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Evaluation of Selected Mechanical Properties of *Blighia sapida* K. Koenig Wood

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ABSTRACT— ***Over exploitation of economic tree species in the forest due to their high demand has made wood loggers shift their attention to Lesser Used Species such as Blighia sapida as alternative source of wood in Nigeria. The knowledge on the quality of the wood would to a long extent enhance the utilization of the wood. However, little information is provided on the mechanical properties of the wood species and the general belief among most wood users is that it is not a good timber species and that it cannot be utilized for any wood-based products that require strength. Therefore, investigating the mechanical properties of the timber species for better acceptability in the timber market becomes necessary.***

Three standing trees of Blighia sapida were purposively felled in the University of Ibadan community, Ibadan, Nigeria. 500 mm billets were gotten from wood dics at the top, middle, and base of the tree and each partitioned into three, the outerrwood, middlewood and the innerwood, in line with specified standard for each selected mechanical property test (Modulus of Elasticity, Modulus of Rupture, Impact bending strength, and Compressive strength parallel to grain) were all evaluated.

Modulus of rupture with mean value 118.47 ± 1.96 N/mm^2, ranged from 103.67 ± 3.42 to 144.26 ± 3.68 N/mm^2. Modulus of Elasticity with mean value 10649.99 ± 167.51 N/mm^2, ranged from 9237.14 ± 399.22 to 12877.35 ± 284.61 N/mm^2. Compressive strength parallel to grain with the average value 52.86 ± 0.81 N/mm^2, ranged from 42.88 ± 1.32 to 62.62 ± 1.65 N/mm^2. Mean impact bending strength was 28.05 ± 0.58 N/mm^2, ranged from 24.56 ± 0.86 to 35.09 ± 1.71 N/mm^2.

The average Modulus of Rupture and Modulus of Elasticity of Blighia sapida wood indicated that the wood falls within the category of medium construction strength timbers. The maximum compressive strength value for Blighia sapida wood revealed that it compared well with other economic tree species that are widely known for various structural

applications. Therefore, the general belief among wood users that it is not a good timber species and that it cannot be utilized for any wood-based product that requires strength is far from the truth. It can therefore be concluded that the timber can be used for some building constructions, sheeting and lining, furniture, carpentry, veneer wood production, cabinet work, and so on.

Keywords— Lesser Used Species, *Blighia sapida*, mechanical properties, wood products

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1. INTRODUCTION

Blighia sapida tree is a tropical hardwood species whose cultivation is known mainly for fruit production. It could also make a good timber species and compensate for scarcity and exorbitant prices of economic tree species in the timber market. *Blighia sapida* wood has been found useful in Imeko-Afon Local Government in Ogun State, Nigeria and other states in southwest Nigeria for general utility purposes [27]. It is particularly useful for utility furniture e.g., boxes, benches, stools, trading cabinet for petty traders etc. It has also been found useful in structural works, and medium strength constructions. The tree species is very easy to cultivate and can grow naturally as a result of the effects of agents of dispersal of the seed which are majorly birds and some other animals. Upon meeting favourable conditions wherever the seed is dispersed to, the seed germinate and then grow to tree size which is then felled by loggers in the natural forest when matured.

The strength of a timber is largely dependent on the species and the effects of certain growth features [32]. Various wood species are characterized by different strength properties, and these properties may also differ within the species. [20] stated that physical properties are the quantitative features of wood and its behavior in the presence of external factors other than applied forces. An in-depth knowledge of the physical properties of wood is important since they determine the strength property of the wood as well as the performance of wood used for structural purposes. The ultimate resistance of a material to applied loads is defined by its strength qualities. The strength of wood varies a lot depending on the species, the loading condition, the load duration, and a variety of other material and environmental factors [20]. Mechanical properties are a material's intrinsic characteristics in response to external forces. These include elastic properties, which determines resistance to distortion and deformation, as well as strength properties which determines resistance to applied loads [31].

Mechanical properties are usually the most important characteristics of wood products to be used in structural applications [18]. Testing wood and timber products is most commonly done in order to determine their ultimate or breaking strength in tension, compression, and flexure [23]. Wood that is subjected to mechanical testing is used in the construction, furniture and various wood-based products manufacturing industries. The measured strength properties of the wood and timber materials will to a long extent predict and determine if the wood is an acceptable candidate for a specific end use or not.

