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Effect of Cooking Time on Select Physical and Mechanical Properties of Dried Pigeon pea *(Cajanus cajan)*

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Abstract: *Improvement of the processing technology of pigeon pea requires accurate information on the physical and mechanical properties of the legume, as affected by primary processing. This study investigated the effect of cooking duration on select physical and mechanical properties of dried pigeon pea. The physical properties measured were length, breadth, thickness, mass, density, sphericity, aspect ratio and moisture content, using standard methods. Force at yield, break and peak; energy to yield, break and peak; deformation at break and peak; and Young modulus, were the mechanical properties measured using a Testometric device. Cooking times (1, 2, 3, 4, 5, and 6 hours) at 100^oC was used. Means of 250 replicates were calculated and data analysed using ANOVA and regression. The length, breadth, and thickness of the samples varied from 6.29 ± 0.39 to 8.18 ± 0.61mm, 5.59 ± 0.30 to 6.95 ± 0.84 mm and 4.18 ± 0.29 to 5.40 ± 0.61 mm, respectively. With increase in cooking time, mass, sphericity, aspect ratio, density and moisture content, ranged from 0.11 to 0.20 g, 71.1 ± 7.8 to 100.0 ± 9.4, 63.7 ± 4.1 to 88.0 ± 6.5, 0.91 ± 0.1 to 1.47 ± $0.3kg/cm^3$, and 8 ± 0.7 to 66 ± 4.1%, respectively. Effect of cooking time on mechanical properties of force, energy, deformation, and Young modulus was significant at 5% level of significance. Polynomial models were fit to express the relationships. Coefficient of determination R^2 of the equations ranged from 0.7 to 1.0. Cooking duration of two hours was adequate to soften the pea, using strength as the criterion. The data generated can be applied in the design of processing equipment.*

Keywords: *Pigeon pea, cooking, duration, physical properties, mechanical properties*

1. Introduction

Pigeon pea (*Cajanus cajan*), also known as *red gram, Congo pea, gungo pea, no eye pea, dhal, gandul, gandure, frijol de árbol, pois cajan, and otili,* occurs in several varieties. The legume grows on a wide range of well-drained soils, from sands to clays, over sedimentary, igneous, and metamorphic parent materials. The pea tolerates pH values from 4.5 to 8.4, and some varieties tolerate 6 to 12 mmhos/cm of salinity (Francis, 2011). However, the varieties are sensitive to water-logging. The pigeon pea is an important legume in developing tropical countries. As an excellent source of protein, the seeds (and sometimes the pods) are consumed as a vegetable, as a flour additive to other foods, in soups, and with rice (CNCPP, 2002). Pigeon pea forms root nodules in association with *Rhizobium* sp. bacteria, and it is capable of fixing 41 to 280 kg/ha of nitrogen (APS, 2002). The seed contains moisture (10.1%), protein (18.8%), fat (1.9%), carbohydrates (53.0%), fiber (6.6%), and ash (3.8%) (Saxena, 2008).

Additionally, mineral and trace elements found in the legume are calcium (120 mg/g), magnesium (122 mg/g), copper (1.3 mg/g), iron (mg/g) and zinc (2.3 mg/g); vitamins are carotene (469.0 mg/g), thiamin (0.3 mg/g), riboflavin (0.3 mg/g), niacin (3.0 mg/g), and ascorbic acid (25.0 mg/g). In spite of the nutritional potential of this crop, it is still classified as underutilised.

Processing of pigeon pea involves de-podding, cleaning, cooking, drying, and milling. The seed of the pigeon pea is enclosed in a hard, tough, and relatively thick coat that has a semi-permeable membrane. Movement of water through the mesocarp is restricted, because the adhesive force that binds the mesocarp to the seed is relatively high (Ghadge, Shewalkar and Wankhede, 2008). Therefore, cooking is necessary to soften the firmly attached seed coat for easy dehulling. The traditional boiling time of 8-10 hrs discourages use. A reported method of reducing cooking time is soaking in water for six hours, then boiling in 6% Na_2CO_3 (Achi, 2005). The cooking time is reduced to 3 hours, and de-hulling efficiency is increased to 78%.

