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Effects of Drying On Some Engineering Properties of African Locust Bean Seeds

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ABSTRACT: *The effect of heat and moisture content on engineering properties of locust bean seeds was determined in this study. The locust bean seeds were subjected to oven drying in reducing moisture range of 18.06 to 14.90% dry basis. The properties of the seeds at each moisture content were determined by following standard procedures. The average values obtained for the properties such as length, width, thickness, arithmetic mean diameter, geometric mean diameter, sphericity, volume, surface area, true density, bulk density, porosity, angle of repose and cracking energy were in the range of 10.17-15.09 mm, 4.13-8.61mm, 4.65-5.53mm, 6.32-9.84mm, 5.80-9.02mm, 0.57-0.59, 102.72-403.01mm^3, 166.92-215.12mm^2, 1034-1488kg/m^3, 572.60-955.70kg/m^3, 31.73-49.51%, 30.14-43.65^0 and 0.38-1.48J respectively. The differences in the values obtained were statistically significant at 95% level for all the properties except the thickness, arithmetic mean diameter, geometric mean diameter and sphericity. All the properties decrease as the moisture content decreases except the volume, surface area and porosity which increase as the moisture content decreases. The data obtained in this study will be useful for the design of machines for processing, handling and transportation of locust bean seeds.*

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I INTRODUCTION

African locust bean is a perennial tropical legume which is not usually cultivated but grows abundantly in grass land of West and Central Africa. The tree can be found around savannah area of Nigeria like Oyo, Kwara, and Plateau states. It belongs to a family of monosaccharide in the order leguminous. The two most common botanical names of Africa locust bean are *ParkiaBioglobosa*and*ParkiaFilicodea*. Locust bean comes from a type of evergreen Mediterranean, specifically Syria and Asia minor. The fruit comes in long narrow pods, each containing about 30 seeds about one centimeter long (Zainab, 2016). It is a dicotyledonous seed and has thick gum made from carbohydrate reserve of the seed (Dionisio and Grenha, 2012).

The fruits of African locust beans are in bunches of pod which may vary between 12.5cm and 24.4cm in length according to soil fertility. It contains a yellow dried powder pulp which is sweet to taste, inside which is embedded a number of dark or black seeds which can be processed into “*Dorowa*”, a viable carbohydrate food taken by northern people of Nigeria (Tee et al, 2009). A dried ‘*iru*’ cake is a type of fermented locust beans used as a condiment in cooking (Ajayi, 2014). It is very popular among the Yoruba people of Nigeria who used it in cooking of *egusi* soup and it can be found fresh or dried after being fermented. During fermentation, the reducing sugar content is increased and the total free amino acid content decreases (Omafuvbe et al, 2004).

The annual production of locust bean was estimated to be about 200,000 tonnes in Northern Nigeria (Onnyi et al, 2004). A survey carried out at Arigidi-Akoko in Ondo State showed a locust bean tree could yield between 500 and 700 pods (bean sword) of which each can produce about 6-18kg of raw beans (Adejumo et al, 2014).

Processing of locust beans is majorly done in Nigeria using traditional method. The process of dehulling locust bean using traditional method is not only laborious and time consuming but also yields low quality production. The cooked seeds are usually poured into mortar and mixed with sharp sand to remove the seed coat by abrasion method. The mixture is washed several times in clean water to remove the floating chaff and the denser sand settle to the bottom of the container (Adewumi and Olalusi, 1995). The cotyledons are then separated from the sand. During decortication, when the seed is heated up, more moisture penetrate into the seed coat and it is softened, thereby making it easy to decorticate.

The purpose of steaming is to increase the peeling yield and to improve storage characteristics. The steaming also improves the firmness after cooking and achieves better vitamin and salt retention in the peeled locust bean seed. Heating with steam can cause the following changes in the locust bean seeds:

i. The moisture content of the locust bean seed increases because of access water formed by condensation
ii. Water solution substance spreads inside the seed
iii. Texture of the endosperm becomes softened due to the increase in the moisture content level.
iv. The cracking force becomes very low during decortication due to the nature of the endosperm.

