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Some Engineering and Chemical Properties of Cooked Locust Bean Seed *(Parkia biglobosa)*

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Abstract: *This study was conducted to determine effect of cooking duration on some engineering and chemical properties of locust bean seed. The locust bean seed was cooked for 1, 2, 3, 4, 5, and 6 hours. Length, breadth, and thickness of locust bean were 10.38 to 12.52 mm, 8.61 to 10.04 mm and 4.79 to 5.83 mm, respectively. Bulk density ranged from 0.77 to 1.62* g/cm^3*. Cooking of the bean increased moisture content from 4.4 to 61.4%. Compressive forces required reaching the yield, breaking and peak point of the samples ranged from 10.22 to 211.26 N, 51.70 to 384.39 N, and 51.88 to 385.87 N, respectively. Young modulus decreased with increased cooking time while deformation increased. Cooking has significant influence on chemical properties at 5% level of significance. Thermal conductivity of un-cooked locust bean increased from 0.22 to 0.52 W/mK and specific heat increased from 1.92 to 2.60 kJ/kgK.*

Keywords: *Locust bean, cooking, physical properties, mechanical properties, proximate composition, thermal properties*

1. Introduction

Locust bean (*Parkia biglobosa*) is used in many food dishes in West Africa. The most important use of locust bean is found in its seeds which are rich in protein, lipids, carbohydrate, vitamin B_2 and when fermented are also rich in lysine (Akande, Adejumo, Adamade and Bodunde, 2010). *Iru* the fermented locust bean is a valuable food condiment in Nigeria and other countries of West Africa. Processing of locust bean fruits to food condiment (*Iru*) involves different unit operations including depodding, cleaning, boiling, dehulling, washing, re-cooking, and fermentation. The method of its processing is still largely traditional and labourious. Cooking of the bean was reported to consume highest proportion of energy and time among the unit operations (Adedayo, 2011).

Engineering properties of crops are essential parameters in utilisation, development of processing methods and design of equipment (Akinoso and Raji, 2011a). Such properties include rheological, thermal, optical, electrical, physical, and mechanical properties. Some published works on engineering properties of agricultural products are Ogunsina, Koya, and Adeosun, (2008) on dika nut, Kibar and Ozturk (2008) on soybean and Tavakoli, Mohtasebi and Jafari, (2009) on wheat straw. Findings from these researches clearly showed that engineering properties of biomaterial significantly depend on treatments.

Production of sufficient food at affordable cost is a challenge in most developing countries. Therefore, there is need to ensure that all potential sources of foods are exploited effectively and utilised industrially. The improvements of technology of processing locust bean require accurate information on properties of the crop as affected by primary processing. Study on effect of cooking duration on engineering properties will form a platform for mechanisation of the process. Therefore, objective of this research work was to determine effect of cooking duration on some engineering properties and proximate composition of cooked locust bean seed.

2. Materials and Methods

2.1 Determination of physical properties

A 1 x 6 factorial design was employed. Six levels of cooking time were 1, 2, 3, 4, 5 and 6 hours. Locus bean seed was cooked at atmospheric pressure (760-mmHg≈ 1 bar) and boiling temperature (100°C). Physical properties of size, mass, shape and density of the samples were determined using standard methods. Length, breadth, and thickness were measured using venier caliper with 0.01mm accuracy (Cappera precision, China). Digital weighing balance (Scout™ Pro model SPU401) of accuracy ± 0.001g was used for mass. Mean of randomly selected cooked 250 seeds was recorded as obtained data. The sphericity and aspect ratio were determined according to reported method (Mohsenin, 1986). Relationship between mass and volume was applied for bulk density determination. Also determined was moisture content of the seeds using standard method for oilseed (ASABE, 2008).

2.2 Determination of mechanical properties

Mechanical properties viz: force at break, deformation at break, energy to break, force at peak, deformation at peak, energy to peak, force at yield, energy to yield and the Young modulus were determined using Testometric AX Type DBBMTCL 2,500 kg (Rochdale, England). These tests were carried out using reported method (Akinoso and Raji, 2011a). A unit of locust bean from the samples was placed between the compression plates of the testing equipment. Each seed was compressed at a constant deformation rate 10.00 mm/min., and readings were made using data logger. The procedures were repeated in 250 replicates. Mean values were recorded as data. This was subjected to analysis of variance (ANOVA) and regression analysis at $p < 0.05$.

