

Determination of Some Engineering Properties of *Gmelina Arborea* Seed

ABSTRACT

The properties of kernels, grains and seeds are important in the development of equipment for transportation, handling and processing. Physical and mechanical properties of *Gmelina arborea* were experimentally determined. The moisture content of *Gmelina Arborea* was determined as 1.76%wb. The major, minor and intermediate diameters were 18.16 ± 1.79 mm, 10.52 ± 0.93 mm and 9.40 ± 0.81 mm respectively. The geometric and arithmetic mean diameter were calculated as 12.12 ± 1.10 and 9.56 ± 0.90 mm respectively. The sphericity was 66.91%, aspect ratio, 58.19, bulk and true densities, 0.64 kg/m^3 and 0.96 kg/m^3 respectively. The porosity and mass of a 1000 seeds were 66.67% and 621.33g respectively. The coefficient of friction determined on four different surfaces were; on wood, $21.91 \pm 3.51^\circ$, on galvanized steel, $20.40 \pm 3.35^\circ$, on glass, $19.98 \pm 2.21^\circ$ and on aluminum, $18.62 \pm 3.22^\circ$. The compressive test conducted on the three major axes; vertical, horizontal and transverse shows that the energy needed for cracking of the *Gmelina arborea* is least on the horizontal axis, 0.808 ± 0.19 kN, followed by the vertical axis, 1.496 ± 0.35 kN and then the transverse axis, 2.39 ± 0.20 kN, with corresponding stress as 1.52 ± 0.35 , 2.90 ± 0.45 and 4.90 ± 0.44 MPa respectively.

Keywords: *Gmelina* seed; Physical and mechanical properties; Cracking energy

INTRODUCTION

Gmelina arborea Roxb. is a big forest tree belonging to the family Verbinaceae [2; 4]. It is a fast growing tree that can attain moderate to large height up to 40 m and 140 cm in diameter. It grows on different localities and prefers moist fertile valleys with 750-5000 mm rainfall [12]. The *Gmelina* tree grows naturally in countries such as India, Myanmar, Thailand, Laos, Cambodia, Vietnam, and in southern provinces of China. Currently, it has been extensively planted in Sierra Leone, Nigeria and Malaysia [3]. The tree is commonly planted as a garden and an avenue tree; growing in villages along agricultural land and on village community lands and wastelands. Flowering takes place around February to April while fruiting starts from May onwards up to June. The fruit is up to 2.5 cm long, smooth, dark green, turning yellow when ripe and has a fruity smell [2]. *Gmelina* is popular for its

wood which is used for plywood, furniture, paper, matches, musical instruments, ornaments, and more. Some livestock holders use its fruit as feeds. But most often, these fruits are just left to scatter around the trees [5]. *Gmelina* is one the most widely propagated and cultivated species of the family Verbenaceae with essential medical properties as different parts of the plant, such as the root, fruit, leaf, flower, bark are used for medicinal purpose [4]. According to [2], a kernel with very high oil content is enveloped inside the *Gmelina arborea* seed. The properties of kernels, grains and seeds are important in the development of equipment for transportation, handling and processing; the aim of this work was to determine the physical and mechanical properties of *Gmelina arborea* which are vital in the development of equipment for transportation, handling and processing.

MATERIALS AND METHODS

Sample preparation

Freshly fallen *Gmelina* fruits were picked from under the trees (Fig. 1). The fleshy part was crushed to press out the kernel from the fruits. The kernels were washed and dried (Fig. 2).



Fig. 1. *Gmelina* fruits



Fig. 2. *Gmelina* nuts

Moisture content determination

Initial moisture content of the sandbox seeds was determined using ASABE standard for oven drying method as adopted by [6, 13] for Moringa and African star apple seeds respectively. Equation 1 below was used to calculate the mc (wet-basis).

$$\%age\ Moisture = [(W_i - W_f)/W_i] \times 100 \quad 1$$

Where W_i = initial weight of the seeds and W_f = final weight of the seed

Determination of the physical properties of the *Gmelina* seed

One hundred samples of the *Gmelina* seeds were randomly selected from the bulk sample for the evaluation of the physical properties which include: geometric, gravimetric and frictional properties

Size determination

The axial dimensions; major, intermediate and minor diameters of the Gmelina seed samples were determined. The measured quantities were measured using an electronic Vernier caliper of 0.001mm accuracy. The geometric mean diameter, D_g , and arithmetic mean diameter, D_a were determined from the expression in Equations (2) and (3) as given by [7] according to [11, 14, 13].

