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Effect of Processing Methods on Qualities of Bambara Groundnut (*Voandzeia subterranea* (L.) Thouars) Flour and their Acceptability in Extruded Snacks

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ABSTRACT

This study evaluated the effects of either germination, roasting or germination-roasting of Bambara groundnut (BGN) seeds prior to milling into flour, on their chemical composition and determined acceptability of the flour samples in extruded snacks. The flour samples were mixed with equal proportion of other ingredients such as acha (*Digitaria exile* Staff), carrot, sugar, fat and spices and extruded using a single screw Brabender laboratory extruder at 150°C, 170 rpm screw speed and 20% feed moisture content. The extrudates were cooled and subjected to proximate, anti-nutrient, functional and sensory analyses using standard methods. Data generated was subjected to one way analysis of variance using SPSS version 17, while means were separated using Duncan's new multiple range test and significance was accepted at $p = 0.05$. Result of proximate analysis revealed that the protein contents of roasted (23.09%) and germinated-roasted (23.20%) flours were significantly ($p<0.05$) higher than those of other samples. The samples differed significantly ($p<0.05$) in their trypsin inhibitor, tannic acid, phytate and haemagglutinnin activities. Roasting process reduced concentration of trypsin inhibitor by 37.5%, germination reduced it by 17%, while a combination of germination and roasting caused highest reduction (68%). There were significant ($p<0.05$) differences in Water Binding Capacity (WBC), Foaming Capacity (FC) and Nitrogen Solubility (NS) of the samples. Roasting BGN flour yielded extruded snack with improved taste, aroma/flavor and overall acceptability. Acceptable snacks of adequate nutritional and anti-nutritional qualities were produced by roasting or/and germination of BGN seeds prior to extrusion cooking of their flour with other ingredients. Bambara groundnut should be exploited in combating protein-energy malnutrition prevalent in Nigeria and other African countries.

Key words: Roasting, germination, anti-nutritional factors, extrusion, organoleptic properties

INTRODUCTION

Bambara groundnut (*Voandzeia subterranea* L., Thouars) is an indigenous African crop that is grown across the continent (Mkandawire, 2007). Though, Bambara groundnut is grown extensively in Nigeria (Enwere, 1998), it is one of the under-utilized legumes in the country. Nigeria produced over 100,000 metric tons yearly, followed closely by Niger with 30,000 metric tons and Ghana 20,000 metric tons (Asiedu, 1989). In Africa, Bambara groundnut is the third most important legume after peanut and cowpea (Mkandawire, 2007). The crop has a number of production advantages in that it can grow on poor soils with little rainfall and can produce substantial yield under better conditions. It is nutritionally superior to many legumes and is the preferred crop for many local people (Linnemann, 1990; Brough and Azam-Ali, 1992). Bambara is a rich source of protein (20-25%) and its seeds are valued for their nutritional and economic importance (Mkandawire, 2007). It contains about 60% carbohydrate; its protein is reported to be higher in the essential amino acid methionine than other grain legumes (Stephens, 2003) and contains 6-12% oil which is half of peanuts. The gross energy value of Bambara is greater than that of other common pulses such as cowpea and pigeon pea (FAO., 1982). In Nigeria, freshly harvested pods or seeds are cooked, shelled and eaten as snacks (Alobo, 1999) or milled into nutritious flour used for preparation of "moin moin" analogue called "Okpa" which is very popular among the Igbo tribe of the Eastern Nigeria (Enwere, 1998; Olapade and Adetuyi, 2007) but cannot keep for more than 12 h. Since Bambara is very nutritious and of economic importance, it could be utilized in the development of more acceptable shelf stable food products such as extruded snacks. Presently, the commonly consumed traditional snacks are produced by germination, frying, roasting, boiling, baking, drying and these includes snacks such as akara, okpa, dodo, dodo-ikire, moin-moin, cassava chips, tapioca, roasted groundnut, ekoki, massa, melon cake, ikpan, sinasir etc. (Adelaja *et al*., 2010; Okafor, 2012). Some of these traditional snacks are unhygienically produced and packaged and are not shelf stable, keeping only for few hours or days at ambient temperature. So, Bambara could be utilized in the production of more shelf stable, hygienically processed, well packaged and acceptable product such as extruded snacks.