However, the dearth of information on the mechanical properties of *B. sapida* wood which would better depict the strength properties is a constraint to its acceptability for various end-uses. Few wood users that have used the species are of the opinion that the wood is a good timber species most especially for wood products that require medium density but the general belief among most wood end users and plank sellers is that the tree species is not a good timber species and cannot be utilized for any wood-based product that requires strength, but the insinuation has not been proved scientifically. This research work was done to evaluate the selected mechanical properties of *B. sapida* wood as a lesser used timber species to provide technical information on its mechanical properties as well as proffer possible utilization potentials, as an alternative to the economical wood species and for better acceptability in the timber market.

2. METHODOLOGY

2.1 Sampling Strategy

The wood samples used in this study were obtained within the campus of University of Ibadan, Nigeria. Property tests were carried out in Forestry Research Institute of Nigeria (FRIN), Nigeria. Matured trees (three) of *B. sapida* were felled, delimbed and crosscut at the merchantable height. 500 mm long bolts were obtained at three positions (base (10%), middle (50%) and the top (90%)) along the merchantable length of each tree [28,30]. A centre plank of 500 mm long was obtained from each bolt, and the radial length was partitioned into innerwood, middlewood and outer wood i.e., from the pith to the bark for all the properties tested following the sample dimension used by [25].

2.2 Preparation of Wood Samples

All sample demarcations, i.e., the base, middle, and top bolts extracted from the sampled trees, were cut into test samples of 500 mm long centre planks, which were then reconverted to various dimensions needed for the property tests.

The wood samples were processed to dimensions of 20 mm x 20 mm x 300 mm for modulus of elasticity, modulus of rupture, and impact bending strength as well as 20 mm x 20 mm x 60 mm for maximum compressive strength (MCS) parallel to grain using circular machine and plane machine, and in accordance with [13]. The following is a list of the selected wood indices and the number of test samples they correspond to:
Mechanical properties: 45 test samples were obtained from each tree, 135 samples each for Modulus of elasticity and Modulus of rupture, 135 each for Maximum Compressive Strength (MCS) parallel to grain and impact bending strength to make a total of 540.

2.3 Determination of Modulus of Rupture (MOR)

The static bending tests were carried out in accordance with [13]. A standard test specimen of 20 mm x 20 mm x 300 mm was employed, using a universal testing machine. The peak and breaking force of each sample were recorded after which Modulus of Rupture (MOR) was calculated using the formula below:

$$MOR\left(\frac{N}{mm^2}\right) = {}^{3PL}/_{2bd^2} \qquad (1)$$

Where,
MOR = modulus of rupture
P = load needed for failure
L = span of the material between support (length)
b = width of the material
d = thickness of the material

2.4 Determination of Modulus of Elasticity (MOE)

This was carried out using the clear samples of dimension 20 mm x 20 mm x 300 mm in accordance with [13]. Using Universal Testing Machine, the force needed to reach the elastic limit and its displacement were obtained for each sample. The modulus of elasticity was then calculated from the values derived using the formula below:

$$MOE\left(\frac{N}{mm^2}\right) = {}^{3PL}/_{4\Delta bd^3} \qquad (2)$$

Where,
MOR = modulus of rupture
P = load needed for failure
L = span of the material between support (length)
b = width of the material
d = thickness of the material
Δ = the displacement at beam centre at proportional load

2.5 Maximum Compressive Strength (MCS) Parallel to Grain

The maximum compressive strength parallel to grain was determined using Universal Testing Machine. Tests samples of 20 mm x 20 mm x 60 mm were obtained in accordance with the provisions of [13]. Wood samples were then loaded at the rate of 0.01mm/sec, and the corresponding force at the point of failure was taken directly. This was then divided by the cross-sectional area of the test specimen to obtain a value for maximum compressive strength parallel to grain. This follows the method adopted by [25].

$$Compressive\ Strength\ (N/mm^2) = \frac{Force\ of\ Failure}{Cross-sectional\ area} \qquad (3)$$

