

# Mechanical Properties of African mahogany (*Khaya Senegalensis*) Seeds

Usman, D. D<sup>1</sup>; Ibrahim, M. E<sup>2</sup>. ; Yakubu, I. T<sup>3</sup> ; & Kabri, U. H<sup>3</sup>.

<sup>1</sup>Agricultural and Bioresource Engineering Department, Abubakar Tafawa Balewa University, Bauchi. Bauchi State.

<sup>2</sup>Mechanical Engineering Department, Modibbo Adama University of Technology Yola, Adamawa State.

<sup>3</sup>Agricultural & Environmental Engineering Department, Modibbo Adama University of Technology, Yola, Adamawa State.

Correspondence: [drambiusman@gmail.com](mailto:drambiusman@gmail.com) , +2347036689063

## ABSTRACT

Mahogany seed is among the best of oilseeds in production of oil used for various applications. The processing of the seeds for the extraction of oil is mostly done manually, which has adversely affected the quality, efficiency and oil yield of the seeds. This research work investigated the mechanical properties of the seed at 12.20% mc (w.b) which includes; the hardness, compressive breaking force at yield and breaking points and rupture energy along the principal axes. The hardness was determined using Myer's apparatus for hardness test, while the compressive force and rupture energy was determined using instron universal compressive tester 3369. The computed mean value of the seed hardness

for 50 replica was  $3.02\text{kN/m}^2$ , while the mean compressive force and rupture energy (at break and yield points) for 50 replication were  $20.13\text{N}$  and  $429 \times 10^{-3} \text{J}$  (major axis),  $19.37\text{N}$  and  $239 \times 10^{-3} \text{J}$  (minor axis) and  $620.06\text{N}$  and  $759 \times 10^{-3} \text{J}$  (intermediate axis) respectively. These results indicate that the seeds are weaker along the major and minor axes, but stronger along intermediate axis. Compressive force and rupture energy at yield point (along minor axis) has a positive correlation at 0.05 level of significance. All results obtained from this investigation could be used as design parameters for the development of mechanical expression for oil extraction from seed.

**Key words:** Mahogany seed, Mechanical property, Hardness, Compressive force, Rupture energy.

## 1 INTRODUCTION

African mahogany (*Khaya senegalensis*) is an important multipurpose tree in its natural range in Africa and Madagascar [1]. The tree is 20-35 m tall with a trunk over 1 m in diameter and often buttressed at the base, it thrives well in Riverine forest and scattered in rainfall Savannah woodlands with 700 - 1750 mm rain per year[2]. The plant begin producing seeds at 15-25 years and in most places fruiting is regular and remain on the tree for most of the dry season. Beside timber, the plant is valued for its

medicinal purposes especially the bark, which is used to treat a number of diseases such as jaundice, fever, syphilis etc [2]. In Nigeria, the seed oil is used for edible and cosmetics purposes with an oil content of 67% (21% palmitic acid, 10% stearic acid, 65% oleic acid and 45 unidentified acids [2]. The mechanical properties of the African mahogany (*Khaya senegalensis*) seeds are considered to be necessary for the proper design of equipment for the mechanical expression of oil, drying, storage, and other processes [3]. There was no published literature found on

mechanical properties of khaya seeds and their dependency on operational parameters like compressive force, hardness and rupture energy, which may be useful for the design of equipment for the mechanical expression of oil from the seeds.

However, mechanical properties of oil bearing seeds have been reported [4; 5; 6]. Reference [4] reported that the minimum force at corresponding deformation to rupture shelled nut of shea nut were found to vary from 980 N, 4.9 mm to 1615.3 N, 9.586 mm for moisture range of 20 – 48% (wb). The average hardness value of 38 KN/m<sup>2</sup> and 14.2 KN/m<sup>2</sup> were reported by [5] for Dura Tenure and pisifera varieties of palm kernel seeds respectively, while fracture force for sunflower increased from 42.4 to 63.8 N with increasing moisture (7.4 – 9.2% wb) and insertion and crushing forces decreased from 48.64 to 30.65 N and from 75.39 to 62.3 N respectively as reported by [6]. Reference [7] reported that mechanical properties of pea as a function of location and orientation indicates that the values of failure stress, failure strain, failure energy and Young's modulus on the specimen orientation and location were affected by orientation, latitudinal cross section and depth, but not by longitudinal cross section of the specimen. Thus, various mechanical properties of seed appear to be important in the design of handling and processing equipment. In this study, some mechanical properties of mahogany seeds investigated are hardness, compressive breaking force at yield and breaking point) and rupture energy at a safe storage moisture content of 12.20% (wb).

