International Food Research Journal 21(5): 2025-2032 (2014)

Journal homepage: *http://www.ifrj.upm.edu.my*

Quality attributes of *fufu* (fermented cassava) flour supplemented with bambara flour

*Olapade A. A., Babalola, Y. O. and Aworh, O. C.

Department of Food Technology, Faculty of Technology, University of Ibadan, Ibadan Nigeria

Article history

Received: 4 November 2013
Received in revised form: 22 March 2014
Accepted: 23 March 2014

Keywords

Fermented cassava flour
Bambara nut
Supplementation
Protein quality
Organoleptic attributes

Abstract

In an attempt to improve the nutritional value of *fufu* flour, the effects of supplementation with bambara nut on its proximate composition, pasting, and physical characteristics, as well as the biological evaluation of the protein quality were investigated. Thirty-five growing albino rats were used to assess the quality of cassava-bambara composite flours using five treatment diet of fermented cassava flour containing different levels of bambara nut (10, 20, 30, 40 and 50%) in a 28 days feeding experiment to assess the protein quality on the growth response. *Fufu* samples were prepared and evaluated for sensorial attributes from the blends. The composite flours were higher in protein (13.35-18.87%) and fat (2.12-9.21%), while the gross energy increased from 409.30 to 423.91 kCal. Bulk density, water absorption capacity, least gelation capacity, and dispersibility were also affected by supplementation with significant ($p < 0.05$) increase in least gelation capacity, water absorption capacity, bulk density and low dispersibility of cassava-bambara flour. Pasting characteristics of the composite flour such as the peak viscosity, trough, final viscosity and set back decreased with increase bambara supplementation. Sensory evaluation indicated that at 10% level of supplementation there was no significant ($p > 0.05$) difference in the overall acceptability of the composite flour and that obtained from the control. The biological evaluation showed that the average final live weight, weekly weight gain and feed intake, food consumption ratio, protein energy retention, protein retention efficiency and net protein utilization of the group fed with the composite flour and the skimmed milk (control) were significantly ($p < 0.05$) different. Among the organs measured, the relative weight of the liver was significantly ($p < 0.05$) influenced by the dietary treatment.

Introduction

Protein-energy malnutrition is a major public health problem in some parts of the world, including Nigeria and the West Africa sub region. This is because diets in these areas are predominantly starchy foods; the major crops mostly roots and tubers, and cereals (Olapade and Aworh, 2012a). Cassava (*Manihot esculenta* Crantz) is a root crop cultivated and consumed as a staple in many regions of the developing countries (Oladunmoye *et al.*, 2010). The crop's ability to provide a staple food base is a function of its flexibility in terms of planting and harvesting strategies and because of its relative tolerance of poor soils and pest/disease problems (Adebowale, 2005). It is a major source of dietary energy for low income consumers in many parts of tropical Africa, including major urban areas (Berry, 1993; Dahniya *et al.*, 1994; Nweke, 1994). However, cassava is low in protein content and so the consumption of its products has been implicated in protein malnutrition. Some traditional cassava products include *fufu*, '*akpu*', *lafun*, *garri*, *abacha* and *tapioca*.

The low protein intake in Africa has been attributed to the increasing high cost of traditional sources of animal protein (Osho, 2003). Legumes are some of the low-priced sources of protein rich foods that have been important in alleviating protein malnutrition (Aykroyd *et al.*, 1992). Compositional evaluations of leguminous seeds as well as studies on the enrichment of local starchy foods with legumes such as soybean, cowpea, groundnut, pigeon pea, chicken pea and red gram have been carried out in different locations by many investigators (Oluwole and Olapade, 2011; Olapade and Aworh, 2012 a ,b) in other to improve their nutritional qualities.

Bambara nut (*Voandzeia subterranean* L. Verdc) is a legume crop of African origin used locally as a vegetable or snack. Bambara nut is one of the most adaptable of all plants and it tolerates harsh conditions better than most crops. The seed is regarded as a balanced food because when compared to most food legumes, it is rich in iron and the protein contains high lysine and methionine (Adu Dapaah and Sangwan, 2004). It is cultivated principally by farmers as a "famine culture" crop because it has numerous advantages. It is, unfortunately, one of the neglected and under-utilized crops in sub

*Corresponding author.
Email: aa.olapade@ui.edu.ng / aaolapade@yahoo.com
TEL: +234-8023418735

Saharan Africa. In addition, bambara nut is known to contain 63% carbohydrates, 18% protein and the fatty acid content comprises predominantly linoleic, palmitic and linolenic acids (Minka and Bruneteau, 2000). Bambara nut is eaten in several ways and at different stages of maturation. The young fresh seeds may be boiled and eaten as a snack and can be made into bean porridge in some parts of Nigeria. It was reported that in Zambia, bambara nut is used for bread making (Brough *et al*., 1993), while Poulter and Caygill (2006) reported that it could be used for milk making.