Engineering properties of crops are essential parameters in utilisation, in the development of processing methods, and in equipment design (Akinoso and Raji, 2011). These properties include rheological, thermal, optical, electrical, physical, and mechanical. Mohsenin (1986) described various methods for measuring crushing force. These methods include the use of automatic recording universal hardness of testing machines. Studies in engineering properties of agricultural products include Koya and Faborode (2005) on palm nuts, Chemperek and Rydzak (2006) on maize grain, and Altuntas and Yildiz (2007) on faba bean. Others are Andrejko et al. (2008) on pea seed, Kibar and Ozturk (2008) on soybean, and Fathollahzadeh and Rajabipour (2008) on barberry. Altuntas and Sekeroglu (2008) and Tavakoli et al. (2009) have reported on chicken egg and wheat straw, respectively. Researchers have clearly shown that engineering properties of biomaterial significantly depend on moisture content, maturity, shape, and size of crop.

Improvement of the processing technology of pigeon pea requires accurate information on the physical and mechanical properties of the legume, as affected by primary processing. Studies on cooking time reduction, without compromising food value, will provide info that can be used to reduce energy demand, encourage interest in its consumption, thereby increasing its utilisation. Therefore, the objective of this study was to determine the effect of water-cooking duration on select physical and mechanical properties of dried pigeon pea.

2. Materials and Methods

2.1 Samples Preparation

Dried pigeon peas (32C variety) of 8% moisture content (wet basis) were collected from the Institute of Agricultural Research and Training Ibadan, Nigeria was used for the study. A 1 x 6 factorial design was used (Christopher, 1983). Cooking times were 1, 2, 3, 4, 5 and 6 hours, at atmospheric pressure (760-mmHg≈ 1 bar) and boiling temperature (100^{o}C). The peas were cooked in distilled water using 3mm thick stainless steel container placed on a kerosene stove. At attainment of the desired heating duration, the container was removed, the water drained after which the peas were cooled to ambient temperature (29^{o}C) in desiccators containing silica gel as the desiccant.

2.2. Physical Properties

Physical properties of size (length, breadth, thickness), mass, shape, and density of the samples, were determined using standard methods (Akinoso and Raji, 2011). Length, breadth, and thickness were determined using a venier calliper with 0.01mm accuracy (Cappera precision, China). A digital weighing balance (Scout™ Pro OHaus model SPU401) of accuracy ± 0.001g was used for mass measurement. Means of 250 cooked seeds, randomly selected, were calculated and recorded. The sphericity and aspect ratio were determined according to Mohsenin (1986), using Equations 1 and 2, respectively.

$$SI = \frac{(\alpha\beta\delta)^{1/3}}{\alpha} \, x \;\; 100 \qquad (1)$$

$$Ra = \frac{\beta}{\alpha} \, x \;\; 100 \qquad (2)$$

Where *SI* was sphericity (%), was aspect ratio (%), and α, β, δ were length, breadth and thickness in mm respectively.

2.3 Moisture Content

The relationship between mass and volume was applied for bulk density calculation. Moisture content of the peas was determined using the ASABE (2008) standard method for oilseed. Three samples (15g each) were placed in an oven set at 130^{o}C for 6 hrs. The samples were then cooled to ambient temperature (29^{o}C) in desiccators containing silica gel as the desiccant. The dried samples were weighed using a digital weighing balance (Scout™ Pro OHaus model SPU401). The difference in weight before and after drying was calculated as moisture loss. The ratio of moisture loss to weight of wet material in percentage was recorded as moisture content, wet basis (%, wb).

2.4 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 Young modulus, were determined using a Testometric AX Type DBBMTCL 2500 kg (Rochdale, England). These tests were conducted using the method of Akinoso and Raji (2011). The seed samples were placed between the compression plates of the testing equipment. Each pea was compressed at a constant deformation rate 10.00mm/min., and readings were made using a data logger. The procedure was repeated in 250 replicates. Mean values were recorded. Data obtained were subjected to ANOVA and regression analysis at $p < 0.05$.

3. Results and Discussion

3.1 Size Characteristics

Length, breadth, and thickness of pigeon peas were 6.29 ± 0.39 to 8.19 ± 0.60 mm, 5.59 ± 0.30 to 6.95 ± 0.65 mm and 4.18 ± 0.29 to 5.37 ± 0.51mm, respectively. As cooking time increased, ANOVA of the data showed significant ($p<0.05$) impact of cooking on the three spatial dimensions. Graphical illustration of the relationship is given in Figure 1.

