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Research Article

Evaluation of Selected Physical Properties of Breadfruit Wood (*Artocarpus altilis*, Parkinson ex. F.A. Zorn) Fosberg Grown in the South-western, Nigeria

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Abstract

Background and Objective: *Artocarpus altilis* wood is rapidly being utilized for structural construction and majorly in the furniture industry despite the death information regarding some of its physical properties. This study was conducted to evaluate the *A. altilis* wood quality grown in South-western Nigeria. **Materials and Methods:** Four matured trees (dbh class of 40-50 cm, 45-55 years of age) were randomly selected and sampled at stem height levels (10, 50 and 90%) and radial positions (corewood, innerwood and outerwood). Tested samples prepared were dried to about 12% moisture content before tests. Some physical properties tests (basic density, specific gravity and volumetric shrinkages) were carried out in accordance with ASTM standards. Data collected were processed by using a combination of descriptive and inferential statistics. **Results:** The mean basic density was 581 kg m^{-3}, the mean specific gravity was 0.58, tangential, radial and volumetric shrinkages were 4.3, 1.42 and 5.6%, respectively. It was observed that the site factor did not significantly affects the pattern of variations in the wood properties, but the intra-tree variations in the properties were pronounced across the radial plane in the individual tree while sampling height only affected the density significantly. **Conclusion:** The significant differences found between the trees demonstrate the possibility of selection and improvement for increased wood quality. From this study, *A. altilis* is suitable for low load carrying structural timber and light furniture construction.

Key words: *Artocarpus altilis*, specific gravity, density, shrinkage, wood variations

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Population growth, economic development, urbanization in terms of infrastructures and industrialization places an increasing demand both on the forest estates as well as various products derived from the forest especially timber products[1,2]. Nigeria, the most populous Africa country is faced like any other developing countries, with increasing demand for wood products and this situation has led to rapidly shrinking of natural forests. Despite restrictions imposed by government regulations in preserving the world's existing forest, pressure on the forest for logging activities have increased in many developing countries[3].

The biodiversity of timber species in Nigeria natural forest has been a resource based and an important source of wood supply as well as offers an array of timber species suitable for structural and non-structural purposes as well as furniture making. Attention has been on the economic species known over the years and this has made them both scarce and expensive; however, lesser-known wood species which are readily available could also performed the same purpose that the economic timber species have been put to[4-6]. Natural forest cover, as far as the wood based industry is concerned has severely decreased as a result of indiscriminate extraction of economic trees and the takeover of forest land for other developmental purposes such as; agricultural land, urbanization and industries[7]. Hence, research into timber and other uses of forest plants have been intensified to meet rising demand for wood products, foods, medicine and raw materials for industries[8]. The demand for economic species such as; *Milicia excelsa*, *Triplochiton sceleroxylon*, *Nauclea diderrichi*, *Afzelia africana*, *Entandrophragma cylindricum*, *Afzelia pachyloba*, *Albizia zygia*, *Celtis zenkeri*, *Daniella ogea*, *Daniella oliveri*, *Diospyros mespiliformis*, *Distemonanathus benthamiamus*, *Entandrophragma candollei*, *Funtumia elastic* and *Anogeissus leiocarpus* among others is borne out of their desired mechanical, aesthetics and durability properties which has subsequently led to the over-exploitation and consequently threatening their survival in the Nigeria forest. This has left the forest with more juvenile or immature wood, this juvenile wood is characterized by large proportion of sapwood which is not durable as the matured timber of the same species[9]. As a result of increasing demand for and inconsistent supplies of choice timber species in several developing countries, it is important to promote the Lesser Used Species (LUS) to complement the traditional species. Utilization of LUS is being promoted in many countries to enlarge the resource base of wood industry and to reduce the pressure on the commercial timbers[10]. Lucas *et al.*[11] reported that the branches of Guava (*Psidium guajava* L.) have been used for truss fabrication in Nigeria several years back. Hence, based on the assertion of Yeom[12] opined that the utilization of non-commercial timbers produced a larger amount of choice timber for utilization and possibly reduced pressure on the commercial wood species. To ensure the continuous availability of wood resources and the continuous utilization of tropical hardwood species, there is need to shift attention from the common wood species to the lesser used species, especially those that meet the industrial requirements for end users. Panshin and de Zeeuw[13] noted that tree size and wood quality are considered as the major factors that determines the suitability of wood for various industrial end uses.

Artocarpus altilis a lesser used species belonging to the family Moraceae which does not belong to the class of the commercially known wood species such as; *Milicia excelsa*, *Triplochiton scleroxylon*, *Afzelia africana*, *Nesorgordonia papaverifera* and *Terminalia ivorensis* etc. It was therefore, chosen for evaluation because of its large size of up to 25 m (82 feet) or more in height. The species is popular as an agro-forestry species planted as a fruit tree and recently as a good construction timber. Recent surveys of timber market in the south west zone of Nigeria shows good representation of this emerging species. Knowledge of the physical property of the wood in respect of its utilization is necessary.