2.6 Impact Bending Strength

The impact bending test was carried out using the Hatt-turner impact testing machine in Forestry Research Institute of Nigeria, Ibadan, using the British [13]. Standard test specimens of 20 mm × 20 mm × 300 mm were supported over a span of 240 mm on a support radius of 15 mm with spring-restricted yokes fitted to arrest rebounce. The specimens were then subjected to repeated blow from 1.5 kg weight at increasing height initially from 50.8mm, at every 25.4mm, until there was a complete failure. The height at which failure occurred was recorded in metres as the height of maximum hammer drop. This is in accordance with the method adopted by [6].

$$Impact\ Bending\ Strength\ (N/mm^2) = \frac{Force \times Distance\ (Workdone)}{Surface\ Area} \qquad (4)$$

2.7 Experimental Design

The experimental design adopted was a two-factor split-plot in a Randomized Complete Block Design (RCBD), with the three trees felled standing as replicates. The following are the variables representing the functions:

i. Sampling Height- Base, Middle, and Top
ii. Radial Position- Innerwood, Middlewood, and Outer wood

In the split-plot design, the longitudinal section represented the main factor (Base, Middle, and Top) while the radial regions represented the sub-factor (Innerwood, Middlewood, and Outerwood).

3. RESULTS

3.1 Modulus of Rupture

The mean value of the Modulus of Rupture of *Blighia sapida* wood was 118.47 ± 1.96 N/mm^2. Axially, the modulus of rupture decreased from the base to the top, with the base having 129.44 ± 3.01 N/mm^2, the middle having 116.58 ± 3.54 N/mm^{2,} and the top 109.38 ± 3.00 N/mm^2 as shown in Table 1.

Radially, a slight increment from the innerwood to the middlewood and increased greatly towards the outerwood, with the innerwood having the average value 111.52 ± 2.76 N/mm^2, the middlewood 111.98 ± 2.76 N/mm^{2,} and the outerwood 131.90 ± 3.73 N/mm^2. At the base, the modulus of rupture increased from innerwood to the outerwood, with the innerwood having 121.30 ± 5.49 N/mm^2, the middlewood 122.77 ± 4.27 N/mm^2 and the outerwood 144.26 ± 3.68 N/mm^2. At the middle, the modulus of rupture decreased from innerwood towards the middlewood and then increased towards the outerwood, with the innerwood having the average value of 109.59 ± 4.34 N/mm^2, the middlewood 109.19 ± 4.03 N/mm^{2,} and the outerwood 130.97 ± 7.82 N/mm^2. At the top, the modulus of rupture increased from the innerwood to the outerwood, with the innerwood having the average value of 103.67 ± 3.42 N/mm^2, the middlewood 103.99 ± 4.92 N/mm^{2,} and the outerwood 120.47 ± 6.01 N/mm^2 as presented in Table 1.

The analysis of variance in Table 2 shows that there was a significant difference among the Modulus of Rupture of the trees, along the sampling heights and radial direction. But the interaction between the sampling height and radial levels showed no significant difference. The follow-up test using the Duncan Multiple Range Test at a probability level of 0.05 showed no significant differences as presented in Table 1.

Table 1: The mean values of MOR, MOE, MCS parallel to grain and impact bending strength of *B. sapida* (Ackee apple) wood.