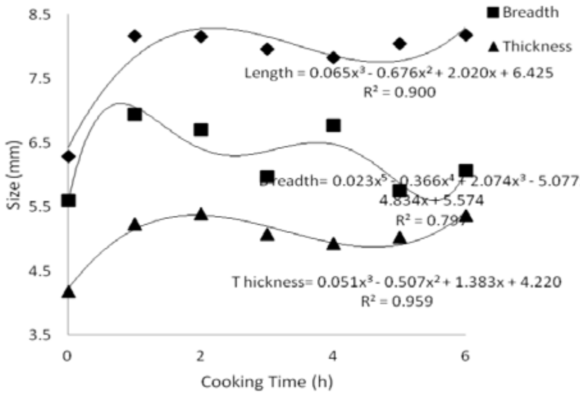

Figure 1. Plot of cooking time against size

Effect of cooking duration on breadth was fit to fifth order polynomial, while third order polynomial best represented the behaviour of length and thickness to treatment. Seed size is important in the design and selection of equipment for primary processing of separation (Akinoso and Raji, 2011). The significant effect of cooking duration on size may be related to moisture absorption capability of the legume. Sobukola and Onwuka (2011) reported similar observations when locust beans were soaked in water.

3.2 Mass

Mean mass recorded after 0, 1, 2, 3, 4, 5 and 6 h of cooking were 0.11± 0.00 g, 0.195 ± 0.00 g, 0.190 ± 0.00 g, 0.20 ± 0.00 g, 0.185 ± 0.00 g, 0.185 ± 0.00 g, and 0.185 ± 0.00 g, respectively. The observed differences were not significant when subjected to ANOVA at 5% level of significance. Weight of crops is one of the major determinants in the selection of handling equipment (Mijinyawa, 2007). Therefore, the results suggest that consideration for mass in the design of handling equipment such as conveyors, could be generalised regardless of cooking duration. Illustration of the relationship is shown in Figure 2. Third order polynomial equation was suitable to express the cooking effect on seed mass.

3.3 Density

Bulk density of the samples ranged from 0.91 ± 0.01 to 1.47 ± 0.3 kg/m^3. Bulk density has practical application in determining separation of product from undesirable materials (Fellows, 2000). Cleaning is an important unit operation in food processing (Fellows, 2000). The sink and floating method is applicable for these samples because none of their densities was equal to density of water (1g/cm^3) (see Figure 2).

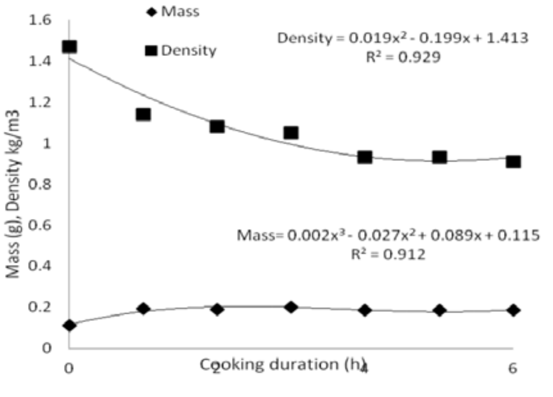

Figure 2. Plot of mass and density against cooking duration

3.4 Moisture Content

Cooking of the seed increased its moisture content from 8.10 ± 1.03 to 66.0 ± 2.7 % (wet basis). Significant effect ($p<0.05$) of cooking on moisture content of the crop was recorded. Figure 3 shows the effect of increased cooking time on moisture content of the peas. Second order polynomial fits well for the curve. Increased moisture content with increase in cooking time was an expected phenomenon. Pigeon pea is a biomaterial that has affinity for water. However, it should be noted that water absorption causes re-distribution of chemicals within the peas (Ihekoronye and Ngoddy, 1985). Effect of variation in composition of a food on thermal properties has been reported (Choi and Okos, 1987). Design of an efficient boiler is a function of thermal properties (Barbosa-Canovas et al., 2006).

