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EVALUATION OF SELECTED MECHANICAL PROPERTIES OF *ARTOCARPUS ALTILIS* WOOD, (PARKINSON EX F.A. ZORN) FOSBERG GROWN IN SOUTHWESTERN NIGERIA

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ABSTRACT: Nigeria population has steadily increased to the point that it had led to a dwindling natural forest resources because of demand for wood products. The utilization of lesser-used species (LUS) will contribute to efficient forest management and utilization of tropical forest. A recent survey in the south west of Nigeria timber market shows good representation of *Artocarpus altilis* as emerging species. Four matured trees (dbh: 40-50cm; age: 45-55years) were randomly selected and sampled at 10%, 50% and 90% along the stem height and radially (corewood, innerwood and outerwood). Test samples dimensions for shear (20x20x20) mm, and modulus of rupture, modulus of elasticity, Impact bending strength, and maximum compressive strength parallel to grain (20x20x300) mm were obtained and oven dried at 103±2°C in Gallemp Oven to about 12% moisture content following ASTM standards. Flexural and tensile properties such as MOR, MOE, IM, MCS// and Shear strength were evaluated. Data collected were subjected to Analysis of Variance. MOR and MOE mean values were highest at the base 42.1±8.8, 3993±512.24 and least at the top 32.9±5.4, 3145±520.4, but decreased from corewood 37.6±1.9, 3630.1±555.5 to outerwood 36.6±7.2, 2986.0±410.6. Impact bending mean values increased from base 14.3±3.9, to top 16.5±4.0 and varied from 14.5±3.1 (corewood) to 17.6±4.4 (outerwood). Shear strength and MCS// mean values decreased significantly from base 9.7±1.7, 23±4.1 to the top 8.5±0.9, 18±2.7 and from corewood 10.8±1.4, 22.5±2.5 to outerwood 8.5±1.1, 18±3.6, respectively. *A. altilis* could be classified as a timber for light construction based on MOR and MOE values. The significance found between the trees demonstrates the possibility of selection and improvement for increased wood quality. This study provides base line information on utilization potentials and wood quality of *A. altilis*. Thus, the wood is suitable for furniture industry and some building applications.

Keywords: *Artocarpus altilis*, modulus of rupture, modulus of elasticity, Impact bending strength, lesser used species

1. INTRODUCTION

Demand for various forest products an especially timber product has a direct effect on population growth, urbanization, industrialization and economic development (Shakhes *et al.*, 2011, Izekor, 2010). Natural forest has been resource based and an important source of wood supply for the Nigerian population (Food and Agriculture Organization, 2001, Fuwape and Fabiyi, 2003). Steady increase in

population growth in Nigeria has led to the demand for wood products and this situation has led to a dwindling of the natural forests. Despite shrinkage of the natural forests, demand for quality timber is still on the increase. Thus, increasing logging activity on the already lean forest in spite of government regulations imposed, as well as restrictions advocated for by environmentalist in preserving the world's existing forests (Cherdchim *et al.*, 2004). Although, Nigeria is blessed with over 100 timber species that are being

utilised for structural and non-structural purpose as well as furniture making, many of these timber species are becoming scarce and endangered. The few and well known once available in the plank market are usually expensive and in high demand due to their multipurpose uses.

The demand for preferred species and their popularity is borne out of their mechanical, durability and aesthetics properties. Consequent upon these, they have been over-exploited and their survival threatenend in the Nigeria forest. According to Ogunsanwo, *et al.*, (2006) reported that juvenile or immature wood were characterized with large proportion of sapwood that is not durable compared with matured timber of the same species. Meanwhile, lesser-known wood species which are readily available could also performed the functions this choice timber species have been utilized for (Zziwa *et al.*, 2012).

The demand for forest products and services in Africa is growing rapidly, due to population growth and an expanding economy, while by 2030, it was reported that the domestic demand for round-wood by wood industries may become twice or even triple from the annual level of 96.2 million m³.(United Nations Environmental Programmer,2015). Again, undue pressure and encroachment of other sectors on forests areas, may contributes to deforestation and unsustainable exploitation culminating into loss and a diminishing of biodiversity. Moreover, increasing demand for and inconsistent supplies of choice timber species in several developing countries will continue, thus it is important to promote the lesser-used species (LUS) to complement the traditional species. Utilization of LUS may contribute to efficient utilization of the tropical forest and sustainable forest management (Poku *et al.*, 2001). The long rotation periods of the choice species coupled with enormous demand and persistent scarcity, has led to the felling of lesser-known wood species such as fruit trees like *Artocarpus altilis* and *Mangifera indica* as alternative to the expensive ones. Lucas *et al.* (2006), reported the use of Guava branches (*Psidium guajava* L.) for truss in Nigeria. These tree crops that are often established for fruit and related use often outlive their purpose after several years of exploitation. These species are sometimes used in agroforestry systems, which provide the locals with fruits supply and domestic fuelwood (FAO, 2001).

