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Determination of Some Physical and Mechanical Properties of *Gmelina arborea* Seed

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Authors' contributions

This work was carried out in collaboration among all authors. Author DNO helped to conceptualize the manuscript and prepared the study protocol. Author PO collected the sample and also did experimental evaluations. Author MGA analyzed the manuscript and wrote the report. All authors read and approved the final manuscript.

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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 G*melina arborea* where experimentally determined. The moisture content of Gmelina *arborea* was determined as 41.30%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, 0.4 ± 0.7, on galvanized steel, 0.37 ± 0.6, on glass, 0.36 ± 0.4 and on aluminum, 0.34 ± 0.6. The angle of repose was 24.09^o. The compressive test conducted on the

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three major axes; vertical, horizontal and transverse shows that the energy needed for cracking of the Gmelina a*rborea* 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.

1. INTRODUCTION

"Gmelina arborea Roxb is a big forest tree belonging to the family Verbinaceae [1,2]. 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" [3]. "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" [4]. "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" [1]. "G*melina* 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 [2]. According to Basumatary et al [1], a kernel with very high oil content is enveloped inside the G*melina arborea* seed.

"The properties of kernels, grains and seeds are important in the development of equipment for transportation, handling and processing". Onwe et al. [6] Nyorere and Uguru [7,8] studied "the effect of seed size on the mechanical properties and effect of moisture content on the physical properties of *Gmelina* seed. The current work evaluated the physical and mechanical properties of G*melina arborea* at its natural moisture content".

2. MATERIALS AND METHODS

2.1 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).

2.2 Moisture Content Determination

Initial moisture content of the sandbox seeds was determined using ASABE standard for oven drying method as adopted by Fakayode and Ajav [9] Ogunsina et al. [10] for Moringa and African star apple seeds respectively. Equation 1 below was used to calculate the mc (wet-basis).

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

Where W_i = Initial weight of the seeds and W_f = Final weight of the seed

Fig. 1. Gmelina fruits

Fig. 2. Gmelina nuts

2.3 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.

2.4 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 (Fig. 3). 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 Mohsenin [11] according to Nyorere and Uguru [8], Okoroigwe et al. [12], Ogunsina et al. [10].

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

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

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

2.5 Determination of Surface Area, Sphericity, Aspect Ratio, and Volume

The surface area, S_a was determined using the expression in Eq. (4) adopted from [12] and [10].

$$S_a = \pi D_g^{\ 2} \quad (4)$$

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 [11] and adopted by Ogunsina et al. [10].

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

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 Nyorere and Uguru [7].

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

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 Nelkon [13]. "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" [6].

2.6 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" [14].

2.7 Volume, Bulk and True Density Determination

"Volume of the Gmelina seed was determined using Archimedes's principle of water displacement" as described by Nelkon [13]. "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". [6]

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" [15]. The weight of the seeds was obtained by subtracting the weight of the cylinder from the weight of both the cylinder and seed [16]. 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 Mohsenin [15].

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

2.8 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

2.9 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:

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

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

2.10 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 [15]. 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.

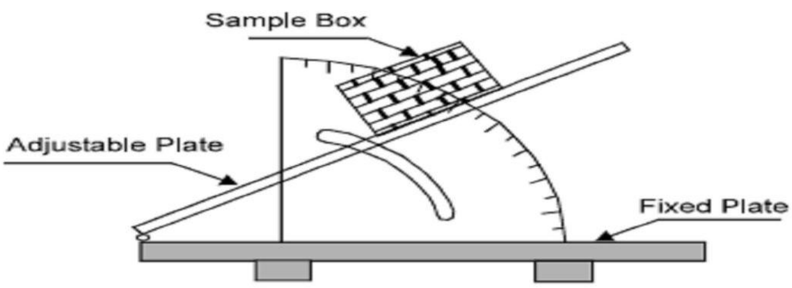

Fig. 4. Pictorial view of determination of coefficient of friction

3. RESULTS AND DISCUSSION

The results of the physical properties of the Gmelina arborea are presented in Table 1.

3.1 Physical Properties

The moisture content of Gmelina *Arborea* was determined as 41.30%wb. [8], varied Gmelina moisture content from 30-51%wb, which is around the natural moisture content of 41.30%wb as obtained. 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, arithmetic mean diameter and the surface area were calculated as 12.12 ± 1.10, 9.56 ± 0.90 mm and 464.15 mm^2 respectively. These dimensions were marginally higher than figures obtained by Nyorere and Uguru [8]. The variation in these parameters might be as a result in maturity of the seeds; *Gmelina* seeds investigated by Nyorere and Uguru [8] were all green, indicating they were not fully matured. The *Gmelina* seeds evaluated in this work were matured fallen seeds. 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 sphericity, bulk and true densities are within the range obtained by Nyorere and Uguru [8].

