI URL: https://doi.org/10.52589/AJAFS-PO1ZG9QP

Diet 4	$5.0^{e}\times10^{2}\pm0.46$	$6.0^{a}\times10^{2}\pm0.47$	$2.0^{b}\times10^{2}\pm0.13$	Nil	Nil	Nil	Nil
Diet 5	$1.0^{c}\times10^{3}\pm0.23$	$2.0^{d}\times10^{2}\pm0.13$	$1.0^{c}\times10^{2}\pm0.21$	Nil	Nil	Nil	Nil

Values are means ± SD of triplicate determinations. means differently superscripted along the vertical columns are significantly different (p<0.05). Diet 1:90:0:10, Diet 2: 85:5:10, Diet 3:80:10:10, Diet 4:75:15:10, Diet 5:70:20:10 of Cooking banana: African breadfruit: Carrot flour blends. Diet 6: Control (Cerelac). NA: Nutrient Agar, MSA: Mannitol salt agar, SDA: Sabouraud Dextrose Agar. SSA: Salmonella Shigella Agar, MCA: Macconkey Agar, EMB: Erosyl methylene blue, TCBS: Thiosulphate citrate bile salt sucrose agar, THBC: Total Heterotrophic bacteria count, THFC: Total Heterotrophic fungal count.

Sensory Qualities of Complementary Foods Formulated from Cooking Banana, African Breadfruit Seed and Carrot Flour Blends

Results of sensory qualities of complementary diets prepared with sugar and salt are presented in Table 8. Mean sensory score varied from 6.13 – 7.07 for appearance, 6.33 – 7.40 for taste, 5.47 – 6.87 for aroma, 6.33 – 7.00 for texture, 5.93 – 7.40 for mouthfeel, 5.93 – 7.87 for aftertaste and 6.00 – 6.80 for general acceptability.

The control sample (Diet 6) had higher sensory scores than the formulated samples in terms of all the parameters accessed (appearance, taste, aroma, mouthfeel, aftertaste and general acceptability), and was significantly different (p<0.05) from Diets 2, 3, 4 and 5. There was no significant difference (p>0.05) among Diets 2, 3, 4 and 5. Diet 1 shared similarities with Diet 6 in appearance, taste, mouthfeel and aftertaste. Diet 6 was most accepted followed by Diet 1 and Diet 4. The difference could be as a result of the raw materials used for the formulation of the Diets. Diet 6 is formulated from maize and soybean, which are entirely different from the materials of Diet 1 – 5.

Table 8: Sensory Qualities of Formulated Complementary Foods from Cooking Banana, African Breadfruit and Carrot Flour Blends

Samples	Appearance	Taste	Aroma	Texture	Mouthfeel	Aftertaste	General acceptability
Diet 1	$7.07^{ab}\pm0.88$	$7.07^{ab}\pm0.88$	$6.67^{b}\pm0.98$	$6.80^{b}\pm1.08$	$7.00^{ab}\pm0.93$	$6.93^{ab}\pm1.16$	$6.80^{b}\pm1.11$
Diet 2	$6.40^{b}\pm1.12$	$6.40^{b}\pm1.12$	$6.40^{b}\pm0.91$	$6.53^{b}\pm1.25$	$6.53^{b}\pm1.55$	$6.20^{b}\pm1.32$	$6.73^{b}\pm1.16$
Diet 3	$6.40^{b}\pm2.10$	$6.40^{b}\pm2.10$	$5.80^{b}\pm1.47$	$6.20^{b}\pm1.5$	$6.33^{b}\pm1.35$	$6.00^{b}\pm1.69$	$6.00^{b}\pm1.41$
Diet 4	$6.13^{b}\pm1.81$	$6.13^{b}\pm1.81$	$6.47^{b}\pm0.83$	$6.60^{b}\pm1.06$	$6.40^{b}\pm1.24$	$5.87^{b}\pm1.13$	$6.80^{b}\pm1.37$
Diet 5	$6.13^{b}\pm1.06$	$6.13^{b}\pm1.06$	$5.87^{b}\pm1.54$	$6.33^{b}\pm1.54$	$5.93^{b}\pm1.10$	$5.93^{b}\pm1.10$	$6.60^{b}\pm1.24$
Diet 6 (control)	$8.27^{a}\pm0.80$	$8.27^{a}\pm0.80$	$8.07^{a}\pm0.80$	$8.20^{a}\pm0.86$	$8.33^{a}\pm0.82$	$8.13^{a}\pm1.13$	$8.40^{a}\pm0.74$

Values are means + SD of 15-panel member determinations. Means differently superscripted along the vertical columns are significantly different (p<0.05). Diet 1:90:0:10, Diet 2: 85:5:10,

Article DOI: 10.52589/AJAFS-PO1ZG9QP
DOI URL: https://doi.org/10.52589/AJAFS-PO1ZG9QP

Diet 3:80:10:10, Diet 4:75:15:10, Diet 5:70:20:10 of Cooking banana: African breadfruit: Carrot flour blends. Diet 6: Control (Cerelac).

CONCLUSION

This study showed that acceptable complementary diets could be developed using cooking banana, African breadfruit and carrot flour blends. Based on the result obtained, Diet 5 could compete favorably with control samples (Cerelac) in terms of iron (Fe) content, protein and vitamin content while Diet 2 had higher mineral content than the control. The formulated complementary food showed superiority over the control in terms of vitamin A, vitamin C, protein, ash, fiber and carbohydrate. The inclusion of the African breadfruit in the complementary diets improved the protein content (which is an essential nutrient for rapid growth in infants) and could serve as a relief for malnutrition, while the inclusion of carrot was found to improve the Vitamin A (carotenoids) and Vitamin C (antioxidant) content, which helps to improve eye sight and in neutralizing the effects of free radicals respectively. This could serve as a means of tackling and reducing vitamin A deficiency and improve the health status of the infants. Also, the inclusion of cooking bananas had a great effect on the carbohydrate content; the diets with higher cooking banana proportion had higher carbohydrate and vitamin content. African breadfruit and cooking bananas are underutilized crops with potentially high economic and nutritive value. The incorporation of these food crops in formulation of complementary diets would greatly enhance their utilization in developing countries.

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