Chemical, functional and sensory properties of roasted bambara groundnut (*Vigna subterranea* L. Verdc) and cooking banana (*Musa* spp., ABB genome) weaning diet

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The cooking banana and bambara groundnut were processed into flour, mixed in ratios of 90:10, 80:20, 70:30 and 60:40 respectively and chemical, functional and sensory properties were evaluated. The protein contents of formulated samples were significantly higher than ogi, but lower than nutrend (p < 0.05). Also, the energy values of CBR$_4$ (384.4 ± 0.3 kcal.) was significantly lower than the nutrend (397.1 ± 1.8 kcal.) (p < 0.05) and there was no significant difference with the ogi (383.1 ± 0.1 kcal.) (p < 0.05). The mineral composition of CBR$_4$ had the highest amount of calcium, magnesium, iron, potassium, sodium and phosphorous when compared with other formulated food samples. The CBR$_4$ had the highest water absorption capacity, least gelation capacity and swelling capacity, while CBR$_1$ had the lowest values of the formulated food samples. The overall acceptability of the formulated food samples were significantly lower than the ogi and nutrend (p < 0.05). The amount of CBR$_3$ and CBR$_4$ needed to meet the RDA for energy, protein and minerals of infant were comparable with that of nutrend, but lower than ogi. The study concluded that the nutrient composition of CBR$_4$ was better than ogi, but lower than nutrend. Hence, it may be used as a substitute for ogi and the expensive commercial weaning formula.

Key words: Chemical composition, functional properties, cooking banana, bambara groundnut, infant mix.

INTRODUCTION

Childhood malnutrition is very common in developing countries (Plahar and Hoyle, 1991; Kim, 2000; FAO, 2004). This is because infants at this stage of development require higher energy and proteins in their diet so as to meet increasing demand for metabolism. The nutritional status of children less than 5 years of age is of particular concern, since the early years of life represent the period for optimal growth and development (Prechulek et al., 1999). Their nutritional well-being reflects household, community and national investments in family health thereby contributing both directly and indirectly to overall country development and in particular, development of human resource (Central Bureau of Statistic, 1999).

Malnutrition contributes directly or indirectly to more than 60% of ten million child deaths each year (WHO, 2002). It has been reported that over 226 million children below 5 years old are stunted, 67 million are wasted and 183 million weight less than they should for their age (UNICEF, 1998). The prevalence of malnutrition increases dramatically from the age of 6 - 18 months as a result of poor feeding practices and low purchasing power that characterized many homes. Diets in developing countries are frequently deficient in macronutrients (protein, carbohydrates and fat, leading to protein-energy malnutrition), micronutrients (electrolytes, minerals and vitamins, leading to specific micronutrient deficiencies) or both (Brabin and Coulter, 2003; Pinstrup-Andersen et al., 1993; Levin et al., 1993; Millward and Jackson, 2004). In order to solve this nutrition problem many researchers have worked extensively on cereal-legume combinations in Nigeria. For example, Fashakin and Ogunsoola (1982) formulated nut-ogi (a mixture of corn gruel and peanut), Akinrele and Edwards (1989) formulated soya-ogi (corn gruel plus soya bean). The traditional weaning foods could be improved upon by combining locally available foods that complement each other in such a way that new pattern of amino acids created by this combination is similar to that recommended for infants (Fashakin et al.,

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In view of this, the present study therefore was undertaken to develop low cost formulations, using cooking banana fruits (Musa spp., ABB Genome) and roasted Bambara groundnut seeds (Vigna subterranean L. Verde) with locally available technology and an attempt was made to evaluate the chemical composition and functional properties of the food samples.

MATERIALS AND METHODS

Materials

The materials, that is, raw green cooking banana (Musa spp. ABB genome), Bambara groundnut (V. subterranean L. Verde), nutrend (a commercial weaning food) and Ogi (a traditional weaning food) were purchased from a local market in Akure town, Ondo state, Nigeria.

