The Effect of Sprouting and Heat Treatment on the Proximate Composition, functional and pasting properties of Bambara groundnut flour

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Abstract

The possibilities of applying bambara groundnut flour as nutrient-dense and functional food ingredients were investigated through sprouting and heat treatment (oven drying and toasting) of the seeds. Before the evaluation of the proximate composition, functional properties and pasting changes, the 5 days sprouted bambara nuts were divided into two. One portion was toasted at 120 ^{0}C while the other was oven-dried at 60 ^{0}C and the flours obtained from the dehulled seeds were compared with flour from non-sprouted- dehulled seeds. Both the sprouting and heat treatments produced significant effects on the proximate composition, functional properties and pasting properties of the bambara groundnut flour samples. Crude protein increased from 21.28% in the non-sprouted to 25.21% in the sprouted and blanched while fat reduced from 5.52 % in non-sprouted to 4.91% in sprouted-oven dried. Both sprouting and heat treatment increased the cold-water absorption capacity from 1.35 g/g in non-sprouted to 3.40 g/g in sprouted and toasted. Possibly the increase is due to gelatinization of starch during heat treatment. A starchy ingredient with such functionality would be incorporated into ready to eat breakfast cereals/meals. Although foam capacity was increased due to sprouting but toasting drastically reduced it. Non-sprouted flour shows very high peak viscosity of 426 RVU. An evidence that the native starch of bambara groundnut swells very well under high heat and moisture. Due to higher breakdown and disintegration of the paste, it could be an appropriate ingredient in infant formulas.

Keywords: Bambara groundnut, sprouting, heat treatment, functionality, pasting

Introduction

At this advent of global food crisis and inflation especially the high cost of wheat, sourcing of food ingredients from underutilised local food crops would provide the much needed alternatives. Innovation in food product development should consider consumers on special diet and diet-related illness. The processing of underutilised local food crops into dry powders (flours) with appropriate nutritional composition and functionality would increase nutrition security in developing nations. Food processing operations such as blanching, drying and sprouting may be better techniques for the production of functional food ingredients.

Bambara groundnut could be promoted into dry food ingredients following processing methods that transform its major components such as starch, protein, fat and fibre. Compared to other local food crops, bambara groundnut contains protein (28%) which when combined with its high starch content (60%) could result to food ingredients with diverse applications (FAO, 2002; Bamishiye *et al*., 2011).

Sprouting, also known as germination is a process where edible dried seeds is subjected to rapid growing (germination) process under moist condition and appropriate temperature for an increased nutrients and lower calories. Germination involves chemical changes such as the hydrolysis of starch, protein and fat by amylolytic, proteolytic and lipolytic enzymes, respectively. When grains and seeds are hydrated (soaked) and then held (sprouted) under ambient conditions, both endogenous and newly synthesized enzymes begin to modify seed constituents (Gebreegziabher *et al.*,2015). Thus, complex macromolecules are broken down into lower molecular weight molecules which are more digestible and more readily absorbed by the body. The resulting seed which is known as sprout, has higher fibre, vitamin (vitamin C) and mineral (folate). According to Nonogaki *et al*., (2010), germination is a complex process during which seed must recover physically from maturation drying and resume a sustained intensity of metabolism. It is an essential cellular event that allow embryo to emerge and prepare for subsequent seedling growth. Sprouts are high in ingredients that potentially have antioxidant for cancer fighting, blood sugar and cholesterol lowering properties (Cho and Lim, 2016; PennState Extension, 2018).

Therefore, the aim of this study is to sprout and heat-treat bambara groundnut seeds and evaluate its potential as nutrient-dense and functional food ingredients by determination of composite composition, functional properties and changes (pasting properties) occurring in its starchy flour suspension during gelatinisation (cooking process).

Materials and Methods

Materials

The Bambara groundnut (1.5kg) was bought from Eke Oko Market, Orumba North Local Government Area, Anambra state, Nigeria.

Methods

Preparation of sprouted, toasted and oven-dried bambara groundnut flour

Bambara groundnut weighing 1.5 kg was manually sorted and washed with clean tap water before soaking in 10 L tap water for 12 hours. At the end of the soaking period, the seed steep water was drained and the seeds were stored in jute bags and kept for sprouting. During the sprouting period, water was sprinkled on the seeds at 12 hours interval to aid the seeds sprouting. The sprouting process lasted for 5 days. At the end of the sprouting, the non-sprouted seeds were discarded. The viable seeds were divided into 2 portions. The first portion was oven dried at 60 ^{o}C temperature while the second portion was toasted in an open pan over a mild fire of 120 ^{o}C. The two portions of the sprouted seeds after the heat treatment were manually dehulled by rubbing between palms and dry-milled into flour using hammer mill. The native non-sprouted seeds were also dry milled into flour and used for the analysis while the results were compared with sprouted seed flour.