## 2 MATERIALS AND METHODS

For this study, matured variety of African Mahogany (*Khaya senegalensis*) seed widely found in Adamawa state were collected from Crop Science Department, Federal University of Technology, Yola, and Michika Local Government Area of Adamawa state, in April, 2010.



**Plate 1:** *Khaya Senegalensis* (Mahogany) seeds

The seeds were cleaned manually to remove foreign materials, broken and immature seeds. Since the seed is an oil seed, the storage moisture content was determined by oven drying at 105°C in 24 hours [8]. The moisture content was obtained as 12.20% (wb). In order to determine the hardness of the seed, Myer's apparatus (Plate 2) for hardness test from Mechanical Engineering Department of FUTY, was used. The apparatus has a flat form and a vertically placed pipe through which the indenter is dropped on the seed from a known height. After dropping the indenter from a known height, the diameter of indenter (d), and the mass of the indenter were measured and recorded. Meyer's Hardness Number (MHN) expression was used to compute the seed hardness.



**Plate 2:** Myer's Apparatus for Hardness Test.

$$P_m = \frac{F}{\left(\frac{\pi}{4}\right)d^2} \text{ kg/mm}^2 \text{ ----- (1)}$$

Where  $P_m$  = Mean Pressure/ Hardness of seed (kN/m<sup>2</sup>)

F = Applied Force (N)

The compressive breaking force (at yield and breaking point) and rupture energy were determined using Instron Universal Compressive Tester 3369 (Plate 2.2) from Engineering Material Development Institute (EMDI) Akure, Ondo State. The experimental test was conducted at the different loading position along the principal axis of the seed. The seeds were loaded individually on the compressive lower jaw, while the upper jaw was lowered to grip the specimen and the test commenced. Compression force was exerted and the biomaterial fails, then, the "End Test" button was pressed on the computer. Thus, the force – deformation graph was concurrently plotted. Reading was recorded directly via a computer print-out connected to the universal tester 3369.

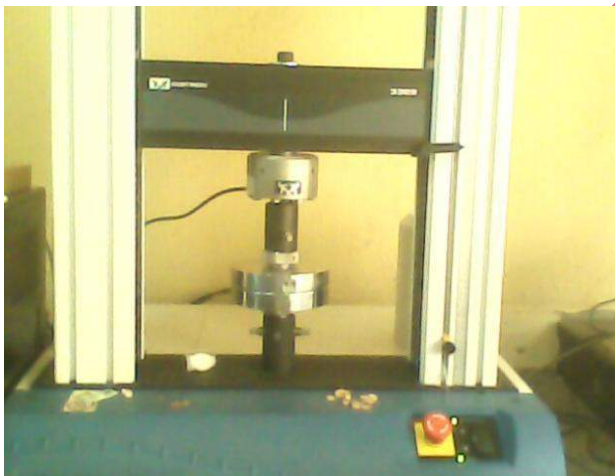


Plate 3: Instron Universal Compressive Tester

All the experiments were replicated ten times, unless stated otherwise and the average values reported. The data were

### 3.1 HARDNESS

analyzed using descriptive Statistic (mean) and SPSS to establish a correlation the parameters investigated at different significant level.

## 3 RESULTS AND DISCUSSION

The mean values and ranges of tested mechanical properties of Africa mahogany (*khaya senegalensis*) seed as obtained from the test were shown in table 1 and discussed below.