Sampling height	Radial direction	MOR (N/mm^2)	MOE (N/mm^2)	MCS (N/mm^2)	Impact
Base	Innerwood	121.30 ± 5.49^b	11250.63 ±515.50^b	56.19 ± 1.92^b	25.84 ± 1.28^b
	Middlewood	122.77 ± 4.27^b	11652.24 ±445.07^b	59.12 ± 1.23^{ab}	25.60 ± 0.86^b
	Outerwood	144.26 ± 3.68^a	12877.35 ± 284.61^a	62.62 ± 1.65^a	35.09 ± 1.71^a
Pooled Mean		**129.44 ± 3.01**	**11926.74 ± 262.04**	**59.31 ± 0.99**	**28.84 ± 1.00**
Middle	Innerwood	109.59 ± 4.34^b	9925.39 ± 289.16^b	44.93 ± 1.93^c	26.21 ± 1.82^a
	Middlewood	109.19 ± 4.03^b	9237.14 ± 399.22^b	52.40 ± 0.87^b	29.40 ± 2.10^a
	Outerwood	130.97 ± 7.82^a	11622.38 ± 499.56^a	56.97 ± 0.7^a	30.74 ± 1.81^a
Pooled Mean		**116.58 ± 3.54**	**10261.64 ± 274.00**	**51.44 ± 1.04**	**28.78 ± 1.12**
Top	Innerwood	103.67 ± 3.42^b	9267.45 ± 203.28^b	42.88 ± 1.32^b	24.56 ± 0.86^b
	Middlewood	103.99 ± 4.92^b	9316.83 ± 389.41^b	49.13 ± 2.26^{ab}	25.66 ± 1.20^{ab}
	Outerwood	120.47 ± 6.01^a	10700.47 ± 473.12^a	51.53 ± 3.54^a	29.33 ± 2.01^a
Pooled Mean		**109.38 ± 3.00**	**9761.58 ± 232.88**	**47.84 ± 1.53**	**26.52 ± 0.87**
Total Mean		**118.47 ± 1.96**	**10649.99 ± 167.51**	**52.86 ± 0.81**	**28.05 ± 0.58**

Means ± Standard mean error of 5 replicate samples. Values with the same superscript on the same section (base, middle and top) were not significantly different and those different were significantly different at 0.05 probability level

Table 2: Analysis of variance of means of *MOR, MOE, MCS parallel to grain and impact bending strength* of *B. sapida* (Ackee apple) wood.

Sources of variation	df	MOR	MOE	MCS	Impact
Tree	2	0.0000*	0.1435^{ns}	0.0000*	0.0000*
Sampling height (SH)	2	0.0000*	0.0000*	0.0000*	0.0127*
Main plot error	4				
Radial direction (RD)	2	0.0000*	0.0000*	**0.0000***	0.0000*
SH x RD	4	0.9537^{ns}	0.5505^{ns}	0.3243^{ns}	0.0047*
Subplot error	120				
Total	134				

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

3.2 Modulus of Elasticity

The mean value of the Modulus of *Elasticity of Blighia sapida* was 10649.99 ± 167.51 N/mm^2. Axially, the Modulus of Elasticity was high at the base and decreased to the middle and then to the top, with the base having an average value of 11926.74 ± 262.04 N/mm^2, the middle 10261.64 ± 274.00 N/mm^2 and the top 9761.58 ± 232.88 N/mm^2 as shown in Table 1.

Radially, Modulus of Elasticity decreased slightly from innerwood towards the middlewood and then increased towards the outerwood, with the innerwood having 10147.82 ± 238.53 N/mm^2, the middlewood 10068.74 ± 287.25 N/mm^2 and the outerwood 11733.40 ± 277.29 N/mm^2. At the base, it increased from innerwood to the outerwood, with the innerwood having average value of 11250.63 ± 515.50 N/mm^2, the middlewood 11652.24 ± 445.07 N/mm^2 and the outerwood 12877.35 ± 284.61 N/mm^2. At the middle, it decreased from innerwood to the middlewood and then increased towards the outerwood, with the innerwood having 9925.39 ± 289.16 N/mm^2, the middlewood 9237.14 ± 399.22 N/mm^2 and the outerwood 11622.38 ± 499.56 N/mm^2. At the top, it increased from innerwood to the outerwood, with the innerwood having 9267.45 ± 203.28 N/mm^2, the middlewood 9316.83 ± 389.4N/mm^2 and the outerwood 10700.47 ± 473.12 N/mm^2 as shown in Table 1.

As shown in Table 2, the analysis of variance showed that there was no significant difference among the Modulus of Elasticity and the interaction between the sampling height and radial direction of the trees, but significantly different at the sampling height and radial direction. The Duncan Multiple Range Test follow up test at a probability level of 0.05 further shows the level of significant differences as shown in Table 1.

3.3 Maximum Compressive Strength Parallel To Grain

The mean value of compressive strength parallel to grain was 52.86 ± 0.81 N/mm^2. Axially, it is high at the base and decreased to the top, with the base having the average value of 59.31 ± 0.99 N/mm^2, the middle 51.44 ± 1.04 N/mm^{2,} and the top 47.84 ± 1.53 N/mm^2 as presented in Table 1.

