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Some Engineering and Chemical Properties of Cooked Bambara Groundnut

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The effect of cooking duration on the chemical, physical and thermal properties of bambara groundnut were investigated. The samples were analyzed for chemical composition, physical properties (length, width, and thickness, arithmetic mean, geometric mean, sphericity, surface area and aspect ratio) and thermal properties (specific heat capacity, thermal conductivity and thermal diffusivity). Data were analyzed using analysis of variance (ANOVA) and means were separated using the Duncan multiple range test at $p<0.05$. Times required for samples to be cooked were 1, 2 and 3 hours respectively. The results of chemical composition for uncooked and cooked bambara groundnut showed that protein (18.32 - 21.70%); fat (4.12 – 5.29%); crude fibre (3.15 – 4.34%); ash (1.17 - 3.13%); moisture content (6.33 – 15.03%) and carbohydrate (54.27 - 61.34%). Length, width, and thickness of uncooked to cooked bambara groundnut at different time interval were 12.49 to 15.22 mm, 11.46 to 13.67 mm and 10.90 to 12.54 mm, respectively. The arithmetic mean diameter and geometric mean diameter of the sample were 11.62 to 13.81 mm and 11.59 to 13.75 mm respectively. The sphericity, surface area and aspect ratio of the samples varied from 0.89 to 0.93, 423.31 to 595.88 mm and 88.22 to 92.13%, respectively. Thermal conductivity varies from 0.15 to 0.20 W/mk, specific heat capacity varies from 1.298 to 1.5898 kJ/kgK. Thermal diffusivity varies from $1.10x10^{-4}$ to $1.12\ x10^{-4}m^2/s$. The chemical, physical and thermal properties of bambara groundnut studied were significantly different ($p<0.05$).

Keywords: Bambara groundnut, Cooking, Engineering properties, Thermal properties, Proximate composition.

INTRODUCTION

Bambara groundnut (*Voandzeia subterranean* L.*)* belongs to the family of *Leguminosae*. The varieties of the seeds have four colours which are black, red, brown and cream. Although bambara groundnut is a nutritious crop, however, it is underutilized in Nigeria. The crop is essentially grown for human consumption. Ouedraogo *et al.* (2008) described Bambara groundnut seeds as a complete balanced diet, making it a good supplement to cereal - based diets. Bambara groundnut contains about 63% carbohydrates, 19% protein, and 6.5% oil and is consumed in different forms which makes it rank highly as a complete food (Goli, 1997).

However, lack of adequate processing techniques to overcome the hard-to-cook effect has limited its utilization and hence reduced its production. According to farmers, the decline in bambara groundnut production is due to lack of adequate processing techniques to promote utilization (Christina, 2009). The fresh seeds may be boiled and eaten as snacks or the dry seeds may be ground into flour, spiced and made into paste, then boiled as *moi-moi* or *okpa*. The paste may also be fried and eaten as *akara* (Tanimu and Aliyu, 1995; Swanevelder, 1998; Jonah *et al.*, 2010). Processing of bambara groundnut into these aforementioned products often involves heat treatment either by heat addition (drying, dry-aeration to prevent spoilage during storage, sterilization, freezing, etc) or heat removal (cooling or tempering), all of which required a good knowledge of the thermal behaviour of bambara groundnut. Knowledge of thermal properties of food and agricultural products is essential for equipment design and prediction of heat transfer operations involving foods and vegetables (Viviana *et al.*, 2008).

In most developing countries, production of sufficient food at affordable cost is a challenge. As a result of this, there is need to ensure that all potential sources of bambara groundnut are exploited effectively and utilized industrially. Study on effect of cooking duration on engineering properties will form a platform for mechanization of the process. Therefore, objective

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of this research work was to determine the effect of cooking duration on chemical composition and some engineering properties of cooked bambara groundnut.

MATERIALS AND METHODS

Materials

Sample preparation

Bambara groundnut (*Voandzeia subterranea (L.) Thouars*) was obtained from a local market in Ogbomoso, Oyo state, Nigeria. The samples were manually cleaned to remove foreign matters such as; dust, dirt, broken and immature grains. Cleaned bambara groundnuts were cooked for 1, 2 and 3 hours. The cooking was done at boiling temperature (100^{o}C).

Determination of proximate composition

Method of AOAC (2005) was used to determine protein, ash, crude fibre, fat, moisture and carbohydrates were determined by difference.