Extrusion technology has many advantages over traditional/conventional methods (Balley *et al*., 1991; Rizvi *et al*., 1995). It is one of the most efficient processes currently used for solving world's hunger and nutritional challenges (Hauck, 1981). Its application in Nigeria has been reported for soybean flour blended with either cereals, roots, tubers, bread fruit or other low protein legumes (Dashiell *et al*., 1990; Lasekan and Akintola, 2002; Iwe *et al*., 2004; Nwabueze, 2006). However, there is little or no information on application of extrusion cooking in Bambara groundnut processing.

This study was therefore conceived to evaluate the effect of processing methods on the composition of Bambara groundnut flour and determine their acceptability in ready-to-eat extruded snacks.

MATERIALS AND METHODS

Preparation of raw materials: The seeds of Bambara groundnut (BGN) were purchased from Ogige market Nsukka, Enugu State, Nigeria, together with other needed raw materials. The research project was carried out at the Department of Food Science and Technology, University of Nigeria, Nsukka, from April-November, 2009.

Bambara groundnut seeds (16 kg) were cleaned by sorting to remove extraneous materials and shared into four lots designated A, B, C and D. They were either germinated, roasted, germinated and roasted or unprocessed (control), as described below.

Germination (A): BGN seeds (4 kg) were washed with water and soaked for 12 h at an average room temperature of 28±2°C. After soaking, the seeds were spread on wet jute bags and covered with moistened muslin cloth to germinate for 48 h. Germinated seeds were evenly spread on oven trays and dried in an air oven (Gallenkamp) at 60°C for 12 h. The vegetative parts of the dried BGN seeds were removed by rubbing between palms and winnowed. The cleaned BGN seeds were milled using Apex mill, sieved to pass through 0.4 mm mesh size, packaged in high density polyethylene bag and stored in a refrigerator at 4°C till used.

Roasting (B): Cleaned BGN seeds (4 kg) were evenly spread on trays and roasted at 140°C for 40 min in an electric oven (Memmert GmBH, model KG 8540), cooled, milled using Apex mill, sieved to pass through 0.4 mm mesh size, packaged in a high density polyethylene bag, sealed and stored in a refrigerator at 4°C till used.

Germination and roasting (C): Germination of BGN seeds (4 kg) was carried out prior to roasting as described above.

Unprocessed raw BGN (D): Lot D sample of the BGN (4 kg) seeds was not subjected to either germination or roasting process after the initial sorting activity. The sample was milled with an Apex milling machine, sieved to pass through 0.4 mm mesh size, packaged in a high density polyethylene bag, sealed and stored in a refrigerator at 4°C till used.

Extrusion of samples: The A, B, C and D flour samples were mixed with equal proportion of other ingredients such as acha (*Digitaria exile* Staff), carrot, sugar, fat and spices, prior to extrusion using a single screw Brabender laboratory extruder (Duisburg DCE-330 model) at 150°C, 170 rpm screw speed and 20% feed moisture content. The extruder was powered by a decoder drive (Type 832,500) and driven by a 5.94 kw motor. The grooved band had a length/diameter ratio of 20:1. The extruder has variable screws and heaters with a fixed die diameter (2 mm) and length (40 mm). A feed hopper mounted vertically above the end of the extruder and equipped with a screw that rotated at a constant speed of 80 rpm on a vertical axis, takes feed into the extruder. The flour was allowed to equilibrate for 2-3 h before extrusion. The extruder runs were stabilized using Bambara groundnut flour.

Analyses

Proximate composition: The official methods of the American Association of Cereal Chemist (AACC., 1990) was used to determine moisture, crude protein, lipid, ash and crude fiber contents of the Bambara nut flour and extruded products. Moisture content was determined according to method 44-19. Crude protein was determined by an automated Kjedahl method, using Kjedahl 2006 digester. Crude fat content was determined using soxlet apparatus, with petroleum ether to extract the lipid according to method 20-26. Method 48-06 was used to determine crude fiber content. The carbohydrate content was obtained by difference (100-crude protein, moisture, fat and crude ash contents), while the caloric value was obtained by multiplying the values of the crude protein, fat and carbohydrate by their physiological fuel values of 4, 9 and 4, respectively.