Determination of Functional Properties

The functional properties such as bulk density, water and oil absorption capacity, foam capacity and stability, emulsion capacity, water solubility index and swelling power were determined with the method described by Ngoma *et al*., (2019).

Determination of the pasting properties of bambara groundnut flour

The pasting properties were determined using the RVA (Rapid Visco Analyser) super 4 model by Newport Scientific Australia according to the method reported by Agume *et al*. (2017)

Statistical analysis of data

All data reported are mean value and standard deviation of triplicate analyses. Data were analyzed using One-way ANOVA and mean separated with Tukey's HSD test to determine statistical significance (p<0.05) of data. The statistical analyses were carried out using IBM SPSS version 21 software.

Results and Discussion

Proximate composition

Moisture contents of bambara groundnut flours were significantly (p< 0.05) influenced by sprouting and drying (heating) methods as depicted in Table 1. The mean value of moisture content in the non-sprouted seeds (8.01%) decreased to 6.80% in sprouted-toasted flour and 7.78% for sprouted-oven dried due to vapourisation of water during the heating process. The decrease in moisture content of seed depends on the number of cells within the seed to be dehydrated through heating (Nonogaki *et al*., 2010). Meanwhile, Agume *et al.* (2017) reported that roasting soybean led to a significant decrease of moisture content, from a mean value of 7.2 to 5.7 g/100 g.

Table 1: Proximate Composition of Sprouted and Non-sprouted Bambara Groundnut Flour

Samples	**Moisture (%)**	**Protein (%)**	**Ash (%)**	**Crude fibre (%)**	**Lipid (%)**	**Carbohydrate (%)**
NSB	8.01^{a}	21.28^{c}	3.60^{a}	5.82^{a}	5.52^{a}	56.62^{a}
SOB	7.78^{b}	25.21^{a}	3.19^{c}	4.10^{b}	4.91^{a}	54.81^{b}
STB	6.80^{c}	24.37^{b}	3.21^{b}	4.00^{b}	5.10^{a}	56.52^{c}

Mean value with different superscript on the same column are significantly different P<0.05

NSB: Unsprouted bambara groundnut flour
SOB: Sprouted oven dried bambara groundnut flour
STB: Sprouted toasted bambara groundnut flour

Results related to the ash contents of control, sprouted-roasted and sprouted-oven dried bambara groundnut flour samples shows the values as 3.60%, 3.21% and 3.19% respectively. These results revealed that sprouting-toasting and oven drying had significant (p< 0.05) effect in decreasing the ash content. Similarly, a significant (p< 0.05) decrease in ash content was observed by Sood *et al*. (2002) in chickpea after sprouting while Nzewi and Egbuonu (2011) reported a decrease in ash content of roasted asparagus bean (*Vigna Sesquipedalis*) from 3.71% to 3.35%. Ash content may be associated with the amount of minerals present in a sample; hence the decreased crude ash noted in this study apparently suggests a reduction in mineral contents of the bambara groundnut flour. The toasting could lead to reduction of heat liable antinutrients which may interfere with the bioavailability of minerals (Alonso *et al*., 2010; Anigo *et al*., 2009).

The crude fat contents were 4.91% and 5.52% in sprouted-oven dried and non-sprouted flours respectively. Fat contents usually plays a role in the shelf life stability of food products. The relatively low fat content of the oven-dried and toasted would result to high shelf life stability of the flours (Mixer *et al*., 2011). This result is in agreement with the finding by Olawuni *et al*. (2012) who reported a decrease in the fat content of asparagus bean flour from 2.5 to 2.08% representing 20% reduction on toasting. During sprouting of mung bean (Shah *et al*., 2011) a total lipid loss was found. The loss in crude fat could be due to total solid loss (Wang *et al*., 1997) or it had been used in providing energy for the sprouting process (El-Adawy, 2002).

Crude protein content was significantly ($p < 0.05$) influenced by sprouting and heat treatments. Results indicated increase in protein concent with sprouting from an average value of 21.28% in non-sprouted samples to 25.21% in samples after oven drying and 24.37% in sprouted -toasted. An improvement in protein content in mung bean and chickpea seeds was recorded with sprouting (Khalil *et al*., 2007). Rise in crude protein could be attributed to synthesis of new proteins (e.g., proteases) and compositional change after degradation of other seed constituents (Bau *et al*., 1997). Many researchers reported increase in protein in germinated grains (Kaushik *et al*., 2010). However, decrease was also observed in crude protein with sprouting (Torres *et al*., 2007). The difference in results for protein content of sprouts not only depends on cultivar but also on sprouting conditions (Torres *et al*., 2007).