In view of world food shortages caused by drought, wars and inadequate government attention to agriculture especially in developing countries, it becomes expedient to harness proteins from all available food sources to minimize food and nutritional crises. As observed by Padulosi et al. (2002), neglected and underutilized crops could play prominent roles in sustaining the impoverished rural African populations by increasing their available food and protein basket. Food enrichment is the combination of two or more food stuff to improve the quality of the resultant food for the people who consume it, usually with the goal of reducing or controlling a nutrient deficiency. This strategy is applicable in communities where there is a problem or a risk of a deficiency of the nutrient or nutrients concerned. In some instances enrichment is the easiest, cheapest and best way to reduce a dietary deficiency problem. Two principal methods are available for increasing the protein content of fermented cassava product. First, through controlled fermentation, micro flora can be made to grow in large numbers in the mash. The method, however involves advanced techniques that cannot be performed easily by the people in the target areas. Furthermore, cassava products enriched by this method thus far being destined for animal feed only, due to the high risks involved in microbial manipulations. The second method involves adding protein to the deficient food from external sources in such a way as not to alter significantly the organoleptic qualities of the original food (Numfor, 1994).The latter method has an advantage over the former because of the open choice of protein sources, its simplicity for use by groups with low technological capabilities, and it relative cheapness. In this case, bambara nut is chosen because other plant protein sources are traditional in the diets of the people and also to fulfill the objective of integrating the use of this important crop into the diets of people. This study was aimed at evaluation of fufu flour supplemented with bambara nut flour.

Materials and Methods

Collection of samples

The major raw materials used in this work were matured healthy cassava (TMS-50395) cultivar obtained from International Institute of Tropical Agriculture Ibadan station, while bambara nut was purchased from Bodija market in Ibadan, Nigeria.

Preparation of fufu flour

The fermented cassava flour was produced by soaking cassava that has been peeled and washed in the water for 60 h. The water was allowed to cover the tubers completely. This is known as submerged fermentation process (Oyewole and Odunfa, 1990). After the stipulated time, the tubers were removed from the water, washed and grated. The grated mash was soaked in water for the second time for 48 h, after which it was washed through a sieve and the fibrous material removed. The meal was allowed to sediment, packed in cloth bag and then pressed to expel water until a firm cake was obtained. The cake lump was broken with hand and then dried in a cabinet drier (Mermmet, Germany) at 6^{o}C for 24 h. After drying, it was milled using an attrition mill (Apex, Germany), then sieved through mesh size 212 µm and packaged in moisture-proof polyethylene bags.

Preparation of bambara flour

The bambara nuts were processed into flour using the earlier method reported (Olapade and Adetuyi, 2007) with slight modifications. Bambara nuts were first thoroughly cleaned by picking all the stones and other foreign particles present in them while sorting out the bad ones. The cleaned seeds were soaked in water for 2 h and parboiled (100^{o}C) for 20 min. The seeds were dehulled manually, dried at 60^{o}C for 24 h in the cabinet drier. The dried seeds were then dry-milled into flour using the attrition mill. The milled grain was then sieved through a fine mesh sieve (100 µm) to obtain the bambara flour, which was then packaged in polyethylene bag until used.

Formulation of cassava-bambara blends

The blends of cassava and bambara flours were prepared by mixing the flours in the ratios 70:30, 60:40, 50:50, 80:20, 90:10, respectively using a food mixer (Kenwood, UK). The blends were packaged in polyethylene bags and stored at 10^{o}C until used.

Proximate composition

The moisture, crude protein (Nx6.25), crude fat, crude fibre and ash were determined according to AOAC (1995). Total carbohydrate was obtained by difference and gross energy value was estimated by multiplying the protein, fat and carbohydrate content by Atwater factors 4, 9 and 4, respectively and summing up (FAO, 2003).

Pasting properties

The pasting properties of each of the flour samples were determined using Rapid Visco Analyzer (Newport Scientific, 1998). Each sample (2.5 g) was weighed into a dried empty canister; then 25 ml distilled water was dispensed into the canister containing the sample. The solution was thoroughly mixed and the canister was well fitted into the RVA as recommended. The slurry was heated from 50 to 95^{o}C with a holding time of 2 min followed by cooling to 50^{o}C for 2 min holding time. The rate of heating and cooling were at a constant rate of 11.25^{o}C per min. Peak viscosity, trough, breakdown, final viscosity, set back, peak time, and pasting temperature were read from the pasting profile with the aid of thermocline for windows software connected to a computer (Newport Scientific, 1998).

Functional properties

The bulk density was determined using the method of Akpapunam and Markakis (1981) measuring 10 g of the sample into a 100 ml graduated measuring cylinder. The cylinder with the content was tapped gently ten times and the volume occupied by the content was noted. Bulk density was expressed as mass per volume. Water absorption and least gelation capacities, and dispersibility were determined according to the previous methods described by Olapade *et al.* (2003). For water absorption capacity, 1.5 g of the flour sample was measured into a centrifuge tube, the sample was mixed thoroughly with 10 ml of distilled water for 30 sec after which it was allowed to stand for 10 min at room temperature and then centrifuged at 3000 rpm for 30 min. Water absorption capacity expressed as mass of water bound by the sample. Least gelation capacity was determined by preparing 2-20% (w/v) in 5ml distilled water in test tubes, heated for 1 h in a boiling water bath followed by rapid cooling under running cold tap water. The tubes and the contents were inverted and the least concentration at which the content did not fall or slipped was taken as least gelation concentration. Dispersibility of the sample was determined by weighing 10 g of the test sample into 100 ml graduated measuring cylinder adding distilled water and making up to the volume. The set up was vigorously stirred and allowed to stand for 3 h. The volume of settled particle was recorded and subtracted from 100. The difference was reported as percentage dispersibility.

