Some Physical Properties of Jackbean Seed *(Canavalia ensiformis)*

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ABSTRACT

Jackbean (*Canavalia ensiformis*) is a relatively new crop which is finding use in animal and fish nutrition. A lot of agronomic and nutritional research work has been carried out on the plant without any of its engineering properties studied. This work is an attempt on the study of some physical properties of the plant seed.

The physical properties of the seeds measured were axial dimensions, weight and volume, sphericity, aspect ratio, particle and bulk densities and porosity at a moisture content of 6.0 ±0.73% (wb). Results show that the mean major, intermediate and minor diameters, weight and volume of the seed were 18.66±1.11mm; 13.14±0.85mm; 10.22±1.02mm, 1.59±0.15g and 1.34±0.13cm^3 respectively. The coefficients of variation (CVs) for these measured parameters were 5.97%, 6.50%, 9.98%, 9.50% and 9.88% respectively. Also calculated were the arithmetic mean diameter (AMD) 14.01±0.68mm, geometric mean diameter (GMD) 13.56±0.64mm, square mean diameter (SMD) 13.78±0.70mm and equivalent diameter (EQD) 13.78±0.70mm whose CVs were 4.42%, 4.72%, 4.76% and 4.76% respectively. The sphericity (S_{ph}) 72.88±0.03%, aspect ratio (AR) 0.71±0.05 and particle density (D_p) 1.19±0.08g/cm^3 have CVs 4.31%, 6.97% and 6.86% respectively. The bulk density (D_b) was 0.778±0.024g/cm^3 and porosity (P_o) 0.326±0.001 with CVs 3.08% and 0.31% respectively.

Keywords: Jackbean, physical properties, weight, arithmetic mean diameter, aspect ratio, bulk particle densities, equivalent diameter, geometric mean diameter, sphericity, Nigeria.

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1. INTRODUCTION

Jackbean (*Canavalia ensiformis*) belongs to the family of the *Leguminosae*. Also called Chickasaw Lima bean, sword bean (*canavalia gladiata*), horsebean and gotani bean, it is a tropical climber producing long pendant green beans. It is native to the West Indies and Central America but is now found scattered throughout the tropics and sub-tropics (Kay, 1979). *Canavalia ensiformis* tolerates a wide range of rainfall (650-2000mm) evenly distributed throughout the year. The climber tolerates droughts, survives salinity and water logging. It grows best at altitudes up to 1800m, temperature of 15-30^{O}C, soil pH of 4.5 – 8.0, and tolerates a wide range of soils. As a legume, it fixes nitrogen in the soil and so needs no artificial application of nitrogen. Agronomically, it is sown as an annual cover crop. If grown as a perennial intercrop, the plant needs such strong durable support as cocoa, coffee, sugarcane, maize, millet or sorghum plants. Young pods and beans of Jackbean are eaten as vegetables (Anon, 2007) but only after much preparation and cooking as they contain mild poison in the form of anti-nutritional factors (protease inhibitors, lectins, saponins and tannins). However, the Jackbean seeds coat is not to be eaten. Presently in Nigeria there are no farms where the Jackbean is commercially cultivated. People plant Jackbean as a flower around their homes while some grow wild.

Fig. 1 Jackbean seeds.

The Jackbean seed (Fig. 1) which is white in color and nearly oblong in shape is one of the neglected under-utilized legumes. Legumes are rich in protein and other nutrients such as starch, dietary fiber, protective phytochemicals, oil, vitamins and mineral elements (Saikia et al., 1999). Shimelis et al., (2006) reported that haricot beans contained moisture, crude protein, crude fat, total ash, crude fiber, crude lipid, total carbohydrate, starch, phosphorus and amylase. The mature Jackbean seed has high crude protein content (20 – 32%) and amino-acid profile that makes it suitable for use as a substitute for fish feed while the fully ripened seeds are sometimes used as coffee substitute. (Osuigwe et al., 2002). The proximate composition of the dried beans is shown in Table 1.

Table 1. Food and mineral composition of dried C*anavalia* seeds

		Approximate composition	
S/No.	Parameters	Percentages (%)	Mg/100g
1	Moisture	11 – 15.5	-
2	Protein	23.8 – 27.6	-
3	Fat	2.3 – 3.9	-
4	Fiber	4.9 – 8.0	-
5	Carbohydrate	45.2 – 56.9	-
6	Ash	2.7 – 4.2	-
7	Calcium	-	30 – 158
8	Phosphorus	-	54 – 298
9	Potassium	-	141
10	Magnesium	-	19
11	Iron	-	7

Source: Kay 1979.