Promoting the use of LUS to provide a potential alternative to the endangered known wood species is imperative as possible alternatives. The term “lesser-used species” (LUS) does not imply wood species that are not known but are currently not commonly exploited for utilization. Barany *et al.*, (2003), describes it as “other” timber species which does not belong to the traditional species commonly harvested such as *Milicia excelsa*, *Entandrophragma* species,

Triplochiton scleroxylon, *Azelia africana*, *Nesorgordonia papaverifera*, *Terminalia ivorensis*, *Lovoa trichloides*, etc.

A. altilis a lesser-used species belonging to the family moraceae which does not belong to the class of the commercially known wood species. The species is popular as an agroforestry species planted as a fruit tree and a recent survey of timber market in the southwest zone of Nigeria shows good representation as an emerging species. Hence, adequate knowledge on the wood physical and tensile properties are imperative with the view of promoting *A. altilis* as alternative to traditional timber.

2. MATERIALS AND METHOD

Four trees were purposively selected based on the absence of reaction tendencies, fairly straight and free from natural defects as well as excessive branch; the selected trees were identified and harvested from farmlands locate at Ibusogboro, Onigambari in Oyo State. Age of the trees were considered based on the farmer’s information, noting from when the farmland was being cultivated and growth ring counted immediately after felling to complement information being provided by the farmers. Diameter sizes of trees to fell were equally considered and trees falls within diameter class 150cm to 250cm were selected. These trees fell within the age brackets of trees with more years of stands within the farmlands. Merchantable trees that met the criteria above were felled and cross-cut at 10%, 50% and 90% of the felled trees (i.e., butt, middle-stem and top-stem). 500mm long bolt were collected at the three different positions making a total of 12 bolts. The bolts were further processed at the Wood processing workshop of the Department of Forest Products and Production, University of Ibadan.

2.1 Sample Preparation

Test samples were taking from the Central planks obtained from all the bolts to give 12 planks, because the strength properties of trees decrease from pith to bark and increases from top to bottom of the trees. Thus, central plank is expected to represents the maximum strength of any dicotyledonous trees as against monocotyledon trees. The central planks were sectioned into 6 equal parts from bark to bark, to account for wood portion in the region of outerwood, innerwood and corewood as shown in figure 1. This is in line with standard practice of delineating wood portion radially to evaluate the progressive increase or decrease in their strength properties (Ogunsanwo, *et al.*, 2001). Section 1 and 6 represented the outerwood, 2 and 5 the innerwood while 3 and 4 represented corewood portion as shown in figure 1. Samples for strength properties test were further dimensioned into required standard from the wood portion according to ASTM1413-1983.

Three hundred and sixty (360) samples were apportioned each for the following strength tests: MOR, MOE, Compression strength// to grain, impact bending and shear strength as shown in Table 1. Samples 20mm by 20mm by 300 mm were set aside for MOR, MOE and impact bending strength, while 20mm by 20mm by 60 mm were set aside for compression strength// to grain and 20mm by 20mm by 20mm were set for shear strength. The central planks were further sectioned into

six (6) equal portions from bark to bark. Section 1 and 6 represent the outerwood portion, 2 and 5 represent the innerwood, 3 and 4 represent the corewood portion as shown on (Plate 1). Specific sample for the determination of the wood properties were dimension following ASTM1413 - 1983 standards. Samples were then oven dried at the beginning from 60°C and gradually increased to 103°C until 12% moisture content were achieved.