The heating time and temperature must be controlled precisely in relation to the seed. Steam heating may be done at atmospheric pressure and for the locust bean to be gelatinized with sufficient moisture content, heat must be applied.

The effects of drying engineering properties of locust beans such as size, volume, sphericity, density,porosity, angle of repose and cracking energy were investigated in this study. This study is significant as the data obtained can help in developing handling, processing and storage equipment for locust bean seeds which will lead to higher and more quality production than traditional method.

II MATERIALS AND METHODS

2.1 Sample Preparation

A bulk quantity of locust bean seeds was obtained fromOmuo-Ekiti town in Ekiti State. The samples were cleaned and sorted manually to remove all dirts and foreign materials. They were then stored in polythene bags at room temperature for 24 hours to attain stable moisture content. To investigate the effects of drying on the engineering properties of the locust beans, the seeds were heated using a laboratory oven and samples of equal quantities were taken at six different moisture levels. The moisture content were obtained by following the procedure given by ASAE (1998).

2.2 Determination of physical properties

2.2.1 Size

50 seeds from each of the six moisture content levels were randomly selected by following a similar method reported by Dutta et al (1988). Digital Vernier caliper with an accuracy of 0.01mm was used to measure the three principal dimensions of the locust bean seeds namely: length (L), width (W) and thickness (T)(Zewdu and Solomon, 2008; Nalbandi et al., 2010). The arithmetic mean (D_a)and geometric mean (D_g) of the seeds were then determined by using the following relationships (Mohsenin, 1986):

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

$$D_g = (LWT)^{1/3} \quad (2)$$

2.2.2 Sphericity (Ø), Volume (*V*) and Surface area (S)

The sphericity is defined as the ratio of the surface area of a sphere with the same volume as the seed to the surface area of the seed. This measurement was determined using the following equation (Mohsenin, 1986):

$$\phi = \frac{(LWT)^{1/3}}{L} \quad (3)$$

The three principal dimensions (L, W and T) were used to calculate the volume (V) and surface area (S) of the locust bean seed using the following equations(Jain and Bal, 1997):

$$V = 0.25\left[\left(\frac{\pi}{6}\right)L(W + T)^2\right] \quad (4)$$

$$S = \frac{\pi BL^2}{(2L - B)} \quad (5)$$

where $B = \sqrt{WT}$

2.2.3 True Density, Bulk Density, and Porosity

The true density is the density of a pure substance or a composite material calculated from the densities of its components considering conservation of mass and volume. If the densities and volume or mass fractions of constituents are known, true density can be determined from the following relationship as given by (Sahin and Sumnu, 2006):

$$\rho_t = \frac{1}{\sum_{i=1}^{n} \frac{x_i^w}{p_i}} \quad (6)$$

where

ρ_i = density of *i*th component (kg/m^3),

x_i^w = mass fraction of *i*th component of each seed

n = number of components of each seed

In this case, the mass and density of each seed in a sample of 50 of seeds were determined using formulas in order to find the true density at different moisture content.

The bulk density (ρ_b) of the locust bean seeds was measured by filling an empty glass container of known volume with seeds poured at a constant height. The ratio of the mass and volume was expressed as bulk density.

The porosity of locust bean seeds at various moisture contents was calculated from bulk density and true density using therelationship given by Singh et al. (2004) as follows:

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100\% \quad (7)$$

where: ε is the porosity in %, ρ_b is the bulk density in kg/m^3 and ρ_t is the true density in kg/m^3.