Determination of physical properties

Physical properties of length (L), width (W), thickness (T) of the samples were determined using standard methods. Means of 100 cooked seeds, randomly selected, were calculated and recorded. Length, width and thickness were measured using vernier caliper with 0.01mm accuracy (Cappera precision, China). The arithmetic (*Da*) and geometric (*Dg*) mean diameter, sphericity (∅), surface area (*S*) were calculated according to Milani *et al.* (2007).

$$D_a = \left(\frac{L+W+T}{3}\right) \quad (1)$$

$$Dg = \sqrt[3]{LWT} \quad (2)$$

$$\emptyset = \frac{(LWT)^{0.333}}{L} \quad (3)$$

$$S = \pi Dg^2 \quad (4)$$

The aspect ratio (R_a) was calculated by applying the relationship given by (Maduako and Faborode, 1990):

$$R_a = \left(\frac{W}{L}\right) \times 100 \quad (5)$$

Determination of Thermal Properties

The thermal conductivity, specific heat capacity and thermal diffusivity of bambara groundnut were determined as a function of their proximate compositions by applying additive principles.

Thermal Conductivity (k) and Specific Heat Capacity (C_p)

The above parameters were determined based on weight fraction of water, fat, ash, protein and carbohydrate component of food using the equations stated below (Singh and Heldman, 2000).

$$k = 0.250X_c + 0.155X_p + 0.160X_f + 0.135X_a + 0.580X_w \quad (6)$$

$$C_p = 4.187X_w + 1.549X_p + 1.675X_f + 0.837X_a + 1.424X_c \quad (7)$$

Thermal Diffusivity (α)

This was determined based on weight fraction of water, fat, protein and carbohydrate component of food using the equation stated below (Stroshine and Hamann, 1994).

$$\alpha = 0.146\times10^{-6}X_w + 0.10\times10^{-6}X_f + 0.075\times10^{-6}X_p + 0.082\times10^{-6}X_c \quad (8)$$

X was the fraction of food component, and the subscripts; *w*, *f*, *p*, *c* and a represented water, fat, protein, carbohydrate and ash respectively.

Statistical Analysis

Data were reported as mean ± standard deviation. Statistical analyses were carried out using SPSS for Windows, version 14.0 (SPSS Inc. Chicago, IL. USA).

RESULTS AND DISCUSSION

Proximate Composition

The proximate composition of un-cooked and cooked bambara groundnut is as shown in Table 1. The protein contents of bambara groundnut samples were between the values of 18.32 and 21.70 %. Significant difference ($p<0.05$) exists among all the samples. Sample A has the highest protein content while sample B has the lowest protein (Table 1). The slightly lower value of protein in cooked bambara groundnut might be as a result of leaching of soluble protein into cooking water. Similar observation was made by Adeparusi (2001) when boiling Lima Beans. Previous work reported decrease in protein content of mangrove legume from 32.1 to 28.1 % after cooking (Seena *et al.,* 2006).

Cooking reduced the fat content of the sample from 5.29 to 4.12 %. There was no significant difference at $p>0.05$ between the samples obtained from un-cooked and cooked methods. The reduction in fat content of the sample can be traced to aqueous extraction of oil from the seed during cooking. Heating fractionated intact oil bodies and rupture cellular structure, thus aided oil extraction. Sample C has the highest fat content while sample B has the lowest fat content as shown in Table 1. The non-significant increase in fat with increase in cooking time is at variance with results of Akinmutimi (2007), who reported significant increase in ether extract of velvet beans with increased cooking time.

Carbohydrate content of the sample varied from 61.34 to 54.27 %. Sample B has the highest carbohydrate content while sample D has the lowest carbohydrate content. Analysis of variance (ANOVA) shown that samples A and B are non-significant ($p>0.05$) while samples C and D are also non-significant ($p>0.05$) from each other as shown in Table 1. The reduction in the carbohydrate content is due to hydrolysis of starch to simple sugars during the cooking period. Hydrophilic groups in carbohydrate molecules caused it to take up moisture in proportion to the relative humidity of the environment (Ihekoronye and Ngoddy, 1985). This characteristic behaviour encouraged moisture uptake and apparent reduction in percentage of carbohydrate.

