Full Length Research Paper

Studies on the microbiological, nutrient composition and antinutritional contents of fermented maize flour fortified with bambara groundnut (*Vigna subterranean L*)

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The nutrient composition, antinutritional factors and microflora in spontaneously fermenting maize flour fortified with bambara groundnut were examined over a period of 72 h. Titratable acidity as well as pH changes was obtained at 12 h interval during fermentation by adventitious microorganisms present in the fortified product. Results obtained showed that microflora gradually changed from gram negative enteric bacteria, molds, lactic acid bacteria and yeast to be dominated by gram positive lactic acid bacteria (LAB) and yeasts. All undesirable microorganisms such as coliforms and molds which were present at the start of fermentation were totally eliminated by 24 h of fermentation. Yeasts and LAB numbers in the fortified dough varied between 4.44 and 7.36 log cfu^{-1}. LAB number increased from 5.40 to 7.36 log cfu^{-1} during fermentation. Yeasts increased from 4.44 to 5.60 log cfu^{-1}. The product pH decreased with concomitant increase in moisture, fat, ash, fibre and titratable acidity with increasing bambara groundnut addition. Bambara groundnut addition caused only minimal changes in the proximate composition with the exception of protein content, which increased remarkably from 18.40 to 21.68% with 30% bambara groundnut addition. Boiling, sprouting and fermentation significantly decreased the tannins and trypsin inhibitors levels. Boiling Bambara groundnut for 20 min before incorporation into the maize flour imparted a desirable flavour. Organoleptic evaluation revealed that the foods were well accepted. Based on the findings the application of bambara groundnut fortification to traditional foods can promote the nutritional quality of African maize - based traditional foods with acceptable rheological and cooking qualities.

Key words: Spontaneous fermentation, fermented maize flour, Bambara groundnut fortification, micropopulation, nutrient quality, antinutritional factors, rheology.
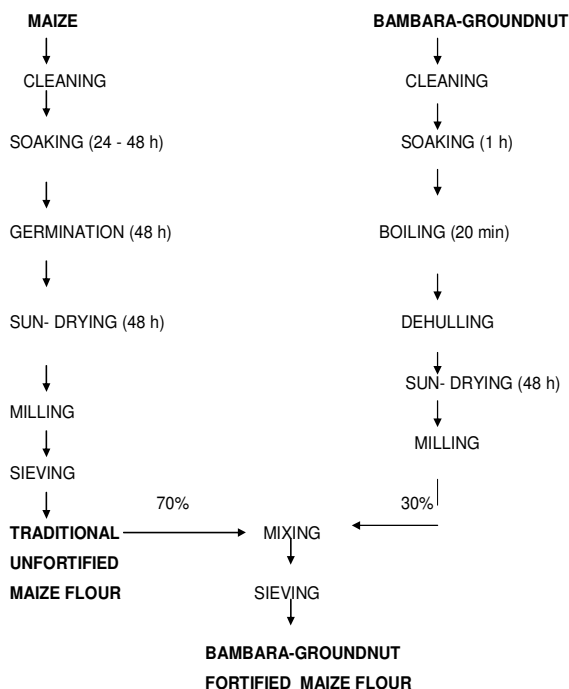
INTRODUCTION

Traditional cereal foods play an important role in the diet of the people of African particularly in cereal producing zones. Flour from various cereals is one of the main raw materials used in the production of popular food products with high acceptability, good storage characteristics and affordable cost (Akinrele, 1970). One such food product is 'Ogi', fermented cereal porridge made from maize (*Zea mays*), produced using simple processing methods. The

"Ogi" porridge is very smooth in texture and has a sour taste reminiscent of that of yoghurt (Banigo and Muller, 1972). Several maize based fermented products, such as Ogi in west Africa, Togwa in Tanzania, Banku in Ghana Kenkey in Ghana, mahewu in South Africa, Mawe in Benin have been documented (Akinrele, 1970; Jespersen et al., 1994; Mugula et al., 2003). A variety of cereals (maize) are used either singly or mixed to produce a number of fermented beverages and foods.