Anti-nutrients: Trypsin inhibitor activity was determined according to the method of Kakade *et al.* (1974). The phytate content of the flour was determined using the method described by Maga (1982). Tannic acid content was determined by the Folis-Denis calorimetric method (Kirk and Sawyer, 1998). Haemagglutinnin activity was carried out using the method described by Pull *et al.* (1978).

Functional properties: Water absorption capacity was determined by the method of Sosulski (1962). Fat absorption capacity was determined by the method of Sosulski *et al.* (1976). Foam capacity was determined by the method described by Lawhon and Cater (1971) and expressed as percentage volume increase. Nitrogen solubility was determined according to the method of Mattil (1971). All the analysis were carried out in triplicates.

Sensory evaluation: The extruded Bambara based snacks were subjected to organoleptic analysis. A total of twenty semi-trained panelist drawn from Staff and students of University of Nigeria, Nsukka, Nigeria, participated in the evaluation. Each of the snack samples were placed in 20 coded clean white plates (30 gram per plate) and served at room temperature (28±2°C) to the panelist in a sensory evaluation booth with fluorescent lights on. The asessors were requested to eat the extruded snacks and score each sample using a 9-point Hedonic scale (Larmond, 1977) where 1 = extremely unacceptable and 9 = extremely acceptable. Attributes evaluated include; color, taste, texture, flavor, mouthfeel and overall acceptability. Water was provided for rinsing mouth in between tests to prevent carry-over of attributes.

Statistical analysis: Data were reported as Mean±SD. Statistical significance was established using One-Way Analysis of Variance (ANOVA) at 5% level of probability and differences between means were compared using Duncan Multiple range test (Duncan, 1955). Statistical analysis was carried out using SPSS for Windows, version 17 (SPSS Inc.) Chicago, IL USA.

RESULTS

Proximate composition: The proximate composition of BGN flour samples obtained from raw, germinated, roasted and combined treatment of BGN seeds is presented in Table 1. The moisture content of the samples ranged from 7.01-10.79% with the roasted BGN flour having the least moisture content (7.01%) while germinated BGN had the highest (10.79%). The protein content of the roasted and germinated-roasted flours were significantly ($p<0.05$) higher (23.09 and 23.20%, respectively) than the rest of the samples. However, the raw, germinated, roasted and germinated-roasted flours did not differ ($p>0.05$) significantly in their ash (3.55-3.85%), fat (6.73-7.33%) and crude fiber (3.21-3.60%) contents.

Anti-nutritional factor: The anti-nutritional factors of the samples presented in Table 2 shows that the samples differed significantly ($p<0.05$) in their tannic acid and phytate contents, as well as their trypsin inhibitor and haemagglutinnin activities. Raw Bambara seed flour had significantly ($p<0.05$) higher content of these components, while germinated-roasted BGN flour had the least. The trypsin inhibitor activity in raw BGN was 17.94 TIU mg g^{-1}, roasted BGN flour (11.21 TIU mg g^{-1}), germinated BGN flour (14.85 TIU mg g^{-1}), germinated/roasted BGN flour

Table 1: Effect of processing methods on the proximate composition of Bambara groundnut flour

Sample code	Moisture	Protein	Fat	Ash	Fibre	Carbohydrate	Energy (kcal)
	(%)						
BGN	10.30±0.91^a	21.85±1.34^b	6.90±1.02^a	3.64±0.98^a	3.42±0.76^a	53.89±1.30^a	365.06
RBGN	7.01±0.73^b	23.09±0.99^a	7.33±1.25^a	3.76±0.70^a	3.21±1.08^a	55.60±1.50^b	380.73
GBGN	10.79±0.67^a	22.18±0.54^b	6.73±0.54^a	3.58±0.50^a	3.60±0.79^a	53.12±0.86^a	361.57
G/RBGN	7.24±0.79^b	23.20±1.80^a	7.16±0.48^a	3.85±1.11^a	3.52±0.90^a	55.03±0.16^b	377.36