3.2 Mechanical Properties

The coefficient of friction determined on four different surfaces were; on wood, 0.40 ± 0.7, on galvanized steel, 0.37 ± 0.6, on glass, 0.36 ± 0.4 and on aluminum, 0.34 ± 0.6. Slightly higher results were obtained for Gmelina seed by Nyorere and Uguru [8] at different seed moistures. The angle of repose for the Gmelina seed was 24.09°. 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 1. Physical properties of *Gmelina arborea*

S/N	Property	Dimension
1	Moisture content	41.30%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

Table 2. Mechanical properties of *Gmelina arborea*

S/N	property		Dimension
1	Coefficient of internal friction	Surfaces	
		Wood	0.40 ± 0.7
		Galvanized steel	0.37 ± 0.6
		Glass	0.36 ± 0.4
		Aluminum	0.34 ± 0.6
2	Angle of repose		24.09°

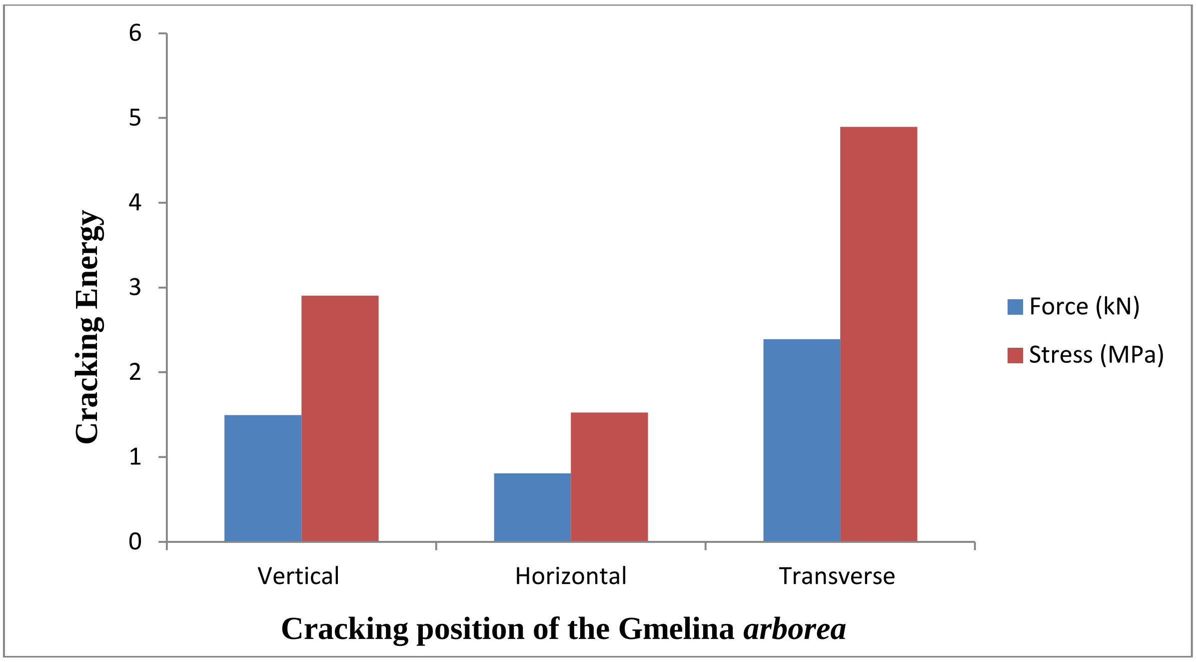

Fig. 5. Cracking energy vs cracking position of the *Gmelina arborea*

4. CONCLUSION

Physical and mechanical properties of G*melina arborea* where determined. Amongst the properties determined, the moisture content of *Gmelina arborea* was 41.30%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, 0.4 ± 0.7, on galvanized steel, 0.37 ± 0.6, on glass, 0.36 ± 0.4 and on aluminum, 0.34 ± 0.6. The angle of repose was 24.09^o. 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. The properties of the Gmelina seed determined are important in the development of equipment for transportation, handling and processing.

COMPETING INTERESTS

Authors have hereby declare that we have no known competing financial interests or personal relationships that could have appeared to influence our work reported in this paper titled: Determination of Some Engineering Properties of *Gmelina Arborea* Seed.

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