Wood density is an important wood property for both solid wood and fiber products in both conifers and hardwoods[14]. Panshin and de Zeeuw[13] reported that density is a general indicator of cell size and is a good predictor of strength, stiffness, ease of drying, machining, hardness and various paper making properties. This work focused on the physical properties of bread fruit (*Artocarpus altilis*) tree as a suitable material for the wood based industries.

MATERIALS AND METHODS

Trees collection: The tree was felled in derived Savannah ecological zone of Nigeria. Wood samples for this study were collected in May, 2017 from harvested trees of *A. altilis* from Longe village which lies within latitude 7°10'37"N to 7°10'34"N and longitude 3°52'50"E and 3°50'59"E. Trees were felled at the cocoa and kola farmland area at Longe village in Oluyole Local Government Area of Oyo state, Nigeria (Fig. 1). Oluyole Local Government lies within latitude 30°50"east of the Greenwich meridian and latitude 70°20"N of the equator[15].

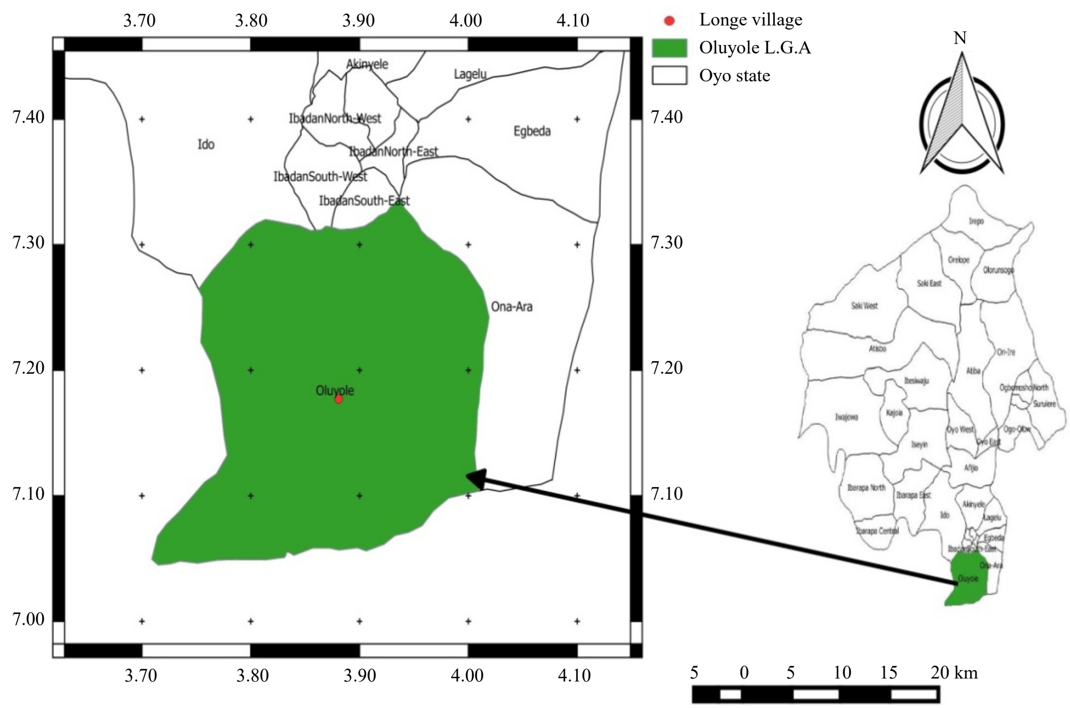

Fig. 1: Map of the study area showing location of sample collection

Table 1: Allocation of wood test samples[16]

Properties	Test	Sample size	No. of samples
Physical parameters	Density	20×20×60 mm	360
	Specific gravity	20×20×40 mm	360
	Volumetric shrinkage	20×20×60 mm	360

Sample selection and harvesting: Four trees were purposively selected based on the absence of reaction tendencies, fairly straight and free from natural defects as well as excessive knot are harvested. Age and diameter sizes of the trees were considered based on the farmer's information and growth ring counts. Felled trees were delimbed and cross-cut into bolts of 500 mm long which were collected at three different positions (butt, middle-stem and top-stem) along the length of the bole i.e., 10, 50 and 90% of merchantable height making a total of 12 bolts.

Sample preparation: Test sample representatives were taking from the central planks obtained from all the bolts to give 12 planks from where test samples were obtained. The central planks were further sectioned into 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 in Palte 1.

Specific sample for the determination of the wood properties were dimensioned by following standards as shown in Table 1.