2.3 Determination of proximate composition

Cleaned locust beans were cooked for four hours. The cooking was done at atmospheric pressure (760-mmHg≈ 1 bar) and boiling temperature (100°C). Appropriate standard methods were used to analyse the proximate composition (AOAC, 2005). AOAC methods 988.05, 958.06, 2003.06, 942.05, and 967.08 were used for determination of protein, fiber content, fat, ash, and moisture content, respectively. Carbohydrate was calculated as reported by McClement (2010). All the experimental procedures were repeated. The mean of three replicate was recorded as data obtained. This was subjected to analysis of variance (ANOVA) at 5% level of significance.

2.4 Determination of protein content

Protein was determined by Kjedahl procedure using a protein factor of 6.25. A sample of about 1.2g was weighed into a digestion tube and conc. tetraoxosulphate (IV) acid (conc. H_2S0_4) was added using a dispenser. The tube was placed in a preheated digester at 420⁰C for about 30 minutes until a clear solution was obtained. The tube was removed from the digester, cooled and diluted with water and placed in the distillation unit. A conical flask containing 25ml of boric acid (indicator) was placed under the condenser outlet. About 25ml of 40% Sodium hydroxide (Na0H) was dispensed in the flask and distillation carried out for 5 min. The ammonium borate solution formed was titrated with 0.1M tetraoxosulphate (VI) acid to purplish-grey end. Percentage nitrogen (percentage N_2) was calculated.

2.5 Determination of fat content

Fat analysis was carried out using soxhlet extraction method. About 25g of ground sample was mixed with about 100ml of n-hexane. The mixture was vigorously shaken with the separation flask knob opened at intervals to release the accumulated air pressure, which may burst the flask if left there. The fat in the spirit was evaporated to dryness over a soxhlet extraction, which extracts n-hexane from its solution of fat. The fat left behind in the flask was placed in the oven to dry at 105°C for 1½ hours. The round bottom flask was cooled in desiccators and weighed. Percentage of fat in sample was calculated.

2.6 Determination of fiber content

Fiber content of the sample was measured using the enzyme-modified, neutral detergent fiber (NDF) method of analysis. Dried samples whose fat content were extracted using soxhlet extraction were treated with standard NDF procedures up to the point that fiber-containing residues were filtered and washed with water. The filtered residues were incubated with a porcine α – amylase solution at 37°C over night. The residues was filtered after incubation, washed very well, and dried. The NDF was calculated as filtered residual.

2.7 Determination of ash content

Ash content of the samples was determined by putting about 25g of sample in a dish of known weight (W_4) and dried in an oven for 4 hours at 105⁰C. It was removed, cooled in desiccators and weighed (W_5). The sample in dish was ash in a muffle furnace at 550°C until white or grey ash resulted. It was cooled and reweighed (W_6). The percentage ash content was calculated.

2.8 Determination of moisture content

Moisture content was determined by weighing 25g of sample into cans of known weights (W_1). The samples in cans (W_2) were placed in an oven for 6 hours at 105°C and then cooled in desiccators and reweighed (W_3). Difference in weight was moisture loss.

2.9 Determination of thermal properties

Thermal properties of the samples were determined by fitting experimental data to existing models (Choi and Okos, 1987). Effectiveness of models based on chemical composition of foods for predicting thermo-physical has been reported (Toledo, 2000). Ambient and cooking temperatures were 29°C and 100°C, respectively. Thermal properties determined were thermal conductivity, specific heat, and thermal diffusivity. Thermal conductivity was calculated using (Equations 1 to 16). Specific heat capacity was determined by application of Equations 17 to 23. While equations 24 to 30 were used for thermal diffusivity determination.