Radially, MCS increased from innerwood to the outerwood, with the innerwood having the average value of 48.00 ± 1.32 N/mm^2, the middlewood 53.55 ± 1.08 N/mm^{2,} and the outerwood 57.04 ± 1.46 N/mm^2. At the base, it increased from innerwood to the outerwood, with innerwood having the average value of 56.19 ± 1.92 N/mm^2, the middlewood 59.12 ± 1.23 N/mm^{2,} and the outerwood 62.62 ± 1.65 N/mm^2. At the middle, at also increased from the innerwood to the outerwood, with the innerwood having 44.93 ± 1.93 N/mm^2, the middlewood 52.40 ± 0.87 N/mm^{2,} and the outerwood 56.97 ± 0.7 N/mm^2. At the top, it increased from innerwood towards the outerwood, with the innerwood having an average value of 42.88 ± 1.32 N/mm^2, the middlewood 49.13 ± 2.26 N/mm^{2,} and the outerwood 51.53 ± 3.54 N/mm^2 as presented in Table 1.

The analysis of variance in Table 2 revealed that there was a significant difference among the Maximum Compressive Strength parallel to grain of the trees, along the sampling heights and radial direction (<0.05). The sampling heights and radial direction interaction were not significant. Follow up test further revealed the level of significant differences at a probability level of 0.05 as shown in Table 1.

3.4 Impact Bending Strength

The mean impact bending strength of *B. sapida* wood was 28.05 ± 0.58 N/mm^2. Axially, it decreased from the base to the top, with the base having 28.84 ± 1.00 N/mm^2, the middle having 28.78 ± 1.12 N/mm^2 and the top having 26.52 ± 0.87 N/mm^2 as presented in Table 1.

Radially, it increased from the innerwood to the outerwood, with the innerwood having an average value of 25.54 ± 0.78 N/mm^2, the middlewood 26.88 ± 0.88 N/mm^2, and the outerwood 31.72 ± 1.10 N/mm^2. At the base, it decreased from the innerwood to the middlewood and then increased towards the outerwood, with the innerwood having 25.84 ± 1.28, the middlewood 25.60 ± 0.86 $N/mm^{2,}$ and the outerwood 35.09 ± 1.71 N/mm^2. At the middle, it increased from the innerwood to the outerwood, with the innerwood having 26.21 ± 1.82 N/mm^2, the middlewood 29.40 ± 2.10 N/mm^2 and the outerwood 30.74 ± 1.81 N/mm^2. At the top, it increased from the innerwood to the outerwood, with the innerwood having average value of 24.56 ± 0.86 N/mm^2, the middlewood 25.66 ± 1.20 $N/mm^{2,}$ and the outerwood 29.33 ± 2.01N/mm^2 as shown in Table 1.

From Table 2 of the analysis of variance, revealed that there were significant differences among the Impact Bending strength of the trees, the sampling height, radial direction as well as their interaction. The follow-up test further revealed the level of significant differences at a probability level of 0.05 as shown in Table 1.

4. DISCUSSION

4.1 Modulus of Rupture

As documented by [22] and as reported by [11], timber species are classified into four main classes in terms of Modulus of Rupture, the heavy construction (>133 N/mm^2), the medium construction (89-132 N/mm^2), the light construction (39-88 N/mm^2) and the very light construction (<39 N/mm^2) timber species. Hence, mean value 118 N/mm^2 of *B. sapida* wood modulus of rupture falls within the medium construction class. The mean value of *B. sapi*da wood was a bit higher than 89. 05 N/mm^2 reported for *Aningera robusta* wood by [26], higher than 85.8 N/mm^2 reported for *Ficus vallis choudae* by [5]. This is an indicator that the wood is a densed wood and of high strength. However, the value was lower than 155.18 N/mm^2, reported for *Chrysophyllum albidum* by [4].

The pattern of variation followed the trend of density that decreased from the base to the top. This validated the fact that wood density strongly correlates with mechanical properties [29]. Modulus of Rupture was more at the base because the density was also higher at the base than the top, as a result of more juvenile wood at the top of the tree. The Modulus of Rupture decreased from the base upward. This pattern of variation conforms to the findings of [24] on the axial variation of *Triplochiton scleroxylon*, [15] on *Nauclea diderrichii*, and [1] on the axial variation of *Ficus mucuso* and *Gmelina arborea*. According to [4], the Modulus of Rupture decreases as the position of sampling moves up the tree.

