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# Selected Physico-Mechanical Properties of Wood of *Anogeissusleiocarpus* (DC.) Guill & Perr

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## ABSTRACT

*This study assessed the physical and mechanical properties of Anogeissusleiocarpus. Four superior trees were felled and used for this study. Variables were obtained from the selected trees. Five bolts of 50cm were collected at 10%, 30%, 50%, 70% and 90% along the merchantable height and were partitioned into inner, middle and outer wood along the radial plane based on the distance of the annual rings from the pith. Quarter sawn wood samples were processed into 180 samples of 20mm x 20mm x 60mm and 600 samples of 20mm x 20mm x 200mmused for physical and mechanical properties. The experiment was laid in a 5 x 3 nested design in a randomized completely block design where LSD was used to separate means where significant differences were observed. The result shows that moisture content has a mean of 17.50% and there was significance in the moisture content along the axial positions at $p \leq 0.05$. The mean value of basic density within trees (wood position) was 762.89kg/m3 which decreased from the base to the top axially and radically but gradually decreases from the inner wood to the outer wood. Variation in Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) were inconsistent and analysis of variance reveals that there was significant difference along the radial positions at $p \leq 0.05$ with a mean value of 19849.73N/mm2 and 108.98N/mm2 respectively. This study provide quantitative information the utilization potential of Anogeissusleiocarpus wood as a good substitute to commercially over-exploited timber species and could favorably compete with other well-known timber species like Mahoganies.*

**Keywords:** *Mechanical properties, Axial position, Wood properties, Radial properties Anogeissusleiocarpus and Physical properties.*

## INTRODUCTION

*Anogeissusleiocarpus* is commonly known as "Axle wood tree or African birch" which is attributed to the silvery cast of the foliage similar to the temperate birch. It is a tropical species found from the Sahel to Forest zones through Senegal to Sudan and Ethiopia (Burkill 1985). The savanna region is known as its habitats. According to Ogunwusi, (2013), *Anogeissusleiocarpus* is a medium grade species used as fuel wood and as an important raw material for charcoal production in the savannah region. It has also been reported to have been use by wood carvers as a substitute for the scarcity of *Cordiamillenii* and recent overexploitation of *Gmelinaarborea* (Aiyeloja, 2015). The physical and strength properties of wood have always been an important factor in its use, but it is becoming even more significant with the increasing competition from other materials and the changing requirements of consuming markets. In making a comparison of species, it is necessary to consider the kind of strength properties or combination of properties essential to the particular use, since different kinds of strength are essential in different uses. The objective of the study was to investigate the density in relations to mechanical properties of *Anogeissusleiocarpus* with a view of identifying its utilization potentials for timber use along the two axial and radial axis .The physical properties such as wood density affect the technical performance of wood, its use and in particular the strength and processing behavior of sawn wood. Consequently, high density timber is generally associated with superior mechanical performance. The mechanical properties are the characteristics of a wood in response to externally applied forces. They include elastic properties, which characterize resistance to deformation and distortion, resulting from applied loads. Mechanical property values are given in terms of stress (force per unit area) and strain (deformation resulting from the applied stress), which are obtained from laboratory tests of lumber of straight-grained clear wood samples devoid of natural defects that would reduce strength, such as knots, checks, splits, etc. (ASTM, 1991, Jamala. et al.,2013). With wood, strength varies significantly depending on species, loading condition, load duration, and a number of assorted material and environmental factors.

## METHODS AND MATERIALS

### Study Areas

Tree used in this study was harvested from Owo-Owu in Atisbo Local Government Area of Oyo State South Western Nigeria. Sawning and resawing of tree blocks was carried out at the wood work shop of the Department of Forest Production University and Products while data on physical characteristics of wood samples was collected at the wood laboratory of the same department. Furthermore, Data on mechanical properties of the wood samples was carried out in the department of forestry and wood product Technology, Federal University of Technology Akure.

### Sample Collection and Parameter Assessment

This study assessed the selected physical and mechanical properties of *Anogeissusleiocarpus* wood. A test material wood sample for this study was collected from the 10%, 30%, 50%, 70% and 90% of four trees of straight bole without defects. The following variables were tested; density, shrinkage characteristics, modulus of rupture, modulus of elasticity, Impact strength and compression strength perpendicular to grain, and the relationship between the physical and mechanical properties of *Anogeissusleiocarpus*.