The interest in and the motivating factor for *canavalia* seeds research is because of the international importance of the seed as future source of food for man, fish and animal (D'Mello et al., 1989; Kessler et al., 1990). A lot of agronomic evaluation has been carried out on Jackbean (Kessler, 1990; Emeribe, 1996; Prabakaran et al., 1996); the nutritional values of *canavalia* seeds and its suitability as food supplements for man, animals and fish (Scorer et al., 1989; Udedibie, 1990; Rajaram and Janardham, 1992; Akpapunam and Sefa-Dedeh, 1977; Carlini and Udedibie, 1997; Osuigwe et al., 2002; Osuigwe et al., 2006). The anti-nutritional substances in the seed have also been reported (D'Mello, 1995; Francis et al., 2001). These substances are both thermo-stable and thermo-liable and can only be deactivated by moist heat treatment and/or extraction prior to use as feedstuff (Ogunsanwo et al., 1994; Udedibie and Carlini, 1998a, b; Fagbenro et al., 2004). In this case the two-stage cooking was advocated (Udedibie et al., 1996; Esonu et al., 1996) as it is a commonly used local method for preparing certain poisonous foodstuff such as Jackbean and Swordbean. Udedibie (2003) opined that for C*anavalia* seeds (*ensiformis, gladiata or braziliensis*) to be rendered nutritionally utilizable for humans and livestock, it should be cracked into pieces (4-6 pieces/seed), soaked in water for two days and then cooked for an hour or pressure cooked for 15 minutes. This method is now internationally accepted and is called the crack and cook (CAC) method (Udedibie and Carlini, 1998b). For this process to be mechanized, the physical properties of the Jackbean seed need to be known.

1.1 Physical Properties

While Rodrigues et al. (2003) evaluated volume, kernel and bulk densities, weight loss and color for the variation of physical properties of coffee bean during roasting; Banks et al. (1999) included bean size and shape among other factors. In the physical characterization of Jackbean, it is important to have an estimate of shape, size, volume, seed and bulk densities, and other physical parameters for that product (Asoegwu, 1995). Because of the irregular nature of the shape and sizes of agricultural products, coefficient of variation (CV) may be used to characterize the quality of dispersion to the measured parameters about their means. Low CVs indicate more uniform dispersion.

Shape is exploited singly or together with other characteristics to determine the free flowing or bridging tendencies of a seed mass in many separators used in seed cleaning. Tabatabaeefar et al., (2003) derived arithmetic mean diameter (AMD) and terminal velocity values to design a sieving and grading machine in Tehran by measuring the three perpendicular diameters of chickpea. They also determined the average, standard deviation, maximum and minimum diameters. Size also refers to the characteristic of an object which determines how much space it occupies and within limits can be described in terms of length, width and thickness. Asoegwu et al. (2006) measured the above parameters for African Oilbean seed and included geometric mean diameter (GMD), square mean diameter SMD), equivalent diameter (EQD) and sphericity (S_{ph}). Adewumi et al., (2006) used spherical shape, equivalent diameter, particle density and other parameters to investigate particle trajectory for grain classifier and selected the length and breadth of the separation chamber.

Physical properties of cheat, such as dimensions, weight, shape (sphericity and aspect ratio) and bulk density were used by Hauhouot-O'Hara et al., (1999; 2000) to establish machine design and operating variables for roller and hammer mills, selecting the optimum gap between rolls and optimum screen opening size for the hammer mill. Seed shape and size are a major consideration in the selection and design of a screen cleaning system. Pod size, true and bulk densities, porosity and moisture content were used by Atiku et al., (2004) as relevant for investigating bulk handling and processing of bambara groundnut by a nut sheller. Bulk density and weight are necessary in sizing machine components and designing related equipment such as conveyors. Bulk and kernel densities which indicate grain degree of filling (Chang, 1988), are used for determining dielectric properties of grains (Nelson and You, 1989) and in storage, transport and separation systems (Oh et al., 2001; Ureña et al., 2002). Because Jackbean will require cook and crack process, its size, surface area and volume are required in the different handling and processing operations such as heat and mass transfer, heating and cooling.