$$k = \sum (k_i X_{vi}) \quad (1)$$

$$k_i = k_w + k_p + k_f + k_c + k_{fi} + k_a \quad (2)$$

$$X_{vi} = X_i \rho / \rho_i \quad (3)$$

$$\rho = 1/\{\sum X_i / \rho_i\} \quad (4)$$

$$k_w = 0.57109 + 0.0017625T - 6.7306 x 10^{-6} T^2 \quad (5)$$

$$k_p = 0.1788 + 0.0011958T - 2.7178 x 10^{-6} T^2 \quad (6)$$

$$k_f = 0.1807 - 0.0027604T - 1.7749 x 10^{-7} T^2 \quad (7)$$

$$k_c = 0.2014 + 0.0013874T - 4.3312 \times 10^{-6} T^2 \quad (8)$$
$$k_{fi} = 0.18331 + 0.0012497T - 3.1683 \times 10^{-6} T^2 \quad (9)$$
$$k_a = 0.3296 + 0.001401T - 2.9069 \times 10^{-6} T^2 \quad (10)$$
$$\rho_w = 997.18 + 0.0031439T - 0.003754T^2 \quad (11)$$
$$\rho_p = 1329.9 - 0.51814T \quad (12)$$
$$\rho_f = 925.59 - 0.4175T \quad (13)$$
$$\rho_c = 1599.1 - 0.31046T \quad (14)$$
$$\rho_{fi} = 1311.5 - 0.36589T \quad (15)$$
$$\rho_a = 2423.8 - 0.28063T \quad (16)$$
$$C_p = \sum (C_{pi} X_i) \quad (17)$$
$$C_{pp} = 2.0082 + 1.2089 \times 10^{-3}T - 1.3129 \times 10^{-6}T^2 \quad (18)$$
$$C_{pf} = 1.9842 + 1.4733 \times 10^{-3}T - 4.8008 \times 10^{-6}T^2 \quad (19)$$
$$C_{pc} = 1.5488 + 1.9625 \times 10^{-3}T - 5.5399 \times 10^{-6}T^2 \quad (20)$$
$$C_{pfi} = 1.3459 + 1.3306 \times 10^{-3}T - 4.6509 \times 10^{-6}T^2 \quad (21)$$
$$C_{pa} = 1.0926 + 1.8896 \times 10^{-3}T - 3.6817 \times 10^{-6}T^2 \quad (22)$$
$$C_{pw} = 4.1762 - 9.0864 \times 10^{-3}T - 5.4731 \times 10^{-6}T^2 \quad (23)$$
$$\alpha = \sum (\alpha_i X_i) \quad (24)$$
$$\alpha_p = 6.8714 x10^{-2} + 4.7578 x10^{-4}T - 1.4646 x10^{-6}T^2 \quad (25)$$
$$\alpha_f = 9.8777 x10^{-2} - 1.2569 x10^{-4}T - 3.8286 x 10^{-6}T^2 \quad (26)$$
$$\alpha_c = 8.0842 x 10^{-2} + 5.3052 x10^{-4}T - 2.3218 x 10^{-6}T^2 \quad (27)$$
$$\alpha_{fi} = 7.3976 x 10^{-2} + 5.1902 x10^{-4}T - 2.2202 x 10^{-6}T^2 \quad (28)$$
$$\alpha_a = 1.2461 x 10^{-1} + 3.7321 x10^{-4}T - 2.2244 x 10^{-6}T^2 \quad (29)$$
$$\alpha_w = 1.3168 x 10^{-1} + 6.2477 x 10^{-4}T - 2.4022 x 10^{-6}T^2 \quad (30)$$

Where,

X_{vi} is volume fraction of each component,
X_i is the mass fraction, %
k is thermal conductivity, W/(m.K)
ρ is composite density, kg/m^3
C_p is specific, kJ/kgK
α is thermal diffusivity, m^2/s
Subscript i, w, p, f, c, fi and a, indicate for pure component, water, protein, fat, carbohydrate, fiber and ash, respectively.

Results and Discussion

Effects of cooking on physical properties

Length, breadth, and thickness of locust bean were 10.38 ± 0.82 to 12.52 ± 1.33 mm, 8.61 ± 1.20-to 10.04 ±1.53 mm and 4.79 ± 0.53 to 5.83 ± 0.71 mm, respectively. ANOVA of the data showed significant ($p<0.05$) impact of cooking only on length. Graphical illustration of the relationship was presented as Figure 1. Effect of cooking duration on length was fit to second order polynomial while third order polynomial best represented the behaviour of breadth and thickness to treatment. Seed size plays important roles in the design and selection of equipment for primary processing of separation (Akinoso and Raji, 2011a).

The significant effect of cooking duration on length may be traced to moisture absorption capability of the crop. Similar observation was reported when locus bean was soaked in water (Sobukola and Onwuka, 2011). Non-significant influence of treatment on breadth and thickness was an indication of low absorption capacity of these sides. There was also possibility of non-uniformity in thickness of the seed coat among the sides, thus encouraging disparity in expansion.