Table 1. Proximate composition of Bambara nut

Sample	Protein (%)	Moisture (%)	Fibre (%)	Ash (%)	Fat (%)	Carbohydrate (%)
A	21.70c	6.33a	4.34c	2.80c	5.14a	59.70b
B	18.32a	9.95b	3.15a	3.13d	4.12a	61.34b
C	19.04ab	13.71c	4.34c	1.79b	5.29a	55.85a
D	20.75bc	15.03d	4.12ab	1.17a	4.68a	54.27a

Mean values with the same alphabets within the same column are not significantly (p<0.05) different from each other.

Keys

Sample A: uncooked bambara nut
Sample B: bambara groundnut cooked at 1hour
Sample C: bambara groundnut cooked at 2 hours
Sample D: bambara groundnut cooked at 3 hours

Crude fibers in bambara groundnut varied from 4.34 to 3.15 %. Samples A and C has the highest fiber content while sample B contains low fiber content, samples A and C were found to be non-significant (p>0.05). There were significant differences at p<0.05 between samples A and B (Table 1). The reduction in fiber content during treatment may be due to dehulling that was noticed during cooking. Hull contains a high portion of the fiber present in the seed (Akinoso and Raji, 2011). Reduction in crude fiber of locust bean from 11.7 to 4.4 % after 6 hours of cooking had been reported (Omafuvbe *et al.,* 2004).

The ash content of bambara groundnut varied from 3.13 to 1.17 %. The observed differences were significantly (p<0.05) different. Sample B contain high ash content of 3.13 % while sample D contain low ash content of 1.17 %. It was observed that the higher the cooking time the lower the ash content. The significant reduction in ash content of seeds with increased boiling period is in agreement with results of Onu and Okongwu (2006) who recorded decreased in ash from 5.31 % in the raw seeds to 4.21 % in the boiled seeds. Amaefule *et al*. (2006) also recorded decrease in ash content of pigeon pea seeds from 5.50 % (raw seeds) to 4.00 % (30 minutes of boiled seeds).

Cooking bambara groundnut for three hours increased its moisture level from 6.33 to 15.03 %. The moisture contents of the samples were significantly (p<0.05) different. Rise in moisture content of Locust bean from 8.8 to 56.7 % after 6 hours of cooking was reported (Omafuvbe *et al.,* 2004). The moisture content of the seeds determine their suitability to microbial attack and hence spoilage (Olusanya, 2008). Significant changes in chemical composition of the crops during cooking are attributed to re-distribution due to moisture uptake.

Physical Properties

The three axial dimensions, including the length, width and thickness of uncooked sample to cooked samples at different time interval ranged from 12.49 to 15.22 mm, 11.46 to 13.67 mm and 10.90 to 12.54 mm, respectively. The length, width and thickness of bambara groundnut samples increased as cooking time increased (Table 2). ANOVA revealed that the difference in axial dimensions of bambara groundnut were statistically significant at p<0.05. The increase in dimensions is attributed to expansion or swelling as the result of moisture uptake in the intracellular spaces within the seeds (Gharibzahedi *et al.*, 2010). Similar observation was reported when locust bean was soaked in water (Sobukola and Onwuka, 2011). Information of the length, width, thickness of the seeds is necessary for determining aperture sizes in the design of seed handling equipment.

The arithmetic and geometric mean diameters increased from 11.62 to 13.81 mm and 11.59 to 13.75 mm, respectively, as the cooking time increased from 1 to 3 hours. The samples were significantly (p<0.05) different. The arithmetic mean of the axial dimensions is useful for describing the characteristic dimension for irregularly shaped solids. Furthermore, the geometric mean diameter is useful for the evaluation of the projected area of a particle moving in the turbulent or near-turbulent area of an air stream. It is therefore usually investigative of its model of behaviour in air streams, particularly with respect to the ease of separating extraneous materials from the particle during cleaning by pneumatic means (Gharibzahedi *et al.*, 2010). Similar trend for physical properties such as axial dimensions, arithmetic and geometric mean diameter, surface area, sphericity and kernel volume were reported for rapeseed (Izli *et al*., 2009).

The mean sphericity, surface area and aspect ratio of the samples varied from 0.89 to 0.93, 423.31 to 595.88 mm2 and 88.22 to 92.13 %, respectively. The ANOVA revealed that effect of cooking was significant at p<0.05 on sphericity of samples A and C, and there is non- significant difference at p>0.05 in the aspect ratio. The shape indices are required to give a comprehensive description of the shape of the seed. Sphericity is an expression of a solid shape relative to that of a sphere of the same volume while the aspect ratio relates the width to the length of the seed which is an indicative of its tendency toward being oblong in shape (Gharibzahedi et al., 2010).