Values are Mean±SD (n = 3), Column means with different superscripts are significantly ($p<0.05$) different, BGN: Raw Bambara groundnut, RBGN: Roasted Bambara groundnut, GBGN: Germinated Bambara groundnut, G/RBGN: Germinated-roasted Bambara groundnut

Table 2: Effect of processing methods on some anti-nutritional factors in Bambara groundnut flour

Processing treatments of Bambara groundnut	TIU (mg g^{-1})	Tannic acid (equivalent) (mg per 100 g)	Phytate (mg per 100 g)	Haemagglutinin (Hu/mg protein)
Raw BGN	17.94±0.58^{a}	0.62±0.89^{a}	255±0.36^{d}	6.50±0.78^{a}
Roasted	11.21±1.23^{c}	0.35±1.01^{c}	178±1.42^{b}	3.80±650^{c}
Germinated	14.85±0.69^{b}	0.49±0.22^{b}	192±0.98^{c}	5.20±1.32^{b}
Germinated and roasted	8.73±1.24^{d}	0.28±0.05^{d}	120±0.73^{a}	2.10±0.96^{d}

Values are Mean±SD (n = 3), Column means with different superscripts are significantly ($p<0.05$) different, TIU: Trypsin inhibitor unit

Table 3: Effect of processing methods on selected functional properties of Bambara groundnut flour

Treatments	Water binding capacity (g g^{-1})	Oil binding capacity (g g^{-1})	Foaming capacity (vol mL^{-1})	Nitrogen solubility (%)
Raw BGN	1.7±0.63^{b}	1.3±0.42^{a}	33.3±0.25^{c}	85.40±0.66^{b}
Roasted	1.6±0.70^{b}	1.3±0.01^{a}	24.0±0.06^{a}	46.80±0.73^{d}
Germinated	1.0±0.29^{a}	1.1±0.83^{a}	41.7±0.41^{d}	92.10±1.32^{a}
Germinated-roasted	1.2±0.44^{a}	1.2±0.92^{a}	28.9±0.11^{b}	49.20±0.95^{c}

Values are Mean±SD (n = 3), Column means with different superscripts are significantly ($p<0.05$) different

Table 4: Sensory profile of the extrudates from treated Bambara groundnut

Treatments	Color	Taste	Texture	Flavor	Mouthfeel	Overall acceptability
ER	6.6±0.96^{b}	6.9±0.71^{ab}	7.1±0.19^{a}	6.8±0.86^{ab}	7.0±0.52^{a}	6.8±0.92^{b}
ERBGN	7.5±1.01^{a}	7.8±0.86^{a}	7.3±0.90^{a}	7.7±0.66^{a}	7.4±0.54^{a}	7.7±0.50^{a}
EGBGN	6.5±0.73^{a}	6.0±0.61^{c}	7.2±0.30^{a}	6.5±0.25^{b}	7.1±084^{a}	6.3±0.80^{b}
EGRBGN	7.0±0.20^{b}	6.6±1.14^{b}	7.2±0.79^{a}	6.9±0.60^{ab}	7.3±0.88^{a}	6.6±0.38^{b}

Values are Mean±SD (n = 20), Column means with different superscripts are significantly ($p<0.05$) different, ER: Extrudate from raw Bambara groundnut, ERBGN: Extrudates from roasted Bambara groundnut, EGBGN: Extrudate from germinated Bambara groundnut, EGRBGN: Extrudate from germinated-roasted Bambara groundnut

(8.73 TIU mg g^{-1}). Tannic acid content ranged from 0.28-0.62 mg per 100 g with the raw flour having the highest value (0.62 mg per 100 g) and germinated-roasted BGN flour having the least 0.28 mg per 100 g. Similarly, the raw BGN flour had the highest phytate content of 255 mg per 100 g, while germinated-roasted BGN flour had the least value (120 mg per 100 g), the roasted and germinated BGN flour had 178 and 192 mg per 100 g, respectively.