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

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

Where D_g and D_a represents the geometric mean and arithmetic mean diameters respectively in mm, and L, W and T are the length, the width and the thickness of the Gmelina seeds (mm) respectively.



Fig. 3. Dimensioning of the Gmelina nuts

Determination of surface area, sphericity, aspect ratio, and volume

The surface area, S_a was determined using the expression in Eq. (4) adopted from [14] and [13].

$$S_a = \pi D_g^2 \quad 4$$

Where S_a = the surface area of Gmelina seeds (mm^2), D_g = Geometric mean diameter (mm)

The degree of Sphericity, S_p was calculated from Eq. (5) as expressed by Mohsenin [7] and adopted by [13].

$$S_p = (LWT)^{1/3}/L \quad 5$$

Where S_p = sphericity (mm), L , W and T are the length, width and thickness of Gmelina seed (mm) respectively

The aspect ratio R_a was calculated using Eq. (6) according to [10].

$$R_a = \frac{W}{L} \quad (6)$$

Where R_a = Aspect ratio of Gmelina seed. L = length and W = width (mm) respectively.

Volume of the Gmelina seed was determined using Archimedes's principle of water displacement as described by [9]. The one hundred (100) seed samples were weighed and immersed in a measuring cylinder containing a known volume of water. Water was used because the texture of the Star apple is like plastic and does not absorb water. The difference in water volume between the new level of water in the measuring cylinder and the initial volume of water was recorded as the volume of the star apple seed, V .

Mass determination

The masses of a 1000 sample seeds were determined using a (Mettler Toledo PL203) electronic weighing balance of 0.001g accuracy. Three replicates of 100 seeds were randomly selected from the bulk sample and then multiplied by 10 to give mass of 1000 seeds [1].

Volume, bulk and true density determination

Volume of the Gmelina seed was determined using Archimedes's principle of water displacement as described by [9]. Seed samples were weighed and immersed in a measuring cylinder containing a known volume of water. Water was used because the texture of the seed does not absorb water. The difference in water volume between the new level of water in the measuring cylinder and the initial volume of water was recorded as the volume of the seed, V .

Bulk density: Bulk density is density of bulk materials including the void air spaces between them. The bulk density was determined by weighing and filling an empty graduated cylinder with the seed and then reweighed without the seeds [8]. The weight of the seeds was obtained by subtracting the weight of the cylinder from the weight of both the cylinder and seed. The volume occupied was recorded. The process was replicated three times and the bulk density for each replication was calculated from the relation:

$$\rho_b = W_s/V_b \quad (7)$$

Where ρ_s is the bulk density, W_s is the sample and V_b is the bulk volume occupied by the sample.

True density: The true density was determined as the ratio between the mass of seeds and the true volume of the seeds.

$$\rho_t = W_s/V_t \quad (8)$$

Where ρ_t is the true density and V_t is the true volume of the seed.

Porosity: The porosity was calculated from the values of bulk and true densities using the relationship by [8].

$$\varepsilon = (1 - \rho_b/\rho_t) \times 100 \quad (9)$$

Angle of Repose

The angle of repose of the Gmelina seed was determined by the use of a cylinder made of cardboard paper, open at both ends. The seeds were poured into the cylinder placed on a flat surface to form a pile. The cylinder was then lifted up gradually until it was completely removed, allowing the samples to spread and form a pile. The experiment was replicated three times, the radius and the height of piled samples were determined and recorded and the relationship used by (Bhatia et al 2009) was used to determine the angle of repose

$$\theta = \tan^{-1}(h/r) \quad (10)$$

Where r is radius of spread and h , is height of piled sample

Determination of Coefficient of Friction

Sliding motion occurs only when static friction has been overcome by an applied force. The coefficient of friction of the Gmelina seed was determined on four surfaces; wood, aluminum, glass and galvanized steel. The surfaces were gently inclined using a screw device and the angle of inclination at which the sample started sliding was recorded as θ (Figs. 4 and 5). The procedure was repeated three times for the all surfaces. The coefficient of friction was determined using the relation:

$$\mu = \tan \theta = h/b \quad (11)$$

Where μ is coefficient of friction, h , is height raised and b is the base distance