### Determination of Physical and Mechanical Properties

Five trees were selected based on superior characteristics. Details of the total log length and diameter of the purposively selected trees was measured. 5 bolts of 50 cm long were collected at 10, 30, 50, 70 and 90% of the merchantable height with a centralized plank with of 60mm thickness was partitioned into three equal zones, namely, inner wood, middle wood and outer wood along the radial plane based on the distance of the annual rings from the pith (Onilude and Ogunsanwo, 2002).Quarter sawn wood samples was processed into desired dimensions of 20mm x 20mm x 60mm and 20mm x 20mm x 300mm for physical and mechanical properties respectively. The blocks were prepared for testing by drying and sterilizing in the oven to a constant weight at 103°C ± 2 for 24 hours. The initial weight and oven dry weight for each wood sample was recorded after which they were bagged in the air tight nylon bag to prevent them from reabsorbing moisture. A total of 150 test samples of dimensions 20 × 20 × 60 mm were collected from each tree to give a total of 600 test samples and 50 test samples of 20mm x 20mm x 300mm to give a total of 200 test samples (ASTM, 1991).

- The moisture content was calculated according with ASTMD 4442-84 (1984) using the equation:

$$MC = \frac{Wm - Wo}{Wo} \times 100 \text{..........................equation 1.0}$$

Where:

MC=Moisture Content

Wm = Weight of the test wood samples before oven-drying (g)

Wo = Weight of the test wood samples after oven-drying (g)

- The volumes of samples at green weight were recorded and the following formula was adopted for the calculation of wood density.

$$D = \frac{m}{v} \text{.............................................equation 2.0}$$

Where

D = Density (kg/m$^3$)

m = Oven-dried weight (kg)

V = Green volume of wood (m$^3$)

- The Modulus of rupture test was carried out in accordance to British standard method BS 373 using universal testing machine. This involve the use of standard test specimen (20mm x 20mm x 300mm) and the load was applied at the rate of 0.1mm/sec with the grain parallel to the direction of loading, that is, specimens were loaded on radial face. The bending strength of wood usually expressed as MOR test was determined. Load at failure was recorded and the corresponding PC monitored values were taken directly from machine. Hence, MOR was calculated as thus;

$$MOR = \frac{3PL}{2bd^2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .equation\ 3$$

MOR = Modulus of Rupture (N/mm$^2$)

P = Load needed for failure

L = Span of the material between support (length)

b = Width of the material

d = Thickness of the material

- Universal testing machine was used to obtain the force needed to reach elastic limit and its displacement. The modulus of elasticity in accordance to British standard method BS 373 was carried out using standard test specimen with dimension of 20mm × 20mm × 300mm from the MOR test, and then corresponding MOE was recorded. MOE was calculated using this formula.

$$MOE = \frac{PL^3}{\Delta bd^3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . equation\ 4$$

Where:

MOE = (N/mm$^2$)

P = load in Newton (N)

L = span / length (mm)

b = width (mm)

d = depth (mm)

Δ = the displacement at beam Centre at proportional load.

- The impact was carried out using the Hatt-turner impact testing machine according to the British standard BS373. Test samples of 20m ×20mm ×300mm was supported over a span of 24cm on a support radius 15mm, spring restricted yokes are fitted in order to arrest rebound. This was then subjected to a repeated blow from weight 1.5kg at increasing height initially from 50.8mm and then every 25.4mm until complete failure occurred at which point the height was recorded in meter as the height of maximum hammer drop.