Porosity depends on geometry and surface properties of the material. The percent voids of an unconsolidated mass of material such as grain, hay and other porous materials are often needed in air flow and heat flow studies (Mohsenin, 1986). Because it allows fluid to pass through the bulk, it is useful in the calculation of rate of aeration and cooling, drying and heating and the design of heat exchangers and other similar equipment (Asoegwu et al., 2006).

This paper reports attempts at measuring and calculating some of the physical properties of Jackbean which may be needed in the design of machines and processes for mechanizing the production and postharvest processing of Jackbean.

2. MATERIALS AND METHOD

Two hundred seeds, brought from varied sources in Imo State Nigeria, were thoroughly mixed, put in thick polyethylene bag and kept in a refrigerator for 48hrs to equilibrate. One hundred of them were selected at random and labeled 1 to 100. The rest were used to determine the moisture content of the seeds using the ASAE (1999) recommended method and found to be 6.0 ± 0.73% (wb). Using the labeled ones the axial dimensions (major diameter L_1, intermediate diameter L_2, and minor diameter L_3) were measured on each seed three times with a venier caliper reading to 0.05mm and averaged. The average values obtained were used to evaluate the mean lengths and their standard deviations; the arithmetic mean diameter (AMD); the geometric mean diameter (GMD), the square mean diameter (SMD), equivalent diameter (EQD), the sphericity (S_{ph}) and the aspect ratio (AR) of the Jackbean seed using the following equations (Mohsenin, 1986; Ciro, 1997):

$$AMD = F1 = \tfrac{1}{3}[L_1 + L_2 + L_3] \quad .....1$$

$$GMD = F2 = [L_1 \times L_2 \times L_3]^{1/3} \quad ......2$$

$$SMD = F3 = [(L_1L_2 + L_2L_3 + L_3L_1)/3]^{1/2} \quad .....3$$

$$EQD = (F1 + F2 + F3)/3 \quad .....4$$

$$S_{ph} = GMD/L_1 \quad .....5$$

$$AR = L_2/L_1 \quad .....6$$

The weights of individual seeds were measured using an electronic weighing balance of sensitivity ±0.005g. The volume of individual seed was measured using the water displacement method. Each weighed sample was tied to a sinker lowered into the cylinder with water and volume of water displaced in a measuring cylinder was read off as the volume of the seed (Asoegwu et al., 2006). The values were used to calculate the seed or particle densities (D_p) (Nelson, 2002).

Bulk measurements of weight and volume of Jackbean seeds were made using a measuring cylinder. The empty cylinder weight was first obtained, and then the seeds were poured into the cylinder. The weights of both the cylinder and seeds were measured. The difference between the combined weight and the empty cylinder weight gave the weight of the seeds. These values were used to evaluate the bulk density (D_b) using AOAC (1990) method. The porosities (P_o) of the Jackbean seeds were determined using Equation 7 (Mohsenin, 1986).

$$P_o = 1 - (D_b / D_p) \quad \ldots\ldots 7$$

Average values of W, L_1, L_2, L_3, V, AMD, GMD, SMD, EQD, S_{ph}, AR, D_p, D_b, P_o were calculated. The frequency distributions of each of the above were shown as skewness and kurtosis (Asoegwu et al., 2006).

3. RESULTS AND DISCUSSION

The means, standard deviations and normal distributions of the measured values of weight W, major diameter L_1, intermediate diameter L_2, minor diameter L_3 and volume (V) of individual seeds at moisture content of 6.0 ±0.73% (wb) are shown in Table 2. It is observed that L_1, L_2, and L_3 have mean values of

Table 2 – Means, standard deviations, normal distribution and coefficients of variation of measured parameters of Jackbean seeds

S/No	Measured parameters	Mean	Standard deviation	Normal distribution	Coeff. of variation, %
1.	Weight (W g)	1.591	0.151	1	9.50
2.	Major diameter (L_1 mm)	18.662	1.114	0.442	5.97
3.	Intermediate diameter (L_2 mm)	13.141	0.854	1	6.50
4.	Minor diameter (L_3 mm)	10.224	1.020	1	9.98
5.	Volume (V cm^3)	1.340	0.132	1	9.88

18.662±1.114, 13.141±0.854 and 10.224±1.020mm respectively, while W and V have mean values of 1.591±0.151g and 1.340±0.132cm^3 respectively. With known axial dimensions, the product can be effectively graded. Sieves can now be designed within a range for separation of the seeds from the chaff. These values may also be used in the design of sieves to be used in the CAC machine for Jackbean. The parameters in Table 2 showed normal distribution while their CVs ranged from 5.97% for L_1 to 9.98% for L_3. The low values of CV for all the measured parameters of between 5% and 10% indicate that they were uniformly dispersed about their mean values.