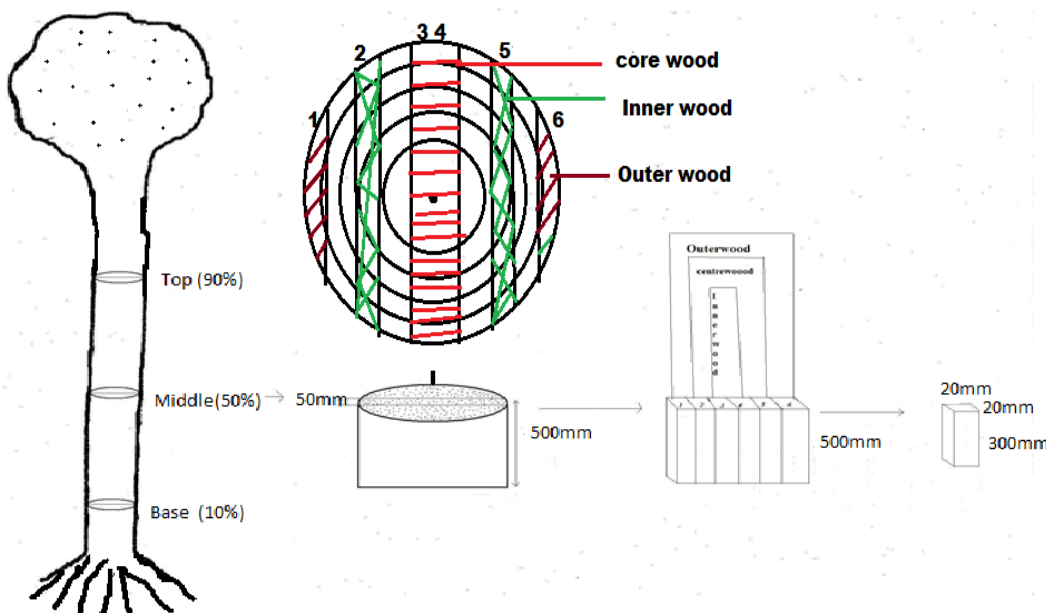


Figure 1: Schematic Sampling Procedure for obtaining test samples for Physical and Mechanical Properties

Table 1: Allocation of wood test samples

| Test | Sample Size | No of Samples |
|---------------------------------|---------------------|---------------|
| MOR | 20mm x 20mm x 300mm | 360 |
| MOE | 20mm x 20mm x 300mm | 360 |
| Compression strength// to grain | 20mm x 20mm x 60mm | 360 |
| Impact bending | 20mm x 20mm x 300mm | 360 |
| Shear strength | 20mm x 20mm x 20mm | 360 |

Strength properties parameters

2.2 Determination of Tensile (MOR) and Flexural Properties (MOE)

The sample dimension required for this test was a clear sample of dimension 20 × 20 × 300 mm as described in the ASTM designation D1037-94 (1994). 90 test samples were obtained from each tree, making a total 360 samples each for MOR and MOE were mounted and determined on the Universal Computer Control Tensile Testing Machine (WDW-20 Class:1) located at the Department of forest products development and Utilization, FRIN, Ibadan, load was applied and progressive additional load of weight were being added until failure occurred load at failure was recorded and the corresponding MOR and MOE were recorded. The

corresponding PC values were taken directly from the machine.

The MOR was calculated using equation according to ASTM designation D1037-94 (1994).

$$MOR = \frac{3PL}{2bd^2} \dots \dots \dots eq. 1$$

Where; MOR Modulus of rupture in N/mm², P = load at some point below the proportional limit (N), L =distance between supports for the beam (mm), b= beam width (mm), d = thickness (depth) (mm)

While, according to Pansin and Dezeeuw, (1980) describe Modulus of Elasticity as resistance ability to stiffness of a beam or other wood member. This is a

material's capacity to restore its original shape and size when stressed, while (Desch, 1988) stated that the ability of a wood member to bend freely and regain normal shape is called flexibility and the ability to resist bending is called stiffness. The MOE was calculated using the equation according to ASTM designation D1037-94 (1994).

$$MOE = \frac{PL^3}{4bd^3 \Delta} \dots \dots \dots eq. 2$$

Where: P = load at some point below the proportional limit (N), L = distance between supports for the beam (mm), b = beam width (mm), d = thickness (depth) of the beam (mm) and Δ = deflection Delta (Δ) which is the deflection of beam center at proportional limit,

2.3 Determination of Maximum Compressive Strength (MCS//) parallel to grain

The (MCS//) test were carried out using wood samples of 20mm x 20mm x 60mm. Ninety (90) test samples were obtained per central plank out of which 10 per wood zone were used for the test MCS// totaling 360 samples. Samples were mounted on the Universal Computer Control Tensile Testing Machine (WDW-20 Class: 1) located at the Department of forest products development and Utilization, FRIN, Ibadan.