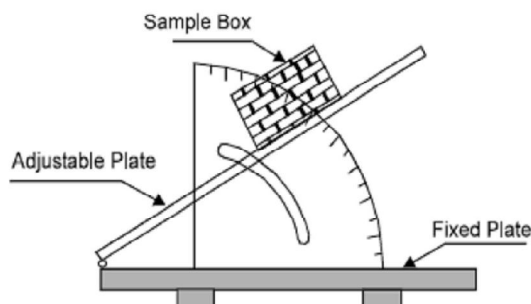


Fig. 4



Fig. 5

Fig 4: Pictorial view of; Fig 5: Laboratory view of; determination of coefficient of friction

Mechanical properties

A digital compression testing machine Model 65-L1232, made in Italy with a capacity of 250kN at the Civil Engineering Laboratory, University of Uyo, Nigeria was used to determine the cracking force and stress for the seed [8]. Five different samples of seeds were loaded at the three major axis; vertical, horizontal and transverse. The cracking force and stress at those axes were determined.

RESULTS AND DISCUSSION

Physical Properties

The moisture content of *Gmelina Arborea* was determined as 1.76%wb. The major, minor and intermediate diameters were 18.16 ± 1.79 mm, 10.52 ± 0.93 mm and 9.40 ± 0.81 mm respectively. The geometric and arithmetic mean diameter were calculated as 12.12 ± 1.10 and 9.56 ± 0.90 mm respectively. The sphericity was 66.91%, aspect ratio, 58.19, bulk and true densities, 0.64 kg/m^3 and 0.96 kg/m^3 respectively. The porosity and mass of a 1000 seeds were 66.67% and 621.33g.

Table 1: Physical Properties of *Gmelina Arborea*

S/N	Property	Dimension
1	Moisture content	1.76%wb
2	Major diameter	18.16 ± 1.79 mm
3	Intermediate diameter	10.52 ± 0.93 mm
4	Minor diameter	9.40 ± 0.81 mm
5	Geometric mean diameter, D_g	12.12 ± 1.10 mm
6	Arithmetic mean diameter, D_a	9.56 ± 0.90 mm
7	Surface area	464.15 mm^2
8	Sphericity	66.91%
9	Aspect ratio, R_a	58.19
10	Volume	105 mm^3
10	Bulk density	640 kg/m^3
11	True density	960 kg/m^3
12	Porosity	66.67%
13	Mass of a 1000 seeds	621.33g

Mechanical Properties

The coefficient of friction determined on four different surfaces were; on wood, $21.91 \pm 3.51^\circ$, on galvanized steel, $20.40 \pm 3.35^\circ$, on glass, $19.98 \pm 2.21^\circ$ and on aluminum, $18.62 \pm 3.22^\circ$. The compressive test conducted on the three major axes; vertical, horizontal and transverse shows that the energy needed for cracking of the *Gmelina Arborea* is least on the horizontal axis, 0.808 ± 0.19 kN, followed by the vertical axis, 1.496 ± 0.35 kN and then the transverse

axis, 2.39 ± 0.20 kN, with corresponding stress as 1.52 ± 0.35 , 2.90 ± 0.45 and 4.90 ± 0.44 MPa respectively.

Table 2: Mechanical Properties of *Gmelina Arborea*

S/N	property	Surfaces	Dimension
1	Coefficient of internal friction	Wood	$21.91 \pm 3.57^\circ$
		Galvanized steel	$20.40 \pm 3.35^\circ$
		Glass	$19.98 \pm 2.21^\circ$
		Aluminium	$18.62 \pm 3.22^\circ$
2	Angle of repose		24.09°