Many brands of low - cost proprietary weaning foods have been developed from locally available high calorie cereals and legumes in tropical Africa (Livingstone et al., 1993; Sanni et al., 2001). This has been suggested by the

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MAIZE
↓
CLEANING
↓
SOAKING (24 - 48 h)
↓
GERMINATION (48 h)
↓
SUN- DRYING (48 h)
↓
MILLING
↓
SIEVING
↓
TRADITIONAL
UNFORTIFIED
MAIZE FLOUR

BAMBARA-GROUNDNUT
↓
CLEANING
↓
SOAKING (1 h)
↓
BOILING (20 min)
↓
DEHULLING
↓
SUN- DRYING (48 h)
↓
MILLING

70% ——→ MIXING ←—— 30%
↓
SIEVING
↓
BAMBARA-GROUNDNUT
FORTIFIED MAIZE FLOUR

Figure 1. Flow diagram for the production of bambara groundnut fortified and unfortified maize flour samples

integrated child Development Scheme (ICDS) and FAO to combat malnutrition among mothers and children of low socio-economic groups.

Despite the reported improvement in the nutrient status of fermented cereal based diets in sub-Saharan Africa, the nutrient needs of infants and sick adults are still not being met. Evidence indicates that it is quite possible to improve the nutrient quality and acceptability of these cereals and legumes and exploit their potentials as human foods by adopting newer scientific processing methods (Malleshi and Desikachar, 1982).

Earlier studies have documented the need for fortification of traditional fermented maize porridge with legume (Nti and Plahar, 1995; Mbata et al., 2007). However, information on the production technology, microbiological and antinutritional properties of maize fermented flour blended with bambara groundnut are limited as is the case for many other traditional fermented beverages in Nigeria. Fermentation has been used by various workers to both remove the antinutritional factors as well as improve the nutrition level (Edema and Sanni, 2006).

Therefore, the study was aimed at investigating the microbiological population, nutrient composition and anti-nutritional factors of fermented maize flour fortified with bambara groundnut.

MATERIALS AND METHODS

Collection of sample

Yellow maize (*Zea mays* L) and cream coat bambara groundnut (*Vigna subterranean* L) were purchased from a local market in Anambra state, Nigeria and used for the study. They were all trans-ported to the laboratory in clean polyethylene bags for later use.

Pre-treatment of bambara groundnut

The bambara groundnut was first thoroughly cleaned by picking all the stones and other foreign particles present in them while sorting out the good ones. The cleaned bambara groundnut were soaked in water for 1 h and boiled at a temperature of 100°C for 20 min. They were then washed by hands to remove the seed coat. The dehulled seeds were sun-dried for 2 - 3 days. The dried seeds were then dry-milled into flour using a disc attrition mill (Hunt No. 2A premier mill, Hunt and Co, UK) to an average particle size of less than 0.3 mm. The milled grain was then sieved through a fine mesh sieve to obtain the bambara groundnut flour.

Preparation of traditional unfortified maize flour

200 g of the cleaned maize samples were soaked in each plastic bucket containing 300 ml of distilled water and steeped for 24 h at room temperature (28 ± 2°C). The steep water was discarded by decantation and the steeped grains were germinated (48 h) by spreading on a clean grease free tray pan and thereafter it was sun dried 2 - 3 days by putting it in a sterilized tray pan. The maize grains were then milled using a disc attrition mill (Hunt No. 2A premier mill, Hunt and Co, UK) to an average particle size of less than 0.3 mm. The milled grain was then sieved through a fine mesh sieve to obtain the maize flour.

Supplementation of fermented maize with bambara groundnut

The bambara groundnut flour and maize flour were mixed together in the ratio 30:70 (w/w) (Bressani and Elias, 1974). 30 g of bambara groundnut flour was mixed with 70 g of maize flour to produce bambara groundnut fortified fermented maize flour (Figure 1).