The means and standard deviations of the calculated values are shown in Table 3. The calculated parameters have low CVs ranging from 4.31% for S_{ph} to 6.97% for Aspect ratio. However, those of P_o (0.31%) and D_b (3.08%) were also found to be low. Air flow and heat flow studies as well as packing factor studies of Jackbean seeds can now be carried out with known values of the porosity. The low CV of the calculated parameters confirms that they were also uniformly dispersed about their mean values. The means of SMD and the EQD are the same (13.78±0.66mm) as observed by Asoegwu et al. (2006) for African oil bean seeds. With known values of bulk density, hoppers, and conveying systems of the CAC machine can be designed to hold the seeds in bulk without damage to the seeds. Sphericity of over 70% shows how close the shape of Jackbean seed is to a sphere. Low aspect ratio indicates the tendency to being oblong in shape. However, with an aspect ratio of over 70%, the Jackbean seed is more likely to roll than to slide. This is important information for hopper, separation and conveying equipment design.

Table 3: Means and standard deviations of some physical properties of Jackbean seed

S/No	Calculated parameters	Means	Standard deviations	Coeff. of Variation %
1.	Arithmetic mean diameter (AMD mm)	14.009	0.675	4.42
2.	Geometric mean diameter (GMD mm)	13.563	0.640	4.72
3.	Square mean diameter (SMD mm)	13.780	0.656	4.76
4.	Equivalent diameter (EQD mm)	13.784	0.656	4.76
5.	Sphericity (S_{ph} dec)	0.727	0.031	4.31
6.	Aspect ratio (AR dec)	0.706	0.049	6.97
7.	Particle density (D_p g/cm^3)	1.190	0.082	6.86
8.	Bulk density (D_b g/cm^3)	0.778	0.024	3.08
9.	Porosity (P_o dec)	0.326	0.001	0.31

The comparison of these parameters for Jackbean with other seeds and nuts (Table 4) shows that its L_1 is about the same with Bambara groundnut (≈ 19.0mm), close to thrice as large as for cheat and wheat and one and a half times that of African breadfruit. Bambara pod is about 20% wider and 40% thicker than Jackbean seed. Both L_2 and L_3 are about twice greater than for African breadfruit. The bulk densities of wheat and Jackbean seeds are the same (0.77kg/m^3) and are about 3.7, 1.8 and 1.3 times higher than those of cheat, Bambara and African breadfruit seeds respectively. The particle density of Jackbean seed (1.190g/cm^3) shows that it will not float in water unlike Bambara (0.755 kg/m^3) and African breadfruit (0.979g/cm^3) seeds. Since the Bambara pods are larger than Jackbean seeds in terms of L_2 and L_3, Bambara porosity (42.77%) is higher than Jackbean porosity (32.6%). Frequency distributions of the various Jackbean seed physical characteristics are shown in Table 5 in terms of skewness and kurtosis. Skewness shows lack of symmetry about the mean in a frequency distribution of the measured and calculated physical properties, while kurtosis shows the extent the frequency distribution is concentrated about the mean. Positive skewness means the frequency distribution is skewed to the right.

Table 4. Comparison of Jackbean parameters with other seeds and pods

Parameter	Jackbean[a]	Cheat[b]	Wheat[c]	Chickpea[d] (Bivanij)	Bambara[e] groundnut	African[f] breadfruit
L_1 mm	18.662	6.85	6.02	10.2	18.9	11.91
L_2 mm	13.141	1.35	2.54	7.74	15.7	5.69
L_3 mm	10.224	1.24	1.79	7.66	14.4	4.64
D_p g/cm^3	1.190	-	-	-	0.755	0.979
D_b g/cm^3	0.778	0.210	0.772	-	0.432	0.614
P_o %	32.6	-	-	-	42.77	-
AR	0.706	0.197	(0.422)	(0.756)	(0.831)	(0.478)
S_{ph} %	72.68	32.12	58.04	(82.94)	(85.86)	(57.10)
GMD mm	13.563	(2.26)	3.49	(8.46)	(16.23)	(6.80)
AMD mm	14.009	(3.15)	(3.45)	(8.53)	(16.33)	(7.41)
SMD mm	13.780	(2.54)	(3.19)	(8.49)	(16.28)	(7.06)

NB: a = This study; b = Hauhouot-O'Hara et al., 2000; c = Stroshine, 1994;
d = Tabatabaeefar et al., 2003; e = Atiku et al., 2004; f = Omobuwajo et al., 1999.
(The values in bracket were calculated from values of L_1, L_2 & L_3 given by the original authors).