Organoleptic evaluation

Fufu dough was prepared from each blend by mixing a measured quantity of the flour with boiling water and continuously stirring the mixture using a wooden ladle until stiff dough was obtained. More water was added and the mixture was allowed to cook for few minutes and then turning properly until uniform in texture. Coded samples of the fufu were served to 30 members of trained panelists in partitioned booths. The taste, aroma, texture and overall acceptability of the samples were evaluated under amber light while appearance was evaluated under bright illuminating light. The attributes were rated on nine point hedonic scale where 9 is extremely like and 1 is extremely dislike. Bambara-free fufu served as control.

Biological quality evaluation

A basal diet was prepared according to the method of Fanimo (1991). The experimental and control diets were prepared by incorporating the composite flours and skimmed milk into the basal diet in order to achieve an isonitrogenous diet at 10% protein level. Thirty five albino rats (male and female) weighing between 22-66 g and about 21-23 days old were distributed randomly into seven groups inside metabolic cages and fed a stabilizing diet for five days. The animals were re-weighed and re-grouped into seven groups (one for control diet, 5 for experimental diets and the last for the protein free diet). The animals were housed in individual metabolic cages where food and water were supplied ad libitum. They were acclimatized to their new environment for one week by feeding them with stabilizing diet. The individual weights of the animals were taken prior to the commencement of the experiment. The diets were fed to the animals for a period of 28 days which is a period that is nutritionally accepted to be enough to observe biological and chemical changes in animals' tissues. Both the dietary intakes and live weights of the animals were recorded twice in a week throughout the experimental period. Faeces were collected daily air dried in ambient air and then at 105^{o}C for 24 h. At the end of the test period, the rats were weighed and euthanized after a starving period of 18 h. The carcasses were dried in oven at 105^{o}C for 72 h and then digested for nitrogen evaluation by macro-Kjeldahl method. The nitrogen in dried faeces, test diets, and carcass were used to compute the protein efficiency ratio, net protein retention, true digestibility, and the net protein utilization using the formulae of (Pellet and Young, 1980 and Phillips *et al*., 1981). The liver, pancreas, kidney and adrenal glands were excised from the sacrificed animals, blotted dry with tissue paper and then weighed.

Statistical analysis

The statistical significance of the observed differences were determined by analysis of variance, while means were separated using Duncan's multiple range tests. The analysis was carried out using SPSS (16.0).

Results and Discussion

Proximate composition

Table 1 shows the proximate composition of fermented cassava-bambara blends. The protein, fat, ash and fiber increased from 13.40%, 2.12%, 0.34% and 0.02 at 10% level of supplementation to 18.90%, 5.36%, 0.72% and 0.10% at 50% level of inclusion while the carbohydrate content decreased from 84.20% at 10% to 75.10% at 50% level of supplementation respectively. These values were significantly different ($p < 0.05$) compared with the values obtained for the control at 7.13%, 1.44%, 0.17%, 0.14% and 91.25%, respectively even though the carbohydrate contents of cassava flour alone was higher than that of 10% and 50% level of bambara inclusion. It is thus obvious that the bambara nut flour is the major source of protein in the composite flours, while cassava flour provided the bulk of carbohydrates. It could also be observed that the protein content of the blends increased significantly with increase in the supplementation level with bambara flour, thus confirming earlier report by Fashakin *et al.* (1986) on the beneficial effect of vegetable protein supplementation. The energy value increased with increase in the amount of bambara nut in the blends indicating that bambara has contributed more energy to the blends. This observation can be attributed to higher protein and fat contents of the legume.

Pasting properties

Pasting properties of the composite flours showed that the peak viscosity, which is the maximum viscosity developed during the heating portion, of the cassava-bambara composite flour ranged from 4162-7783 RVU for 50% and 10% bambara inclusion respectively, while that of cassava flour alone was 7900 RVU (Table 2). The differences observed in the peak viscosity may be attributed to different rates of water absorption and swelling of starch granules of these flours during heating (Ragaee and Abdel-Aal, 2006). Peak viscosity has been reported to be closely

Table 1. Proximate composition of cassava-bambara flour

Cassava flour containing	Protein (%)	Fat (%)	Ash (%)	Moisture (%)	Crude Fibre (%)	CHO (%)	Gross Energy (Kcal)
10%Bambara flour	13.4^{f}	2.12^{e}	0.34^{d}	5.47^{de}	0.02^{e}	84.2^{b}	409^{e}
20%Bambara flour	14.5^{e}	2.92^{d}	0.58^{c}	8.99^{b}	0.15^{bc}	81.8^{b}	412^{d}
30%Bambara flour	16.0^{d}	3.04^{d}	1.21^{b}	7.15^{cd}	0.17^{b}	79.8^{c}	410^{e}
40%Bambara flour	17.2^{c}	4.12^{c}	0.35^{d}	6.03^{e}	0.12^{cd}	78.3^{c}	420^{c}
50%Bambara flour	18.9^{b}	5.36^{b}	0.72^{c}	11.44^{a}	0.10^{d}	75.1^{c}	424^{b}
100%Bambara flour	20.4^{a}	9.12^{a}	2.02^{a}	8.45^{bc}	0.32^{a}	68.3^{d}	438^{a}
100%Cassava flour	7.13^{g}	1.44^{f}	0.17^{d}	4.91^{e}	0.14^{bc}	91.3^{a}	407^{ef}

Means within the same column followed by the same letter are not significantly ($p > 0.05$) different.