Determination of density: The 360 test sample of dimension ($20\times20\times60$ mm^3) were produced from the central planks obtained at each sampling height (that is, from the base, middle and top) for each of the four trees. Samples were taken from each sampling height radially from bark to bark to make 5 test samples from each of the sampling position. Therefore, 30 test samples were obtained for each replicate to make 90 and 360 test samples for the 4 trees harvested. The test samples were soaked in distilled water for 72 h. Samples were oven-dried at 103 ± 2°C as prescribed by Smith[17] and then weighed at interval with a sensitive G and G measuring scale until a constant weight was obtained. Thereafter, the samples were then cooled in a dry gel desiccators and weighed. Density gradient across and along the bole were determined in accordance with ASTM[18] D2395-02:

$$D = \frac{M}{V}\left(\frac{kg}{m^3}\right)$$

Where:

D = Density
M = Weight of the wood
V = Volume of wood

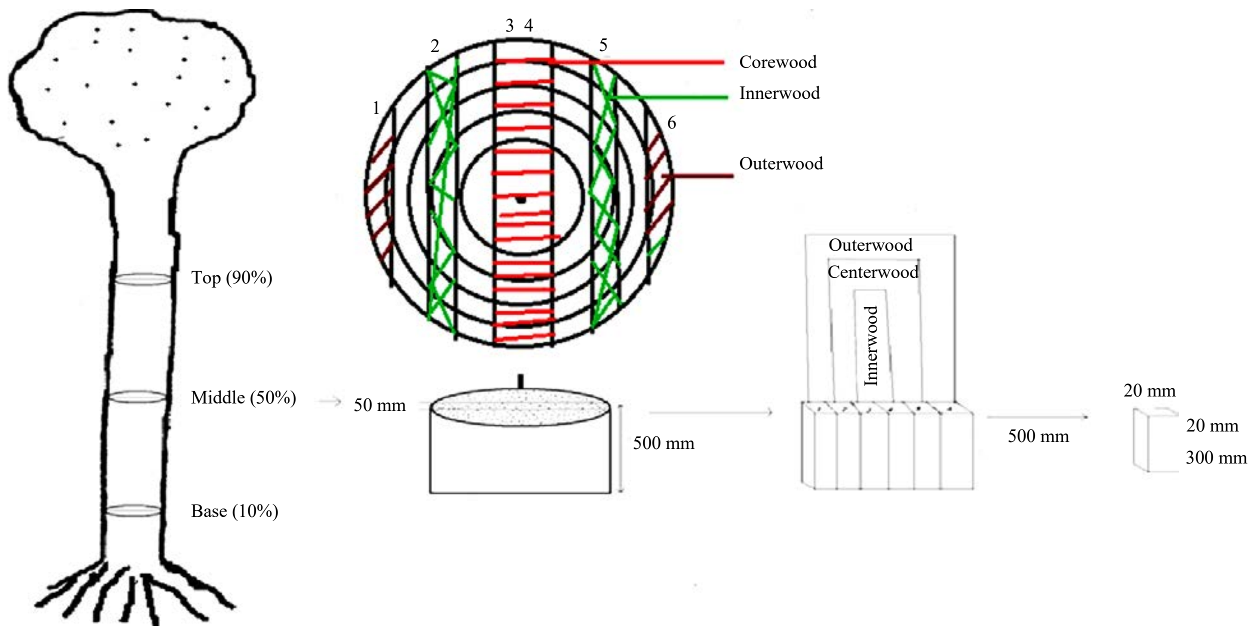

Plate 1: Schematic sampling procedure for obtaining test samples for physical and mechanical properties

Determination of percentage shrinkage: The 360 test specimens of 20×20×40 mm^3 were prepared for this test, the samples were properly marked and denoted 'T' and 'R' for both Tangential and Radial direction. They were soaked in distilled water for 72 h in order to get them conditioned to moisture above Fibre Saturation Point (FSP). Test samples were then removed one after the other and left to drain off excess water, thereafter, their dimensions in wet condition were taken to the nearest millimeter by using sensitive veneer calipers. Percentage shrinkages along the two planes were measured after specimens had been oven-dried at 103±2°C to 12% moisture as prescribed by Smith[17].

$$S = \frac{D_s - Do}{D_s} \times 100$$

Where:

- S = Shrinkage (%)
- D_S = Dimension at saturated condition
- D_0 = Dimension of oven dry condition

$$V_S = S_R + S_T$$

Where:

- VS = Volumetric shrinkage
- S_R = Radial shrinkage
- S_T = Tangential shrinkage

This is in accordance with approximations done by Dinwoodie[19].