Table 5. Frequency distribution of Jackbean seeds as skewness and kurtosis

Parameters	Skewness	Kurtosis
L_1	-0.5454	-.1.0620
L_2	1.0692	3.8350
L_3	2.4418	6.4711
W	1.3852	0.5532
V	2.1808	4.7471
AMD	1.3936	3.3673
GMD	1.2536	1.6595
SMD	1.3143	2.4780
EQD	1.6141	3.2571
S_{ph}	1.7631	1.9238
AR	1.8611	2.1156
D_p	1.1732	-0.2643

Kurtosis is the degree of peakedness of the distribution with respect to a normal distribution which is mesokurtic. High kurtosis means the frequency is concentrated about the mean. Of all the measured and calculated physical parameters of Jackbean seeds, it is only the L_1 that is moderately skewed to the left (-0.5454). The L_3 has the highest positive skewness (2.4418) as observed for African oil bean seeds (2.3170) (Asoegwu et al., 2006), followed by the V (2.1808). It is also observed that for all the other parameters, their skewness ranged between 1.0 and 2.0 with that of L_2 being the lowest (1.0692). The L_1 and D_p had platykurtic distributions with values -1.0620 and -0.2643 respectively. This platykurtic distribution of L_1 was also observed for African oil bean seeds (i.e -0.2699 close to ±1.0) (Asoegwu et al., 2006). All the other measured and calculated physical parameters of Jackbean seeds were found to have leptokurtic distribution ranging from 0.5532 for W and 6.4711 for L_3. Again, L_3 was observed to have the highest leptokurtic distribution (5.0052) for African oil bean seeds. It could be said that the seed weight of Jackbean has a close to normal distribution (0.5532) termed mesokurtic as was observed for African oil bean seed weight (-0.6842). However the frequency distribution for seed density (D_p) of Jackbean was found to be mesokurtic (-0.2643). Further to the above frequency distributions for Jackbean seeds, it was observed that 90% of its L_1 ranged between 17.0 and 20.0mm, 93% of its L_2 between 12.0 and 14.0mm, 86% of L_3 between 9.50 and 10.50mm, 91% of W between 1.40 and 1.80kg and 87% of V between 1.20 and 1.50cm^3. While 78% of EQD lie between 13.0 and 14.0mm, 77% of S_{ph} lie between 0.70 and 0.75 and 88% of AR lie between 0.65 and 0.75.

4. CONCLUSIONS

1. The physical properties of Jackbean seeds L_1, L_2, L_3, W and V were measured at a moisture content of 6.0 ±0.73% (wb) and the following results were obtained: 18.662±1.114mm, 13.141±0.854mm, 10.139±0.577mm, 1.591±0.151g, and 1.340±0.132cm^3 respectively.
2. The calculated physical properties AMD, GMD, SMD and EQD were found to be 14.009±0.675mm, 13.563±0.640mm, 13.780±0.656mm and 13.784±0.656mm respectively. SMD and EQD were equal as was found for African oil bean seeds.
3. D_p was 1.190±0.082g/cm^3 and D_b was 0.778±0.024g/cm^3 showing that Jackbean seeds will not float in water.
4. S_{ph} was 0.728±0.031, AR was 0.706±0.049 and P_o was 0.326±0.001. This shows that S_{ph} and AR for Jackbean are approximately 70% with the propensity to roll instead of sliding.
5. All physical parameters of Jackbean investigated in this work had positive skewness except L_1 (-0.5454) with L3 being the most skewed (2.4418).
6. W with kurtosis 0.5532 and D_p with kurtosis -0.2643 are both very nearly mesokurtic. L_3 is the most platykurtic (6.4771) as observed in African oil bean seeds.
7. All CV of all the measured parameters ranged between 5 and 10% showing near uniform dispersion about their respective mean values.

5. RECOMMENDATION

Further studies on the engineering properties of Jackbean should be carried out. There is a need to deal with seeds that are harvested from the same farm area or locality and also subjected to the same conditions of drying and other treatments.

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