The ability of any grains or fruits to either roll or slide depends on the aspect ratio and as well as sphericity. Moreover, the relatively high sphericity and aspect ratio of bambara groundnut indicate that it will be easier in getting the seeds to roll, a property which is quite important in the design of hoppers and dehulling equipment.

Thermal Properties

The result of the thermal properties of bambara groundnut is as shown in Table 3. Cooking for three hours increased thermal conductivity of bambara groundnut from 0.23 to 0.26 W/mK. There was significant difference (p<0.05) in thermal conductivity value between the samples cooked as shown in Table 3. Bamgboye and Adejumo (2010) reported rise in thermal conductivity of Roselle seed from 1.56 to 1.22 W/mK with increased moisture content of 8.8 to 19.0 %, respectively.

The increase in thermal conductivity may be due to absorbed moisture by the seed during cooking.

Table 2. Physical properties of Bambara groundnut at different cooking time

Sample	Length (mm)	Width (mm)	Thickness (mm)	Arithmetic Diameter (mm)	Geometric Diameter (mm)	Sphericity (%)	Surface Area (mm^2)	Aspect Ratio (%)
A	12.49a	11.46a	10.90a	11.62a	11.59a	0.93b	423.31a	92.13a
B	13.27b	11.997ab	11.10ab	12.12a	12.08a	0.91ab	461.82a	90.55a
C	14.35c	12.64c	11.70b	12.89b	12.83b	0.89a	521.49b	88.22a
D	15.22d	13.67d	12.54c	13.81c	13.75c	0.91ab	595.88c	89.89a

Mean values with the same alphabets within the same column are not significantly (p< 0.05) different from each other.

Table 3. Thermal Properties of Bambara nut

Sample	Thermal conductivity, *k* (W/mk)	Specific heat capacity, *Cp* (kJ/kgK)	Thermal diffusivity, α x10^{-4} (m^2/s)
A	0.23a	1.68a	1.10a
B	0.25b	1.79b	1.12b
C	0.26c	1.88c	1.10a
D	0.26d	1.92d	1.10a

Mean value of different superscript along the same column are significantly different from each other at (p<0.05).

In addition, food composition and temperature are the important factors affecting thermal properties (Rahman, 1995; Saravacos and Maroulis, 2001). Thermo-physical properties are significantly dependent on changes in moisture content and temperature (Barbosa-Canovas et al., 2006). Thermal conductivity is important to predict or control heat flux and processing time. This ensures the efficiency of equipment, improves economics of the process, and enhances quality product.

Cooking duration increased specific heat of bambara groundnut from 1.68 to 1.92 kJ/kgK (Table 3). Bambara groundnut cooked for three hours has the highest specific heat capacity. Changes in specific heat capacity were significant at p<0.05. These values are higher than specific heat capacity of 1.39 kJ/kgK for guna seed (Aviara et al., 2008). Bamgboye and Adejumo (2010) reported value lower than 5.63 kJ/kgK for Roselle seed. Specific heat capacity is an essential parameter in design of heat exchanger. The information will be useful in choice of heat transfer medium and processing conditions.

Cooking duration increased thermal diffusivity of bambara groundnut from 1.10x10-4 to 1.12x10-4 m2/s. These values are significantly greater than 9.78 x10-5m2/s reported for raw Ubi (Creasel et al., 2011). Cooking as a treatment significantly (p<0.05) influenced thermal diffusivity of bambara groundnut (Table 3). Thermal diffusivity relates to the ability of the material to conduct heat compared to its ability to store heat. Thermal diffusivity is the ratio of thermal conductivity to density and specific heat. Therefore, speed of heat diffusion through a material is also relevant information in processing-time prediction models.

CONCLUSION

The following conclusions are drawn from the investigations on selected physical, chemical properties and thermal properties of bambara groundnut. Cooking duration influenced axial dimensions and moisture absorption capacity of bambara groundnut. Effects of cooking on physical properties of bambara groundnut increase gradually as the cooking time increase. Cooking of bambara groundnut for three hours changed its chemical, physical and thermal properties significantly (p<0.05). Generated data will be useful in choice of heat transfer medium and processing condition. The result obtained from physical and thermal properties will serve as a useful tool in process and equipment design and this will go a long way in assisting to improve yield and quality of bambara groundnut.

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