Determination of specific gravity: The specimen for specific gravity were carried out by obtaining a dimension of 20×20×60 mm where they were subjected to a gravimetric procedure developed by Smith[17], where wood samples were completely saturated by soaking in distilled water for 72 h. Each treatment was removed from water and blotted to remove excess water. Samples were oven-dried at 103±2°C and then weighed at interval with a sensitive G and G measuring scale until a constant weight was obtained. Specific gravity was determined by using this equation:

$$\text{Specific gravity} = \frac{1}{\frac{W_s - W_0}{W_0} + \frac{1}{1.53}}$$

Where:

- W_s = Saturated weight of wood
- W_o = Oven dry weight of wood

This is in accordance with approximations done by Stamm[20].

Statistical analysis: Data was analyzed by using Analysis of Variance (ANOVA). Analysis of Variance (ANOVA) was conducted to estimate the relative importance of various sources of variation in the physical properties test. The factors considered were the differences among treatment means, sampling height (Base, middle and top) radial position and bark to bark (Core, inner and outerwood). Separations of treatment means were conducted with the use of Duncan Multiple Range Test (DMRT) to know the differences between the means and to choose the best treatment combination from the considered factors.

RESULTS

Wood density: The mean basic density (at 12% moisture content) of *A. altilis* was 581.48±57.61 kg m^{-3}, with the average range between 602.67±59.47 kg m^{-3} at the base, 571.01±47.36 kg m^{-3} at the middle and 570.70±56.02 kg m^{-3} at the top (Table 2). This shows that density decreases from base to the top, while it ranged between 590.41±59.41 to 629.28±54.32 kg m^{-3} from corewood to outerwood at the base, 572.67±49.93 to 570.79±44.02 kg m^{-3} core wood to outerwood at the middle and 570.52±86.45 to 579.02±54.33 kg m^{-3} from core wood to outer wood at the top (Table 2).

The analysis of variance in Table 3 shows that there is no significant effect of sampling height and radial position on the density of *A. altilis* (p = 0.006) at 0.05% probability level. Duncan Multiple Ranged Test (DMRT) at 0.05% probability level shows that the density at the base is significant along the sampling height. While, along the radial position density is significantly different at the corewood, middlewood and outerwood (Table 3).

Specific gravity: The mean specific gravity of *A. altilis* was 0.58±0.07 with the average range between 0.60±0.06 at the base, 0.58±0.06 middle and 0.57±0.06 at the top (Table 2). This shows that specific gravity decreases from base to the top, while it ranged between 0.59±0.07 to 0.59±0.08 from core wood to outer wood across the bole at the base, 0.59±0.06 to 0.61±0.10 corewood to outerwood across the bole at the middle and 0.57±0.05 to 0.59±0.04 from corewood to outerwood across the bole at the top (Table 2).

The ANOVA in Table 3 shows that radial position significantly influenced the specific gravity of the wood species (p = 0.903) and sampling height at p = 0.834 at 0.05% probability level. Duncan Multiple ranged Test (DMRT) at 0.05% probability level, the result shows that specific gravity of *A. altilis* decreases from the base to the top along the sampling height while increase was observed along the radial direction from core to outer.

Tangential Shrinkage (TS): The overall mean tangential shrinkage (at 12% moisture content) of *A. altilis* is 4.3±0.71%, with the average range value between 3.69±0.81% at the base, 4.33±0.38% at the middle and 4.74±0.39% to the top, respectively (Table 4). This shows that tangential shrinkage increases from base to the top, while it ranged between 3.93±0.77 to 3.56±0.99% from core wood to outerwood across the bole at the base, 4.33±0.54 to 4.39±0.18% corewood to outerwood across the bole at the middle and 4.69±0.38 to 4.75±0.17% from corewood to outerwood across the bole at the top (Table 4).

Table 2: Mean values of density (kg m^{-3}) and specific gravity of breadfruit (*A. altilis*) wood along sampling height and radial position

Sampling height	Radial position	Density (Mean±SD) (kg m^{-3})	Specific gravity (Mean±SD)
Base	Corewood	590.41±59.41	0.59±0.07
	Innerwood	581.28±64.88	0.61±0.04
	Outerwood	629.28±54.32	0.59±0.08
Pooled mean		602.67±59.47	0.60±0.06
Middle	Corewood	572.67±49.93	0.59±0.06
	Innerwood	569.56±58.57	0.54±0.05
	Outerwood	570.79±44.02	0.61±0.10
Pooled mean		571.01±47.36	0.58±0.06
Top	Corewood	570.52±86.45	0.57±0.05
	Innerwood	562.56±30.57	0.57±0.06
	Outerwood	579.02±54.33	0.59±0.04
Pooled mean		570.70±56.02	0.57±0.07
Mean		581.48±57.61	0.58±0.06

Each value is the mean and standard deviation of 5 replicate sampled trees of breadfruit