Fermentation of maize fortified meal

100 g of the sample was mixed with 100 ml of distilled water. The mixture was allowed to ferment naturally at room temperature (28°C) for 72 h for microbiological, pH and titratable acidity.

Physico-chemical analysis

At 12 h intervals samples of dough was taken during fermentation and analyzed for, titratable acidity and pH.

pH Determination

The pH of the samples was determined according to the method of AOAC (1998).10 g of sample was mixed in 100 ml of CO_2 - free distilled water. The mixture was allowed to stand for 15 min, shaken at 5 min interval and filtered with Whatman No. 14 filter paper. The pH of the filtrate was measured using a pH meter (Model HM-305, Tokyo, Japan).

Total titratable acidity (T.T.A)

10 ml aliquots (triplicates) were pipetted and titrated against O.1 M NaOH to phenolphthalein end-point and the acidity was calculated as g lactic acid/100.

Microbiology analysis

At 12 h intervals (0, 12, 24, 36, 48 and 72 h). 1.0 g of fermenting meal was homogenized in 9.0 ml of sterile 0.1% peptone water for 30 s. The mixture was serially diluted in sterile peptone water by the method of Maynell and Meynell (1970) and from the 10 fold dilutions, colony-forming units (cfu) were determined using the spread plate method. Spread plate counts were carried out using the following media, temperature and incubation periods. DeMann Rogosa-sharpe (MRS) agar (Oxoid, UK) 37°C, 48 h; sabouraud dextrose agar (SDA) (LAB M, idg plc, UK) 28°C, 72 h; MacConkey agar (Oxoid), UK) 37°C, 48 h.

Isolation and characterization of bacteria

At 12 intervals, colonies were randomly picked from MRS and MacConkey plates used for the viable counts. The isolates were purified by repeated sub-culturing before being tested for Gram reaction (Claus, 1992), morphology and motility. Isolates were grouped according to their colony appearance and cell morphology. The discriminatory scheme of Sneath et al. (1986) identified repre-sentative isolates of the groups with supplementary carbohydrate test using API 50 CH strips for isolates from MRS plates and API 20 E for isolates from MacConkey plates (API systems, Biomerieur).

Isolation and characterization of yeasts and moulds

At 12 intervals, colonies were randomly picked from the SDA plates used for fungal counts. The isolates were purified by sub-culturing and grouped according to their culturing features and micro-morphology (slide culture) as described by Frey et al. (1979). Representative yeast isolates were identified to the level of species according to the procedure of Kreger-Van Rij (1984), by pattern of assimilation of glucose, sucrose, xylose, maltose, galactose and ethanol production of acid from glucose, sucrose, xylose, trehalose, raffinose and lactose production of urease, growth at 37°C as well as citrate and nitrate assimilation.

Viscosity measurement

The cooked paste viscosity of the slurries were determined with a brabender viscoamylograph (Brabender, Duisburg Germany) equip-ped with a 700 cm - g sensitivity cartridge. A 10% slurry (dry matter basis) of each flour was prepared with 200 ml distilled water and the slurry was heated uniformly from 25°C at a rate of 15°C per min to 95°C and held for 15 min and cooled at the same rate to 50°C. The brabender viscoamylograph rheological indices (gelatinization temperature, peak viscosity, viscosity at 95 and 95°C hold, viscosity on cooling to 50°C, the index of gelatinization and starch stability) were determined from obtained values.

Proximate analysis

Samples of the fermented dough were analyzed by standard proce-dures as adopted by AOAC (1998), for moisture, protein, fat, ash, fibre, carbohydrate and energy.

Amino acid analysis

Lysine concentration in the sample was determined in triplicates, by digestion under vacuum with 6 M HCl in sealed ampules at 110°C for 22 h. The hydrolysates were derivatized and analyzed for amino-acids on a water HPLC system controlled by Millenium 2010 software (water DIV, Millipore Corp, Milford, MA, USA). Trypto-phan was determined according to the AOAC (1998) method.