- The maximum compressive strength perpendicular to grain was determined from a polynomial linear regression model derived from the relationship between wood specific gravity and maximum compression strength parallel to the grain of *Triplochitonscleroxylon.* 88%.Variation of MCS// was accounted by specific gravity (Onilude and Ogunsanwo, 2002). The wood specific gravity was replaced by density values obtained from *Anogeissusleiocarpus*. The density value was converted to specific gravity value and then use to evaluate the predicted maximum compression strength.

$$MCS// = 2.01 + 5.29(D) + 185.14\,(D^2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots Equation\ 5$$

Where:

D = Density (Kg/m$^3$)

MCS//=Maximum compression strength parallel to the grain

## Experimental Layout and Data Analysis

The experimental design adopted for this study 5×3 nested design experiment in a randomized complete block design with (5) replicate of test samples for each variable that was measured. Analysis of variance was used to determine the effect of the sources of variation on the physical and mechanical properties of *Angeinossusleiocarpus* wood, pattern of variation of wood properties. Follow up test using least significant difference (LSD) was used to separate means where significant differences are observed. Correlation analysis was used to determine the relationship among the properties. These properties include: Moisture content, Density, Modulus of Rupture, Modulus of elasticity, Compression strength perpendicular to grain, Impact strength.

# RESULTS

## Physical Properties of *Anogeissusleiocarpus* Wood

### *Moisture Content*

The result of moisture content of *Anogeissusleiocarpus* showed a mean of 17.51% (Table 1). This values ranges from 17.40% to17.63% across radial position and 16.35% to18.90% along the axial direction (10%,30%,50%,70% and 90% of the merchantable height) of the trees. There was while no significant difference across the radial positions (inner wood, middle wood and outer wood) at 5% probability level. Although the mean value from Table 1 shows moisture content decreases from the outer wood (17.63%) to the inner wood (17.40%). This pattern of variation showed that moisture content varies significantly within trees especially along the bole (axial direction) while it remains constant across the bole (radial direction). *Anogeissusleiocarpus* has a low moisture content of approximately 18% which suggest its high tendency to reduce the activities of bio-deterioration agents such as fungi since high moisture content increases the susceptibility of wood to fast decay. In this study, the axial pattern of variation of moisture content decreases from base to the top following a similar trend as reported by Lausberg *et al* (1995) and similarly the radial pattern of variation as it decreases from inner to outer wood (Shupe *et al.*1995). The evaluated mean value of moisture content for *Anogeissusleiocarpus* indicate a remarkable mechanical property making it a suitable substitute for well-known commercially exploited timber species used for structural applications.

### *Basic Density*

Potential utilization of any timber species involves the consideration of wood density as it is a good indicator of strength and other properties of wood. Density is defined as the mass or weight per unit volume of wood. The mean basic density for the sample species is 762.90kg/m$^3$. The average value was higher than the previous finding by Ogunwunsi *et al.*, (2013) who reported the density to be 731kg/m$^3$. The mean values ranges from 754.45kg/m$^3$to 770.72kg/m$^3$across the radial position while its ranges from 712.69kg/m$^3$to 836.59kg/m$^3$ along the axial position. The radial pattern of variation of basic density in this study opposes the common pattern found in the young trees which increases from the inner to the outer wood (Akachuku, 1982). This is owing to the growth promoting substance arising from apical meristem with the crown of the younger tree than the cambium in older trees. However, this uncommon variation pattern observed in this study may have been attributed to the masking effect of the presence extractives acting to modify the effect of the wood anatomy as reported by Bamber and Burley, (1983). While the axial variation pattern follows the usual trend as density decreases from the base to the top of most tree species. The mean value of density of *Anogeissusleiocarpus* was greater than *Miliciaexcelsa, Cordiamillenii, Mansoniaaltissima, Khayaivorensis, Trilochitonscleroxylon,* and *Celtismildbredii* except for *Khayasenegalensis and Afzelia Africana.* Wood density being the mostly used wood quality indicator is related to other wood properties, such as timber strength and shrinkage, as well as other properties (Panshin and de Zeeuw 1980). This is attributed to the close relationship between wood density and cell wall thickness (Zobel and van Buijtenen 1989) that influences all other properties of wood.