2.3 Determination of Mechanical Properties

2.3.1 Angle of Repose

The angle of repose was determined on stainless steel surface as stainless steel is the recommended material for machines handling food material. This was determined by using a topless and bottomless cylinder of 30 cm diameter and 50 cm height. The cylinder was placed at the centre of a raised circular plate having a diameter of 70 cm and was filled with the seeds. The cylinder was raised slowly until it formed a cone on a circular plate. The height of the cone was measured carefully with a meter rule while the base radius traced out was also measured with a divider. This procedure is similar to that reported by (Owolarafe et al., 2007). The angle of repose was estimated using the relationship below:

$$\alpha = \frac{\tan^{-1}(2h)}{d} \quad (8)$$

Where α = angle of repose, *h* = height of the cone (mm) and *d* = diameter of the cone (mm)

2.3.2 Cracking Energy

Impact and cracking forces of the locust bean seeds were determined using impact tester machine. A mass of 0.05kg was dropped at a height on 50 seeds at different moisture content. The cracking energy was estimated from the potential energy formula as follow:

Cracking energy, $E = mg(h - T)$ (9)

where m = mass of the dropped weight, h = height of the dropped weight from the tester base, T = thickness of the seed and g = acceleration due to gravity.

III RESULTS AND DISCUSSION

The results of some engineering properties of locust bean seeds at different moisture contents obtained in this study are shown in Table 1.

Table 1: Average values of properties of locust beans at six different moisture contents

Property	Unit	n	Moisture content (% dry basis) 18.06	17.60	17.00	16.80	16.00	14.90	P-value at α = 0.05
Length, L	mm	50	15.39	14.31	13.07	13.26	12.23	10.17	0.0025
Width, W	mm	50	8.61	7.74	7.04	6.92	5.96	4.13	0.0111
Thickness, T	mm	50	5.53	5.39	5.29	4.87	4.77	4.65	0.9187
Arithmetic Mean Diameter, Da	mm	50	9.84	9.15	8.47	8.35	7.65	6.32	0.0522
Geometric Mean Diameter, Dg	mm	50	9.02	8.42	7.87	7.65	7.03	5.80	0.0820
Sphericity, ϕ		50	0.59	0.59	0.60	0.58	0.57	0.57	0.9999
Volume, V	mm^3	50	403.01	323.00	260.13	241.42	184.35	102.72	2.55×10^{-23}
Surface Area, S	mm^2	50	215.12	204.46	192.58	194.39	184.78	166.92	8.66×10^{-14}
True Density, ρ_t	kg/m^3	50	1488.00	1303.30	1208.00	1124.00	1044.00	1034.00	1.45×10^{-25}
Bulk Density, ρ_b	kg/m^3	50	955.70	867.14	721.70	724.80	678.95	572.60	8.62×10^{-25}
Porosity, ε	%	50	31.73	33.47	40.26	35.52	34.97	49.51	1.47×10^{-8}
Angle of Repose, α		50	43.65	40.05	36.45	35.09	31.23	30.14	7.81×10^{-8}
Cracking Energy, E	J	50	0.38	0.46	0.47	0.49	0.57	1.48	0.0003