The MCS// load at failure were recorded and the corresponding PC values were taken directly from the machine. The values obtained were used to calculate the compressive strength using the equation below, according to ASTM designation D1037-94 (1994).

$$MCS// = \frac{P_{max}}{A} N/mm^2 \dots \dots \dots eq. 3$$

Where; P_{max} = maximum load to failure (N) and A = sectional area of test sample (mm)

2.4 Determination of Impact bending strength

Impact bending is widely used as an indication of toughness of wood material. The impact-bending test was carried out using the Hatt-Turner Impact Testing Machine at the Department of Forest Product Development and Utilization, Forestry Research institute of Nigeria, Ibadan; following British Standard BS 373 (1957). Standard test specimen 20 x 20 x 300mm were supported over a span of 240mm, on a support radius 15mm, spring restricted yokes are fitted in order to arrest re-bounce. This was then subjected to a repeated blow from a weight 1.5kg at increasing height of 50.8mm, and then every 25.4mm until failure occurred. The maximum distance of hammer drop was read, and recorded directly from the impact-bending

machine and calculated as shown in the equation below, according to ASTM designation D1037-94 (1994).

$$IM = \frac{w}{A} = \frac{fxd}{bxd} \dots \dots \dots eq. 4$$

Where, IM = Impact work (J/m²), d = distance of hammer drop, W = Work-done, b = length of sample, A = area of the samples, d = depth of sample and F = weight of the hammer

2.5 Determination of Shear Strength Properties

Shear strength attributes refer to the capacity of wood to resist internal sliding of one portion over another against the grain. Three hundred and sixty (360) 20x20x20mm test specimens were obtained for each of the four trees from the central planks collected at each sampling level. Specimens were tested radially from bark to bark from each sampling level for each sample location in compliance with British Standard BS 373 (1957) for measuring small and clear timber samples. The maximum shear strength property was calculated using the equation below; according to ASTM designation D1037-94 (1994).

$$\text{Shear} = \frac{P}{bd} \dots \dots \dots eq. 5$$

Where, P = Load in Newton, b = width in mm² and d = depth in mm²

3. RESULTS

3.1 Modulus of Rupture (MOR)

The overall mean of modulus of rupture of *A. altilis* is 36.05± 8.32N/mm², with the average range value between 42.07±8.79N/mm², 33.11±7.12N/mm² and 32.99±5.39N/mm² for base, middle and top respectively. This shows that modulus of rupture increases from base to the top, while it ranged between 37.64±1.98N/mm² to 46.81± 4.04N/mm² from corewood to outerwood across the bole at the base. From 28.54±7.14N/mm² to 39.10±2.92N/mm² corewood to outerwood across the bole at the middle and 30.41±2.75/mm² to 36.58±7.23N/mm² from corewood to outerwood across the bole at the top (Table 2). The analysis of variance in Table 3 shows that MOR between the trees, along sampling height as well as radial position was significantly different; however, the radial position did not significantly affect the sampling height of *A. altilis* and there is no significant effect of radial position on sampling height of *A. altilis* wood ($p=0.9467$) at 0.05% probability level. Duncan Multiple ranged Test (DMRT) at 0.05% probability level shows that the MOR at the base, middle and top is significant along the sampling height as shown in Table 2.

Table 2: The mean MOR, MOE, MCS//, Impact and Shear test values for sampling position and radial location of *A. altilis* Wood

| Sampling Height | Radial Position | MOR (N/mm ²) | MOE (N/mm ²) | Impact (J/m ²) | Shear (N/mm ²) | MCS// (N/mm ²) |
|-----------------|-----------------|--------------------------|------------------------------|----------------------------|----------------------------|----------------------------|
| Base | Corewood | 37.64±1.98 ^c | 3526.61±604.28 ^c | 12.92±4.55 ^c | 9.1±0.8 ^b | 22.5±2.5 ^a |
| | Innerwood | 41.76±7.68 ^b | 4822.25±376.95 ^a | 15.50±2.37 ^a | 9.3±1.8 ^b | 22.5±5.3 ^a |
| | Outerwood | 46.81±4.04 ^a | 3630.06±555.49 ^b | 14.52±3.06 ^{ab} | 10.8±1.4 ^a | 22.5±3.3 ^a |
| Pooled Mean | | 42.07±8.79 | 3992.97±512.24 | 14.31±3.92 | 9.7±1.7 | 23±3.7 |
| Middle | Corewood | 28.54±7.14 ^c | 2707.50±407.01 ^b | 13.89±1.83 ^{ab} | 8.0±1.6 ^c | 18.5±3.1 ^c |
| | Innerwood | 31.69±6.50 ^b | 2923.96±692.67 ^{ab} | 18.61±4.12 ^a | 9.0±2.1 ^b | 19±1.9 ^b |
| | Outerwood | 39.10±2.92 ^a | 3140.24±308.39 ^a | 14.63±4.60 ^b | 9.3±2.1 ^a | 21±2.7 ^a |
| Pooled Mean | | 33.11±7.12 | 2923.89±493.25 | 15.70±4.39 | 8.7±2.1 | 20±2.7 |
| Top | Corewood | 30.41±2.75 ^c | 3344.18±637.01 ^a | 15.86±3.04 ^c | 8.4±0.7 ^b | 18±3.6 ^b |
| | Innerwood | 31.98±3.98 ^b | 3105.32±549.52 ^b | 16.10±3.99 ^{ab} | 8.7±1.2 ^a | 18±2.9 ^b |
| | Outerwood | 36.58±7.23 ^a | 2986.02±410.64 ^c | 17.64±4.42 ^a | 8.5±1.1 ^b | 19±1.7 ^a |
| Pooled Mean | | 32.99±5.39 | 3145.17±520.37 | 16.53±4.04 | 8.5±0.9 | 18±2.7 |
| Mean | | 36.05±8.32 | 3354±1286 | 15.51±4.17 | 8.9±1.7 | 20±3.7 |