**Table1.** *Mean value of selected physical properties of wood samples of A.leiocarpus along the axial and radia positions*

| Wood properties | Moisture Content | Density | Longitudinal Shrinkage | Tangential Shrinkage | Radial Shrinkage | Volumetric Shrinkage |
|---|---|---|---|---|---|---|
| **Axial Position** | | | | | | |
| 10% | 20.0021 | 836.587 | 0.3007 | 4.6739 | 5.0342 | 9.7081 |
| 30% | 17.2508 | 787.615 | 0.329 | 4.209 | 4.9033 | 9.1123 |
| 50% | 17.1026 | 739.448 | 0.3746 | 4.8384 | 4.8487 | 9.6871 |
| 70% | 16.2301 | 738.146 | 0.3646 | 5.3742 | 4.9385 | 10.3127 |
| 90% | 16.9456 | 712.691 | 0.3354 | 5.7567 | 4.4435 | 10.2002 |
| **Mean** | **17.5062** | **762.897** | **0.3409** | **4.9704** | **4.8336** | **9.8041** |
| **Radial Position** | | | | | | |
| Inner wood | 17.4034 | 770.719 | 0.2963 | 4.7548 | 4.9664 | 9.7212 |
| Middle wood | 17.4842 | 763.527 | 0.3503 | 4.9158 | 5.0033 | 9.9191 |
| Outer wood | 17.6311 | 754.446 | 0.376 | 5.2407 | 4.5312 | 9.7719 |
| **Mean** | **17.5062** | **762.897** | **0.3409** | **4.9704** | **4.8336** | **9.8041** |

### Mechanical Properties of *Anogeissusleiocarpus* Wood

Table 2 depicts the summary of the mean value of selected mechanical properties of wood samples of *Anogeissusleiocarpus* along the axial and radial position. The mechanical properties are Maximum compression strength (MCS), Modulus of Elasticity (MOE), Modulus of Rupture (MOR) and Impact Strength with pooled mean of 147.23N/mm$^2$, 19849.73N/mm$^2$, 108.98N/mm$^2$, and 28.36N/mm$^2$respectively.

The pooled mean for all the mechanical properties of wood samples at 10%, 30%, 50%, 70% and 90% merchantable height among the four trees species of *Anogeissusleiocarpus* varies and differs. The mechanical properties are Maximum compression strength (MCS), Modulus of Elasticity (MOE), Modulus of Rupture (MOR) and Impact Strength with pooled mean of 147.23N/mm$^2$, 19849.73N/mm$^2$, 108.98N/mm$^2$, and 28.36N/mm$^2$ respectively.

The mean for all the mechanical properties of wood samples varies along the radial position from inner wood towards outer wood among the four trees of *Anogeissusleiocarpus*. The means values of maximum compression strength decreases from the inner wood to outer wood while Modulus of Elasticity (MOE), Modulus of Rupture (MOR) and Impact Strength and increases from inner towards the outer wood respectively. The correlation result of the selected physical and mechanical properties of *Anogeissusleiocarpus* reveled the association between two wood properties both physical and mechanical alike. The selected physical and mechanical properties includes the moisture content, density, longitudinal shrinkage, tangential shrinkage, radial shrinkage, maximum compression strength parallel to grains, modulus of elasticity, modulus of rupture and impact strength (Table 2) .

**Table2.** *Summary of mean value of selected mechanical properties of wood samples of Anogeissusleiocarpus along the axial and radial positions*

| Wood properties | Max. Compression Strength | Modulus of Elasticity | Modulus of Rupture | Impact Strength |
|---|---|---|---|---|
| | | **Axial positions** | | |
| 10% | 160.545 | 18633.4 | 110.655 | 29.6863 |
| 30% | 152.27 | 20093.5 | 113.023 | 27.5034 |
| 50% | 142.694 | 19746.4 | 104.094 | 28.4956 |
| 70% | 143.249 | 19513.3 | 103.178 | 27.0272 |
| 90% | 137.367 | 19513.3 | 113.946 | 29.0909 |
| **Mean** | **147.225** | **19849.7** | **108.979** | **28.3607** |
| | | **Radial positions** | | |
| Inner wood | 148.778 | 19219.3 | 99.199 | 24.3126 |
| Middle wood | 147.409 | 19798.7 | 110.3 | 30.2657 |
| Outer wood | 145.679 | 20531.3 | 117.439 | 30.5038 |
| **Mean** | **147.289** | **19849.7** | **108.979** | **28.3607** |