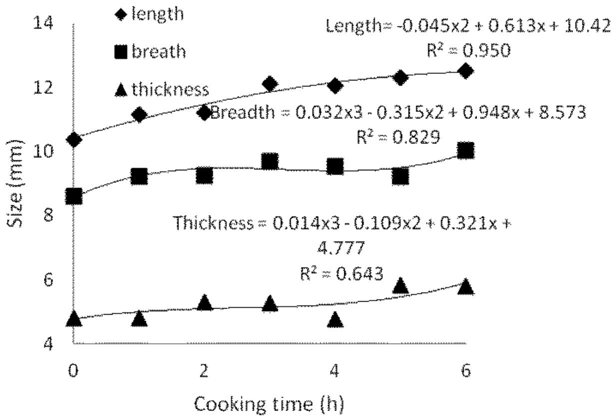

Figure 1. Plot of Size against Cooking Time

Mean mass recorded after 0, 1, 2, 3, 4, 5 and 6 hours of cooking were 0.25 ± 0.08 g, 0.32 ± 0.03 g, 0.41 ± 0.01 g, 0.49 ± 0.06 g, 0.48 ± 0.08 g, 0.43 ± 0.05 g and 0.47 ± 0.04 g, respectively. The observed differences were not significant when subjected to ANOVA at 5% level of significance. Visual illustration of the relationship was showed as Figure 2. Trend of the plot revealed a polynomial. Fourth order polynomial equation was suitable to express the effect of cooking on the bean mass. The weight of crops is one of the major determinants in the choice of handling equipment (Minjinyawa, 2007). Resultant effect of cooking on breadth and thickness might have influenced the non-significance of cooking on mass. Therefore, this result suggested that consideration for mass in design of handling equipment such as conveyor could be generalised regardless of cooking duration.

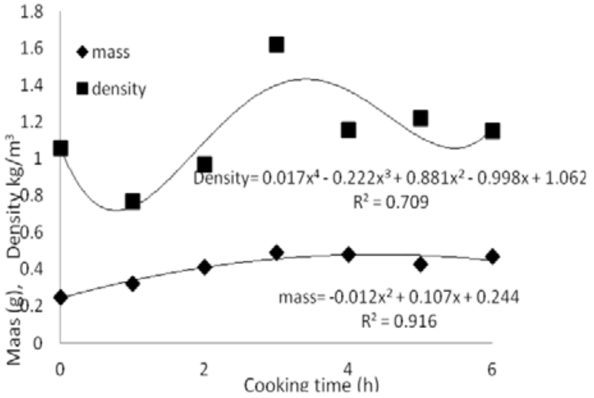

Figure 2. Plot of Mass and Density against Cooking Time

Bulk density of the samples ranged from 0.77 ± 0.03 to 1.62 ± 0.51 g/cm^3. Cooking of the bean increased its moisture content from 4.4 ± 0.9 to 61.4 ± 1.7 % wet basis. Bulk density has practical application in determining separation of product from undesirable materials (Owolarafe et al., 2011). Water flotation method is applicable for these samples because none of their densities was equal to density of water (1g/cm^3). Cleaning is an important unit operation in food processing.

Significant effect ($p<0.05$) of cooking on moisture content of the crop was recorded. Figure 3 shows plot of moisture content versus cooking time. Second order polynomial fitted the curve. Rise in moisture content with increase in cooking duration is an expected phenomenon. Locust bean is a biomaterial, which has affinity for water. However, it should be noted that water caused re-distribution of chemical composition of crop. Effect of variation in composition of a food on thermal properties had been reported (Choi and Okos, 1987). Design of efficient boiler is a function of thermal properties.

The mean sphericity and aspect ratio of the samples varied from 67.83 ± 4.27 to 73.21 ± 5.49 % and 74.99 ± 8.00 to 83.20 ± 9.70 %, respectively. Effect of cooking was significant ($p<0.05$) on both properties. From Figure 4, aspect ratio fitted well into fourth order polynomial model.