3.1 Moisture content

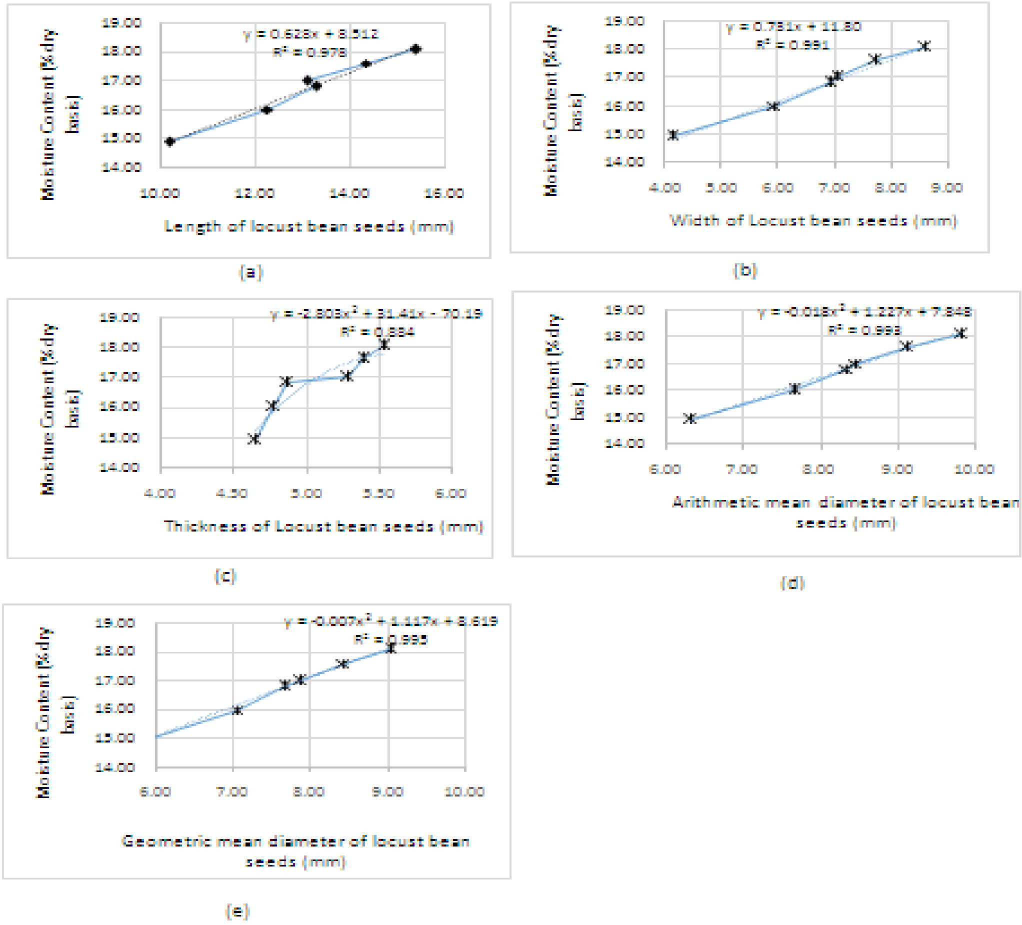
The initial moisture content of the locust bean seeds was unknown. After subjecting them to oven drying, six different moisture contents obtained were 18.06%, 17.60%, 17.00%, 16.80%, 16.00% and 14.90% dry basis. Table 1 showsthe values of the different moisture content.

3.2 Seed dimensions

As the moisture content of the locust bean seeds varied, there was significant variation in the dimensions of the seeds. The length decreases from 15.39mm to 10.17mm as the moisture content decreases from 18.06% to 14.90%. The same decrease was observed for both width and thickness as the moisture content decreases.There is linear relationship between moisture content and the length and width of the locust bean seeds except the thickness which exhibits polynomial relationship as shown graphically in Fig.1. The variation in thickness as moisture content decreases is not significant at $p < 0.05$ (Table 1).This is inversely related to the result by Oriola et al (2016) who investigated the effect of moisturizing the seeds which result in increase in the geometric dimensions as the moisture content increases. Bamigboye and Sadiku (2015) also obtained a linear relationship between moisture content and length and width of locust bean seeds but they got inverse relationship for the thickness. For the heated seeds at same moisture content range, the arithmetic and geometric mean diameters were decreased from 9.84mm to 6.32mm and from 9.02mm to 5.80mm respectively though the decrease was not significant ($p > 0.05$) (Table 1). Both also exhibited polynomial relationship respectively with correlation coefficient of 0.9931 and 0.9954 as shown in Fig. 1(d) and 1(e).

