

## Some Selected Physical and Mechanical Properties of *Brachystegia Eurycoma* Seeds

G. N. Ugama<sup>a</sup>, P. O. Orji<sup>a</sup>, A. Ugoani<sup>b</sup>, Y. A. Unguwanrini<sup>c</sup> and H. S. Garuba<sup>a</sup>

<sup>a</sup>National Agricultural Extension and Research Liaison Services, Ahmadu Bello University, Nigeria

<sup>b</sup>Department of Agricultural Technology, Akanu Ibiam Federal Polytechnic, Uwana-Afikpo, Nigeria

<sup>c</sup>Department of Agricultural and Bio-Resources Engineering, Ahmadu Bello University, Zaria, Nigeria

*Corresponding Author: sirugamagodwin@gmail.com*

### ARTICLE INFO

Received: February, 2020

Accepted: August, 2020

Published: October, 2020

#### Keywords:

Brachystegia eurycoma

Mechanical properties

Moisture

Physical properties

Seeds

### ABSTRACT

The engineering properties of agro-materials are prerequisites in the design of functional and efficient agro-processing machines. This research was conducted on some physical and mechanical properties of *Brachystegia eurycoma* at a moisture content of 17.68 % (wet basis). Digital vernier caliper, electronic oven, electronic balance and universal testing machine were used to conduct the experiment. The axial dimensions length, width and thickness represented with *a*, *b* and *c* were found to be 20.58 ( $\pm 1.5$ ), 16.46 ( $\pm 1.83$ ) and 3.14 ( $\pm 0.36$ ) mm respectively. The mean values of arithmetic mean diameter *Da*, square mean diameter *Ds* and geometric mean diameter *Dg* were calculated to be 13.41mm, 12.44mm and 13.41mm respectively and their respective standard deviations were found to be 1.13, 1.09, and 0.82 correspondingly. The mean of equivalent mean diameter, projected area, elongation ratio, flakiness ratio represented with *De*, *PA*, *ER* and *FR* were also computed to be 11.99, 271.39, 1.27 and 0.19 respectively. From the result of kurtosis and skewness conducted on the parameters of 50 samples of *Brachystegia eurycoma*, the result indicated that they were moderately skewed and platykurtic in distribution. The compressive strength was conducted on the five samples of *Brachystegia eurycoma* and mean 0.00234 KN ( $\pm 0.00288$  KN) was obtained. These results concerning this specimen will serve as guidelines when designing an equipment to handle/process *Brachystegia eurycoma*.

### 1. INTRODUCTION

*Brachystegia eurycoma* is an economical tree that grows in the tropical rain forest of West Africa. In Nigeria, the seeds of these trees are used in making soup or serves as a soup thickener for other soups like egusi, ukazi, ofe onugbu and ngwo ngwo. *Brachystegia eurycoma* has the potential of controlling body temperature as well as good source of nutrition (Orimawo and Egbekun, 1998). The Igbo call it "Achi" and Akwa Ibom/Calabar call it "Akpa". The seed is dry, flat and round in shape. It is an emulsifier and thickener for traditional soups. After grinding it, it comes out in a white brownish powdery form. A powdered 100g of *Brachystegia eurycoma* contains water 10 – 12g, fat 13 -14g, protein 10 – 13 g, dietary fiber 1 – 2 g, carbohydrate 51 – 61g and ash 1.5 – 4g. Achi is a rich source of protein, carbohydrate, and crude fiber. It is also rich in minerals such as calcium, potassium, magnesium, calcium, manganese, iron and sodium (Orimawo and Egbekun, 1998).

Achi is useful in controlling cholesterol and diabetes. It contains hydrocolloids which when ingested can effectively and moderately reduce blood cholesterol and glucose level in diabetic patients. It has also been observed that ethanol extract from *Brachystegia eurycoma* can be used to control insects and fungi (Akaaimo and Raji, 2006).