Means±Standard mean error for 5 samples repeated. Values in and column of the same alphabet are not substantially different at alpha = 0.05 using the multiple range test Duncan

Table 3: Analysis of Variance of means for MOR, MOE, Impact, Shear, and MCS//across the sampling position and radial direction of *A. altilis* wood.

| Source of variation | Df | MOR | MOE | Impact | Shear | MCS// |
|---------------------|----|----------------------|----------------------|----------------------|----------------------|----------------------|
| Tree | 3 | 0.0005* | 0.0011* | 0.000* | 0.7856 ^{ns} | 0.0000* |
| Sampling Height | 2 | 0.0001* | 0.0001* | 0.081 ^{ns} | 0.0021* | 0.0001* |
| Major Plot Error | 6 | | | | | |
| Radial position | 5 | 0.0001* | 0.9011 ^{ns} | 0.003* | 0.1305 ^{ns} | 0.7742 ^{ns} |
| SH* RP | 10 | 0.9467 ^{ns} | 0.927 ^{ns} | 0.6811 ^{ns} | 0.3405 ^{ns} | 0.7182 ^{ns} |
| Sub-Plot Error | 45 | | | | | |
| Total | 71 | | | | | |

ns= not significant (p-values > 0.05), * = significant (p-values < 0.05)

3.2 Modulus of Elasticity (MOE)

The overall mean of MOE at 12% M.C. is 3354±1286N/mm², with the average value 3993±1983N/mm², 2924±493N/mm² and 3145±520N/mm² for base, middle and top respectively (Table 2). This shows that MOE decreases from base to the middle, and increase from middle to the top. The result in Table 2 also shows that MOE ranged between 3526.61±604.28N/mm² to 3630.06±555.49N/mm² from core to outerwood across the bole at the base. 2707.50±407.01N/mm² to 3140.24±308.39N/mm² corewood to outerwood at the middle and 3344.18±637.01 N/mm² to 2986.02 N/mm² from core to outerwood at the top.

The Analysis of variance in Table 3 revealed an insignificant effect at the radial position and the interaction between sampling heights and radial positions on the MOE of *A. altilis* wood ($P=0.927$) at 0.05% probability level. Further test using Duncan Multiple Range Test (DMRT) at 0.05% probability level shows that the modulus of elasticity at the base, middle and top is significant along the sampling height as presented in Table 2.

3.3 Impact Bending Strength Test (IM) Parallel to the Grain

A cumulative mean impact bending test (with moisture content of 12 percent) of *A. altilis* wood was 15.51±4.17J/m², with an average value at the base of 14.31±3.92J/m², middle 15.31±4.39J/m² and top 1653±404J/m² (Table 2). This indicates that the strength of the impact bending rises from base to top, although it ranged from 12.92±4.55J/m² to 14.52±3.06J/m² from wood-core to wood-outer across the bole at the bottom. 13.89±1.83J/m² to 14.63±4.60J/m² wood-core to wood-outer across the bole at the centre, and 15.86±3.04J/m² to 17.64±4.42J/m² wood-core to wood-outer of wood trunk to the peak as shown in Table 2.

The variance analysis in Table 3 indicates a sampling direction and radial location are insignificant effect with the impact bending strength ($p=0.081$ and $p=0.003$) at a likelihood level of 0.05%. Further testing using Duncan Multiple Range Test (DMRT) at 0.05 percent likelihood stage reveals that the effect of bending strength across the sampling location at the bottom, centre and peak is important.