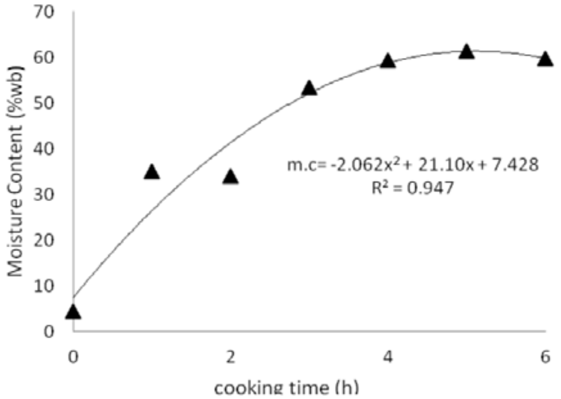

Figure 3. Plot of Moisture Content against Cooking Time

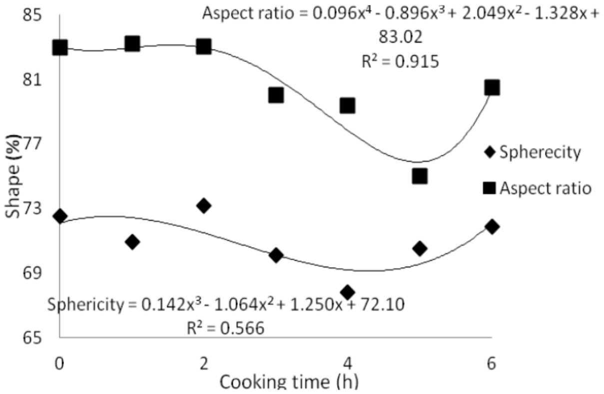

Figure 4. Plot of Shape against Cooking Time

However, fitness of sphericity into polynomial model was low with coefficient of determination R^2 of 0.556. High sphericity and aspect ratio is an indication of the crop tending to sphere shape. These properties are useful in design of dehulling equipment. Dehulling is one of the unit operations in locust bean processing.

3. Effects of cooking on mechanical properties

Compressive forces required to reach the yield, break and peak point of the samples ranged from 10.22 ± 1.03 to 211.26 ± 13.1 N, 51.70 ± 3.38 to 384.39 ± 7.68 N and 51.88 ± 3.37 to 385.87 ± 7.77 N, respectively. Applied forces reduced with an increase in cooking time (see Figure 5). Second order polynomial model was fit to illustrate the relationship between the forces and cooking duration. No significant ($p>0.05$) difference was recorded between the forces at break and peak. Generally, the treatment effect was significant on compressive forces.

Deformation increased with increase in cooking time (see Figure 6). Cooking effect was significant on deformation at 5% level of significance. Compressive strength of food is used in determining cooking quality objectively.

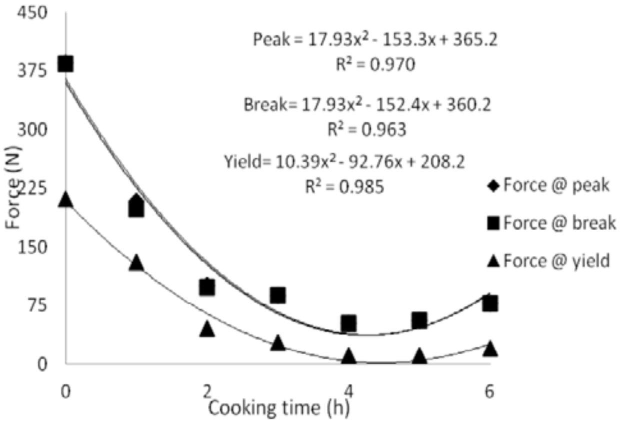

Figure 5. Plot of Force against Cooking Time

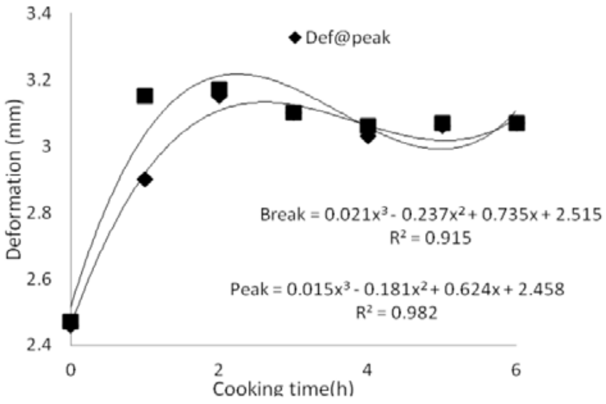

Figure 6. Plot of Deformation against Cooking Time

The obtained results on mechanical properties agreed with Olayanju et al. (2006) who reported significant influence of hydrothermal treatment on physic-chemical properties of soybean. A similar trend was reported on pea seeds subjected to thermal processing using infrared radiation (Andrejko et al., 2008).