### *Modulus of Elasticity (MOE)*

The results obtained from the Modulus of Elasticity of *Anogeissusleiocarpus* are evaluated in Table 2. The mean value of Modulus of Elasticity was 19849.73N/mm$^2$. The mean value ranges from 18633.40N/mm$^2$to 21262.08N/mm$^2$ at 10% and 30% merchantable height respectively along the axial positions. While at the radial position, its ranges from 9219.26N/mm$^2$ in the inner wood to 20531.27 N/mm$^2$ in the outer wood. In this study, the values along the radial direction follow a definite pattern as it increases from the inner wood to outer wood. This study shows inconsistency in the pattern along the axial direction as the mean value fall and rises. Ogunsanwo, (2006) reported that variation in MOE was most inconsistent of all the mechanical properties. The outstanding high MOE observed at 90% merchantable height is attributed to the dynamic nature of the crown region of trees. The wood obtained from the crown region is often fault finding for lumber because this zone is knotty. Since photosynthetic activities are predominant in this zone, its properties are influenced more compared with wood obtained from the lower bole. This report was similarly to that of Sanwo (1983) in his study on plantation- grown *T. grand is* in Nigeria. Across the radial position, increase in MOE from inner to outer wood was observed and this trend opposed what was reported by Ogunsanwo and Onilude (2000).

### *Maximum Compression Strength par (MCS)*

The maximum compression strength predicted mean value was 147.29N/mm$^2$. Along the axial position, the mean value of MCS ranged from 161.32N/mm$^2$ to 137.73N/mm$^2$ at 10% and 90% merchantable height respectively. While along the radial position, the mean value of MCS ranged from 145.68N/mm$^2$ (outer wood) to 148.78N/mm$^2$ inner wood) respectively. The Axial at 10% merchantable height with his corresponding radial position (inner wood) gives the highest mean of Maximum compression strength of 163.33N/mm$^2$.MCS varied consistently along the axial position of the *Anogeissusleiocarpus* tree as well as variation across the radial plane increased consistently from inner to outer wood. Table 5 shows that the result of analysis of variance for Maximum Compression Strength perpendicular to grains (MCS) of *Anogeissusleiocarpus* wood samples which show a significant difference along the axial positions and across the radial positions, while there were no significant differences in the interaction between axial and radial positions at 5% probability level. The predicted maximum compression strength from the regression equation was superior to other timber species as the mean value was greater than its compared timber species in this study.

### Impact strength

The results obtained from the impact strength of *Anogeissusleiocarpus* are evaluated in Table 2.

The mean value of Modulus of Rupture was 28.36 N/mm$^2$. The value along the axial plane ranges from 27.03N/mm$^2$ to 29.69N/mm$^2$ at 70% and 10%% merchantable height respectively. While at the radial position, its ranges from 24.31 N/mm$^2$ in the inner wood to 30.50 N/mm$^2$ in the outer wood. In this study, the values along the radial direction follow a definite pattern as it increases from inner wood to outer wood. This study shows inconsistency in the pattern along the axial direction fall and rise. The result in the analysis of variance reveals that there is significant difference between the radial position, while there was no significant difference with the axial positions and the interaction between of axial and radial positions at 5% probability level.

Table 5reveals the post mortem of impact strength across the radial positions trees at 5% probability level and this shows that there was no significant different in the mean value of the impact strength between the middle and outer wood. Both have the highest impact strength and therefore any wood from this radial position will be of excellent use for floor works since impact bending is the ability of wood to absorb shocks that result into stresses that exceed proportional limit.

**Table3** *Correlations result for the selected physical and mechanical wood properties of Anogeissusleiocarpus*

| | MC | Density | MCS | MOE | MOR | Impact Strength. |
|---|---|---|---|---|---|---|
| **MC** | 1 | | | | | |
| **Density** | 0.618* | 1 | | | | |
| **MCS** | 0.618* | 1.000* | 1 | | | |
| **MOE (N/mm^2** | -0.394* | -0.421* | -0.421* | 1 | | |
| **MOR(N/mm^2** | -0.085 | -0.025 | -0.025 | 0.500* | 1 | |
| **Impact Strength** | 0.134 | 0.215* | 0.215* | -0.129 | 0.089 | 1 |

**Note:** *MC = Moisture content, Density, MCS//-Maximum compression strength perpendicular to the grain, MOE- Modulus of elasticity , MOR-Modulus of rupture and impact strength*