3.4 Shear Strength Test Parallel to Grain

The average mean shear strength (M.C. 12%) of *A. altilis* $8.9 \pm 1.7 \text{N/mm}^2$, with an average mean value of $9.7 \pm 1.7 \text{N/mm}^2$ at the base, $8.7 \pm 2.1 \text{N/mm}^2$ at the center and $8.5 \pm 0.9 \text{N/mm}^2$ at the peak as shown in (Table 2). This indicates a reduction in shear strength from bottom to peak, ranging from $9.1 \pm 0.8 \text{N/mm}^2$ to $10.8 \pm 1.4 \text{N/mm}^2$ from wood-core to wood-outer at the bottom, $8.0 \pm 1.6 \text{N/mm}^2$ to $9.3 \pm 2.1 \text{N/mm}^2$ from wood-core to wood-outer at the centre of the bole to wood-outer at the bottom, and $8.4 \pm 0.7 \text{N/mm}^2$ to $8.5 \pm 1.1 \text{N/mm}^2$ from wood-core to wood-outer across the trunk at the peak (Table 2).

The variance analysis in Table 3 indicates that the sampling direction had a substantial effect on *A. altilis* along the radial position ($p = 0.341$) at 0.05% likelihood level. Further testing with the Duncan Multiple Range Test (DMRT) indicates that the shear strength at the bottom, at the centre and peak across the sampling direction is significant

3.5 Maximum Compressive Strength Test (MCS//)

Mean compressive strength at (M.C. 12%) of *A. altilis* was $20 \pm 3.7 \text{N/mm}^2$, and average mean ranged from $23 \pm 4.1 \text{N/mm}^2$ at the base, $20 \pm 2.7 \text{N/mm}^2$ at the middle and $18 \pm 2.7 \text{N/mm}^2$ at the top. This indicates that the compressive strength decreases from base to top, ranging from $22.5 \pm 2.5 \text{N/mm}^2$ to $22.5 \pm 3.3 \text{N/mm}^2$ from wood-core to wood-outer at the base across the bole, $18.5 \pm 3.1 \text{N/mm}^2$ to $21 \pm 2.7 \text{N/mm}^2$ from wood-core to wood-outer at the center across the bole and $18 \pm 3.6 \text{N/mm}^2$ to $19 \pm 1.7 \text{N/mm}^2$ from wood-core to wood-outer at the tip across the bole as shown in Table 2.

The variance analysis in Table 3 reveals that the sampling height had a substantial effect on the maximum compressive force ($p=0.0001$) but had no significant influence on the compressive intensity of *A. altilis* along the radial position ($p=0.7742$). *A. altilis* wood with a chance level of 0.05 percent. Further test using the DMRT shows that the Compressive Strength along the sampling height is significant at the bottom, at the centre and at the peak.

Table 4: Timber species classification based on Density, MOE and MOR

| Classification | MOR (Nmm ²) | MOE (Nmm ²) | \bar{n} (kgm ³) |
|---|-------------------------|-------------------------|-------------------------------|
| Heavy construction | > 133 | > 14 | 700 - 720 |
| Medium construction | 89 - 1329 | 900-14,700 | 480 - 720 |
| Light Construction | 39 – 88 | 6860-9800 | 400 - 480 |
| Very low density (very light construction) | < 39 | < 6860 | < 400 |
| <i>Artocarpus heterophyllus</i> | 11 | 96378 | 458 |
| <i>Artocarpus altilis</i> (Present Studies) | 36 | 3354* | 581* |

Source: Kityo and Plumptre (1997).

*Values for present study

4. DISCUSSIONS

4.1 Modulus of Rupture

Strength is a very important wood property to be considered for load bearing applications of timber, especially structural uses. The strength of timber is commonly expressed as modulus of rupture. MOR is the measure of the ultimate short-term load carrying capacity is applied slowly on a piece of timber. The Modulus of rupture for *A. altilis* wood decreases from base to the top of the tree and increases from corewood to outerwood across the bole

MOR values generally decreased from base to the top. The MOR values obtained in this study compared with the values reported in literature, the observed decreased in MOR from base to top agrees with the report of Ogunsanwo (2000) and Jamala *et al.* (2013) for *Triplochiton scleroxylon*, Fuwape and Fabiyi (2003) on MOR values for *Nauclea diderichii*. MOR decreased from base to the top, this decrease in MOR agree with the Olayanu, *et al* (2022) which reported a mean MOR

value of 118.47N/mm^2 for *Bligha sapida*, Jamala, *et al.* (2013) mean value 30.87N/mm^2 for *Triplochiton scleroxylon* and Zziwa *et al.* (2012) mean value 119N/mm^2 for *Artocarpus heterophyllus*.