Methods

Preparation of samples

The Bambara groundnut seeds were sorted, soaked for 24 h in hot water, drained and roasted in hot fine sand at 180°C for 15 min. The roasted seeds were winnowed, dried milled, sieved through 0.4 mm wire mesh screen (Figure 1). Cooking banana fruits were peeled, sliced into pieces, oven-dried at 60°C for 24 h, milled and sieved through 0.4 mm wire mesh screen. The flours were stored in sealed cellophane bag at room temperature (Figure 2). The cooking banana flour and roasted Bambara groundnut flour were mixed in ratios of 90:10, 80:20, 70:30 and 60:40 respectively and the flour were then stored in cellophane bag at room temperature prior to analysis.

Chemical analyses

The nutrient composition of the food samples was determined using the standard procedures of association of official analytical chemists (1990). Triplicate samples of each sample were determined for moisture content in a hot-air circulating oven (Galenkamp). Ash was determined by incineration (550°C) of known weights of the samples in a muffle furnace (Gallenkamp, size 3). Crude fat was determined by exhaustively extracting a known weight of sample in petroleum ether (boiling point, 40 to 60°C) in a soxhlet extractor. Protein (N × 6.25) was determined by the Kjeldahl method. Crude fiber was determined after digesting a known weight of fat-free sample in refluxing 1.25% sulfuric acid and 1.25% sodium hydroxide. The carbohydrate content was determined by subtracting the total crude protein, crude fiber, ash and fat from the total dry weight (100 g) of the food sample differences. The gross energy was determined with a Gallenkamp ballistic bomb calorimeter (Gallenkamp ccb-330-010L UK).

Minerals content (sodium, potassium, calcium, magnesium, iron, copper, zinc, manganese and selenium) of the flour samples was determined using association of official analytical chemists (1990) method. Flour was digested with a mixture of concentrated nitric acid, sulfuric acid and perchloric acid (10:0.5:2, v/v) and analysed using an atomic absorption spectrophotometer (GBC 904AA; Germany). The total phosphorus was determined as orthophosphate by the ascorbic acid method after acid digestion and neutralization using phenolphthalein indicator and combined reagent (APHA, 1995). The absorbance was read at 880 nm (Spectronic 21 D, Miltonroy, New York, USA) and KH$_2$PO$_4$ (Merck, Mumbai, India) served as a standard.

Anti-nutrient determinations

Phytic acid was extracted from each 3 g flour sample with 3%
trichloro-acetic acid by shaking at room temperature followed by high speed centrifugation as described by Wheeler and Ferrel (1971). The phytic acid in the supernatant was precipitated as ferric phytate and iron in the sample was estimated. Phytate-phosphorus (phytate-P) was calculated from the iron results assuming a 4:6 iron: phosphorus molecular ratio. The phytic acid was estimated by multiplying the amount of phytate-phosphorus by the factor 3.55 based on the empirical formula C
_{4}P
_{2}O
_{7}H
_{4}. Tannin contents were determined by the modified vanillin-HCl methods (Burns 1971; Price et al., 1978). A 2 g sample was extracted with 50 ml 99.9% methanol for 20 min at room temperature with constant agitation. After centrifugation for 10 min at 653 x g, 5 ml of vanillin-HCl (2% vanillin and 1% HCl) reagent was added to 1 ml aliquots and the colour developed after 20 min at room temperature was read at 500 nm. Correction for interference light natural pigments in the sample was achieved by subjecting the extract to the conditions of the reaction, but without vanillin reagent. A standard curve was prepared using catechin (Sigma Chemical, St. Louis, MO) after correcting for blank and tannin concentration was expressed in mg/100 g. Oxalate was determined by AOAC (1990) method. 1 g of the sample was weighed into 100 ml conical flask. 75 ml of 3 M H
_{2}SO
_{4} was added and the solution was carefully stirred intermittently with a magnetic stirrer for about 1 h and then filtered using whatman No.1 filter paper. The sample filtrate (extract) (25 ml) was collected and titrated against hot (80 - 90 °C) 0.1 N KMnO
_{4} solution to the point when a faint pink colour appeared that persisted for at least 30 s. The concentration of oxalate in each sample was obtained from the calculation: 1 ml 0.1 permanganate = 0.006303 g oxalate.