Sensory evaluation

Sensory characteristics of the fortified fermented maize dough products were assessed by 20 trained members of the department of microbiology university of Benin, Nigeria. Fresh samples of cooked porridge prepared by boiling 10% (w/v) slurry of the dough for 15 min were assessed for their colour, texture, flavour (aroma), taste and overall acceptability. The panelists were instructed to sip water before and after assessing each product. The judges recor-ded sensory characteristics of each sample using 8 - point hedonic scale as described by Ihekoronye and Ngoddy (1985), where:

8 = like extremely
7 = like very much
6 = like moderately
5 = like slightly
4 = dislike slightly
3 = dislike moderately
2 = dislike very much and
1 = dislike extremely

Each treatment was evaluated three times by each panelist.

Antinutritional properties

Trypsin inhibitor activity was determined by the method of Hamer-strand et al. (1981). 1 g portions of the sample were extracted by soaking overnight at 4°C in 50 ml 0.01 NaOH, pH was adjusted to 8.4 -10.0.The suspension were diluted so that 2 ml of the sample extract inhibited 40 - 60% of standard trypsin used in the analysis. For the analysis on inhibition of trypsin, synthetic benzoyl DL arginine-p-nitro anilde (BAPNA) was used as substrate. Residual enzyme activities were determined in systems containing 2 ml ali-quots of the sample extracts by measuring the absorbance at 410 nm. Trypsin inhibitor activity (TIA) in term of milligrams pure trypsin sample was calculated as:

$TIA = (2.632 \times D \times A_1)/S$ mg pure trypsin inhibited/g sample

Where A_1 = change in absorbance due to trypsin inhibition /ml diluted sample extract, D = dilution factor and S = weight of sample (g).

Tannin content of each blend was measured by the modified vanillin-hydrochloric acid method (Price, 1978). Here, 0.2 g of dried sample was extracted with 1% HCL in methanol for 20 min at 30°C and the product centrifuged using an eagle model 20 centrifuge (Eagle Scientific Ltd, Nottingham, UK). To 1 ml of the extract, 5 ml of vanillin reagent was added. The reaction mixture was left for 20 min at 30°C after which the absorbance was read at 500nm against a blank using a spectrophotometer (Spectronic 20). The blank contained 4% HCL in methanol. Tannin concentration in mg/g was extrapolated from a standard curve. Values were converted to mg/g using the formula:

$$\text{Tannin content (mg/g)} = \frac{OD_{500} \times \text{vol of extract}}{\text{Slope} \times \text{Weight of sample}}$$

Statistical analysis

The data were subjected to analysis of variance in a completely randomized design using the method of Snedecor and Cochran (1967). Significance difference was accepted at $p \leq 0.05$ levels.

Table 1. Microbial counts for bambara groundnut-maize fortified dough during the 3 days of fermentation.

Days of fermentation (h)	Coliforms	Yeast	*Lactobacillus* spp	*Leuconostoc* spp
0	2.85±0.23[a]	4.44±0.04[a]	-	-
24	0.00±0.00[b]	5.63±0.24[b]	6.35±0.12[a]	5.40±0.09[ab]
48	0.00±0.00[b]	5.80±0.24[b]	7.30±0.19[b]	6.20±0.05[a]
72	0.00±0.00[b]	5.60±0.07[b]	7.36±0.09[b]	7.36±0.04[b]

Means of 3 independent determinations.
Mean values in the same column with different superscripts differ significantly (p < 0.05).

Table 2. Effect of bambara groundnut and fortification method on the rate of fermentation of traditional maize dough.

Bambara-nut fortification (level and treatment)	pH				Titratable acidity mgNaOH/g sample			
	0	24	48	72	0	24	48	72
Control traditional dough (0%) Bambara groundnut	6.55[a]	4.5[ab]	4.0[a]	3.6[c]	1.3[d]	5.3[c]	6.2[c]	6.5[e]
Fortification level 30% Bambara-groundnut	5.40[b]	3.90[b]	3.75[a]	3.62[c]	5.0[a]	8.0[a]	8.4[b]	10.6[a]

Means of 3 independent determinations on dry weight basis.
Mean values in the same column with different superscripts differ significantly (p < 0.05).