The pattern of variation of MOR values from base to top could be attributed to the normal and consistent stem of *A. altilis* tree. Haygreen and Bowyer, (1989) and Ogunsanwo (2000), reported that the increasing trend of MOR values from core to outerwood could be associated with variations in some morphological factors such as fibre length, fibre diameter and lumen width.

Fuwape and Fabiyi (2003) also gave this observation for the increasing trend of modulus of rupture from core to outerwood of *Nauclea diderichii* wood. Ogunsanwo (2000) observed an increase in MOR from pith to bark in *Triplochiton scleroxylon* and Quaking aspen wood. The morphology of wood fibres, especially the dimensions of wall-cell thickness on tracheid and lumen diameter influences wood mechanical properties consequently affecting the

processing and properties of lumber (Kibblewhite and Bawden, 1991).

The MOR of *A. altilis* value obtained compared favourably with *Triplochiton scleroxylon*, *Antiaris toxicaria* and *Alstonia boonei* or light construction works as common timber been used for furniture production in Nigeria. Hence, the mean MOR of *A. altilis* puts it in the light construction group. According to Kityo and Plumptre (1997), puts the mean MOR in the low-density category (Table 4). *A. altilis* timber could be categorized as a timber for light-medium construction based on the MOR and MOE values. The values show that the wood of *A. altilis* could be considered appropriate for use in the furniture industry. Analysis of variance for MOR showed the changes in sampling height, both radial positions and sampling height contributed significantly to its variation at 0.05 probability levels (Tables 4). Effect of interaction between Sampling height and radial position is not significant at 0.05 probability levels as shown in Table 3.

4.2 Modulus of Elasticity

The MOE values obtained in this study decreased from base to the middle and slightly increased from middle to the top (Table 2). MOE varied non-uniformly along the sampling height with a maximum value of 3993N/mm² recorded at 10% sampling height, and there was inconsistent pattern of variation in MOE. Generally, the trend in variations of MOE across the radial position showed a decrease from core to the innerwood and slightly increased to the outerwood (bark to bark). The observed non-uniformly trend in MOE is likely due to the variations in anatomical characteristics of the *A. altilis*. Similar trend in MOE was recorded in *A. heterophyllus* by Zziwa, *et al.* (2012) and Ali, *et al.* (2012), Blackwood (Machado, *et al.*, 2014), *Nauclea diderichii* (Fuwape and Fabiyi, 2003), *Triplochiton scleroxylon* (Ogunsanwo, 2000) and Slash Pine (Macpeak *et al.*, 1990).

MOE variation observed in this present study is consistent with that reported by other researchers. For example, Ishengoma and Nagoda (1991) observed that variations along the tree bole could be attributed to; decreasing uniformly, decreasing in the lower bole and increasing in the upper bole and increasing from base to top in a non-uniform pattern. Meanwhile, all tested parameters in this study varied non-uniformly and this further confirms wood is anisotropic in nature. According to Kityo and Plumptre (1997), puts the mean MOE in the low-density category (Table 1). Hence, MOE and MOR are the most important elastic properties; *A. altilis* timber could be classified as a timber for light construction based on the MOR and MOE values. This shows that the wood could be considered appropriate for use in the furniture industry.

Analysis of variance for MOE showed the changes in sampling height contributed significantly to its variation while at the radial position; the variation is not significant at 0.05 probability levels (Table 3). Effect of interaction between Sampling height and radial position is not significant at 0.05 probability levels.

4.3 Impact Bending Strength Test (IBS)

Impact bending strength properties mean of *A. altilis* was 15.51±4.17 J/m², with the value range between 14.31±3.92 J/m² at the base 15.31±4.39 J/m² at the middle and 16.53±4.04 J/m² at the top, while it ranged between 12.92±4.55 J/m² to 14.52±3.06 J/m² at wood-core to wood-outer along the bole bottom, 13.89±1.83J/m² to 14.63±4.60 J/m² wood-core to wood-outer across the bole centre and 15.86±3.04 J/m² to 17.64±4.42 J/m² at wood-core to wood-outer wood along the bole at the stem-top. This indicated that impact-bending strength rises consistently from bottom to the peak. This is similar to a research report in *Ficus Mucoso* (Adejoba, 2008), *Anningeria robusta*, (Ajala, 2005) and *Triplochiton scleroxylon*, (Ogunsanwo, 2000). It was observed that the IBS trend is the same at any sampling position of the wood.