Trypsin inhibition activity (TIA)

The trypsin inhibition activity was assayed in terms of the extent to which an extract of the defatted flour inhibited the action of bovine trypsin (EC 3.4.21.4) on the substrate benzoyl-DL-arginine-p-nitriilide (BAPNA) hydrochloric (Kakade et al., 1974). The samples (1 g each) were extracted continuously at ambient temperature for 3 h with 50 mL 10 mM NaOH using a mechanical shaker (GallenKamp orbital shaker Surrey, UK). The pH of the resulting slurry was adjusted to 9.4 - 9.6 with 1 M NaOH. After extraction, the suspension was shaken and diluted with distilled water such that 1 cm
_{3} of the extract produced trypsin inhibition of 40 - 60% at 37°C. The respective dilutions were noted. Consequently, TIA was calculated in terms of mg pure trypsin (Sigma type III, lot 20H0868)

\[ TIA = \frac{2.632DA}{S} \]

Where D is the dilution factor, A is the change in absorbance at 410 mm due to trypsin inhibition per cm
_{3} diluted sample extract and S is the weight of the sample.

Functional property determination

Water absorption capacity was determined using the method of Salunkhe (1985) modified by Adebowale et al. (2002). 10 ml of distilled and deionized water was added to 1.0 g of the sample in a beaker. The suspension was stirred using magnetic stirrer for 5 min. The suspension obtained was centrifuged at 3500 rpm for 30 min and the supernatant was measured into a 10 ml graduated cylinder. Water absorbed was calculated as the difference between the initial volume of water added to the sample and the volume of the supernatant. Least gelation property was determined using the method described by Coffman and Garcia (1977). Sample suspensions of 2 - 16% were prepared in distilled water. 10 ml of each of the prepared dispersions was transferred into a test tube and heated in a boiling water bath for 1 h, cooled rapidly in a cold water bath and allowed to cool further at 4 °C for 2 h. The least gelation concentration was determined when the sample from the inverted test tube did not slip or fall. Swelling capacity was determined by weighing 20 g of the food sample into a cleaned, dried graduated cylinder. The cylinder was tapped 3 times on the table and then 80 ml of distilled water was poured into the cylinder. The cylinder was allowed to stand for 1 h after which the final volume of the food sample was noted. The ratio of the final volume to initial volume gave the swelling capacity on volume basis. The supernatant was decanted and the weight of food sample and the cylinder was obtained and the ratio of final weight to initial weight of the food sample gave the swelling capacity on weight basis.

Sensory evaluation

The 4 formulated samples obtained from the different fractions of cooking banana and bambara groundnut mixes were made into light gruels, using about 20 g and 60 ml of water. The reconstituted formulated and control food samples (that is, nutrend, a commercial weaning food and Ogi, a traditional weaning food) were coded and presented to 30 panelists that were familiar with the product. The samples were rated based on colour, aroma, taste, mouth feel and overall acceptability using 9 point hedonic scale scored from dislike extremely (1) to like extremely (9).

Statistical analysis

The data were analysed using SPSS version 13.0. The mean and standard error of means (SEM) of the triplicate analyses were calculated. The analysis of variance (ANOVA) was performed to determine significant differences between the means, while the means were separated using the new Duncan multiple range test.