Crude fibre ranged from 4.00% in sprouted-toasted flour to 4.82% in non-sprouted. The significant ($p < 0.05$) decrease in the crude fibre content could be due to the utilization of starch during sprouting and degradation of non-starch polysaccharides during heat treatments.

Functional properties

Functional properties are the intrinsic physicochemical characteristics which affects the behavior of food systems during processing, storage and formulations. The results of the effect of processing method on the functional properties of bambara groundnut flour are shown in Table 2.

Loose Bulk Density [LBD]

There was no significant difference ($p<0.05$) among the flour in loose bulk density although the values obtained ranged from 0.40 for non-sprouted flour to 0.43g/ml for sprouted-oven dried bambara groundnut flour. Hence sprouting, oven drying and toasting did not affect the loose bulk density of the samples. These values obtained were lower than the value (0.65 g/ml) obtained by Akaerue and Onwuka (2010) for mungbean.

Pack Bulk Density [PBD]

The packed bulk density (PBD) of bambara groundnut flour which ranged from 0.57 - 0.59 g/ml shows no statistical difference ($p<0.05$). However, Akaerue and Onwuka (2010) reported no significant differences ($p<0.05$) among mung bean seeds flour with packed bulk density of 0.98 g/ml. In contrast to the present study, Odoemelam (2005) observed that dry heat processing (roasting) lowered the bulk density of jackfruit flour.

Water Absorption Capacity (WAC)

There was significant difference (P<0.05) among the samples in water absorption capacity (WAC)

Samples	LBD (g/ml)	PBD (g/ml)	WAC (g/g)	OAC (g/g)	FC (%)	FS (%)	EC (%)	WSI (%)	SP (ml/g)
NSB	0.40ª±0.00	0.58ª±0.02	1.35ᶜ±0.01	0.88ᵇ±0.02	40.0ᵇ±0.0	96.43ᵇ±0.09	11. 11ᵇ±0.10	55.0ᶜ±0.00	8.80ª±0.10
SOB	0.43ª±0.02	0.57ª±0.02	2.00ᵇ±0.0	0.76ª±0.20	50.0ª±0.0	96.67ª±0.10	20.0ª±00.0	70.0ᵇ±0.0	6.75ᵇ±0.02
STB	0.42ª±0.02	0.59ª±0.01	3.40ª±0.01	0.58ª±0.02	5.00ᶜ±0.0	0.00ᶜ±0.00	12.22ᶜ±0.10	80.0ª±0.0	7.30ᶜ±0.10

with the values ranging from 1.35 to 3.40 g/g obtained for unsprouted sample and sprouted-toasted sample respectively. From this study toasting was found to increase the water absorption capacity of the bambara groundnut. Flours with high water absorption capacity are required in the manufacturing of bakery products.

Oil Absorption Capacity (OAC)

The oil absorption capacity significantly (p<0.05) increased from 0.88 g/g in the non-sprouted flour to 1.58 g/g in the seed subjected to sprouting and toasting. There was no significant difference (p<0.05) in OAC among the toasted and oven dried sprouted flour. This suggested that oven drying and toasting heat treatment has similar effect in the oil absorption capacity of bambara groundnut. Akaerue and Onwuka (2010) reported that the oil absorption capacity (OAC) of the raw non-dehulled mung bean flour which was 1.9 ml/g was significantly (p<0.05) increased by toasting and boiling heat treatments. Increase in oil absorption capacity due to toasting could also be attributed to the heat dissociation of proteins, gelatinization of starch in the flour and swelling of crude fiber. These results suggest that non-sprouted bambara groundnut flour would be suitable for bakery products where improved handling (kneading) characteristics is required. Ingredients with high oil absorption capacity play important role in stabilizing food systems with high fat content and can also act as emulsifiers. (Akubor *et al.*, 2000). The ability of foods to absorb oil may help to enhance sensory properties such as flavor retention and mouth feel.