The method of processing *Brachystegia eurycoma* in Nigeria is mainly based on traditional method by roasting or frying the seeds for about 10 to 15 minutes in order to soften the shell. The fried or roasted *Brachystegia eurycoma* seeds are soaked in the water for about 6 to 12 hours to separate shells from the seeds. Once the shells have been removed the next stage is to grind it with machine or to pound it with mortar for onward preparation of soup. This method of processing *Brachystegia eurycoma* is time consuming and labour intensive, bearing in mind that it has great potentials in terms of nutritional and medicinal values. In order to alleviate the stress associated with the traditional method of processing *Brachystegia eurycoma*, there is need to study the mechanical and physical properties of *Brachystegia eurycoma* to serve as a guiding principle in the design and development of *Brachystegia eurycoma* processing machines.

The engineering properties of bio-materials are important in the design and development of agricultural machinery. Some of the physical properties of bio-materials that are needed in the development of machinery include size, shape, sphericity, volume, porosity, moisture content, weight, bulk and true density. These properties are pertinent in designing screen/sieve holes, in determining the terminal velocity of chaff and the seeds during cleaning/separation, ensuring that hopper is inclined at an appropriate angle in order to ensure easy and free flow of material during its temporary stay in the hopper. It is also useful in determining the volume and capacity of a hopper. The knowledge of physical properties is applicable in the design of a conveyor that conveys agro-materials from one point to another. It is also vital information in predicting the aerodynamic and hydrodynamic characteristics of bio-materials.

It is pertinent to know that true and bulk densities are essential in knowing the weight of the crop per unit volume and useful in handling operations (Akaaimo and Raji, 2006). The knowledge of volume is applied in the area that shapes interrupt the process such as separation and product loading, example hopper. The knowledge of weight is useful in operations such as conveying and cleaning, because the differences in the weight of seeds and its chaff enable the designer to predict the capacity of blower that can generate the volume of air required to separate the chaff from the seeds with the help of terminal velocity. According to Raji and Favier (2004), weight and volume are useful in mathematical modeling of handling and processing operations where the behaviour of the bulk system is predicted from the microscopic behavior, especially individual seed.

The knowledge of shape and size is critical in the design of a threshing machine. If the clearance between the beater and the screen is too large, under-threshing will be the resultant effect, but if the clearance is too small compared to the size and shape of the crop undergoing threshing, the percentage of damaged crop will be high. According to Mohsenin (1986) the sphericity values of most agricultural produce ranged from 0.32 to 1.00 and the more the regular and object is, the lower the sphericity. The particle density of an agricultural produce is relevant in the design of silos and storage bins, maturity and quality evaluation of products which are essential to agricultural produce marketing (Balami *et al.*, 2012). The arithmetic and geometric mean diameter are useful in determining the diameter of a sieve hole, which will enable the sieve to function very well, with the elimination of blockage of sieve hole

The knowledge of physical and mechanical properties of bio-materials is useful in processing operations. For instance, mechanical properties like compressive strength, rupture strength, deformation and toughness are necessary in designing dehullers, harvesters, threshers, shellers and peelers so that excess losses due to breakages will not be encountered. The knowledge of mechanical properties will enable a designer to select the appropriate prime mover, speed and force that is suitable to process any crop without undue losses.

It is obvious that *Brachystegia eurycoma* is an important food crops most especially to the Southern part of Nigeria: it deserves a place in the field of research. Due to the fact that its consumption is geographically/ethnically restricted, many researchers are yet to show much interest in this vital crop. This has resulted in dearth of information concerning the physical and mechanical properties of this particular crop. Thus, the need to conduct research on the physical and mechanical properties of this crop is hereby borne out of necessity, so that it can be easily processed and handled.

## 2. METHODOLOGY

*Brachystegia eurycoma* was purchased in Eke Aja market in Umunaga Uburu in Ohaozara local Government Area, Ebonyi State. The seeds were sieved in order to remove foreign materials. The seeds were sorted as much as possible in a bid to remove immature seeds as well as to ensure near uniformity of the samples. The moisture content of the crops was determined using oven – dry method on wet basis (wb). The seeds were soaked in water for six hours, sieved, weighed and recorded as  $W_w$ . After that it was put in the oven and dried for 24 hours at 105°C in the Agricultural Engineering Laboratory, Ahmadu Bello University, Zaria. After 24 hours, the seeds were brought out and weighed with electronic balance and its weight recorded as  $W_d$ . Plate 1 displays the Oven used in the determination of moisture content of *Brachystegia eurycoma*.