RESULTS AND DISCUSSION

The proximate composition of the formulated food samples are shown in Tables 1. The formulated diet containing 60% cooking banana fruit flour and 40% bambara groundnut flour (CBR
_{6} ) had the highest energy value (384.4 ± 1.3 kcal.), while the sample containing 90% cooking banana and 10% bambara groundnut flour (CBR
_{9} ) had the least energy value (361.5 ± 1.0 kcal.). The energy value of CBR
_{6} was insignificantly high when compared with other formulated diets and ogi (traditional weaning diet, corn gruel) (p > 0.05), but significantly lower when compared with the nutrend (commercial weaning diet) (p < 0.05). The protein content of CBR
_{6} (13.8 ± 0.01 g) was significantly higher than ogi (5.60 ± 0.02 g) and other formulated foods, but also significantly lower than nutrend (16.00 ± 0.2 g). In this present study it was shown that the protein content of the formulated diet increases progressively as the % of bambara groundnut increases. Also, it was observed that the protein content of cooking banana diet supplemented with roasted bambara groundnut (13.8 ± 0.01 g) was lower when compared with the cooking banana and fermented bambara ground nut mixed (Ijarotimi, 2008). Quite a number of studies have reported that fermentation method improves the nutritive values of food products compared with other processing methods, such as roasting, cooking, etc (Paredes-López and Harry, 1988; Adams, 1990; Obizoba
Table 1. Mean (SEM) of proximate composition of cooking banana and bambara groundnut formulated diets.

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>RCB</th>
<th>RBG</th>
<th>CBR1</th>
<th>CBR2</th>
<th>CBR3</th>
<th>CBR4</th>
<th>Ogi</th>
<th>Nutrend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (Kcal)</td>
<td>361.5 ± 1.0d</td>
<td>387.8 ± 1.9b</td>
<td>359.7 ± 1.5d</td>
<td>368.8 ± 1.0c</td>
<td>382.5 ± 3.0b</td>
<td>384.4 ± 0.3b</td>
<td>383.1 ± 0.1b</td>
<td>397.1 ± 1.8a</td>
</tr>
<tr>
<td>Moisture (g)</td>
<td>8.9 ± 0.2a</td>
<td>4.6 ± 0.3e</td>
<td>5.9 ± 0.01d</td>
<td>6.4 ± 0.03c</td>
<td>6.7b ± 0.03e</td>
<td>6.9 ± 0.02b</td>
<td>2.9 ± 0.06f</td>
<td>4.8 ± 0.02e</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>3.3 ± 0.1h</td>
<td>18.9 ± 0.1a</td>
<td>6.7 ± 0.18f</td>
<td>8.6 ± 0.02e</td>
<td>11.5 ± 0.02d</td>
<td>13.8 ± 0.01c</td>
<td>5.6 ± 0.02g</td>
<td>16.2 ± 0.2b</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>1.5 ± 0.1f</td>
<td>6.6 ± 0.2b</td>
<td>2.4 ± 0.02e</td>
<td>3.3 ± 0.06d</td>
<td>3.6 ± 0.23d</td>
<td>5.9 ± 0.05c</td>
<td>0.80 ± 0.02g</td>
<td>8.5 ± 0.03a</td>
</tr>
<tr>
<td>Fibre (g)</td>
<td>1.2 ± 0.2e</td>
<td>3.8 ± 0.2b</td>
<td>3.9 ± 0.01b</td>
<td>2.8 ± 0.03c</td>
<td>2.7 ± 0.01c</td>
<td>2.3 ± 0.01d</td>
<td>0.5 ± 0.01f</td>
<td>4.5 ± 0.01a</td>
</tr>
<tr>
<td>Ash (g)</td>
<td>2.6 ± 0.2bc</td>
<td>3.5 ± 0.1a</td>
<td>3.4 ± 0.4a</td>
<td>3.1a ± 0.03b</td>
<td>2.9 ± 0.02ab</td>
<td>2.3 ± 0.06cd</td>
<td>1.7 ± 0.002d</td>
<td>2.7 ± 0.02bc</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>83.7 ± 0.1b</td>
<td>63.3 ± 0.7f</td>
<td>77.8 ± 0.2c</td>
<td>76.1 ± 0.2d</td>
<td>75.9 ± 0.3d</td>
<td>68.9 ± 0.2e</td>
<td>88.4 ± 0.01a</td>
<td>64.0 ± 0.2f</td>
</tr>
</tbody>
</table>