**Table 1: Mechanical Properties of African mahogany  
(*K. Senegalensis*) Seed At 12.20% wb**

Properties	Unit	Replica	Mean	Range
Hardness	kN/m <sup>2</sup>	10	3.02	3.65 - 2.21
<b>Compressive Force ( at breaking point)</b>				
Major Axis	N	10	20.13	25.80 – 10.28
Minor Axis	N	10	19.37	24.30 – 9.92
Inter. Axi	N	10	620.06	640.30 – 560.02
<b>Rupture Energy (at breaking point)</b>				
Major Axis	J	10	429 x 10 <sup>-3</sup>	25.80 – 10.28
Minor Axis	J	10	239 x 10 <sup>-3</sup>	24.30 – 9.92
Inter. Axis	J	10	759 x 10 <sup>-3</sup>	640.30 – 560.02
<b>Compressive Force (at yield point)</b>				
Major Axis	N	10	6.60	15.37 – 0.00
Minor Axis	N	10	12.29	16.61 – 9.31
Inter. Axis	N	10	-	-
<b>Rupture Energy ( at yield point)</b>				
Major Axis	J	10	22 x10 <sup>-3</sup>	25.80 – 10.28
Minor Axis	J	10	23 x10 <sup>-3</sup>	24.30 – 9.92
Inter. Axis	J	10	-	-

The hardness of the mahogany seeds as obtained from the experiment are given in table 1. The results shows

that hardness varies from 2.21 to 3.65 kN/m<sup>2</sup>, with a mean value of 3.02 kN/m<sup>2</sup>, these results were far much less than those of the three varieties of palm kernel seeds [5]. A positive correlation was established between the hardness and seed density and weight at 0.05 significant levels. These results are important in evaluating size reduction and milling characteristics of the seeds during and after processing as emphasized by [9].

### 3.2 COMPRESSIVE BREAKING FORCE

The compressive breaking force at yield and breaking points as obtained from the experimental test are given in table 1. The compressive breaking force was determined along the three principle axis. Along the major axis, it was observed to varies from 10.28 to 37.69 N at breaking point with a mean value of 23.89 N while at yield, it has a mean value of 6.60 N. The force along the minor axis varies from 21.56 – 28.30 N at breaking point with a mean of 20.25 N and from 9.31 to 16.61 N at yield points, with mean 12.29 N. While the forces along the intermediate axis varies from 561.02 to 692.30 N at breaking point, with mean of 529.82 N. It was observed that no force was experienced at yield point for the intermediate axis. This indicates that the seeds are weaker along the major and minor axes, while it is much stronger along the intermediate axis. This behaviour is similar to trend reported by [7], that compressive force is significantly affected by orientation of the specimen. Positive correlation exists between forces along major and intermediate axis (at breaking point) at 0.05 significant levels.

### 3.3 RUPTURE ENERGY

The results obtained from rupture energy at break and yield points were given in Table 1. The rupture energy along the major axis varies from 67 x 10<sup>-3</sup> to 282 x 10<sup>-3</sup> J (at break point) with a mean of 429 x 10<sup>-3</sup> J. While it varies from 65 x 10<sup>-3</sup> to 10 x 10<sup>-3</sup> J (at yield point) with a mean of 22 x 10<sup>-3</sup> J. The energy obtained along the intermediate axis varies from 999 x 10<sup>-3</sup> to 534 x 10<sup>-2</sup> J (at break point) with a

mean of 759 x 10<sup>-3</sup> J, the energy obtained along the minor axis varies from 349 x 10<sup>-3</sup> J to 171 x 10<sup>-3</sup> J (at break point) with a mean of 239 x 10<sup>-3</sup> J, while at yield point, it varies from 44 x 10<sup>-3</sup> J to 14 x 10<sup>-3</sup> J with a mean of 23 x 10<sup>-3</sup> J. These results showed that more energy is required to rupture the seed along the intermediate axis than the major and minor axes. These results are similar to those reported by [10] for pea seed, [11] for chick pea and [6] for sunflower seeds. A positive correlation was established for rupture energy (at break) and compressive force (at yield) along major axis at 0.01 significant level, while positive correlation at 0.05 significant level was established along major axis (at break and yield point) for rupture energy.

### 3.4 GRAPHICAL PATTERN OF FORCE-DEFORMATION

The behavior of African mahogany seeds under load differ with respect to the orientation of the specimen, i.e. major, minor and intermediate axes (Fig. 3.1, 3.2 and 3.3). These figures illustrate how the seeds deform under load and provide information on the Linear Limit (LL), Yield Point (Y) and Rupture Point (R) respectively.