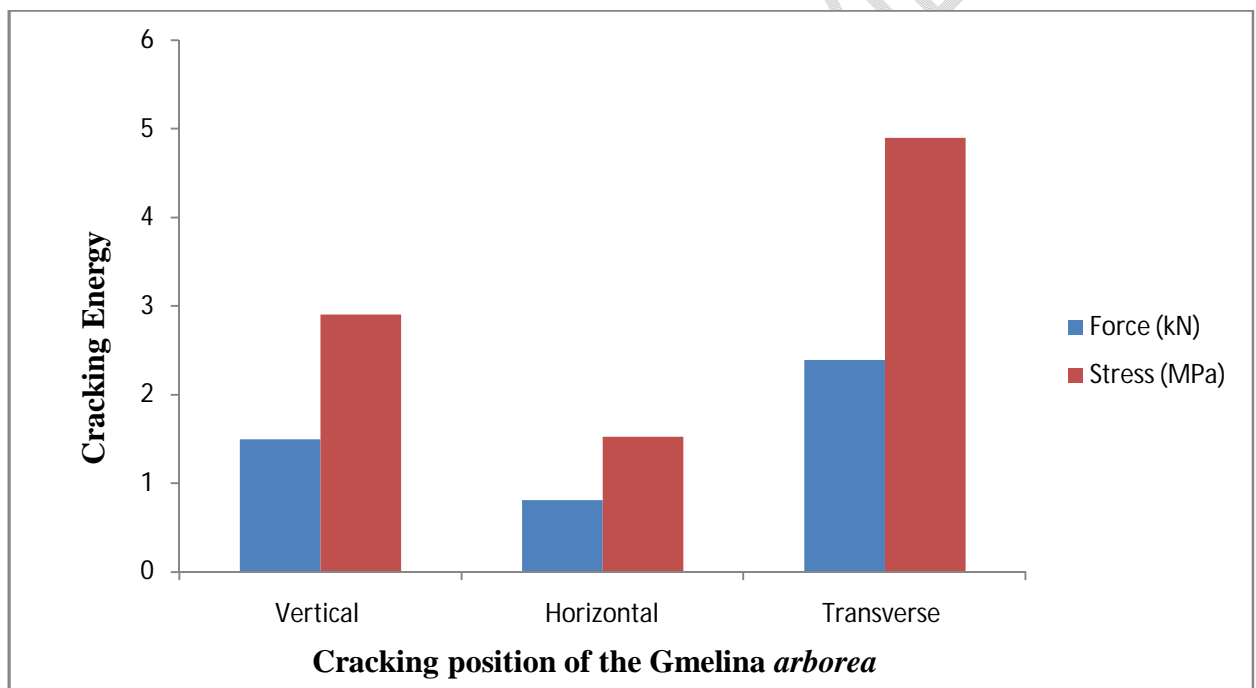


Fig. 6. Cracking position of the *Gmelina arborea*

REFERENCES

1. Bamgboye AI, Adebayo SE. Seed moisture dependent on physical and mechanical properties of *Jatropha curcas*. Journal of Agricultural Technology. 2012;8(1):13-26.
2. Basumatary S, Deka, Dinesh C, Deka, Dibakar C. Composition of biodiesel from *Gmelina arborea* seed oil, Adv. Appl. Sci. Res. 2012;3(5):2745-2753.
3. Choudhury EH. Workforce planning in small local governments. Review of Public Personnel Administration. 2007;27(3):264-280.

4. Deepthi P, Harini A, Prakash LH. A Review on Gambhari (*Gmelina arborea* Roxb.). Journal of Pharmacognosy and Phytochemistry. 2015;4(2):127-132.
5. Dragon RG, Reyes AE. A comparative study on the percent crude oil content of *Gmelina arborea*. Proceeding of the International Seminar on Chemistry. 2008:290-293
6. Fakayode OA, Ajav EA. Process optimization of mechanical oil expression from Moringa (*Moringa oleifera*) seeds. Industrial Crops and Products. 2016;90:142-151.
7. Mohsenin NN. *Physical properties of plant and animal materials* (end ed.). New York, NY: Gordon and Breach Science Publishers. 1986.
8. Mohsenin NN. *Physical Properties of Plant and Animal Materials*. Gordon and Breach Science Publishers, New York. 1970.
9. Nelkon M. *Principles of Physics for Senior Secondary Schools*, 6th (Ed.), Heinemann London, London. 2005.
10. Obi OF, Offorha LC. Moisture-dependent physical properties of melon (*Citrullus colocynthis* L.) seed and kernel relevant in bulk handling, Food Sci. & Technol. Cogent Food & Agric. 2015 1020743, doi: 10.1080/23311932.2015.1020743 .
11. Ogunsina BS, Koya OA, Adeosun OO. Deformation and fracture of Dika nut (*Irvingia gabonensis*) under uni-axial compressive loading. International Agrophysics. 2008;22:249-253.
12. Okoroigwe E, Li Z, Stuecken T, Saffron C, Onyegegbu S. J. Appl. Sci. 2012;12:369.
13. Onwe DN, Umani KC, Olosunde WA, Ossom IS. Comparative analysis of moisture-dependent physical and mechanical properties of two varieties of African star apple (*Chrysophyllum albidum*) seeds relevant in engineering design. Scientific African. 2020; 8:e00303.
14. Tavakoli H, Rajabipour A, Mohtasebi SS. Some moisture-dependent engineering properties of soybean grains. Agricultural Engineering International: the CIGR Ejournal. 2009;XI:1110.