CBR1 - Cooking banana + roasted bambara groundnut (90:10)
CBR2 - Cooking banana + roasted bambara groundnut (80:20)
CBR3 - Cooking banana + roasted bambara groundnut (70:30)
CBR4 - Cooking banana + roasted bambara groundnut (60:40)
Nutrend - commercial weaning (Nutrend)
Ogi - Traditional weaning food
RBG - Raw bambara groundnut
RCB - Raw cooking banana.

et al., 1997), such as protease inhibitors, lectins, goitrogens, antivitamins, saponins, tannins, phytoestrogens, flatulence factors (Rachis, 1975), lysinoalanine, allergens, phytate (Leiner, 1994), soytoxin (Vasconcelos et al., 1997). Legumes consumption has been related to various deleterious effects, such as growth retardation (Martinez et al., 1995a), lowered digestibility and absorption of dietary nutrients (Pusztai et al., 1995) and physiological, metabolic and immunological disturbances (Hajobs et al., 1995; Martinez et al., 1995b). However, it is evident that the antinutrient concentration in legumes can be eliminated or reduced to tolerable level through processing methods like roasting, fermentation, soaking etc. (Grant et al., 1989; Leiner, 1994; Vasconcelos et al., 1997; Agbede and Aletor, 2003; Khokhar and Chauham, 1986). The functional properties of the formulated food samples are shown in Table 4. The water absorption capacity of food materials is an index of the maximum amount of water that it can take up and retain, hence determine the
Table 2. Mean (SEM) mineral composition of cooking banana and bambara groundnut formulated diets.

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>RCB</th>
<th>RBG</th>
<th>CBR1</th>
<th>CBR2</th>
<th>CBR3</th>
<th>CBR4</th>
<th>Ogi</th>
<th>*Nutrend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium (mg)</td>
<td>30.45 ± 0.06e</td>
<td>60.0 ± 0.30a</td>
<td>19.79 ± 0.11g</td>
<td>27.11 ± 0.26f</td>
<td>39.38 ± 0.56d</td>
<td>45.95 ± 0.24c</td>
<td>51.85 ± 0.65b</td>
<td>39 ± 0.00d</td>
</tr>
<tr>
<td>Magnesium (mg)</td>
<td>62.98 ± 0.23e</td>
<td>57.19 ± 0.21f</td>
<td>65.69 ± 0.08d</td>
<td>102.28 ± 0.37c</td>
<td>136.44 ± 0.51b</td>
<td>184.80 ± 0.90a</td>
<td>14.29 ± 0.39g</td>
<td>ND</td>
</tr>
<tr>
<td>Zinc (mg)</td>
<td>0.28 ± 0.03c</td>
<td>5.70 ± 0.20a</td>
<td>0.013 ± 0.002d</td>
<td>0.15 ± 0.02cd</td>
<td>0.016 ± 0.002d</td>
<td>0.016 ± 0.002d</td>
<td>-</td>
<td>0.7 ± 0.00b</td>
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<tr>
<td>Iron (mg)</td>
<td>2.60 ± 0.02b</td>
<td>5.50 ± 0.2a</td>
<td>0.15 ± 0.01d</td>
<td>0.24 ± 0.02d</td>
<td>0.22 ± 0.01d</td>
<td>0.24 ± 0.02d</td>
<td>-</td>
<td>ND</td>
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<tr>
<td>Potassium (mg)</td>
<td>94.06 ± 0.12b</td>
<td>33.32 ± 0.21g</td>
<td>41.93 ± 0.16f</td>
<td>47.22 ± 0.30e</td>
<td>70.19 ± 0.84d</td>
<td>75.31 ± 0.89c</td>
<td>97.55 ± 0.15a</td>
<td>22.0 ± 0.00h</td>
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<td>Phosphorus (mg)</td>
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<td>Magnesium (mg)</td>
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<td>Copper (mg)</td>
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<td>Aluminum (mg)</td>
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<td>Lead (mg)</td>
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<td>Chromium (mg)</td>
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<td>Mercury (mg)</td>
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</tbody>
</table>

*The values as specified by the manufacturer.