**Plate 1:** The Oven used in the determination of MC (%)

### 2.1 Moisture Content (MC)

Oven-dry method was used to determine the moisture content of *Brachystegia eurycoma*. The weight of wet seed was denoted as  $W_w$  and the weight of oven-dry seed was denoted as  $W_d$ . Equation 1 (Uduma *et al.*, 2016), was used to calculate the moisture content:

$$MC = \frac{W_w - W_d}{W_w} \times 100\% \quad 1$$

Where: MC is the moisture content (%)

$W_w$  is the weight of wet seeds (g)

$W_d$  is the weight of oven dried seeds (g)

The moisture content of the seeds was found to be 17.68 %.

### 2.2 Dimensional Properties of *Brachystegia Eurycoma*

#### Size and shapes

In order to determine axial dimensions of the seeds, digital Vernier Caliper with an accuracy of 0.001 mm was used to measure the major (a), minor (b) and the thickness (c) of the seeds. After the axial dimensions were recorded, the arithmetic mean diameter ( $D_a$ ), geometric mean diameter ( $D_g$ ), square mean diameter ( $D_s$ ), equivalent mean diameter ( $D_e$ ), projected area (PA) were calculated based on the Equations 2 – 5 (Mohsening, 1986; Ciro, 1997; Pabis *et al.*, 1998; Ebrahimzadeh *et al.*, 2013; Igbozulike and Muofunaanya, 2016). Plate 2 illustrates the determination of axial dimensions of *Brachystegia eurycoma* with the aid of digital Vernier Calliper.

**Plate 2:** Digital Vernier Calliper

$$\text{Arithmetic mean diameter, } D_a = \frac{a+b+c}{3} \quad 2$$

Where:  $D_a$  is the arithmetic mean diameter (mm)

$a$  is the major diameter (mm)

$b$  is the minor diameter (mm)

$c$  is the thickness (mm)

$$\text{Geometric mean diameter, } D_g = \sqrt[3]{abc} \quad 3$$

Where:  $D_g$  is the geometric mean diameter (mm)

$$\text{Equivalent diameter, } D_e = \frac{D_a + D_g + D_s}{3} \quad 4$$

Where:  $D_s$  is the square mean diameter (mm)

$$\text{Square mean diameter, } D_s = \frac{\sqrt{(ab+bc+ac)}}{3} \quad 5$$

Where:  $D_s$  is the square mean diameter ( $\text{mm}^2$ )

### Projected Area (PA)

PA is an essential physical property of an agro produce that is needed in determining the aerodynamic properties of a bio-material. Projected area was calculated using Equation 6 while surface area was obtained by Equation 7 as reported by Mohsening (1986).

$$\text{Projected area, } PA = \frac{\pi ab}{4} \quad 6$$

Where: PA is the projected area ( $\text{mm}^2$ )

$$\text{Surface area, } SA = \pi D_e^2 \quad 7$$

Where: SA is the surface area (mm)

### Volume

The volume of *Brachystegia eurycoma* was calculated using Equation 8 as reported by Mora and Kwan (2000):

$$\text{Volume, } V = \frac{\pi D_g^3}{6} \quad 8$$

Where: V is the volume ( $\text{mm}^3$ )

**Flakiness Ratio (FR)**

Flakiness of the seeds was determined using Equation 9 as reported by Mora and Kwan (2000).

$$FR = \frac{c}{b} \quad 9$$

Where: FR is the flakiness ratio

c is the thickness (mm)

b is the minor diameter (mm)

**Elongation Ratio (ER)**

The elongation ratio of the seed was calculated using Equation 10 as reported by Mora and Kwan (2000).

$$ER = \frac{a}{b} \quad 10$$

Where: ER is the elongation ratio

a is the major diameter (mm)

b is the minor diameter.