Table 3: Summary of ANOVA of mean variation for density and specific gravity of *A. altilis*

Sources of variation	Df	Density	Specific gravity
Tree (block)	3	0.0006^{ns}	0.0000^{ns}
Sampling height (SH)	2	0.0471^{ns}	0.834
Major plot error	6	-	-
Radial Position (RP)	5	0.5504	0.9025
SH×RP	10	0.855	0.0857^{ns}
Sub-plot error	45		
Total	71		

^{ns}p>0.05 are not significant, *p<0.05 are significant

Table 4: Summary of some descriptive statistics (mean) of shrinkage of *A. altilis* wood

Sampling height	Radial position	T (%)	R (%)	V (%)
Base	Corewood	3.93±0.77	1.14±0.09	5.08±0.75
	Innerwood	3.57±0.81	1.44±0.49	4.86±0.73
	Outerwood	3.56±0.99	1.33±0.29	4.89±1.01
Pooled mean		3.69±0.81	1.31±0.35	4.94±0.77
Middle	Corewood	4.33±0.54	1.33±0.35	5.66±0.76
	Innerwood	4.27±0.36	1.48±0.25	5.66±0.33
	Outerwood	4.39±0.18	1.53±0.47	5.92±0.56
Pooled mean		4.33±0.38	1.45±0.43	5.75±0.56
Top	Corewood	4.69±0.38	1.43±0.34	6.12±0.48
	Innerwood	4.77±0.25	1.33±0.19	6.22±0.43
	Outerwood	4.75±0.17	1.64±0.55	6.39±0.68
Pooled mean		4.74±0.39	1.49±0.37	6.24±0.54
Mean		4.3±0.71	1.42±0.37	5.64±0.82

T: Tangential direction, R: Radial direction, V: Volumetric, Each value is the mean and standard deviation of 5 replicate sampled trees of breadfruit

Table 5: Analysis of variance for tangential, radial and volumetric shrinkage of *A. altilis*

Source of variation	Df	Sum of squares	Mean of square	F-cal	p-values
Tangential					
Trees (block)	3	2.7771	0.934	3.711	0.0003**
Sampling height	2	13.461	6.730	27.028	0.000**
Major plot error	6	10.426	1.738	6.980	
Radial position	5	0.563	0.113	0.454	0.0021**
SH×RP	10	19.329	0.199	0.800	0.8424^{ns}
Sub-plot error	45	11.212	0.249		
Total	71	35.338			
Radial					
Trees (block)	3	3.2246	1.0749	10.365	0.0000**
Sampling height	2	0.4729	0.2365	2.2806	0.1319^{ns}
Major plot error	6	0.1104	0.0184	0.1774	
Radial position	5	0.9596	0.1919	1.8505	0.279^{ns}
SH×RP	10	1.1452	0.1145	1.1041	0.653^{ns}
Sub-plot error	45	4.6661	0.1037		
Total	71	10.5788			
Volumetric					
Trees (block)	3	2.551	0.850	0.850	0.015**
Sampling height	2	20.578	10.289	41.656	0.000**
Major plot error	6	11.460	1.910	7.733	
Radial position	5	1.095	0.138	0.559	0.796^{ns}
SH×RP	10	1.380	0.138	0.559	0.978^{ns}
Sub-plot error	45	11.091	0.247		
Total	71	48.155			

^{ns}p>0.05 are not significant, *p-values< 0.05 are significant

The analysis of variance in Table 5 shows that there is significant effect of sampling height, but there is no significant difference in radial position on the tangential shrinkage of *A. altilis* (p = 0.0021) at 0.05% probability level. Duncan Multiple Ranged Test (DMRT) at 0.05% probability level shows that the tangential shrinkage at the base, middle and top is significant along the sampling height.

Radial Shrinkage (RS): The overall mean radial shrinkage (at 12% moisture content) of *A. altilis* 1.42±0.37%, with the average range value between 1.31±0.35% at the base, 1.45±0.43% middle and 1.49±0.37% at the top (Table 4). This shows that radial shrinkage increases from base to the top, while it ranged between 1.14±0.09 to 1.33±0.29% from corewood to outer wood across the bole at the base, 1.33±0.35 to 1.53±0.47% core wood to outerwood across the bole at the middle and 1.43±0.34 to 1.64±0.55% from corewood to outer wood across the bole at the top.

The analysis of variance in Table 5 shows that there is no significant effect of sampling height and in radial position on the radial shrinkage of *A. altilis* (p = 0.279) at 0.05% probability level. Duncan Multiple Ranged Test (DMRT) at 0.05% probability level shows that the radial shrinkage at the base, middle and top is significant along the sampling height.