Table 3. Mean (SEM) antinutritional contents of cooking banana and roasted bambara groundnut mixed.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Oxalate (mg/100 g)</th>
<th>Tannic acid (mg/100 g)</th>
<th>Phytic acid (mg/100g)</th>
<th>Phytin phosphorous (mg/100 g)</th>
<th>Trypsin inhibitor (mg/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBR1</td>
<td>0.32 ± 0.02d</td>
<td>0.06 ± 0.01b</td>
<td>7.0 ± 0.02d</td>
<td>2.05 ± 0.15d</td>
<td>1.75 ± 0.15d</td>
</tr>
<tr>
<td>CBR2</td>
<td>0.54 ± 0.04c</td>
<td>0.08 ± 0.01b</td>
<td>14.12 ± 0.25c</td>
<td>4.10 ± 0.20c</td>
<td>3.30 ± 0.20c</td>
</tr>
<tr>
<td>CBR3</td>
<td>0.81 ± 0.2b</td>
<td>0.16 ± 0.02a</td>
<td>19.70 ± 0.80b</td>
<td>6.10 ± 0.20b</td>
<td>5.00 ± 0.20b</td>
</tr>
<tr>
<td>CBR4</td>
<td>1.16 ± 0.06a</td>
<td>0.24 ± 0.03a</td>
<td>27.25 ± 0.46a</td>
<td>7.5 ± 0.30a</td>
<td>7.40 ± 0.50a</td>
</tr>
</tbody>
</table>

energy and nutrient dense of a food. Recently, several studies have reported that the high prevalence of protein-energy malnutrition in many parts of developing countries is as result of low-dense energy and other vital nutrient intakes (Levin et al., 1993; Pinstrup-Andersen et al., 1993; Brabin and Coulter, 2003; Milward and Jackson, 2004). The least gelation concentration of the formulated food samples increased with successive substitution levels and there were no significant difference between the formulated samples beyond 20% substitution levels and the ogi and that of nutrend samples respectively (p > 0.05). The high gelation value implies that the diet would require more energy consumption to cook and hence the gel strength of the diets would be weak and undesirable (Enujiugha, 2006). The swelling capacity increased with the % increase of bambara groundnut flour. However, the swelling capacities of the formulated diets were significantly higher than ogi but lower than the nutrend (p < 0.05).

Table 5 shows the results of sensory attributes of prepared formulated diets, ogi and nutrend. All the sensory attributes of the formulated diets samples were significantly low compared to the nutrend (a commercial weaning food) and ogi (a traditional weaning food) (p < 0.05). The disparity between the flavour and taste of the formulated diets samples and the control food samples could be attributed to the characteristics beany aroma and taste of bambara groundnut flour. The poor rating of the formulated diets samples in term of aroma, taste, texture and colour compared with the ogi and nutrend could also be attributed to the familiarity of the panel of judges to these food
The findings in this present study justify the use of bambara ground seeds and cooking banana flour mixes, particularly 60% of cooking banana and 40% bambara groundnut flour, as a substitute for ogi (a traditional weaning food) and expensive commercial weaning formula. However, the level of antinutrient composition of the formulated diet could be further reduced either by hydrothermal or fermentation treatments. Also, the possibility of adding sweetening and flavouring agent to the formulated food samples should be employed as a way of improving

### Conclusion

The amount of formulated, ogi and nutrend food samples that needed to meet the recommended daily allowance (RDA) of infant (< 1 year) is shown in Table 6. The amounts of CBR₃ and CBR₄, which are needed to meet the daily energy and protein requirement of infants, were absolutely within the same range with that of nutrend, but lesser amount of CBR₃ and CBR₄ were needed RDA for the protein, phosphorus and potassium requirement of the infant compared with ogi and nutrend. However, the amount of the formulated diets that were needed for RDA for iron and zinc were high compared with the nutrend food sample.
the sensory quality of the formulated diets.

REFERENCES