RESULTS

The microbial isolation from bambara groundnut-maize fermented fortified meal is presented in Table 1. Yeast, coliforms, lactic acid bacteria (Lactobacillus and Leuconostoc) were enumerated in the fermentation. The microflora gradually changed from gram negative enteric bacteria, molds, lactic acid bacteria and yeast to be dominated by gram positive lactic acid bacteria (LAB) and yeasts. All undesirable microorganisms such as coliforms and molds which were present at the start of fermentation were totally eliminated by 24 h of fermentation. Yeasts and LAB numbers in the fortified dough varied between 4.44 and 7.36 log cfu^{-1}. LAB number increased from 5.40 to 7.36 log cfu^{-1} during fermentation. Yeasts increased from 4.44 to 5.60 log cfu^{-1}.

The effect of bambara groundnut treatment, fortification and rate of fermentation of traditional maize dough are shown in Table 2. The addition of 30% bambara groundnut of the dough accelerated acid production. The steeping of maize grains generally encouraged higher lactic acid production by the prevailing microorganism. The rate of acid production increased with increase in the level of fortification. The bambara groundnut blend with the maize resulted in an increased in titratable acidity (5.0 - 0.6) during the different periods of fermentation. The pH of the formulated food decreased (5.4 - 3.6) as fermentation lasted.

Table 3 showed the proximate, ash, crude protein, total fibre, total fat, moisture and carbohydrate of the traditional fermented maize and bambara groundnut-maize dough. The bambara groundnut fortified maize meal had higher values of ash, crude fibre, crude protein and total fat, while unfortified sample had higher values in moisture and carbohydrate than in the fortified maize meal.

Table 4 showed the brabender amylograph pasting vis-cosities of fermented maize dough fortified with bambara-nut. The addition of boiled bambara-nut to maize had relatively large effect on the hot paste viscosity characteristics of traditional fermented maize dough. The overall acceptability scores of the various sensory attributes are shown in Table 4.

DISCUSSION

A wide variety of microorganisms were found associated with maize fermented meal fortified with bambara groundnut in this study. Previous studies suggest that microorganisms are associated with cereal grains and their products and that the bacterial inoculum for natural fermentation process is derived from the grains (Odunfa and Adeyele, 1985). The composition of the micro-population as well viable counts obtained showed a succession of gram negative enteric bacteria and a mixed fungal population with lactic acid bacteria and yeasts, respectively. The microorganisms in a fermenting maize fortified meal such as the one under study could originate above all from the flours, utensils and possibly from the tap water used for mixing. When water is added to flour, the micro-population in the flour begins to grow and metabolize. This process is the basis of the preparation of cereal gruels which are common weaning foods in developing countries (Akinrele, 1970). In this study, both homo and heterofermentative lactic acid bacteria were found to be present at the end of the fermentation, (Table 1) with the dominating species being *Lactobacillus* spp and *Leuconostoc* spp. This was contrary to the report of Lonner et al. (1986) who found that all bacterial isolates from the final sour dough were homo-fermentative Lactobacilli and *Pediococcus* spp. Such variations in the composition of micro-flora can be accounted for by

Table 3. Proximate composition of the maize flour and bambara groundnut- maize flour.

Nutrient (%)	Fermented maize flour	Bambara groundnut-maize fortified flour
Moisture	13.20^a	12.60b
Crude protein	18.40^b	21.68^a
Crude fat	5.40^a	6.60^b
Crude fibre	5.20^a	5.40^b
Ash	3.79^a	4.00^a
Carbohydrate	67.21^a	63.32^b
Energy (Kcal)	1638.45^b	1673.48^a

Means ± SD of 3 independent determinations.
Mean values within a row with different superscripts differ significantly (p<0.05).

Table 4. Brabende*r* amylograph pasting viscosities of bambara groundnut-maize fortified dough.