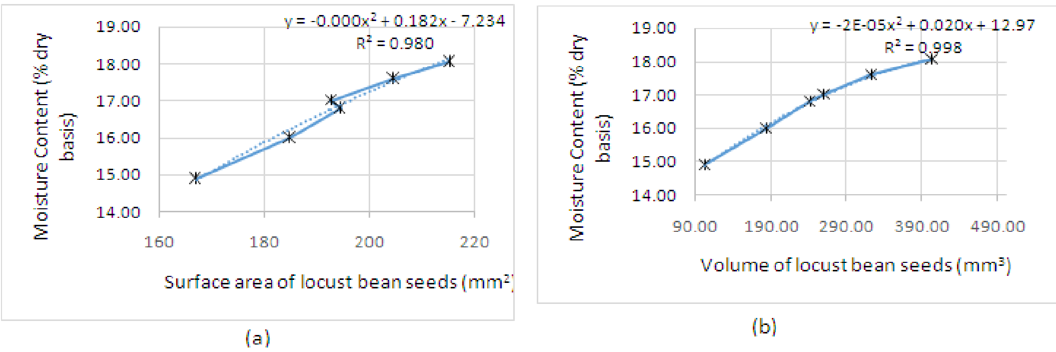
3.3 Sphericity

The tendency of a seed to easily roll on any of its three axes depend on its sphericity. The higher the sphericity, the higher the tendency. As the moisture content decreases, the ability to roll increases (Bamigboye and Sadiku, 2015). This is a very important parameter in the design of handling, conveying and processing machines for seeds. The sphericity for most agricultural seeds, as stated by Mohsenin (1986) is in the range 0.32 – 1.00. The sphericity of the locust bean seeds decreased from 0.59 at 18.06% moisture content to 0.57 at 14.90% moisture content. Though the differences in the sphericity is not statistically significant as the moisture content decreases (Table 1), the values obtained fall within the standard range. The slight decrease in the sphericity as the moisture content decreases may be due to the reduction in thickness of the seeds. Similar observation was reported by Bamigboye and Sadiku (2015). Oriola et al (2016) also reported an increase in the sphericity of locust bean seeds as the moisture content increases with correlation coefficient of $R^2 = 0.9836$.



3.4 Surface Area and Volume

The surface area for locust beanseeds significantly increased from 215.12 to 166.92 mm^{2}as the seed moisture content decreased from 18.06% to 14.90% in second order polynomial relationship with correlation coefficient of R^2 = 0.9806 as shown in Fig. 2(a). Similar relationship for locust bean seeds was reported by Sobukola and Onwuka (2010), Bamigboye and Sadiku (2015) and Oriola et al (2016).Significant decrease in volume of the seeds was also observed as the moisture content decreases($p < 0.05$)(Table 1). This was expressed by a polynomial relationship as shown in Fig. 2(b). This characteristic may be very useful in loading and transportation of the seeds.



3.5 True and Bulk Densities

Bulk density is an important parameter in aeration, loading and drying system of agricultural seeds while true density is important in developing a separation system for the seeds (Tamirat, 2012). The true density and bulk density of the seeds decreased from 1488kg/m^3 to 1034kg/m^3 and from 955.70kg/m^3 to 572.60kg/m^3 respectively as the moisture content decreases. Fig. 3(a) and 3(b) show the polynomial relationship between the moisture content and true density with correlation coefficient of $R^2 = 0.8998$. Similar relationship was observed for the bulk density with correlation coefficient of $R^2 = 0.9836$. Table 1 shows that the differences observed in the values of both bulk and true densities as the moisture content of the seed decreases are statistically significant with p values less than 0.05. Previous researches have shown that bulk and true densities do increase or decrease with increasing or decreasing moisture content of crop seeds. This is evident from the works of Aviara et al (2014), Sadiku et al (2014) and Oriola et al (2016).