The increase in modulus of rupture from the innerwood to the outerwood, agrees with the findings of [15] on *Nauclea diderrichii* which had a similar increase in the modulus of rupture. [24], [2], [1] and [10] also reported a similar pattern of increase from innerwood to outerwood on *Triplochiton scleroxylon*, *Ficus mucuso*, *Gmelina arborea*, and *Mangifera indica* wood. This radial pattern of variation could be attributed to the relationship of strength to the age of the cambium [33]. The formation of juvenile wood close to the pith is always associated with low-density wood [33] and that may have also caused the decrease in Modulus of Rupture in the innerwood.

4.2 Modulus of Elasticity

The mean Modulus of Elasticity of 10649.99 N/mm^2 observed for *B. sapida* wood was lower than what was observed by [9] who reported Modulus of Elasticity of *B. sapida* to be 12686 N/mm^2 in Ghana. The reason may have been as a result of the mean density of 702 kg/m^3 observed for the wood in this study, which is lower than 899 kg/m^3 observed by [9] in Ghana. [17] reported that the higher the proportion of wood substance is, the greater the density and also the higher the mechanical properties. Also, [7] reported that [29] documented that the extent of wood maturity played a major role in the magnitude and pattern of wood property variability. As a result of that, wood maturity may have also been the reason behind the difference in value observed in Ghana.

The sampled trees depict a significant difference in the modulus of rupture along the sampling heights and radial direction. As documented by [22], and as reported by [12], timber species are classified into four main classes in terms of Modulus of Elasticity, the heavy construction (>14,700 N/mm^2), the medium construction (9,800-14,700 N/mm^2), the light construction (6,860-9,800 N/mm^2) and the very light construction (<6,860 N/mm^2) timber species. The average mean value recorded in this study 10,649.99 N/mm^2 falls within the range of medium construction timbers.

The modulus of elasticity decreased from base to the top which followed the same pattern with that of the density, which decreased from base to the top. It is in line with the report of [21]. As documented by [18], the strength of wood is usually closely correlated to the wood density and through it, wood strength can be estimated based on density without having any detailed knowledge of the species. This pattern of variation follows what was observed by [25] for *Gmelina arborea* wood, [8] for *Mangifera indica*, and [10] for *Mangifera indica* also.

An inconsistent trend at the radial direction as it decreased slightly from innerwood towards the middlewood and then increased towards the outerwood. This variation may have been due to the variation in the anatomical properties of wood. This pattern of variation was also observed by [12] in *Artocarpus altilis* wood. The pattern did not conform to the pattern reported by [6], [10], [24], and [3] on *Khaya grandifoliola*, *Mangifera indica*, *Triplochiton scleroxylon*, and *Ficus mucuso* respectively. The pattern of variation may have been due to the fact that wood is a natural material, therefore it is subject to many changing influences [16]. It may also have been as a result of a defect as reported by [4] which could limit the relationship between Modulus of Rupture and sampling positions, therefore, the variation observed might be a result of a defect in the tree.

The average Modulus of Rupture and Modulus of Elasticity of *B. sapida* indicated that the wood falls within the category of medium construction timbers, it can therefore be concluded that the timber can be used for some building constructions and furniture uses.

4.3 Maximum Compressive Strength Parallel to Grain

The maximum compressive strength parallel to grain is the ability of a piece of material to be able to absorb and withstand load in compression parallel to grain till the point with which failure occurs [29]. The mean value for Maximum Compressive Strength parallel to grain (MCS//) of *B. sapida* wood ranges from 59.31 N/mm^2 at the base to 47.84 N/mm^2 at the top of the tree which was a bit higher than the value obtained for *Chrysophyllum albidum* by [4], 13 N/mm^2 obtained for *Mangifera indica* by [10], 20 N/mm^2 obtained for *Artocarpus altilis* by [12], 13.7 N/mm^2 for *Ficus mucuso* by [2], and [19] reported 43.7 N/mm^2, but lower than 58.5 N/mm^2 and 75.4 N/mm^2 for 15- year old, 20-year old and 25-year old *Tectona grandis* wood. The maximum compressive strength value for *B. sapida* wood shows that it compared well with other economic tree species that are widely known for various structural applications. This implies that the wood will be able to withstand load during use for construction. According to [14], timbers that are high in density have high compression strength across the grain, therefore, the wood species with high density compared to other economic trees will have high compression strength while in service.