**2.3 Gravimetric Properties of *Brachystegia Eurycoma*****Mass and one thousand seed weight**

Since the mass of single brachystegia eurycoma was too insignificant to be measured individually with a scale balance, a sample of 100 seeds of brachystegia was weighed with an electronic balance with an accuracy of 0.1g and model no: OPH –I3001. The weight of 100 seeds was measured and its weight recorded and then multiplied by 10 in order to arrive at 1000 seed weight. Plate 3 presents the process and procedure used in determining the mass and one thousand seed weight.



**Plate 3:** Using the Electronic balance to measure the weight of *Brachystegia Eurycoma*

**True Density**

A sample of seeds was measured with an electronic balance with an accuracy of 0.1g and its weight was recorded. Thereafter, the quantified sample was poured in a measuring cylinder that had already been filled with water to a certain level and recorded as  $V_1$ . After pouring the sample, the volume of water increased and recorded as  $V_2$ , thus the volume of seeds were assumed to be the difference between  $V_2$  and  $V_1$ . The true density was calculated using Equation 11 as reported by Uduma *et al.* (2016). Plate 4 demonstrates the set up for determine the volume of a sample through displacement method.



**Plate 4:** Set up for determining the volume of the sample through displacement method

$$\text{True density, } \rho_t = \frac{M}{V_2 - V_1} \quad 11$$

Where:  $\rho_t$  is the true density (g/ml)

$M$  is the mass of the sample (g)

$V_2$  is the final volume (ml)

$V_1$  is the initial volume (ml)

### Bulk Density

In order to determine the bulk density of the seeds, the method reported by Akaaimo and Raji, (2006) was followed and observed as follows: a sample of the seeds were collected and weighed with an electronic balance. After that, the weighed sample was poured into a graduated cylinder and the volume occupied by the sample was taken as the volume of the sample. Hence, the bulk density was calculated by using Equation 12 as reported by Irtwange (2000).

$$\rho_b = \frac{W_s}{V_s} \quad 12$$

Where:

$\rho_b$  is the bulk density (g/ml)

$W_s$  is the weight of the sample (g)

$V_s$  is the volume of the sample (g)

The bulk density was found to be 0.685 g/ml at the moisture content of 17.68 %.

### Porosity

Porosity is one of the important physical properties of crops that affects the bulk density of an agro- produce. Porosity is necessary in the design of dryer, storage and conveyor capacity, so also true density is useful in the design of separation equipment Fathollahzadeh *et al.*, (2008). Thus porosity ( $\epsilon$ ) can be calculated by using Equation 13 as stated by Fathollahzadeh *et al.*, (2008).

$$\epsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100\% \quad 13$$

$\epsilon$  is the porosity (%)

$\rho_b$  is the bulk density (g/ml)

$\rho_t$  is the true density (g/ml)

### Mechanical Properties

Mechanical properties of agro-produce are useful in the design of agro-processing equipment, planting and harvesting machinery. When armed with the basic mechanical properties of bio-materials, it helps in order not to over design or under design, thus ensuring optimum performance of the machinery. The mechanical properties of *Brachystegia eurycoma* were determined using a Universal Testing Machine (UTM), ENERPAC Model: PUJ1200E and product code E3607C in the Strength of Material Laboratory in the Department of Mechanical Engineering, Ahmadu Bello University, Zaria. Plate 5 shows the UTM and the product while the compressive strength testing of *brachystegia eurycoma* was going on and plate 6 shows the sample of *Brachystegia eurycoma*. Five seeds were subjected to compressive testing using UTM under vertical position. The force (KN) at which deformation occurs was digitally displayed and the reading taken once the material failed.



**Plate 5:** Testing of the Compressive Strength of *Brachystegia eurycoma* using UTM



**Plate 6:** A sample of *Brachystegia eurycoma*

### Statistical Analysis

After the laboratory experiment on the specimen, the raw data generated were subjected to statistical analysis in order to obtain the range, maximum and minimum values, sum, mean, error mean, standard deviation, variance, skewness and kurtosis using SPSS 2017.