Table 2. Pasting properties of cassava-bambara flours

Cassava flour containing	Peak (RVU)	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Set Back value (RVU)	Peak time (min)	Pasting temp. (°C)
10%Bambara flour	7783^{b}	4405^{a}	3378^{a}	5689^{b}	1284^{b}	4.77^{e}	75.87^{e}
20%Bambara flour	5608^{c}	3214^{c}	2394^{d}	4206^{c}	991^{c}	5.03^{cd}	76.20^{c}
30%Bambara flour	5672^{C}	3072^{d}	2600^{c}	3989^{d}	917^{d}	4.97^{d}	76.25^{c}
40%Bambara flour	4725^{d}	2742^{e}	1983^{e}	3604^{e}	862^{e}	4.97^{d}	76.55^{e}
50%Bambara flour	4162^{e}	2623^{e}	1540^{f}	3531^{e}	909^{d}	5.20^{b}	77.45^{b}
100% Cassava	7900^{a}	4786^{a}	3114^{b}	6473^{a}	1686^{a}	5.07^{c}	74.65^{d}
100% Bambara	1492^{f}	1477^{f}	15^{g}	2392^{f}	914^{d}	6.97^{a}	83.97^{a}

Means within the same column followed by the same letter are not significantly ($p > 0.05$) different.

associated with the degree of starch damage and high starch damage results in high peak viscosity (Sanni *et al.*, 2001). The trough showed a decrease within the range of 4405-2622 RVU for 10% and 50% supplementation, while that of cassava flour alone was 4786 RVU. The breakdown viscosity of the composite flours ranged from 3378 to 1540 RVU for 10% and 50% levels of supplementation respectively, while that of cassava flour alone was 3114 RVU. The breakdown viscosity is regarded as a measure of the degree of disintegration of starch granules or paste stability during heating.

The final viscosity of the flour samples decreased from 5689 RVU for 10% to 3532 RVU for 50% supplementation, while for cassava flour alone was 6473 RVU. Higher values of final viscosity have been attributed to the aggregation of the amylose molecules in the paste (Oluwamukomi *et al.*, 2004). Bambara flour alone had 15 RVU, thus suggesting that the decrease in the values of peak viscosity for composite flours was due to the presence and interactions of components such as fat and protein from the bambara flour. It is also possible that the available starch in bambara nut had been gelatinized by heating during preparation, thus subsequent heating had very little effect on its swelling capacity. The viscosity when the dough is cooled to 50°C is a measure of the set-back produced by cooling. The increase in the viscosity on cooling reflects the retrogradation tendency of the product. The sample with 10% level of bambara nut had the highest retrogradation tendency (1284 RVU) as this decreased progressively with increase in the amount of bambara nut inclusion. This can be attributed to increasing hydrogen bonding during cooling and used to predict the storage life of a food product prepared from flour (Zaodul *et al.*, 2007).

The apparent pasting temperature of cassava flour alone was the lowest (74.65°C) while for the

Table 3. Functional properties of cassava-bambara flours

Cassava flour containing	Bulk density (loose) g/cm^3	Bulk density (packed) g/cm^3	Dispersibility (%).	Water absorption capacity (%)	Least gelation concentration (%)
10% Bambara flour	0.417^a	0.717^{bc}	70.67^b	136^c	4.00^d
20% Bambara flour	0.411^a	0.884^b	70.00^b	114^c	4.00^d
30% Bambara flour	0.371^b	0.556^c	68.00^c	124^c	8.00^c
40% Bambara flour	0.407^a	1.204^a	70.67^b	195^b	16.00^a
50% Bambara flour	0.424^a	1.226^a	68.67^c	199^b	16.00^a
100% Cassava flour	0.423^a	0.707^{bc}	72.33^a	174^b	2.00^d
100% Bambara flour	0.319^c	0.579^c	50.33^d	251^a	16.00^a

Means within the same column followed by the same letter are not significantly ($p > 0.05$) different.

Table 4. Organoleptic qualities of cooked cassava-bambara flour and control

Cassava flour containing	Texture	Taste	Aroma	Colour	Overall Acceptability
10% Bambara	6.80^a	6.00^a	6.37^a	6.00^a	6.20^a
20% Bambara	5.87^{bc}	5.37^b	5.70^{ab}	4.50^b	5.93^a
30% Bambara	5.63^{bc}	4.90^{bc}	5.13^b	5.70^a	5.83^a
40% Bambara	4.63^c	5.97^b	4.00^c	5.50^a	6.33^a
50% Bambara	4.87^c	3.50^c	4.13^c	3.83^b	4.10^b
100% Cassava	6.97^a	6.80^a	6.13^{ab}	6.24^a	6.43^a

Means within the same column followed by the same letter are not significantly ($p > 0.05$) different.

composite flours; it ranged from 75.87°C for 10% level of inclusion to 77.45°C at 50% supplementation level. There were significant ($P < 0.05$) differences in the pasting temperatures. The pasting temperature is an indication of the minimum temperature required for sample cooking, cost of energy involved and other components stability. The higher values obtained for the composite flour could be due to the buffering effect of fat of bambara flour on the gelling properties of the starch component of the flours which is mainly a carbohydrate food (Egounlety and Aworh, 1991).