Pasting characteristics	Traditional unfortified maize dough	Ratio of Bambara-nut added (30%)
Gelatinization Temp. (^{o}C)	70.1±0.7^a	63.8±0.5b
Peak Viscosity at 95°C (BU)	300±5^b	270±10^d
Viscosity at 95°C (BU)	280±10^a	270±5^c
Viscosity after 15min at 95°C	270±5^a	250±0^c
Starch stability (BU)	30±7^{bc}	20±5^d
Viscosity on cooling to 50°C	400±10^c	340±5
Index of gelatinization	130	90

Means ± SD of 3 independent determinations.
Mean values within a row with different superscripts differ significantly (p < 0.05).

differences in incubation time and temperature, type of cereals used and mixture recipe among other factors.

The results of the various identification tests performed were in line with the descriptions of Barnett et al. (1990). Aerobic and anaerobic plate counts taken at 24 h intervals during the spontaneous fermentation showed that the growth of yeasts and lactic bacteria increased gradually throughout fermentation while the numbers of molds and enterics decreased (Table 1). The molds (*Aspergillus* and *Penicillium* species) isolated in the study are commonly present as contaminants in cereals and do not appear to play any significant important role in the fermentation. Jespersen et al. (1994) similarly reported the presence of moulds such as *Penicillium* and *Aspergillus* in maize fermentation during kenkey production with drastic reduction in their numbers from 10^5 to less 10^2 cfu/g within 24 h of dough fermentation. The subsequent disappearance of molds after 24 h observed in the present study as well as previous studies was probably due to the low oxygen tension in the fermenting matrix. Previous workers have found several yeasts species in spontaneous lactic fermenting cereals including species of *Saccharomyces* and *Candida* (Jespersen, 1994). In the present work, the pH of the formulated weaning foods decreased from 5.4 to 3.6, while the titratable acidity increased from 5.0 to 10.6 mg NaOH/g sample (Table 2). The pH of the unfortified products also decreased from 6.5 to 3.6 and titratable acidity increased

from 1.3 to 6.5 mg NaOH/g sample with 0% Bambara-nut addition (Table 2). The pH of maize fermented fortified dough was originally 5.4 and decreased to 3.6 during production of sourdough. There was complete disappearrance of the coliforms after 24 h of fermentation as pH dropped to 3.9. Coliforms are acid intolerant (Steinkraus, 1996). The final pH of the maize fermented fortified dough was 3.6 after 72 h. The yeast counts in the maize fermented fortified dough increased from 4.44 ± 0.04 to 5.80 ± 0.24 log cfu Ml^{-1} after 48 h with a slight decrease thereafter. The increase in the yeast numbers after 24 h of fermentation is attributed to the decrease in the pH that creates conditions ideal for yeast growth (Serna-Saldivar and Rooney, 1995). This is similar with the finding that is reported for other fermented beverages (Abegaz et al., 2002). The *Lactobacillus* and *Leuconostoc* ranged from 5.40 ± 0.09 to 7.36 ± 0.00 log cfu Ml^{-1} during fermentation. The greatest increase in lactic acid bacteria was noted between 24 and 48 h. Higher number of *Lactobacillus* than *Leuconostoc* was observed, though at end of 72 h same microbial populations were noted. The acidic nature of the product could be due to the production of lactic acid produced by microorganism associated with maize dough fermentation. It has also been reported that microorganisms involved in fermentation affect the nutritional level of fermented food (Newman and Sands, 1984). In this study, bambara-nut fortification increased the acid production. This was also probably due to

Table 5. Organoleptic characteristics and acceptability of bambara groundnut-maize fortified dough.