## 3. RESULTS AND DISCUSSION

A total of 50 samples of the specimen whose data were measured have a mean major diameter, minor diameter and thickness of 20.85, 16.46 and 3.14 mm respectively. Their error mean were also found to be 0.21, 0.25 and 0.51 respectively. The variance of a, b, c were observed to be 2.25, 3.37 and 0.13, while their respective standard deviation were found to be 1.50, 1.83 and 0.36 respectively.

The mean value of Da, Ds, Dg, De, PA, ER, EL, FR, V, and SA were found to be 13.41, 10.13, 12.44, 11.99, 271.39, 1.27, 0.19, 574.59, and 325.03 respectively. The variance follows sequentially as 2.25, 3.37, 0.13, 1.28, 1.19, 0.84, 2093.24, 0.01, 0.001, 19487.43 and 2745.46 respectively. Their standard deviations also follow thus, 1.50, 1.83, 0.36, 1.13, 1.09, 1.13, 0.82, 1.09, 0.91, 45.75, 0.10, 0.10, 0.023, 139.59 and 52.39 respectively.

**Table 1:** The Statistical Summary of the Physical Properties of Fifty Samples of *Brachystegia eurycoma*.

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
A	50	6.54	16.94	23.48	1042.94	20.8588	0.21227	1.501	2.253
B	50	7.53	12.45	19.98	823.34	16.4668	0.25969	1.8363	3.372
C	50	1.67	2.3	3.97	157.32	3.1464	0.05106	0.36103	0.13
Da	50	4.5	10.96	15.46	670.62	13.4124	0.16041	1.13426	1.287
Ds	50	4.62	10.49	15.11	622.31	12.4462	0.15451	1.09252	1.194
Da	50	4.5	10.96	15.46	670.62	13.4124	0.16041	1.13426	1.287
Dg	50	3.31	8.54	11.85	506.83	10.1365	0.11703	0.82752	0.685
Ds	50	4.62	10.49	15.11	622.31	12.4462	0.15451	1.09252	1.194
De	50	3.43	10.33	13.75	599.92	11.9984	0.1297	0.91711	0.841
PA	50	170.37	189.28	359.65	13569.75	271.3949	6.47032	45.75204	2093.249
PA	50	170.37	189.28	359.65	13569.75	271.3949	6.47032	45.75204	2093.249
ER	50	0.49	1.09	1.58	63.77	1.2755	0.01489	0.10528	0.011
FR	50	0.09	0.15	0.24	9.62	0.1924	0.00325	0.023	0.001
V	50	550.07	334.2	884.27	28729.75	574.595	19.74205	139.59741	19487.436
SA	50	212.11	229.21	441.33	16251.67	325.0334	7.41008	52.39717	2745.464

From the analysis, the skewness result/values indicated that the values are moderately skewed. With the result gotten from the values of kurtosis with regard to the parameters investigated, it can be deduced that the data has a platykurtic distribution. Table 1 briefly summarizes the statistical information concerning the physical properties of 50 samples of *Brachystegia eurycoma*.

From the result obtained from the study conducted on the compressive strength of *Brachystegia eurycoma* under vertical condition, the average compressive strength of the sample was found to be 0.00234 KN, the compressive strength ranges from 0.0021 KN to 0.0028 KN and standard deviation of 0.00288 KN.

Based on the fact that *Brachystegia eurycoma* has not been seen seriously as an important food crop, many researchers are yet to conduct in-depth research on its physical and mechanical properties of *Brachystegia eurycoma*, thus there is a dearth of information pertaining to *Brachystegia eurycoma*. Ndukwu (2009), conducted research on the physical properties of *Brachystegia eurycoma* by sampling 20 samples at a moisture content of 20% wb, and found the mean values of a, b and c to be 21.78 mm, 17.58 mm and 3.73 mm with 1.33, 1.01 and 0.034 standard deviations respectively which showed a slight increase to values obtained in this findings, this may be due to the number of samples used for the experimentations as this current study was conducted on 50 samples under 17.68% moisture content under wet basis. The reports

however showed convincing and close agreement with values obtained in these findings which indicate that the axial dimensions of *Brachystegia eurycoma* are constant and similar in shape.