Volumetric Shrinkage (VS) of *A. altilis* wood: The overall mean volumetric shrinkage (at 12% moisture content) of *A. altilis* is 5.64±0.82%, with the average range value between 4.94±0.77, 5.75±0.56 and 6.24±0.54% for base, middle and top, respectively (Table 4). This shows that axial shrinkage increases from base to the top, while it ranged between 5.08±0.75 to 4.89±1.01% from corewood to outerwood across the bole at the base, 5.66±0.76 to 5.92±0.56% corewood to outerwood across the bole at the middle and 6.12±0.48 to 6.39±0.68% from corewood to outerwood across the bole at the top (Table 4).

The analysis of variance in Table 5 shows that there is no significant effect of sampling height and in radial position on the volumetric shrinkage of *A. altilis* wood (p = 0.978) at 0.05% probability level. Duncan Multiple Ranged Test (DMRT) at 0.05% probability level shows that the volumetric shrinkage at the base, middle and top is not significant along the sampling height.

Physical properties: Density of the *A. altilis* wood at 12% air-dry MC is 581 kg m^{-3} and varies uniformly along the sampling height across the radial position. This implies that quality wood can be obtained within the region of base and middle of the merchantable height. However, *A. altilis* wood can be regarded as a medium density based on the classification. Specific gravity *A. altilis* wood is 0.58 and varies uniformly and significant along and across for both sampling height and radial position which indicates that consumption of liquor during pulping will be low while the rate of delignification is expected to be high.

From this study tangential shrinkage increased uniformly from the base to the top, while radially, it increased from corewood to outerwood.

Radial shrinkage also increased uniformly from the base to the top, while radially, it increased from corewood to outerwood consistently.

Volumetric shrinkage varied consistently and significantly both along and across the sampling height and radial position. This indicates that the volumetric shrinkage of *A. altilis* wood is moderate because it possesses low ability to shrinkage and can be applied for both indoor and outdoor uses.

DISCUSSION

The density is known to be important factors that affect the behavior of materials especially the physical and mechanical properties. The result obtained was similar to the research findings already reported by Stamm[20], MTC[21], Rincon and Padilla[22], Orwa *et al.*[23] and Ragone[24] also collaborated what was observed in *A. altilis* density 505-645 kg m^{-3} at 15% MC. A greater density at the base of a tree is contributed by the formation of heartwood where the proportion of heartwood is higher than the proportion of sapwood. The density at the upper of the tree is lower because influenced by the presence of juvenile wood around the pith in vertical variation.

These observed decreasing in density values from base to the top of the tree may be due to changes as a results of increase in cell size and physiological development of the wood due to the wood incremental annual growth rings as well as the addition of more wood which result from the formation of new tissues as the tree grows in girth. A similar observation was made by Akachuku[25] for the wood density of Nigeria grown *Gmelina arborea*. It reported that variations in density within trees do occur as a result of changes in cell size and the increasing age of the cambium. A general decrease in wood density was also observed in this study from the bark to pith outward to the bark (bark to bark). The variations of wood density of plantation grown *Nauclea diderichii* and *Triplochyton scleronxylon* were reported by Ali *et al.*[26].

Generally, there is a decrease in wood density of *A. altilis* from the base to the top stem (Table 4). This finding agreed with the report of Zziwa *et al.*[6], who observed a similar pattern of variation on *Artocarpus heterophyllus*. A similar trend of variation in wood density along the axial direction was reported for *Tectona grandis* by Anguruwa[27].

In present studies, *A. altilis* had an average specific gravity of 0.58, this is in line for *A. heterophyllus* (0.46) reported by Ogunkunle and Oladele[28] *Ficus exasperata* had 0.50-29.0.51 in *Gmelina arborea* and 0.46 obtained in *F. thonningii*[29]. Specific gravity is the most important index to the efficient potential use of wood therefore, implication of this on wood utilization of *A. altilis* having low specific gravity is an indication that the wood can be chipped easily without wearing the chipper knives and that consumption of liquor during pulping will be low while the rate of delignification is expected to be high.

This pattern of variation is similar to research finding reported for *A. elasticus* (2.9%). *A. scortechinii* (3.9%) and *Parartocarpus venenosus* (4.4%)[2,20,27,30,31]. Young and Hammett[32] reported that research findings on 9 years old hybrid Poplar clones observed increased tangential shrinkage from the pith to the bark. Ogunsanwo[33] observed similar a decreasing (TS) with height, showed an inconsistent variation pattern along sampling height for all wood types in tangential shrinkage. This might be due to the masking effect of extractive content, which limits the predictability of wood shrinkage from cell wall thickness while in radial shrinkage, similar pattern of variation was reported for *A. elasticus* (1.5%), *A. scortechinii* (1.6%) and *Parartocarpus venenosus* (2%) by MTC[21]. Ali *et al.*[26] also reported that the radial shrinkage of *Triplochiton scleroxylon* decreased drastically from base to the top. These differences according to Desch and Dinwoodie[34] were as a result of the restriction effect of the rays on the radial plane, the differences in the degree of lignifications between the radial and tangential walls, the differences in microfibrillar angle between the two walls and the increased thickness of the middle lamella in the tangential direction in relation with that in the radial direction. The uniform pattern showed that the radial shrinkage is fairly high shrinkage.