Functional properties

Functional properties showed the difference between loose and packed bulk densities which ranged from 0.30 to 0.80 g/ml (Table 3). The bulk density values of the composite flours were higher than that of cassava flour alone. The high bulk densities observed for the flour samples indicated that they are heavy; hence they would occupy less space and would require less packaging materials per unit weight resulting in lower packaging cost (Padmashree *et al.*, 1987). The blend with 50% bambara nut flour had the highest water absorption capacity (199%), while sample with 20% supplementation had the lowest value (114%). The ability of flour materials to absorb water is sometimes attributed to their protein content, thus the observed water absorption capacity of the samples could therefore be attributed to their protein content as provided by the bambara flour. The water absorption capacity of bambara flour alone (251%) was comparatively higher than the value of soy bean flour (130%) and sun flower meal (Padilla *et al*., 1996), African yam bean flour (118-179%) (Oshadi *et al*., 1997) and lima bean flours (130-140%) (Adeyeye and Aye, 2005). This high value of water absorption capacity of the flour is an indication that it would be useful as a functional ingredient in bakery products (Olaofe *et al*., 1998).

The least gelation concentration defined as the lowest sample concentration at which gel remained in the inverted tube is used as an index of gelation capacity. That is, the lower the value, the better the gelling ability of the protein ingredient (Akintayo, 1999). From the results obtained, it could be observed that increase in bambara nut increased the least gelation concentration of the flour samples. This has been attributed to decrease in the thermodynamic affinity of proteins for the aqueous solution (Abdul Rah man *et al*., 2011). The result indicated that gelation capacity of the samples was highest at concentration 4% for sample with 10% supplementation and lowest at 16% for sample with 50% supplementation. The ability of proteins to form gels and provide structure matrices for holding water, flavor and other food ingredients is useful in food application and in new product development, thus providing an added dimension to protein functionality (Oshadi *et al*., 1997). Low gelation concentration observed may be an asset in the use of these flours for the formulation of curd or as an additive to other gel-forming materials in food products (Aremu *et al*., 2007).

The dispersibility index the flour samples ranged from 68.00 to 70.67% and it was observed that the values decreased as the level of bambara nut supplementation increased. This is an indication that bambara flour did not readily disperse in water when compared to *fufu* flour. Dispersibility is a measure of how individual molecules of a food sample, usually flour, are able to disperse and homogenize with the medium of dispersion. This ability to scatter or disperse over a wide surface area is indicative of such sample as an ideal raw material in various food products.

Sensory attributes

Sensory evaluation of fermented cassava flour with different levels of bambara nut inclusion showed progressive decrease in the scores of all attributes evaluated with increase in the amount of bambara nut in the blends. There were no significant ($p > 0.05$) differences between 10% bambara nut supplemented sample and the control sample (fermented cassava flour alone). Other samples were significantly ($p < 0.05$) different in terms of texture, taste, colour, aroma and overall acceptability from the control sample. The texture of the product is characterized by its elasticity, which was significantly ($p < 0.05$) affected by the pasting characteristics of the blends. Also, increase in level of bambara nut in the blend had resulted in browning of the samples, which had been triggered by malliard reaction of protein of bambara nut and some carbohydrates of cassava during heating.

Biological quality

Biological evaluation of the protein quality of bambara-*fufu* composite flour showed the average initial weight, final weight, weight gain, protein intake, food conversion ratio (FCR), protein efficiency ratio (PER), net protein ration (NPR) and net protein utilization (Table 5). The final live weight of the animals fed on control diet was higher at (73.68 g) and significantly different ($p < 0.05$) from those fed on the experimental diets which ranged between 7.80 g for group of rats fed on 10% level of supplementation and 44.35 g for 50%, respectively. Gain or reduction of weight could be as a result of their food intake which also varied from 344 g for control group to 243.06 g for animals on 10% experimental diet. The low values recorded could also be as a result of the protein quality of the diet not being enough to support their growth, hence the reduction in weight. The difference is as a result of differences in protein quality among milk protein, bambara and cassava. Cassava is low in protein (amount) and the little protein is of poor quality i.e. limiting in some essential amino acids, while bambara nut is high in protein, such that when added to cassava increases the protein content of the mixture but the protein of Bambara groundnut is also limiting in sulphur amino acids, so mixing it with cassava will still not give a good quality protein. It could also be as a result of the presence of anti-nutrients that the processing technique was unable to sufficiently reduce, hence causing retarded growth (Martinez *et al*., 1995) and low digestibility (Putszai *et al*., 1995).