#### 4. CONCLUSION

The physical and mechanical properties of *Brachystegia eurycoma* were investigated at 17.68% moisture content wet basis. The physical properties values obtained agreed with the results of other researchers despite the variation in the moisture level considered. The range of major, minor and intermediate diameters ranged from 16.94 – 23.48 mm, 12.45 – 19.98 mm and 2.30– 3.97 mm respectively. The minimum force needed to deform *Brachystegia eurycoma* was 0.0021 kN and the maximum force needed was 0.0028 with the mean force of 0.00234 kN. So if a machine is to be designed to shell *Brachystegia eurycoma* at a moisture content of 17.68%, the operating force should not be below 0.0021 kN and it should not be above 0.0028 kN.

#### References

- Akaaimo, D. I. and Raji, A. O. (2006). Some Physical and Engineering Properties of Prosopis Africana Seed. *Bio-system Engineering*, 95(5): 197 – 205. doi: 10.1016/J. bio-system
- Balami, A. A., Mohammed, I. A., Adebayo, S. E., Adgidzi, D. and Adelemi, A. A. (2012). The Relevance of some Engineering Properties of Cocoyam (*Colocasia esculenta*) in the Design of Post Harvest Processing Machinery. *Academic Research Journal*, 2(3): 104-113.
- Ebrahimzadeh, H., Mirzade, A. H., Lotfi, M. and Azizinia, S. (2013). Gamma Radiation Effects on Physical Properties of Syrjan Region Wild Pistachio Nut. *Agricultural Engineering International*, 15(2): 221 – 230.
- Fathollahzadeh, H., Mobil, H., Jafari, A. and Borghei, A. M. (2008). Effect of Moisture Content on Some Physical Properties of Apricot Kernel (CV. Sonnati Salmas). *Agricultural Engineering International: the CIGR Ejournal*, Manuscript FP 08 008. Vol. X.
- Igbozulike, A. O. and Mofunanya, U. (2016). Determination of some Engineering Properties of Mucunasloanei Seeds related to Thermal Processing. *Umudike Journal of Engineering Technology*, 2(1): 46 – 50.
- Irtwange, S. V. (2000). The Effect of Accession on some Physical and Engineering Properties of African Yam Bean. Unpublished PhD Thesis, Department of Agricultural Engineering, University of Ibadan, Nigeria.
- Mansouri, A., Amir, H. M. and Ahmad, R. (2017). Physical Properties and Mathematical Modeling of Melon (*Cucumis Melo L.*) Seeds and Kernels. *Journal of the Saudi Society of Agricultural Science*, 16: 218 – 226.
- Mohsenin, N. N. (1986). Physical Properties of Plants and Animal Materials. Gordon and Breach Science Publishers, New York.
- Mora, C. F. and Kwan, A. K. H. (2000). Sphercity Shape Factor and Convexity Measurement of Coarse Aggregate for Concrete using Digital Image Processing. *Cement and Concrete Research*, 30(3): 351 – 358.
- Ndukwu, M. C. (2009). Determination of Selected Physical Properties of *Brachystegia eurycoma* Seeds. *Research Agricultural Engineering*, 55(4): 165 – 169.
- Onimawo, A. and Egbekun, M. K. (1998). Compressive Food Science and Nutrition. Revised Ed., Ambik Publishers, Benin City.
- Raji, A. O. and Favier, J. F. (2004). Model for the Deformation in Agricultural and Food Particulate Materials under Bulk Compressive Loading using Discrete Element Method 11: Compression of Oil Seeds. *Journal of Food Engineering*, 64: 173- 380.
- Uduma, O., Onu, O. O. and Igwe, I. E. (2016). Effect of Moisture Content on some Physical and Mechanical Properties of an African Oil Beans Seeds (*Pentaclethra macrophylla*). *Umudike Journal of Engineering Technology*, 2(2): 78 – 85.