	Mean scores [a,b]				
Supplements	Colour	Texture	Flavor	Taste	Overall
1	6.9[a]	6.9[b]	6.9[c]	6.8[a]	6.9[bc]
2	6.7[b]	7.0[a]	6.8[b]	6.9[c]	6.9[a]
3	6.7[a]	7.0[b]	6.8[a]	6.8[bc]	6.8[c]
4	6.6[b]	6.4[a]	6.7[b]	6.8[b]	6.6[ab]
5	6.7[a]	6.8[b]	6.1[c]	6.4[a]	6.5[c]

[a]Means are scores of 20 Judges and not significant ($p > 0.05$) different b/w supplementary foods.
[b]Panelists used 8 point hedonic scale.

availability of more nutrients for microbial proliferation and enhanced metabolic activities. The early rise in titrateble acidity is important to avoid proliferation of undesirable organisms resulting in poor fermentation. The proximate (fat, fibre and ash) increased, with increased level of bambara-nut fortification. It is also clear from the result that the fortified foods were nutritious, since the products provided one third of the recommended dietary allowance (RDA) with respect to protein (10 to 12%) (Table 3) as recommended by food and agriculture organization (FAO, 1985) and national institute of nutrition (1992) for children and rural mothers. The proximate characteristics of the fortified food was within the range reported for weaning and supplementary food (FAO, 1985).The low moisture value of the product indicate that it would have a good keeping quality. This is because food spoiling microflora thrives where there is adequate moisture (Ene-Obong and Carnovale, 1992). Variations in carbohydrate content were observed with bambara groundnut concentration. The results showed that the carbohydrate content decreased. This agrees with the observation that addition of legume decreases the carbohydrate content of maize-based traditional foods (Sefa-Dedeh et al., 2001).The level of tannins (42.70 - 36.40 mg/100) and trypsin inhibittors (49.70 - 38.20 mg/100) range in the unfortified maize flour and fortified product indicated there was significant difference $p < 0.05$ in the level of the antinutritional factors (Table 4). These antinutritional levels decreased in the fortified product as fermentation lasted and the amounts are insignificant to cause any hindrance to nutrient absorption from other foods. Antinutrients have the capacity of decreasing the digestibility and palatability of protein because they form insoluble complexes with them (Osagie, 1998).

The brabender viscoamylograph as presented in Table 4 showed useful information on the hot and cold paste viscosity of starch based food. The values obtained for gelatinization temperature viscosity at 95°C, peak viscosity and viscosity at 50°C, were similar for traditional unfortified maize dough. On the contrary, fortification of maize with boiled bambara-groundnut reduced peak viscosity (from 300 to 270 BU, in the case of 30% fortification) and viscosity at 95°C. Starch stability, however was improved with 30% increase in level of

fortification. All the blends display desirable starch stability and consistent gelling tendency which are within acceptable limits as observed by similar workers (Livingstone et. al., 1993). This blend could be used as a low-cooked viscosity weaning food, which could potentially increase the food intake of the child.

"Ogi" has poor biological value thus; children weaned entirely on "Ogi" are known to suffer from protein-energy malnutrition (PEM). So, a good supplemental relationship thus exists between "Ogi" and Bambara-groundnut. Addition of 30% bambara-groundnut into Bambara-groundnut supplemented "Ogi' improves the protein content of "Ogi". The organoleptic evaluation showed that, combinations of cereals/maize and legumes/bambara groundnut, to prepare the food mixtures, was liked by the trained panelists (Table 5). None of the panelists developed any side effects like diarrhea and vomiting after the sensory evaluation.

The study has revealed that fortification of maize meal (cereal) with bambara groundnut (legume) is able to alleviate problems of protein energy malnutrition (PEM).

The fortified foods prepared with bambara-nut and maize was nutritious and conformed to specifications as recommended by national institute of nutrition and food and agriculture organization (FAO) to combat malnutrition especially in low economic groups. It has special importance for use in weaning foods, catch-up growth and may improve birth weights. Therefore there is a need for research into the isolation, identification and characterization of the microorganisms involved in the fermentation of bambara groundnut-maize fortified meal to enable the selection of most suitable strains for starter culture development. Starter culture developed may be used to scale up the production of the product from households to small scale level. Furthermore, the introduction of appropriate starter culture techniques may constitute one of the major steps towards improving the safety, quality and security of traditional production of bambara groundnut-maize fermented meal.

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