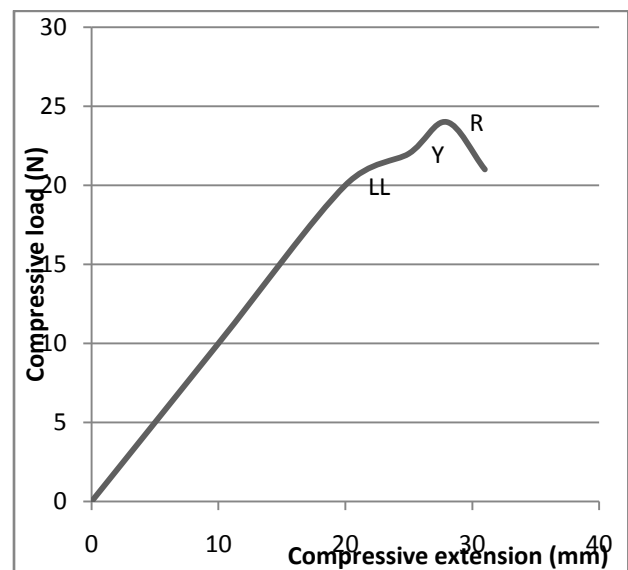


Figure 1: Force – Deformation Characteristics of *Khaya Senegalensis* Seed along Major Axis

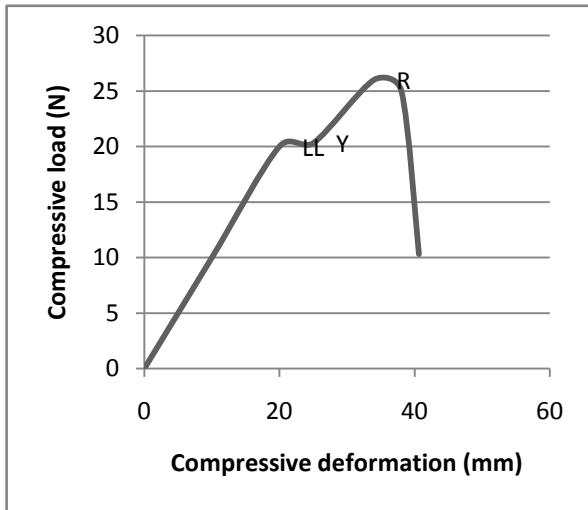


Figure 2: Force – Deformation Characteristics of *Khaya Senegalensis* Seed Along Minor Axis

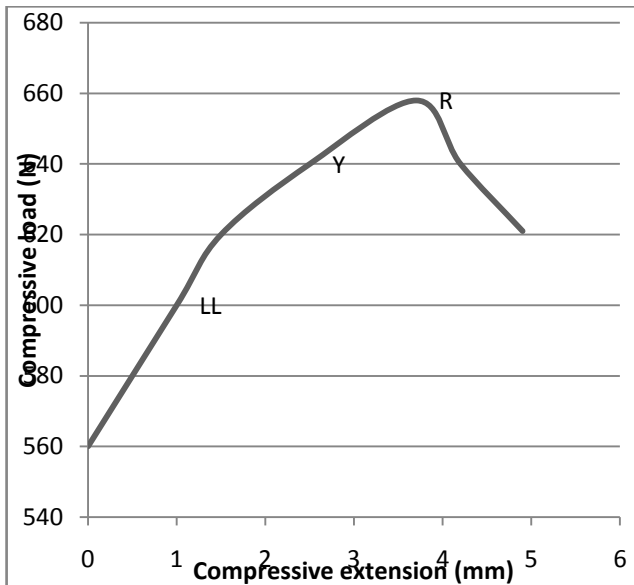


Figure 3: Force – Deformation Characteristics of *Khaya Senegalensis* Seed Intermediate Axis

#### 4. CONCLUSION

The average value of the seeds hardness was 3.02kN/m<sup>2</sup>, this result can aid in determining the method of size reduction and milling process for the seeds.

The seeds were found to be stronger along the its intermediate axis with a mean value of 620.06N at breaking point, compare to 20.13N and 12.29N along major and minor axes respectively. Alternatively, more energy is required to rupture the seed along intermediate axis with a mean energy of 759 x 10<sup>-3</sup> J, as compared to 429 x 10<sup>-3</sup> J and 239 x 10<sup>-3</sup> J along the major and minor axes respectively. From the experimental results obtained, it was observed that compressive force and rupture energy were not obtained along the intermediate axis (at yield point), while the behavior of the seeds under loading along the principal axes (major, minor and intermediate) differs. Statistically, the mechanical properties tend to have a positive correlation at 0.01 and 0.05 significant level.

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