Along the radial position, impact bending increased uniformly from corewood to outerwood, this behaviour of individual wood type shows that both corewood and outer wood varied consistently along the radial position bark to bark. These results corroborated the report of Moreira *et al.* (2017); Adedipe, (2004) and Ogunsanwo, (2000). Hence, the variance may be explained by the fact that wood is a natural substance and the tree is exposed to influences from ongoing changes in wood qualities, according to Green *et al.* (2003) and Emily *et al.* (2018).

4.4 Shear Strength Properties Test

In this present study, the mean values of the shear strength of *A. altilis* 8.9±1.7N/mm², and the mean ranged from 9.7±1.7N/mm² at the base, 8.7±2.1N/mm² at the middle and 8.5± 0.9N/mm² at the top. This reveals that shear strength rises from bottom to the tip. Radially, the means ranged from 9.1± 0.8N/mm² to 10.8±1.4N/mm² at wood-core to wood-outer along the bole at bottom, 8.0±1.6N/mm² to 9.3±2.1N/mm² wood-core to wood-outer along the bole at the centre and 8.4±0.7N/mm² to 8.5±1.1N/mm² at wood-core to wood-outer along the bole at the stem-top.

The shear test calculates the maximal shear stress of a material sliding along a plane parallel to the forces applied before failure occurs. Along the radial position, shear strength was uniformly increased from corewood to the outerwood of the *A. altilis* wood. This is line with the report in *Gmelina* (Sulaiman and Lim, 1989 and Mahmud, *et al.*, 2017).

4.5 Maximum Compressive Strength Properties Test (MCS//)

The mean compressive intensity of *A.altilis* was $20\pm 3.7\text{N/mm}^2$, and the average range from $23\pm 4.1\text{N/mm}^2$ at the base, $20\pm 2.7\text{N/mm}^2$ at the middle and $18\pm 2.7\text{N/mm}^2$ at the top. Radially, values ranged between $22.5\pm 2.5\text{N/mm}^2$ to $22.5\pm 3.3\text{N/mm}^2$ at wood-core to wood-outer along the bole at the bottom, $18.5\pm 3.1\text{N/mm}^2$ to $21\pm 2.7\text{N/mm}^2$ wood-core to wood-outer along the bole at the centre and $18\pm 3.6\text{N/mm}^2$ to $19\pm 1.7\text{N/mm}^2$ at wood-core to wood-outer along the bole at the top. MCS// was found to reduce from the wood base to the top-stem. Ogunsanwo (2000) also reported a related trend in *Triplochiton scleroxylon* and Beaudom *et al* (1989) in Tamarach. The trend may be as a result tree age and sampling height of *A. altilis*. Lausberg, *et al* (1995) also reported that genetic factors and growing condition may cause different variation.

Rulliaty and America (1995) and (Panshin and Dezeew 1980), reported that *Sweetenia macrophylla*'s cell wall thickness decreases from base to top because cell wall thickness regulates mechanical characteristics and the effect of felling stress on wood's attributes at the 90% merchantable height of the tree could be parallel to grain values, which could be responsible for the poor compressive strength recorded at the 90% MH of the tree bole. Across the bole, compressive strength properties values generally increased from pith to bark. Similar pattern was observed by Ogunsanwo (2000), that wood having between 80-90% from pith are homogenous and, this increase in compressive strength properties from pith to bark may be due to the cell wall development. Panshin and Dezeew, (1980) also corroborated that compressive strength properties have control on the tensile properties of wood.

5. CONCLUSION

The findings from the study have provided useful information as regard the potentials of *Artocarpus altilis* as a good alternative for known commercial timber species that are fast going into extinction due to several factors.

1. Based on the finding of this study, the following conclusions were drawn: in this present study, Modulus of Rupture (MOR) varied uniformly from the base to the top and decreased from the core wood to the outer wood but statistically significant along the sampling height and radial position. Modulus of Elasticity (MOE) varied non-uniformly along the sampling height; it decreased from base to the middle and slightly increased to the top, similarly across the radial position. This shows that the wood is suitable as raw materials in furniture industry.
2. Based on the conclusions drawn from this study, this wood possesses valuable potentials needed as

construction materials and as substitute for the commercial timber species. The under listed recommendations are expected to provide a guideline for future development and utilization of *A. altilis* in particular. This study has shown that this wood species is by no means inferior in quality; therefore, it is recommended for veneer and plywood production and low strength bearing application should be encouraged and promoted as this is expected to enhance continuous utilization in Nigeria.

3. Heavy structural and construction work should be done with *A. altilis* wood from the base due to its high strength values at that portion of the wood, which decrease gradually through the mid-log toward the crown-point.
4. Further research studies should be carried out to investigate the machining properties, gluability, drying schedules process of the wood and anatomical property of the wood.

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