Table 2: Functional properties of sprouted, heat-treated and non-sprouted bambara groundnut flour

Samples	**LBD (g/ml)**	**PBD (g/ml)**	**WAC (g/g)**	**OAC (g/g)**	**FC (%)**	**FS (%)**	**EC (%)**	**WSI (%)**	**SP (ml/g)**
NSB	$0.40^{a}\pm0.00$	$0.58^{a}\pm0.02$	$1.35^{c}\pm0.01$	$0.88^{b}\pm0.02$	$40.0^{b}\pm0.0$	$96.43^{b}\pm0.09$	11. $11^{b}\pm0.10$	$55.0^{c}\pm0.00$	$8.80^{a}\pm0.10$
SOB	$0.43^{a}\pm0.02$	$0.57^{a}\pm0.02$	$2.00^{b}\pm0.0$	$0.76^{a}\pm0.20$	$50.0^{a}\pm0.0$	$96.67^{a}\pm0.10$	$20.0^{a}\pm00.0$	$70.0^{b}\pm0.0$	$6.75^{b}\pm0.02$
STB	$0.42^{a}\pm0.02$	$0.59^{a}\pm0.01$	$3.40^{a}\pm0.01$	$0.58^{a}\pm0.02$	$5.00^{c}\pm0.0$	$0.00^{c}\pm0.00$	$12.22^{c}\pm0.10$	$80.0^{a}\pm0.0$	$7.30^{c}\pm0.10$

Mean values in the same column with different superscript are statistically different (P>0.05)

Foam Capacity (FC)

The foam capacity that was 40% in the non-sprouted sample increased significantly (p<0.05) to 50% in the sprouted-oven dried sample. Foam capacity drastically reduced to 5.00% as the sprouted seeds were toasted. These changes in foam capacity may be due to the Maillard reactions which occurred during the toasting. Similar trend was observed in foam stability which ranged from 0.00 to 96.67% with sprouted-toasted sample having very unstable low foam capacity (0%). The highest value of foam capacity was again obtained in the oven dried sample. Akubor *et al*. (2000) reported that toasting decreased the foaming capacity of African breadfruit seeds as it is dependent on the toasting time

Foam Stability (FS)

Foam Stability is related to the rate of decrease of the surface tension of air water interface caused by absorption of protein molecules (Akubor, *et al*., 2000). It is also a function of the type of protein, pH, processing methods etc. Due to sedimentations of bambara groundnut particles caused by the modification of protein during toasting, an unstable foam was produced. Aeration (foam or air bubbles) in beverages such as Cappucino coffee, whipped cream and ice cream increases sensory preferences among consumers. Unstable foam characteristic is required in instant cocoa powder drink in addition to good dispersibility and solubility. Foams are used to improve texture, consistency and appearance of foods. Foam capacity and stability are important parameters for protein ingredients which can reveal the potentials of the protein ingredient to affect the quality and texture of food products (Deotale *et al*, 2020)

Emulsion Capacity (EC)

An improved emulsion activity occurred from raw non-sprouted bambara groundnut flour (11.11%) to sprouted toasted flour (12.22%) and sprouted oven dried (20.00%) significantly (P < 0.05). Similarly, Akaerue and Onwuka (2010) reported an increase in emulsifying capacity of mung bean due to heat application. Sprouting, oven drying and toasting may have caused unfolding of the protein chains and thereby exposed the hydrophilic section of the peptide which enhanced emulsion activity. Bambara groundnut flours showed high emulsion activity when compared to flours like African oil bean (6%) (Ariahu *et al*., 2009). The high emulsion activity could be due to its high protein content. The high emulsion capacity of bambara groundnut flours suggests their possible use in sausage and in stabilizing colloidal food systems (Ariahu *et al*., 2009).

Water Solubility Index (WSI)

Water solubility index also increased significantly from 55% in the non-sprouted sample to 80% in the sprouted and toasted sample. Singh and Sharma (2017) reported a WSI range of 12.4% to 20% in mung bean used for extruded snack. WSI is an indication of solubility of biomolecules (starches, water soluble fibers, proteins and/or sugars etc.) before or after processing in excess water. Therefore, the high water solubility index value of toasted and oven dried sprouted flour is an indication that the starch granules were gelatinized during the heat processing and the solubles (starch and non-starch polymers) easily leached into water. Also, it is a confirmation of heat degradation of non-starch carbohydrates (fibers).

Swelling Power (SP)

Swelling power indicates the water holding capacity of starch when heated. Generally, it is used to demonstrate differences between various types of starches (Crosbie, 2001). The swelling power (index) of the flours significantly ($P < 0.05$) decreased from 8.80 ml/g obtained in the non-sprouted to 6.75 ml/g in sprouted toasted sample. Absence of native starch restricted the swelling of already gelatinised starch and other hydrocolloids in the sprouted and heat treated bambara groundnut flours.