Functional properties: The functional properties of the BGN flour samples shown in Table 3, did not differ ($p>0.05$) significantly in their oil binding capacity. However, there were significant ($p<0.05$) differences among the samples in their Water Binding Capacity (WBC), Foaming Capacity (FC) and Nitrogen Solubility (NS). The raw and roasted BGN flour had higher WBC (1.7 and 1.6 g g^{-1}, respectively), while the germinated and germinated-roasted BGN flours had the least values (1.0 and 1.2 g g^{-1}, respectively).

Organoleptic properties: The sensory evaluation result in Table 4, revealed that extruded snacks made with raw and processed Bambara groundnut flour samples differed ($p<0.05$) significantly in terms of color, taste, flavor and overall acceptability. However, the extrudates did not differ ($p>0.05$) significantly in their texture and mouthfeel. The roasted Bambara groundnut flour based extrudates had significantly ($p<0.05$) higher sensory mean scores compared to the extrudates from germinated and raw Bambara groundnut flour. The germinated BGN flour based extruded snack was the least acceptable.

DISCUSSION

The proximate composition of BGN flour samples processed either by roasting, germination or a combination of both processes is presented in Table 1. The moisture (10.30%), crude protein (21.85%), fat (6.90%), ash (3.64%), crude fiber (3.42%) and carbohydrate (53.89%) of the raw BGN were comparable to values reported by Poulter (1981), Obizoba and Egbuna (1992) and Olapade and Adetuyi (2007). No significant ($p>0.05$) changes were observed in fat, ash and crude fiber content of the BGN flour samples. However, roasting brought about significant ($p<0.05$) reduction of the moisture content and increase in protein content of the flour. The slight increase in the protein (from 21.85-23.09%) and fat (from 6.90-7.33%) contents recorded in the roasted flour sample could be probably due to concentration of nutrients as a result of moisture lost during roasting (FAO., 1982).

Table 2 shows the effect of processing methods on some anti-nutritional factors. Bambara groundnut like most legumes, contain anti-nutritional factors like trypsin inhibitor, tannins, polyphenols, phytate and haemagglutinnin. Processing methods such as dehulling, milling, soaking, cooking, germination, fermentation, autoclaving, roasting and frying have been found to reduce/eliminate these anti-nutritional factors (FAO., 1982) which agrees with the result of this experiment. Roasting, germination and germination-roasting processes significantly ($p<0.05$) reduced the trypsin inhibitor, tannins, phytate and haemagglutinnin in the BGN flour. Roasting reduced the concentration of trypsin inhibitor by 37.5%, germination reduced it by 17%, while a combination of germination and roasting processes brought the highest reduction (68%). The nutritional implication of these reductions in the samples concentration of trypsin inhibitor is that it will lead to improvement in protein digestibility. Negi *et al.* (2001) and Archana *et al.* (2001) reported higher protein digestibility/quality after heat treatment (autoclaving and roasting) which they attributed to destruction of heat labile protease inhibitor and opening up of protein structures by denaturation, leading to increased accessibility of the protein to enzymatic attack. Germination/malting have also been reported to improve protein digestibility (Nnanna and Philips, 1990). Increased protein quality/digestibility upon germination may be probably due to decrease in the anti-nutritional factors like tannin, phytate and trypsin inhibitors, modification and degradation of stored proteins by the action of proteolytic enzymes. Tannins are generally defined as soluble astringent, complex and phenolic substances of plant origin which play significant role in the reduction of dietary protein digestibility by complexing either with dietary protein or digestive enzyme. Tannin content was significantly ($p<0.05$) reduced by up to 45% by roasting, germination reduced it by 21%, while a combination of roasting and germination resulted in 56% reduction. These reductions will bring about improvement in nutritional quality of the flour samples. Phytate level was reduced from the initial content of 255 mg per 100 g in the raw BGN to 178 mg per 100 g in the roasted sample, 192 mg per 100 g in germinated sample and 120 mg per 100 g in the germinated and roasted sample. The reduction in phytate content of the flour during germination could be probably due to increase in freed phosphorous resulting from increased activities of the enzyme phytase, during germination which hydrolyses the bond between protein-enzyme-mineral to free phosphorus (Nnam, 2000; Sulieman *et al.*, 2007; Abdelrahaman *et al.*, 2007). Phytate reduction by 38-46% after germination has been reported by Archana *et al.* (1998) and Salunkhe *et al.* (1985). The reduction was attributed to leaching of phytate ions and increased activity of phytase enzyme during germination.