From present studies in Table 6, volumetric shrinkage increased from the tree base to the top and from the pith to the outerwood. This could be as a result of the presence of a greater amount of extractives in the innerwood which inhibit normal shrinkage by bulking the amorphous regions in the cell wall substance. Hence, volumetric shrinkage is less in the innerwood than the outerwood. This indicated that the volumetric shrinkage of *A. altilis* wood is moderate because it possesses a low ability to shrinkage and can be applied for both indoor and outdoor uses. Based on the conclusions drawn from this study, *A. altilis* wood possesses valuable potentials needed as construction materials and to 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 and other lesser known tropical hardwoods.

This study has shown that *A. altilis* wood is by no means inferior in quality, therefore, it is recommended that the use in veneer and plywood production and low strength bearing application should be encouraged and promoted as this is expected to enhance continuous utilization in Nigeria.

Wood users and industrialist should have basic information on the strength properties of *A. altilis* wood in order to ensure better utilization and quality of their products.

CONCLUSION

The findings from the study has 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.

SIGNIFICANCE STATEMENT

This study discovers the wood possesses valuable potentials needed as construction materials and to substitute for the commercial timber species that can be beneficial for wood users and industrialist. This study would help the researcher to uncover the critical area of utilization that many researchers were not able to explore. Thus, as new theory indicates that consumption of liquor during pulping is low and the rate of delignification is expected to be high on utilization of the species in production of value-added products may be arrived at.

REFERENCES

1. Shakhes, J., M.A.B. Marandi, F. Zeinaly, A. Saraian and T. Saghafi, 2011. Tobacco residuals as promising lignocellulosic materials for pulp and paper industry. BioResources, 6: 4481-4493.
2. Izekor, D.N., 2010. Physico-mechanical characterization and anatomy of teak (*Tectona grandis* L.f.) wood crown in Edo State, Nigeria. Ph.D. Thesis, Department of Forestry and Wood Technology, Federal University of Technology, Akure, Nigeria.
3. Cherdchim, B., N. Matan and B. Kyokong, 2004. Effect of temperature on thermal softening of black sweet-bamboo culms (*Dendrocalamus asper* Backer) in linseed oil. Songklanakarin J. Sci. Technol., 26: 855-866.
4. FAO., 2001. Non-forest tree plantations based on the work of W. Killmann. Working Paper Series FP/6, Food and Agriculture Organization, Rome, Italy, April 2001.
5. Fuwape, J.A. and J.S. Fabiyi, 2003. Variations in strength properties of plantation grown *Nauclea diderrichii* wood. J. Trop. For. Prod., 9: 45-53.
6. Zziwa, A., R. Mugambwa, S. Kizito, O.E. Sseremba and A. Syofuna, 2012. Basic density, modulus of elasticity and modulus of rapture of *Artocarpus heterophyllus*. Uganda J. Agric. Sci., 13: 15-23.
7. Izekor, D.N., S.P.A. Okoro, D.N. Izekor, S.P.A. Okoro and C. Kalu *et al*., 2004. Study on the trends in the volume of logs supply of some common timber species to sawmills in Edo State, Nigeria. Niger. J. Applied Sci., 22: 124-131.
8. Onyekwelu, J.C. and S.O. Akindele, 1995. Stand volume equation for *Gmelina arborea* plantation in oluwa forest reserve, Nigeria. Niger. J. For., 25: 92-95.
9. Ogunsanwo, O.Y., N. Terziev, A. Temiz and T. Elowson, 2006. Evaluation of physical and mechanical properties of two lesser known wood from Nigeria. Research Manuscript, Department of Wood Science, Swedish University of Agricultural Science, Sweden.
10. Poku, K., Q. Wu and R. Vlosky, 2001. Wood properties and their variations within the tree stem of lesser-used species of tropical hardwood from Ghana. Wood Fiber Sci., 33: 284-291.
11. Lucas, E., A. Olorunnisola and N.A. Adewole, 2006. Preliminary evaluation of guava (*Psidium guajava* L.) tree branches for truss fabrication in Nigeria. Agric. Eng. Int.: CIGR J., Vol. 8.
12. Yeom, F.B.C., 1984. Lesser-known tropical wood species: How bright is their future? Unasylva, 36: 2-16.
13. Panshin, A.J. and C. de Zeeuw, 1980. Textbook of Wood Technology: Structure, Identification, Properties and Uses of the Commercial Woods of the United States and Canada. 4th Edn., McGraw-Hill Book Company, New York, USA., ISBN-13: 978-0070484405, Pages: 736.
14. De Guth, E.B., 1980. Relationship between wood density and tree diameter in *Pinus elliottii* of Missiones Argentina. Proceedings of the IUFRO Division V Conference, April 8-16, 1980, Oxford, UK.
15. Ojo, A.D. and I. Sadiq, 2010. Effect of climate change on cocoa yield: A case of Cocoa Research Institute (CRIN) farm, Oluyole local government Ibadan Oyo State. J. Sustain. Dev. Afr., 12: 350-358.
16. ASTM., 1983. Standard test methods of testing small scale clear specimens of timber. ASTM D143-83, American Society for Testing and Materials, Philadelphia, PA., USA., pp: 48-105.
17. Smith, D.N., 1954. Maximum moisture content method for determining specific gravity of small wood samples. Report No. 2014, December 1954, Forest Products Laboratory, U.S. Department of Agriculture Forest Service, Madison, WI., USA.
18. ASTM., 2003. Standard test methods for specific gravity of wood and wood-base materials. ASTM D2395-02, American Society for Testing and Materials, Philadelphia, PA., USA., pp: 1-15.
19. Dinwoodie, J.M., 1989. Wood, Nature's Cellular, Polymeric, Fibre-Composite. Institute of Metals, London, UK., ISBN-13: 9780901462350, Pages: 138.