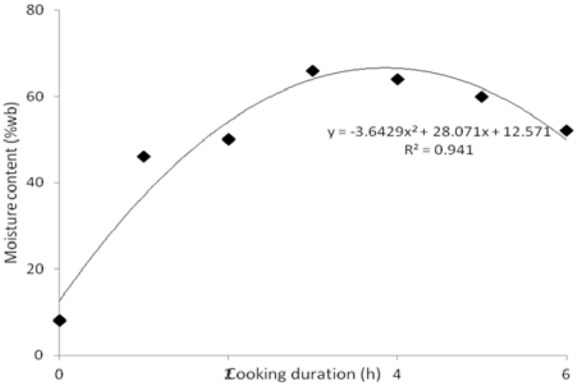

Figure 3. Plot of moisture content against cooking duration

3.5 Shape

The mean sphericity and aspect ratio of the samples varied from 71.1 ±7.8 to 100.0 ± 9.4 %, and 63.7 ± 4.1 to 88.2 ± 6.5 %, respectively. Effect of cooking was significant ($p < 0.05$) on both properties. As seen in Figure 4, both sphericity and aspect ratio were well fit into sixth order polynomial model. Coefficients of determination of the models were 1.

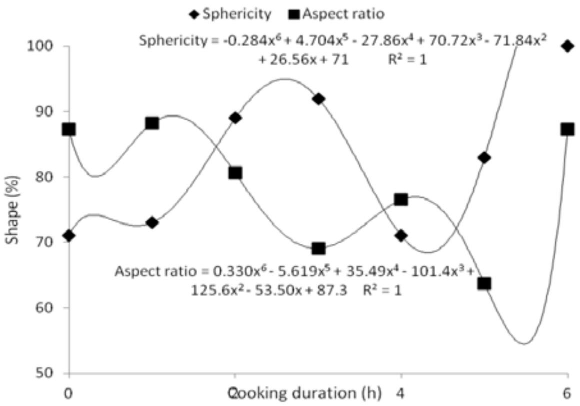

Figure 4. Plot of shape against cooking duration

The ranges of sphericity and aspect ratio fall within 32.0 and 100 as reported by Mohsenin (1986). High sphericity and aspect ratio is an indication of the seeds tending to a spherical shape. These properties are useful in the design of dehulling equipment (Mohsenin, 1986). Dehulling is one of the unit operations in pigeon pea processing (Ghadge, et al., 2008).

3.6 Force

The minimum and maximum forces at yield, break, and peak of the samples were 173.4 ± 25.3 to 2.8 ± 1.3 N, 529.7 ± 37.3 to 12.3 ± 1.7 N and 529.7 ± 37.2 to 11.9 ± 1.7 N, respectively. Applied forces decreased with increased cooking time (see Figure 5). Third order polynomial model fit illustrates 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 increased cooking time (see Figure 6).

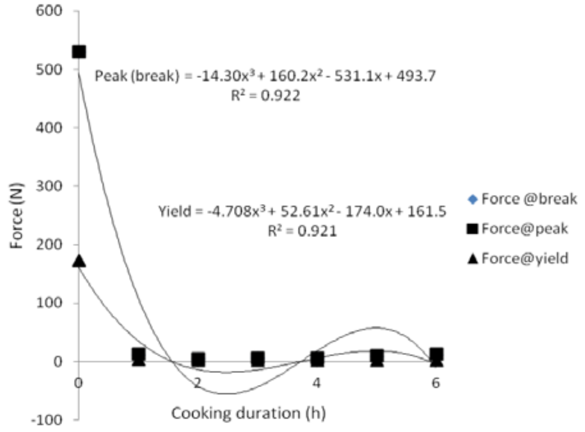

Figure 5. Plot of force against cooking duration

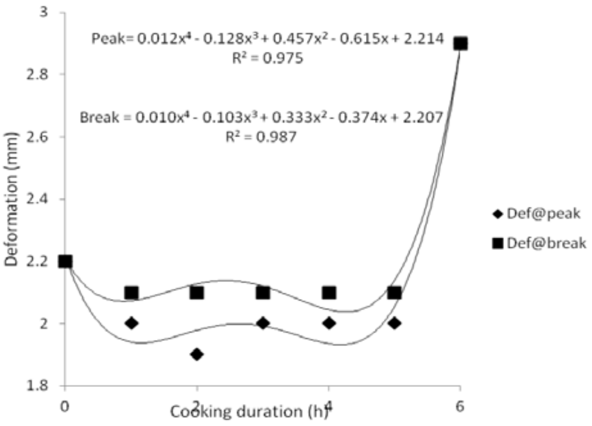

Figure 6. Plot of deformation against cooking duration

It is to be noted that the increment was not linear. The relationship is best described by fourth order polynomial. Cooking effect was significant on deformation at 5% level of significance. Strength of food is used in determining cooking quality objectively (Ihekoronye and Ngoddy, 1985). The results on mechanical properties agreed with Olayanju et al. (2006) who reported significant influence of hypothermal treatment on physico-chemical properties of soybean. Andrejko et al., (2008) reported similarly on dried peas subjected to thermal processing using infrared radiation. 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 tensile strength of the crop might be responsible for complete fracture at break point (Barbosa-Canovas et al., 2006).