There was significant difference ($p < 0.05$) in food conversion ratio, net protein ratio, between group of rats that were fed on the control diet and composite flours respectively. The control group fed on skimmed milk had the highest protein efficiency ratio (2.14) followed by the group that was fed on 50% bambara supplementation (1.73) and 40% group (1.26) while there was no significant difference between the control group (1.26) and group fed on 50% bambara (1.45). The net protein utilization is a more accurate measure of protein quality, because it allows the evaluation of maintenance requirement and the results are independent. True digestibility was highest in the control group (99.60%) followed by diet with 40% (97.80%), and 50% supplementation (97.20), respectively. This showed that there was no significant difference ($p > 0.05$) between the control group and

Table 5. Biological response of rats fed cassava-bambara flours

Cassava flour containing	Initial weight (g)	Final weight (g)	Weight gain (g)	PER	NPR	TD	NPU	FRC	Food Intake	Protein Intake
10%Bambara flour	73.95^{a}	81.75^{c}	7.80^{e}	0.31^{e}	0.07^{d}	97.71^{b}	93.66^{a}	32.53	243.06	24.31
20%Bambara flour	59.08^{ab}	70.60^{c}	11.52^{de}	0.46^{de}	0.15^{d}	95.50^{c}	66.34^{c}	21.94	250.80	25.08
30%Bambara flour	51.98^{b}	70.36^{c}	18.38^{d}	0.70^{d}	0.41^{d}	94.95^{c}	80.24^{b}	14.91	262.44	26.24
40%Bambara flour	43.26^{b}	77.06^{c}	33.80^{c}	1.26^{c}	0.98^{c}	97.84^{b}	82.40^{b}	9.25	268.18	26.82
50%Bambara flour	58.16^{ab}	102.51^{b}	44.35^{b}	1.73^{b}	1.45^{b}	97.23^{b}	79.79^{b}	5.79	267.18	26.73
Skimmed milk	53.06^{b}	126.74^{a}	73.68^{a}	2.14^{a}	1.92^{a}	99.61^{a}	77.73^{b}	3.48	267.32	34.40

Means within the same row followed by the same letter are not significantly ($p > 0.05$) different.

PER-Protein efficiency ratio, NPR-Net protein ratio, TD-Total digestibility, NPU-Net protein utilization, FRC-Feed rate conversion

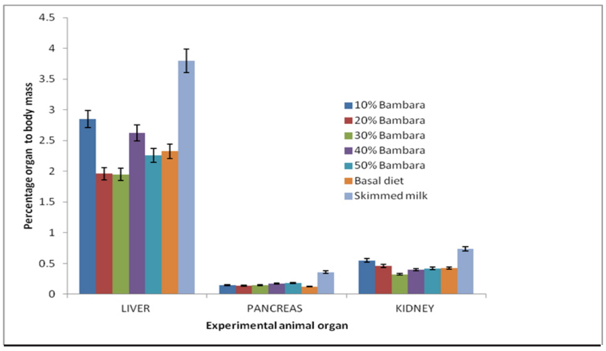

Figure 1. Percentage organ to body weight of rats fed on experimental cassava-bambara diets over a period of 28 days

those fed experimental diet. The feed conversion ratio of the rats fed control diet was significantly lower at (3.84) than those that were fed experimental diet. The values ranged from 5.79-32.50. This could be as a result of inefficient nutrient utilization which might have made it impossible for the animal to totally utilize the nutrients in the food completely. Since the experimental diets were compounded at 10% isonitrogenous level, it then mean that protein in the diet is less utilized and the unpalatability of the meal could have resulted in the lower intake of the diet and consequently lower protein intake. The values of protein intake is highest in the control group (34.4) while for the experimental diet, it ranged from 24.3 for animals fed on 10% level of bambara inclusion to (26.7) for 50% level of inclusion. More so, apart from poor growth and poor protein utilization that were observed from the results above, the overall general appearance of the animals that were placed on the experimental diet particularly those that were fed on 10%, 20% as well as 30% level of bambara inclusion had extensive muscle wasting, skin and hair changes (the hair at the back and those around the mouth were sparse) and the tail became extremely bony while the animals became irritable i.e. ready to attack anyone considered to be an intruder. All these signs could be attributed to signs of malnutrition which indicated that the quality of protein in the bambara groundnut is very low and therefore cannot support their growth, particularly when combined with a carbohydrate source with little or no protein content.

Organ responses

Percentage of organ weight to body weight of rats fed with skimmed milk, composite flours and basal diets were as shown in Figure 1. Percentage of liver weight of rats that were fed on 20% and 30% diets were significantly lower, (1.96, and 1.95%) ($p < 0.05$) than those fed on the other experimental diets while those that were fed on skimmed milk was significantly higher (3.8%) than those fed with the experimental diet which ranged from 1.95 – 2.85%. Lower percentage liver weights has been reported by Aletor and Fetuga (1986) in rats that was fed lima and winged beans, which is presumably due to necrosis arising from the potent toxic components in legumes. It was observed that the percentage liver weight of rats fed 10% inclusion level of Bambara is somewhat higher 2.85% than that of the remaining group (1.95-2.63%). The results of organ weight suggest development of muscularized liver organ in order to handle some extraneous components of the diet (Agbede, 2000). The liver has been considered to be the nutritional indicator of the body of which dietary and toxic factors in the food consumed may interfere with this function. Percentage weight of pancreas to the body weight was observed to be significantly higher in the control group ($p< 0.05$) at 0.36% than in the experimental diet group whose value ranged between 0.14% for group fed 20% inclusion to 0.18% for 50% level of inclusion group. Kidney and adrenal weight was also found to be higher in rats of control group (0.74%) while for the rats on experimental diet, values ranged from 0.33% for group on 30% inclusion level to 0.55% for the group on 10% level of Bambara supplementation. With these variation in the percentage organ weights, diets that are of poor protein quality could be said to cause growth failure and the more pronounced effect due to lack of essential amino acids being made available to the liver which could in turn lead to serious metabolic and physiologic alterations.