20. Stamm, A.J., 2002. Density of wood substance, adsorption by wood and permeability of wood. J. Phys. Chem., 33: 398-414.
21. MTC., 2018. MTC wood wizard version 1.1. Malaysian Timber Council (MTC), Kuala Lumpur, Malaysia.
22. Rincon, A.M. and F.C. Padilla, 2004. Physicochemical properties of breadfruit (*Artocarpus altilis*) starch from Margarita Island, Venezuela. Arch. Latinoam. Nutr., 54: 449-456.
23. Orwa, C., A. Mutua, R. Kindt, R. Jamnadass and A. Simons, 2009. Agroforest tree database: A tree reference and selection guide, Version 4.0. World Agroforestry Centre, Kenya.
24. Ragone, D., 2011. Farm and forestry production and marketing for breadfruit (*Artocarpus altilis*). Species Profiles for Pacific Island Agroforestry, Permanent Agriculture Resources (PAR), Holualoa, HI., USA.
25. Akachuku, A.E., 1981. Wood density of *Gmelina arborea* Roxb. and its biological basis. Agricultural Research Bulletin, Faculty of Agriculture & Foresty, University of Ibadan, Nigeria, pp: 1-29.
26. Ali, M.R., M.J. Alam and N.A. Chowdhury, 2012. Physical, mechanical and seasoning properties of jackfruit (*Artocarpus heterophyllus*) wood in Bangladesh. Scholarly J. Agric. Sci., 2: 103-107.
27. Anguruwa, T.G., 2018. Anatomical, physico-chemical and bioenergy properties of *Ficus exasperata* Vahl. in Ibadan, Nigeria. Ph.D. Thesis, Department of Forest Production and Products, University of Ibadan, Nigeria.
28. Ogunkunle, A.T.J. and F.A. Oladele, 2008. Structural dimensions and paper making potentials of the wood in some Nigerian species of *Ficus* L. (Moraceae). Adv. Nat. Applied Sci., 2: 103-111.
29. Mottonen, V. and K. Luostarinen, 2006. Variation in density and shrinkage of birch (*Betula pendula* Roth) timber from plantations and naturally regenerated forests. For. Prod. J., 56: 34-39.
30. Saralde, T.C., 2006. Evaluation of wood properties of genetically modified trees. M.Sc. Thesis, North Carolina State University, Raleigh, NC., USA.
31. Koubaa, A., R.E. Hernandez and M. Beaudoin, 1998. Shrinkage of fast-growing hybrid poplar clones. For. Prod. J., 48: 82-87.
32. Youngs, R.L. and A.L. Hammett, 2001. Diversity, productivity, profitability, sustainability and the Tao of underutilized species. For. Prod. J., 51: 29-35.
33. Ogunsanwo, O.Y., 2000. Characterization of wood properties of plantation grown Obeche (*Triplochiton sceleroxylon* K. Schum) in Omo Forest Reserve, Ogun State, Nigeria. Ph.D. Thesis, Department of Forest Resources Management, University of Ibadan, Nigeria.
34. Desch, H.E. and J.M. Dinwoodie, 1981. Timber: Its Structure, Properties and Utilization. 6th Edn., Macmillan Education, London, UK., ISBN-13: 9780333257524, Pages: 410.