3.7 Energy and Young Modulus

Energy to yield, break, and peak ranged from 0.00019 ± 0.000 to 0.09 ± 0.00 J, 0.0039 ± 0.000 to 0.566 ± 0.03 J, and 0.0039 ± 0.000 to 0.566 ± 0.03 J, respectively. Energy to break and peak was the same. Nevertheless, significance difference was noticed between energy to yield and others. Cooking duration on energy consumption or usage is shown in Figure 7. Results indicate that decreased energy is required for compression with increased cooking time.

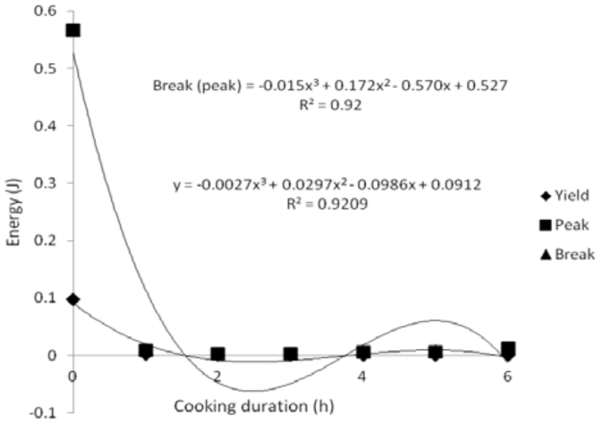

Figure 7. Plot of energy against cooking duration

As seen in Figures 5 and 7, two (2) hours of cooking were adequate to soften the peas. Therefore, results suggest that during traditional cooking of 8 – 10 hrs, reactions occur that affect the physico-elastic and strength of pigeon pea. Young modulus of pigeon pea after 0, 1, 2, 3, 4, 5, and 6 hours of cooking were 546.30 ± 42.77 N/mm^2, 21.09 ± 2.41 N/mm^2, 7.98 ± 1.81 N/mm^2, 8.97 ± 1.61 N/mm^2, 6.91 ±1.33 N/mm^2, 13.69 ±4.08 N/mm^2 and 12.08 ± 4.3 N/mm^2, respectively. Cooking hours influenced Young modulus of the crop significantly at 5% level of significance. Polynomial model was fit to illustrate the relationship (see Figure 8). Young modulus is a material property that describes its stiffness (Barbosa-Canovas et al., 2006).

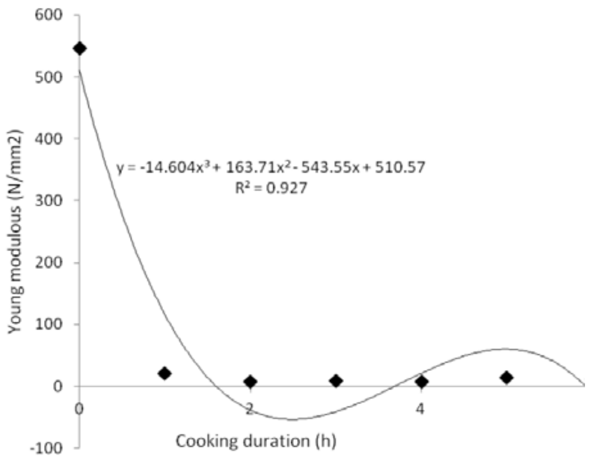

Figure 8. Plot of Young modulus against cooking duration

4. Conclusions

Cooking time influenced size, shape, and moisture absorption capacity of dried pigeon pea. Compressive force and deformation of the crop were functions of the cooking duration. Effects of cooking on physical and mechanical properties of pigeon were not linear, thus optimum cooking time is required. Cooking duration of two (2) hours was adequate to soften the pea, using strength as the criterion. Reduction in cooking duration will save energy requirements for the unit operation, thus reducing pigeon pea processing costs. The data generated can be applied in the design of processing equipment. It is recommended that nutritional values of the cooked pigeon pea at two hours should be determined. In addition, thermal properties of the pea should be studied.

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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