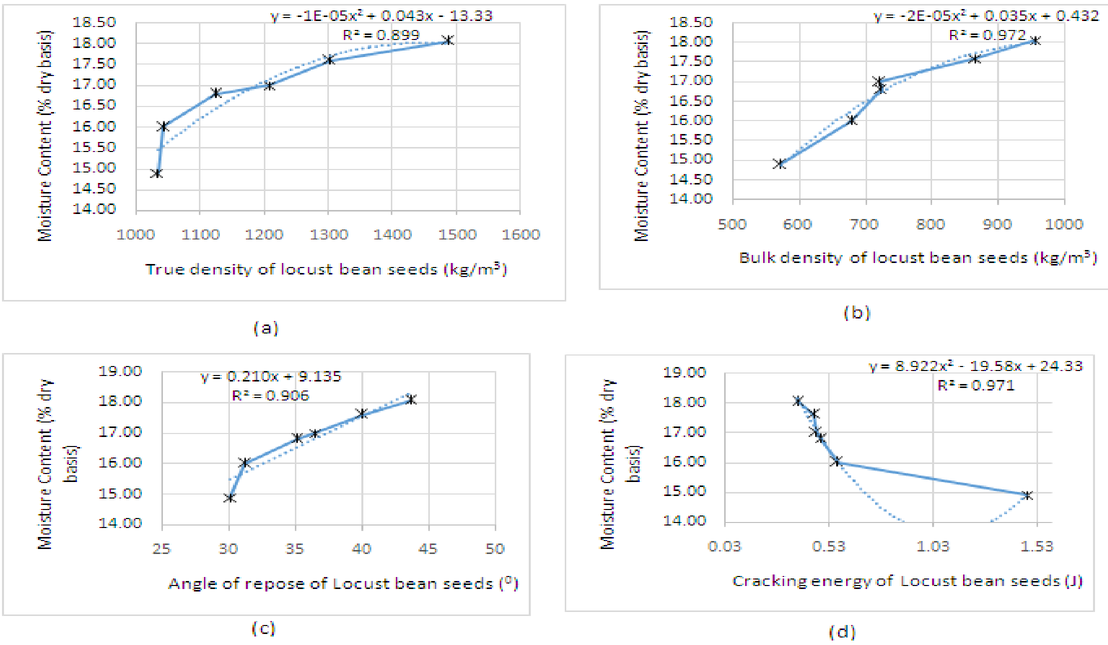


Fig. 3: Effects of heat and moisture content on (a) true density (b) bulk density (c) angle of repose and (d) cracking energy of locust bean seeds

3.6 Porosity

Porosity of the locust bean seeds increased from 31.73 to 49.51% as the moisture content decreases. The differences in the values obtained are significant at 95 % level. This may be due to swelling of locust bean seed because of more void spaces between the seeds. Miezaee et al (2007) and Oriola et al (2016) reported similar trends for cactus pear and locust bean seeds respectively. Table 1 shows that there is significant difference in the values of porosity as the moisture content decreases ($p < 0.05$).

3.7 Angle of Repose and Cracking Energy

The angle of repose was observed to decrease significantly with respect to moisture content as shown in Table 1. The angle of repose decreased as moisture content increased from 18.06 to 14.90%. The angle of repose for the locust bean seeds has a liner relationship with the moisture content as shown in Fig. 3(c). Oriola et al (2016) also observed a similar linear relationship where the angle of repose of locust bean seeds increased with increasing moisture content on stainless steel, aluminum and plywood surfaces. The cracking energy was observed to increase as the moisture content decreases as shown in Fig. 3(d). This is due to increase in hardness of the seeds as more moisture is removed. This makes the cracking energy required to remove the seed coats to be higher at lower moisture content. The trend between the cracking energy and moisture content was exhibited with a second order polynomial relationship as shown in Fig. 3(d).

IV CONCLUSION

In this study, the effects of heat and moisture content on some engineering properties of locust bean seeds were investigated in the range of moisture content 14.90 to 18.06 % dry basis. It was discovered that there was decrease in the seed dimensions such as length, width, thickness, arithmetic mean diameter, and geometric mean diameter as the moisture content decreases. The differences in the sphericity of the seeds across the moisture content range was not statistically significant but fell within the standard range. There was increase in surface area, volume and porosity of the seeds while the cracking energy, true and bulk densities decrease as the moisture content decreases. The data obtained in this study will be useful for the design of machines for processing, handling and transportation of locust bean seeds.

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