Energy to yield, break and peak ranged from 0.01 ± 0.00 to 0.15 ± 0.01 J, 0.05 ± 0.00 to 0.45 ± 0.09 J and 0.05± 0.01 to 0.45± 0.03 J, respectively. Energy to break and peak was the same. Nevertheless, significance difference was noticed between energy to yield and others. Visual illustration of cooking effect on energy is shown in Figure 7. The plot trend showed a decrease in energy required for compression with increasing cooking time. Young modulus of locust bean after 0, 1, 2, 3, 4, 5, and 6 hours of cooking were 493.27± 29.4 N/mm^2, 244.38 ± 18.17 N/mm^2, 126.85 ± 8.11 N/mm^2, 102.62 ± 6.72 N/mm^2, 54.11 ± 3.71 N/mm^2, 65.33 ± 3.28 and 88.62± 4.73 N/mm^2. Cooking hours influenced the Young modulus of the crop significantly at 5% level of significance.

Polynomial model was fit to illustrate the relationship (see Figure 8). Noticeable difference between yield and break point indicated high ductility of the crop. The possibility of moisture uptake influence on the ductility should not be ignored. Low strength of the crop might be responsible for complete fracture at break point. Polynomial trends of the plots suggested that optimum points exist.

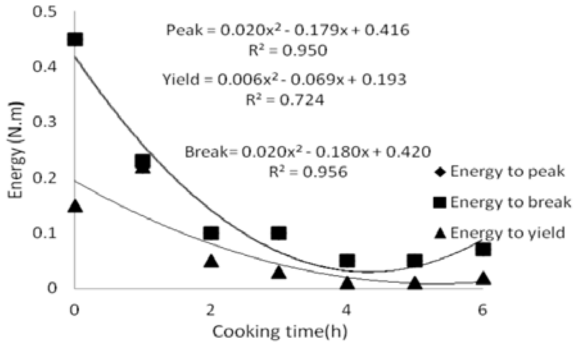

Figure 7. Plot of Energy against Cooking Time

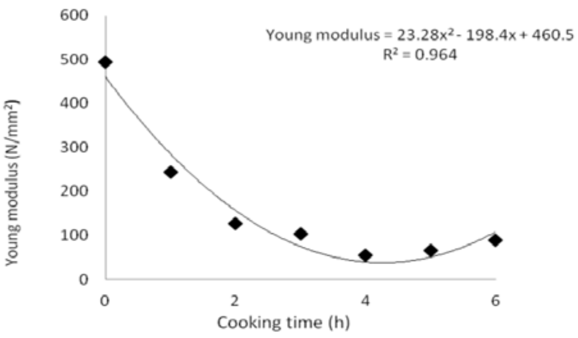

Figure 8. Plot of Young Modulus against Cooking Time

From Figures 5-8, two (2) hours were appropriate. Therefore, there was possibility that during traditional cooking of 8-10 hours, reactions have taken place, which affected physical, chemical, physic-chemical, and strength of locus bean.

4. Proximate composition

Proximate composition of the crop was presented as Table 1. Cooking for four hours had significant influence on all the determined chemical properties at 95% confidence level. Similar observation on wheat cooked at temperatures of 80^{o}C, 100^{o}C, and 120^{o}C was reported (Chukwu et al., 2011).