Along the sampling heights, as well as the radial direction MCS// is an indication that they are significantly different from one another. Along the tree bole height, maximum compressive strength parallel to grain also decreased from the base to the top which agreed with the report of [15], [1], [3], [24], [10], [12], [4], and [5] on *Nauclea diderichii*, *Gmelina arborea*, *Ficus mucuso*, *Triplochiton scleroxylon*, *Mangifera indica*, *Artocarpus altilis*, *Chrysophyllum albidum*, and *Ficus vallis-choudae* wood.

The Maximum Compressive Strength Parallel to the grain increased significantly from the innerwood to the outerwood, which conformed to the report of [24], [1], [3], [10], [4], and [5] on *Triplochiton scleroxylon*, *Gmelina arborea*, *Ficus mucoso*, *Mangifera indica*, *Chrysophyllum albidum*, and *Ficus vallis-choudae* wood respectively. The variation may have been as a result of the fact that natural variation exists in the wood and the variability in wood properties, most especially the anatomical features.

4.4 Impact Bending Strength

The mean value for Impact bending strength for *B. sapida* wood of 28.05 N/mm^2 falls below the 61.4 N/mm^2 reported for the same *B. sapida* wood in Ghana which could be as a result of factors such as site growth, climatic condition, age of the trees studied, and the portion along the bole from which samples were collected [12]. The mean value was higher than 20.4 N/mm^2 reported by [5] for *Ficus vallis choudae* wood and 15.51 N/mm^2 reported by [12] for *Artocarpus altilis* wood.

The decrease from the base to the top agreed with the findings of [24], [1], [4], [10], and [5] on *Triplochiton scleroxylon*, *Gmelina arborea*, *Chrysophyllum albidium*, *Mangifera indica,* and *Ficus vallis choudae* wood. This follows the pattern of density and density is strongly correlated with mechanical properties. Wood density according to [29] is closely correlated to mechanical properties.

The increase in impact bending strength from innerwood to outerwood agreed with the report of [24], [1], and [2] on *Triplochiton scleroxylon*, *Gmelina arborea*, and *Ficus mucuso*. However, the decrease contradicted the report of [4], [10], and [5] on *Chrysophyllum albidium*, *Mangifera indica*, and *Ficus vallis choudae* wood. This may have been as a result of the juvenile wood formed in the early stage of trees life; which comprises growth rings that are formed close to the pith [33]. And according to [33] also, the formation of juvenile wood near the pith is always associated with wood low density. The value of impact bending strength of *B. sapida* wood species observed in this study compared well with other species of proven strength properties and that showed that the wood has the ability to resist impact forces in several applications which shows how tough the wood is and the bending strength. According to [16] Green *et al*., (1999) the height of the maximum drop, or the drop that causes failure, is a comparative value that represents the ability of wood to absorb shocks that cause stresses beyond the proportional limit.

5. CONCLUSIONS AND RECOMMENDATIONS

The average Modulus of Rupture and Modulus of Elasticity of *B. sapida* wood indicated that the wood falls within the category of medium construction timbers. Therefore, the general belief among wood users that it is not a good timber species and that it cannot be utilized for any wood-based product that requires strength is far from the truth. The maximum compressive strength value of *B. sapida* wood showed that it compared well with other economic tree species that are widely known for various structural applications. It can therefore be concluded that the timber can be used for some building constructions of medium density-strength requirement, carpentry works, veneer wood production, and furniture use.

However, to halt the continuous propagation of the general belief among wood users, that *B. sapida* wood species is not suitable for wood-based products that require strength, it could be recommended that sensitization of timber users is done, for them to have the fundamental understanding of the strength properties of the wood species for better acceptability in the timber market and optimum utilisation.

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