The haemagglutinin activity was also reduced from 100% (6.50 Hu/mg protein) in the raw BGN flour to 58.5% in roasted sample, 80% in germinated sample and to 32.3% in the germinated and roasted sample. Igbedioh *et al.* (1994) and Apata and Ologhobo (1994) reported reduction in trypsin inhibitor, tannin content, phytic acid and haemagglutinin contents of some tropical legumes processed by cooking, autoclaving and roasting. Similarly Obizoba and Egbuna (1992) reported reduction in the haemagglutinin content of germinated Bambara groundnuts.

Table 3 shows the effect of processing methods on the functional properties of BGN flour samples. Functional properties of food proteins determine their behavior in food systems during processing, storage, preparation and consumption. These properties and the interaction of proteins with other components directly/indirectly affect processing, applications, food quality and consequently acceptance. Germination significantly ($p<0.05$) reduced water binding capacity of BGN flour, while roasting on the other hand did not have any significant ($p>0.05$) effect on the water absorption capacity. Padmashree *et al.* (1987) reported that polar amino acids of proteins had an affinity for water and denatured proteins bind less water. Fat binding capacity has been attributed to physical entrapment of oil. This is important since fat improves taste, texture and mouthfeel (Kinsella and Melachouris, 1976). Processing methods did not have significant ($p>0.05$) effect on the fat binding capacity. Roasting significantly ($p<0.05$) reduced foaming capacity by 28%, while germination significantly ($p<0.05$) increased it by 25.2%. Germination significantly ($p<0.05$) increased nitrogen solubility by 8.23%. Roasting, however, reduced nitrogen solubility to 46.80% in the roasted Bambara flour and 49.20% in the germinated-roasted flour. Nitrogen solubility profile over a range of pH is used as a guide to protein functionality, because it relates directly to many important properties of protein (Sosulski *et al.*, 1976). Padmashree *et al.* (1987) observed that heat treatment (roasting, puffing, boiling and pressure cooking) significantly ($p<0.05$) reduced protein solubility within the pH range of 2-10. Reduction in nitrogen solubility with heat processing had also been reported for sunflower, rapeseed, groundnut and soybean (Padmashree *et al.*, 1987).

Sensory acceptability of the extrudates from raw (ER), roasted (ERBGN), germinated (EGBGN) and germinated-roasted (EGRBGN) BGN flours is presented in Table 4. There were significant ($p<0.05$) differences in the extrudates color, taste, flavor and overall acceptability ratings. However, there were no significant ($p>0.05$) differences among the extrudates in terms of texture and mouthfeel. The roasted BGN extrudates had significantly ($p<0.05$) higher mean scores relative to color, taste, flavor and overall acceptability compared to the other samples. These relatively higher mean scores of the roasted sample's sensory attributes could be probably due to the roasted flavor/aroma and taste developed by Bambara groundnut during roasting. Controlled roasting of nuts brings about development of desirable roasted aroma in foods which are described as nutty, burnt and coffee like, due to formation of pyrazine compounds that also reflects the extent of brown color development in the product (Powrie and Nakai, 1981). Therefore, roasting improved the organoleptic qualities of the extrudates. The relatively lower mean sensory scores recorded in the germinated BGN based extrudates could be probably due to the slight bitter aftertaste observed in germinated samples. Nevertheless, despite the low mean scores, the samples were not rejected.

CONCLUSION

Bambara groundnut is a valuable food crop that should be utilized in combating protein-energy malnutrition prevalent in Nigeria and other African counties. Acceptable snacks of adequate nutritional and anti-nutritional qualities were produced by extrusion cooking of roasted or/and germinated BGN flour samples. Roasting before extrusion cooking yielded extruded snack with improved taste and flavor which increased overall acceptability of the product.

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