Table 1. Proximate composition of locust bean[#]

Properties	Un-cooked	Cooked
Crude protein	29.99±0.10^a	18.43±0.06^b
Fat	20.03±0.06^a	1.23±0.06^b
Carbohydrate	29.93±0.13^a	18.93±0.06^b
Crude fiber	8.71±0.04^a	6.50±0.10^b
Ash	5.25±0.01^a	2.67±0.15^b
Moisture content	6.09±0.04^a	52.23±0.15^b

[#] - mean of three replicates

[a,,b] - Values in the same row with different superscript are significantly different at $p < 0.05$

4.1 Protein

Crude proteins of un-cooked and cooked locust bean were 29.99 ± 0.01% to 18.43 ± 0.06% respectively. Previous work reported decrease in protein content of canavalia cathartica from 32.1 to 28.1% after cooking (Seena et al., 2006). In addition, Baiyeri et al., (2011), reported reduction in protein content of cooked banana from 3.21 to 2.48%. Locust bean has potential of being source of plant protein. Protein quality is a measure of the usefulness of a food protein for the purpose of growth and maintenance of tissue. Thermal denaturation results in coagulation and decreased solubility (Ihekoronye and Ngoddy, 1985)

4.2 Fat

Cooking reduced the fat content of locust bean from 20.03 ± 0.06% to 1.23 ± 0.06%. Locust bean oil ranged from 19.0 to 22.5% (Akinoso and Raji, 2011b). Wide margin in fat content of cooked and un-cooked locust bean can traced to aqueous extraction of oil from the seed during cooking. Heating fractionated intact oil bodies and rupture cellular structure, thus aided oil extraction.

4.3 Carbohydrate

Carbohydrate content of the raw and cooked locust bean were 29.93 ± 0.13 to 18.93 ± 0.06%, respectively. The remarkable 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.

4.4 Crude fiber

Crude fibers in locust bean were 8.71 ± 0.04% and 6.50 ± 0.15% for raw and cooked samples, respectively. 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, 2011b). 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).

4.5 Ash

The ash content of raw and cooked locust bean were 5.25 ± 0.01% to 2.67 ± 0.15%, respectively. The 5.25% obtained for raw in this study is in consonance with the 5.40% obtained (Omafuvbe et al., 2004) but slightly higher than the 4.24% obtained by (Elemo et al., 2011). Usually there is no appreciable loss of ash in legumes during cooking.

4.6 Moisture content

Cooking locust bean for four hours increased its moisture level from 6.09 ± 0.04% to 52.23 ± 0.15%. Rise in moisture content of locust bean from 8.8% to 56.7% after 6 hours of cooking was reported (Omafuvbe et al., 2004). Moisture uptake of 46.14% was recorded. Significant changes in chemical composition of the crops during cooking are attributed to re-distribution due to this high moisture uptake.

4.7 Thermal conductivity

Cooking for four hours increased thermal conductivity of locust bean by about 100% (see Table 2). Thermal conductivity of the cooked crop close to 0.59 W/mK was reported for tomatoes puree (Choi and Okos, 1987). 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.

Table 2. Thermal properties of locust bean [#]

Properties	Un-cooked	Cooked
Thermal conductivity (W/mK)	0.22 ± 0.00^a	0.52 ± 0.00^b
Specific heat (kJ/kgK)	1.92 ± 0.00^a	2.60 ± 0.00^b
Thermal diffusivity (m^2/s)	0.03 ± 0.00^a	0.14 ± 0.00^b

[#] - mean of three replicates

[a,,b] - Values in the same row with different superscript are significantly different at $p < 0.05$

The increase in thermal conductivity may be due to absorbed moisture by seed during cooking. In addition, the adopted model is a function of temperature. Therefore, an increase in temperature might have also influenced the results as determined. 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.

4.8 Specific heat

Cooking duration increased specific heat of locust bean from 1.92 to 2.60 kJ/kgK (see Table 2). Changes in this thermal property were significant at 5% level of significance. These values are higher than specific heat capacity of 1.39 kJ/kgK for guna seed (Aviara et al., 2008). Nevertheless, lower than 5.63 kJ/kgK was reported for Roselle seed (Bamgboye and Adejumo, 2010). Specific heat is an essential parameter in design of heat exchanger. The information will be useful in choice of heat transfer medium and processing conditions.

4.9 Thermal diffusivity

Cooking as a treatment significantly influenced thermal diffusivity of locust bean at 5% level of significance (see Table 2). 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.

5. Conclusion

Cooking duration influenced size, shape, and moisture absorption capacity of locust bean. Compressive strength and deformation of the crop were functions of the cooking duration. Effects of cooking on physical and mechanical properties of locust beans were not linear, thus an optimum cooking duration is required. Cooking duration of two hours was appropriate-using strength as criterion. Cooking of locust bean for four hours changed its chemical and thermal properties significantly. Generated data will be useful in choice of heat transfer medium and processing condition

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