** Correlation is significant at 0.05 levels (2-tailed)*

## *Correlation*

Result of the simple correlations analysis explains the strength of the linear relationship among the wood properties of *Anogeissusleiocarpus*. According to Lowe (1981) and Ogunsanwo (2000), wood behavior is attributed to the interactive effect of different inherent properties of wood. In this study, it was however observed that the result obtained follow suit according to the correlation analysis. It was noticed that some physical properties has strong linear relationship with some of the mechanical properties. This include the significant linear relationship with moisture content and impacts strength, density and Modulus of Elasticity, volumetric shrinkage and modulus of elasticity. The moisture content was positively significantly correlated with impact bending strength although this relationship is weak with a correlation co-efficient (r) of 0.134 at 5% probability level. Similarly there was a positive significant linear relation between volumetric shrinkage and impact bending strength with a correlation coefficient (r) of 0.222 at 5% probability level. However, it was observed that there was a negative significant linear relationship between density and Modulus of Elasticity and between volumetric shrinkage and Modulus of Elasticity with correlation coefficient (r) of 0.352 and 0.333 respectively at 5% probability level. The physical properties equally shows similar trend as there was a significant linear relationship among the measured variables. The results shows that the moisture content Furthermore there was a strong significant positive linear relationship between volumetric shrinkage and radial as well as between volumetric and tangential shrinkage with correlation coefficient (r) of 0.704and 0.732 respectively at 5% probability level.

## *Comparison of Anogeissusleiocarpus Physical and Mechanical Properties with other Species*

The physical properties of *Anogeissusleiocarpus* when compared with other timber species compete favorably. The mean value of density of *Anogeissusleiocarpus* was greater than *Miliciaexcelsa, Cordiamillenii, Mansoniaaltissima, Khayaivorensis, Trilochitonscleroxylon,* and *Celtismildbredii* except for *Khayasenegalensis and Afzelia Africana*. Wood density being the mostly used wood quality indicator is related to other wood properties, such as timber strength and shrinkage, as well as other properties (Panshin and de Zeeuw 1980). This is attributed to the close relationship between wood density and cell wall thickness (Zobel and van Buijtenen 1989) that influences all other properties of wood. The volumetric shrinkage of *Anogeissusleiocarpus* was lesser when compared with *Miliciaexcelsa, Celtismildbredii* and *KhayaIvorensis.* Although it's wood density mean value is greater than these two timber species but beside the strong correlation of density with volumetric shrinkage other wood factors could have equally have influence. This wood factor includes the fibrillarangle on the S2 layer (Bektaş and Güler, 2001). However, the most important variable affecting wood shrinkage is the wood density (Guler *et al*. 2007).

Table 4 shows the comparison of mean value of *Anogeissusleiocarpus* density and mechanical properties namely Modulus of Rupture (MOR), Modulus of Elasticity (MOE), Maximum compression strength (MCS) and Impact strength with other species namely *Anigeriarobusta, Miliciaexcelsa,. Cordiamillenii, Mansoniaaltissima, Khayasenegalensis, Afzeliaafricana, Khayaivorensis, Trilochitonscleroxylon and Celtismildbredii.*

**Table4.** *Comparison of mean value of Anogeissusleiocarpus density and mechanical properties with other species*

| Tree Species | Wood properties | | | | |
|---|---|---|---|---|---|
| | Density(kg/m$^3$) | MOR (N/mm$^2$) | MOE (N/mm$^2$) | MCS (N/mm$^2$) | IS (N/mm$^2$) |
| **Anogeissusleiocarpus** | 763 | 108.98 | 19850 | 147.29 | 28.36 |
| **Miliciaexcelsa**[a] | 600 | 83.3 | 7910 | 55.09 | NA |
| **Cordiamillenii**[b] | 400 | 76.1 | NA | 39.1 | NA |
| **Mansoniaaltissima**[a] | 660 | 110 | NA | 60 | NA |
| **Khayasenegalensis**[a] | 780 | 86 | 8120 | 54 | NA |
| **AfzeliaAfricana** [c] | 823.81 | 136.71 | 6313.58 | NA | NA |
| **KhayaIvorensis**[c] | 525.83 | 94.82 | 8192.54 | NA | NA |
| **Triplochitonscleroxylon** [c] | 372.46 | 30.87 | 3937.5 | NA | NA |
| **Celtismildbredii**[c] | 732.32 | 149.94 | 7088.69 | NA | NA |