Pasting Properties

The pasting properties of sprouted and non-sprouted bambara groundnut are shown in Table3. Unsprouted shows highest peak viscosity (426 RVU), breakdown (229 RVU) and final viscosity (261 RVU). The highest peak time for formation of peak viscosity was observed in sprouted and toasted along with high pasting temperature.

Table 3: Pasting properties of non-sprouted and sprouted bambara groundnut

Sample	Peak (RVU)	Breakdown (RVU)	Final Visc (RVU)	Setback (RVU)	Peak Time (Min)	Pasting Temp (C.)
NSB	426.21	229	261.79	64.585	4.465	74.77
SOD	158.71	54.165	182.21	77.665	5.035	85.7
STB	18.96	1.42	35.335	17.795	6.965	90.42

Peak Viscosity

Peak viscosity is the maximum viscosity obtained during starch gelatinisation and it indicates the starch granules' water binding capacity. It is therefore used as an important parameter in the processing of starch. The peak viscosity (426.211 RVU) of non-sprouted bambara groundnut was the highest. Earlier this sample had low water absorption capacity due to the presence of native ungelatinized starch but its higher peak viscosity indicated higher ability of the starch to swell under high heat and moisture. The differences in peak viscosity might be due to the differences in the rate at which starch granules swell and absorb water when heated (Falade and Okafor, 2015; Wu *et al*., 2015). According to Wu *et al*. (2015), high peak viscosity is an indication that the starch has high water binding capacity although not possible for already gelatinised starch to swell very well in a second heating process as occur in the pasting process. Hence, low peak viscosities were observed in the sprouted and heat-treated flours.

Breakdown viscosity

Breakdown viscosity gives an indication of the ability of starch organisation structure to withstand disruption during food processing involving mechanical sharing. Therefore, the starch granules susceptibility to disintegrate is known as breakdown viscosity (Falade and Okafor., 2015; Wu *et al*., 2015). Although, the breakdown viscosity of non-sprouted flour paste was higher compared to the sprouted yet it does not indicate that the starch of non-sprouted was more fragile. Rather, the high breakdown could be correlated to its initial high peak viscosity due to presence of native starch. Actually, the gelatinised and swollen starch in the sprouted and heat processed flours which exhibited low peak viscosity was still fragile and shows very high breakdown viscosity. This low value has confirmed their initially low peak viscosity which is evidence of presence of gelatinised starch granule during pasting process. According to Falade and Okafor (2015), higher breakdown viscosity means that the starch has lower ability to withstand heating (relatively low heat stability) and shear stress during cooking while low breakdown viscosity indicates thermal stability. Due to higher breakdown viscosity and disintegration of the paste, the flour could be an appropriate ingredient in baby formulas.

Final viscosity

The final viscosities of non-sprouted bambara flour was higher (261.79 RVU) than sprouted-dried and toasted (182.21 and 35.335 RVU respectively). Final viscosity is used to determine starch quality and stability of the cooked starch paste in food products. Final viscosity gives an indication of the starch ability to form a gel or viscous paste after cooking and cooling. With high final viscosity and retrogradation of starch of non-sprouted flour, it could be used as a prebiotic ingredient in foods since its resistant starch would be metabolised by bilfido bacteria for proper functioning of the digestive system. Amylose retrogradation determines the initial hardness of a starch gel and the stickiness and slow digestibility of processed foods.

Peak time (min) and pasting temperature

The peak time usually measured in minutes shows the time at which the viscosity starts to increase. It is measured when the peak viscosity is formed. Higher peak time (5-6.9 min) and pasting temperature (85-90 ^{0}C) was recorded for the sprouted samples possibly due to the presence of gelatinised and swollen starch in the sprouted flours which limits formation of viscosity at this second heating time and temperature.

Conclusion

Dry heat treatment (oven-drying and toasting) after sprouting should be used in improving the functional and pasting properties of bambara groundnut flour in addition to its low moisture content and fat content which would enhance their storage stability. Although toasting had the most impact in changing the functionality of bambara groundnut flour due to high heat treatment temperature but the raw and sprouted-oven dried bambara groundnut flours still possessed adequate functional properties that would enhance their various food applications. Sprouting and toasting of flour should be adopted in food industries to help diversify the uses of bambara nut flour as functional ingredients in food processing applications. The Bambara groundnut flours are also recommended for use in development of gluten-free products, which have shown a tremendous marketing potential in recent years. Due to colour, nutrient density, functional and pasting properties, the sprouted and toasted bambara groundnut could be used to replace instant cocoa-powder drink. However, in further studies the nutritional, anti-nutritional, sensory properties and the microbiological quality of the food products produced from sprouted-toasted/oven-dried bambara ground nut flour need to be investigated.

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