Conclusion

This study has shown that it is possible to enrich fufu with 10% bambara nut without adverse effect on the sensory attributes. Adding bambara flour to fermented cassava flour resulted in significant ($p < 0.05$) increase in the crude protein content.

References

Adebowale, A.A. 2005. Rheology and Storage Properties of Tapioca. An unpublished Ph.D. Thesis Federal University of Agriculture, Abeokuta, Nigeria 231

Adeyeye, E.L and Aye, P.A. 2005. Chemical composition and the effects of salts on the food properties of wheat flour. Pakistan Journal of Nutrition 4:187 – 196.

Adu-Dapaah, H.K. and Sangwan, R.S. 2004 Improving Bambara groundnut productivity using gamma irradiation and *in vitro* techniques. African Journal of Biotechnology 3:260-265.

Agbede, J.O. 2000. Biochemical compositional nutritive quality of the seeds and leaf protein from underutilized tree and herbaceous legumes. Ph.D.Thesis. Federal University of Technology, Akure Nigeria 293.

Akintayo, E.T., Oshodi, A.A. and Esuoso, K.O. 1999. Effects of Nacl, Ionic strength and PH on the foaming and Gelation of pigeon pea (*Cajanus cajan*) protein concentrates. Food Chemistry 66:51-56.

Akpapunam, M.A. and Markakis, P. 1981. Physicochemical and nutritional aspects of cowpea flour. Journal of Food Science 46:972-973.

Aletor, V.A. and Fetuga, B.L. 1986. Some pathological aspects of raw lima beans (*Phaseolus lunatus* Linn) feeding to growing rats. Nigerian Journal of Animal Production 13:48-57.

AOAC. 1995. Official Methods of Analysis, 16th edn. Washington, DC: Association of Analytical Chemists

Aremu, M.O., Olaofe, O. and Akintayo, E.T. 2007. Functional properties of some Nigerian varieties of legume seed flours and flour concentration effect on foaming and gelation properties. Journal of Food Technology 5 (2):109-115.

Aykroyd, W.R., Doughty, J. and Walker, A. 1992. Legumes in human nutrition. FAO Food and Nutrition paper No. 20, Rome 67-68.

Berry, S.A. 1993. Socio-economic aspect of cassava cultivation and use in Africa: Implication for development of appropriate technology. IITA, Ibadan.

Brough, S.H., Azam-ali, S.N. and Taylor, A.J. 1993. The potential of bambara groundnut (*Vigna subterranea*) in vegetable milk production and basic protein functionality systems. Food Chemistry 47: 277-283.

Dahniya, M.T., Akoroda, M.O. Alvarez, M.B., Kalndaneh, P.M., Ambe-Tumanteh, J., Okeke J.E. and Jalloh, A. 1994. Development and dissemination of appropriate root crops packages to farmers in Africa: In Afort, F. and S.K. Hahn (Eds.) Proceeding of 9th Symposium of the International Society of Tropical Root Crop 20-26 Oct. 1999, Accra, Ghana.

Egounlety M. and Aworh, O.C., 1991. Production and physiochemical properties of Tempeh – fortified maize based weaning foods. In D.S, sofa (Ed), proceedings of seminar on development of the protein energy foods from grain legumes, February 5 – 7, University of Lagos.

Fanimo, A.O. 1991. Substitution of soya bean and animal byproducts for fish meal in pig rations. Ph.D Thesis, Department of Animal science, university of Ibadan, Ibadan Nigeria.

FAO. 2003. Food energy-method of analysis and conversion factors. Food and Nutrition paper 77. Food and Agriculture Organisation of th United Nation, Rome.

Fashakin, J.B., Awoyefa., M.B. and Furst, P. 1986. The application of protein concentrates from locally available legumes in development of weaning food. Journal of Nutritional Science Ernahrungswisse 25: 220-227.

Martinez, J.A., Marcross, R. Mararulla M.T. and Larraide, J. 1995. Growth hormonal status and protein turn over in rats fed on a diet containing peas (*Pisum satevum*) as the source of protein. Plant Foods Human Nutrition 47:211-220.

Minka, S.R. and Bruneteau, M. 2000. Partial chemical composition of bambara pea (*Vigna subterranean* L. Verde). Food Chemistry 68: 273-276.

Newport Scientific 1998. Applications manual for the rapid visco analyzer using thermocline for windows. Newport scientific pty limited. Aust. Pp. 2 – 26.

Numfor, F. A. 1994. An improved method of processing cassava in tropical root crops. IITA Report.