**Sources:** *a = CIRAD (2009), b = Chudnoff (1980) c = Jamala, et al., (2013),*

*MOR = modulus of rupture, MOE = modulus of elasticity, MCS = maximum compression strength parallel to grain, IS = Impact strength. N.A= Not Available*

**Table5.** *Analysis of variance of Moisture content, Density, Modulus of rupture, modulus of Elasticity, Maximum compression strength and Impact strength*

| Source | DF | SS | Mean Square | F | p-value |
|---|---|---|---|---|---|
| | | | **Moisture content** | | |
| **Axial** | 4 | 1008.06 | 252.016 | 23.1 | 0.0001* |
| **Radial** | 2 | 5.32993 | 2.66496 | 0.24 | 0.7834ns |
| **Axial*Radial** | 8 | 64.9293 | 8.11616 | 0.74 | 0.6527ns |
| **Error** | 585 | 6382.73 | 10.9107 | | |
| **Total** | 599 | 7461.06 | | | |
| | | | **Basic density** | | |
| **Axial** | 4 | 1166913 | 291728 | 75.36 | 0.0001* |
| **Radial** | 2 | 26599.8 | 13299.9 | 3.44 | 0.0329* |
| **Axial*Radial** | 8 | 15602.2 | 1950.27 | 0.5 | 0.8538ns |
| **Error** | 585 | 2264687 | 3871.26 | | |
| **Total** | 599 | 3473802 | | | |
| | | | **Modulus of Rupture** | | |
| **Axial** | 4 | 3648.68585 | 912.17146 | 1.08 | 0.3663ns |
| **Radial** | 2 | 10137.63179 | 5068.81589 | 6.02 | 0.003* |
| **Axial*Radial** | 8 | 2941.7623 | 367.72029 | 0.44 | 0.8976ns |
| **Error** | 165 | 138878.8101 | 841.6898 | | |
| **Total** | 179 | 155606.8901 | | | |
| | | | **Modulus of Elasticity** | | |
| **Radial** | 51876108 | 2 | 25938054 | 2.159 | 0.120ns |
| **Axial (Radial)** | 2.25E+08 | 8 | 28136370 | 2.342 | 0.022* |
| **Error** | 1.44E+09 | 120 | 12013954 | | |
| **Total** | 7.47E+10 | 180 | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Max. Compression Strength** | | | | | |
| **Axial** | 4 | 42316 | 10579 | 75.36 | 0.0000* |
| **Radial** | 2 | 965 | 482 | 3.44 | 0.0328* |
| **radial(axial)** | 8 | 566 | 71 | 0.50 | 0.8538ns |
| **Error** | 585 | 82126 | 140 | | |
| **Total** | 599 | 125973 | | | |
| **Impact strength** | | | | | |
| **Axial** | 4 | 115.720535 | 28.930134 | 0.19 | 0.9454ns |
| **Radial** | 2 | 984.373031 | 492.186516 | 3.16 | 0.0466* |
| **Axial (Radial)** | 8 | 1209.372581 | 151.171573 | 0.97 | 0.4637ns |
| **Error** | 105 | 16368.15023 | 155.88715 | | |
| **Total** | 119 | 18677.61637 | | | |

## Conclusion

The density, Modulus of Rupture (MOR), Modulus of Elasticity (MOE) and Maximum compression strength (MCS) of *Anogeissusleiocarpus* falls within the range of the mean value according to the mentioned estimated wood properties of this class of timber species. Generally, the Modulus of elasticity (bending strength) of *Anogeissusleiocarpus* was more superior than *Afzelia Africana* and *Celtismildbredii* which have possess superior carrying capacity (MOR) as the mean value was greater to other compared timber species. This implies that when under higher load, *Anogeissuusleiocarpus* will not suddenly fails because of its nature of elastic ability to resist plastic deformation when compared to the mention timber species. The predicted maximum compression strength from the regression equation was equally superior to other timber species as the mean value was greater than its compared timber species in this study.

## Recommendation

Further research work should be carried out on other physical properties such as shrinkage and swelling more awareness should be provided as regards the Information on the wood quality to appropriate stakeholders in the wood industries.

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