Nweke, F.I. 1994. Farm level practice relevant to cassava plant protection. African Crop Science Journal 2:563 -582.

Oladunmoye, O.O., Akinoso, R. and Olapade, A.A. 2010. Evaluation of some physical-chemical properties of wheat, cassava, maize and cowpea flours for bread making. Journal of Food Quality 33:693-708.

Olaofe, O., Arogundade, L. A., Adeyeye, E. and Falusi, O.M. 1998. Composition and food of the variegated grasshopper. Tropical Science 38: 233-237.

Olapade, A.A. and Adetuyi, D.O. 2007. Comparison of different methods of producing bambara (*V. Subterranean* L. Thou) flours for preparation of moin moin. Nigerian Food Journal 25(2):150-157.

Olapade, A.A., Akingbala, J.O., Oguntunde, A.O. and Falade, K.O. 2003. Effect of processing method on the quality of cowpea (*Vigna unguiculata*) flour for akara preparation. Plants Food for Human Nutrition 58:1-10.

Olapade, A.A. and Aworh, O.C. 2012a. Chemical and nutritional evaluation of extruded complementary foods from blends of fonio (*Digitaria exilis* Stapf) and cowpea (*Vigna unguiculata* L. Walp) Flours. International Journal of Food and Nutrition Science 1(3): 4-9.

Olapade, A.A and Aworh, O.C. 2012b. Evaluation of extruded snacks from blends of acha (*Digitaria exilis*) and Cowpea (*Vigna unguiculata*) flours. Agric. Eng. Mt. C16R Journal 14(13):210-217.

Oluwamukomi, M,O., Eleyinmi, A. F. and Enujuigha V.N. 2004. Effect of soy supplementation and its stage of inclusion on the quality of ogi – a fermented maize meal. Food Chemistry 91: 651-657.

Oluwole, B.O. and Olapade, A.A. 2011. Effect of extrusion cooking of white yam (*Dioscorea rotundata*) and bambara nut (*Vigna subterranean*) blend on some selected extrudate parameters. Food and Nutrition Sciences 2:599-605.

Oshadi, A A., Ipinmoroti, K O. and Adeyeye, E. 1997. Functional properties of some varieties of African yam bean. International Journal of Food Science and Nutrition 48: 243-250.

Osho, S.M. 2003. The processing and acceptability of a cassava based product (*garri*) with Soybean. Nutrition and Food Science 33.

Oyewole, O. B. and Odunfa, S.A. 1990. Characterization and distribution of lactic acid bacteria in cassava fermentation during fufu production. Journal of Applied Bacteriology 68: 45-52.

Padilla, F.C., Alvarez, M.T. and Alfaro, M.J. 1996. Functional properties of bambara nut flour compared to those of soy bean. Food Chemistry 57: 191-196.

Padmashree, T. S., Kshmi, L.V. and Puttaragi, S. 1987. Effect of traditional processing on the functional properties of cowpea (*Vigna catjang*) flour. Journal of Food Science and Technology 24:221-225

Padulosi S, Hodgkin, T, Williams, J.T. and Haq, N. 2002. Underutilized crops: trends, challenges and opportunities in the 21st century. In: Engels JMM *et al.* (eds): Managing plant genetic diversity (pp 323-38). CABIIPGRI, UK and Rome.

Pellet, P.L. and Young, V.R. 1980. Nutritional Evaluation of protein foods. The United Nations University, Tokyo, Japan.

Phillips, D.E., Eyre, M.R., Thompson, A. and Boulter, D. 1981. Protein quality in seed meals of phaseolus vulgaris and heat stable factors affecting the utilization of protein. Journal of Food Science 32: 423-432.

Poulter, N.H. and Caygill, J.C. 2006. Vegetable milk processing and rehydration characteristics of Bambara groundnut (*Voandzeia subterranean* L. Thouars). Journal of Science of Food and Agriculture 31:1158-1163.

Putszai, A., G., Grant, T., Duguid, D.S., Brown, P.J., Peumans, E.J.M., Damme, V.A.N. and Bardoez, S. 1995. Inhibition of starch digestion by amylase inhibitor reduces the efficiency of utilization of dietary protein and lipids and retards the growth of rats. Journal of. Nutrition 125: 1554-1562.

Ragaee S. and Abdel–Aal, E.M. 2006. Pasting properties of starch and protein in selected cereals and quality of their food products, Food Chemistry 95: 9-18.

Sanni, L. O., Ikuomola, D.P. and Sanni, S. A. 2001. Effect of length of fermentation and varities on the qualities of sweet potato *garri.* processing. 8th triennial symposium of the International Society for Tropical Root Crops. Africa Branch (ISTRC- AB), ed . M. O Akoroda, IITA, Ibadan, 12 – 16 November. pp. 208 – 211.

Tietz, P.S., Holman, R.T. Miller L.J. and Larusso, N.F 1995. Isolation and characterization of rat Chlolangiocyte vesicles enriched in apical or basolateral plasma membrane domains. Biochemistry 34: 15436-15443.

Zaodul I. S. M., Yamauchi, H., Kim, S., Hashimoto, N. and Noda, T. 2007. RVA study of mixtures of wheat flour and potato starches with different phosphorus contents. Food Chemistry 102: 1105-1111.