Journal of Research in Forestry, Wildlife & Environment Vol. 11(3) September, 2019
http://www.ajol.info/index.php/jrfwe
jfewr ©2019 - jfewr Publications
E-mail:jfewr@yahoo.com
ISBN: 2141 – 1778
Sotannde and Riki, 2019

WOOD QUALITY STUDIES OF SOME WOOD SPECIES IN SUDANO-SAHELIAN ENVIRONMENT OF BORNO STATE, NIGERIA

Sotannde A.O.[1] and Riki, J.T.B.[2*]

[1]Department of Forestry and Wildlife, Faculty of Agriculture, University of Maiduguri, Borno State Nigeria.
[2]Department of Forestry and Wildlife Management, Faculty of Agriculture and Life Sciences, Federal University Wukari, Taraba State.
*__Corresponding author:__ *rikijosiah @gmail.com* /+234-803-559-2140

ABSTRACT

This study investigates wood properties of Azadirachta indica, Eucalyptus camaldulensis, and Khaya senegalensis to determine their potentials for timber in Nigeria. The species were randomly selected from a Forestry and Wildlife Nursery plantation within University of Maiduguri, Borno State in the North-eastern part of Nigeria. Three sampled trees were felled approximately 15cm to the ground and neatly de-branched. From each tree, 3 discs of 6cm height and a billet of 30cm were cut from each bole making a total of 9 discs and 3 billets from each stem, and 27 discs were taken at three height levels: base, middle and top of the merchantable height (MH) to determine their physical properties. Selected wood properties varied considerably among the species (P < 0.05). Wood density, annual ring, bark, sapwood and hardwood proportions decreased from the base to the top while moisture content, bast and pith proportions increased from base to top of the all the species along the sampling heights. The hygroscopicity of the wood shows that longitudinal shrinkage increased from base to top of all the selected species and others do not follow a particular pattern. This results however, when compared with other research results on bark portion shows the juvenility of the sample tress. The shrinkage behaviour of this species are low and indicates that the problems of cracking, splitting, opening of joint and warping in service will be minimal. The average annual ring of the selected species is estimated to be 6 A. indica, 5 in E. camaldulensis and 6 in K. senegalensis, this showed that the trees are still at the juvenile sap stage.

Keywords: *Azadirachta indica, Eucalyptus camaldulensis, Khaya senegalensis* Wood quality, Hygroscopicity

INTRODUCTION

Wood is one of the oldest, best known structural material, and one of the few renewable natural resources. The ubiquitous nature of wood has made it a valuable material in every stage of human development (Fuwape, 2000; Falemara *et al.,* 2012). All wood is composed of cellulose, hemicelluloses, lignin, and minor amount (5% to 10%) of extraneous materials contained in a cellular structure. Variations in the characteristics and volume of these components and differences in cellular structure make wood heavy or light, stiff or flexible, and hard or soft. However, to use wood to its best advantage and most effectively in engineering applications, specific characteristics or physical properties must be considered. Each wood species has unique cellular structure that creates differences in wood properties and ultimately determines the suitability for a particular use (Brian and Peter, 2002).

Wood quality characteristics can be inherent to particular species, but are also influenced by tree growing conditions. This connection to tree growth gives forest managers both an opportunity and an obligation to manage the tree judiciously for value on every site be it only through choice of rotation length, species selection, and initial spacing and stocking control on some sites, to fertilization, thinning and pruning on others. Many wood quality attributes are heritable, and differences in tree-to-tree quality within species can be traced to genetic differences. Forest managers rely on tree improvement programs to ensure that genetics are considered prior to regeneration and planting. Once an appropriate species is selected, its genetic code will govern tree form, tree growth and inherent wood quality. Through stocking control and other silvicultural treatments, however, the forest manager will embark on live crown management, which will determine growth rate, base of live crown, branch size, stem taper, heartwood/sapwood distribution, and juvenile/mature wood content (Josue, 2004).

The ever increasing market demand for 'traditional' high quality timber in Nigeria has resulted in over exploitation of very strong and durable species like *Milicia excelsa, Khaya spp., Afzelia africana, Nuclea diderrichii, Triplochiton scleroxylon, Terminalia spp* etc. The resultant effect of this is the scarcity of these species in timber market. This become more pronounced in markets located in the Sudano-sahelian region which hitherto depend on the supply of timber from rainforest and derived savannah zone of the country. This is because the traded timber comes from the rainforest and derived savannah regions, there is very little information on the properties of timber species from sudano-sahelia region, hence their utilization potential is limiting. However, in selecting a tree species for structural and construction works and its inclusion in future large forest plantation programme, information on the wood properties is essential (Sotannde *et al*., 2010). This study was therefore carried out to identify and describe the basic physical properties of *Azadirachta indica, Eucalyptus camaldulensis* and *Khaya senegalensis* in Sudano-Sahelian Environment of Borno State, Nigeria to provide wood property information as well as technical information for wood user and proffer possible utilization potentials as an alternative to the economical wood species.

MATERIALS AND METHODS

Study Area

The trees of *A. indica, E. camaldulensis* and *K. senegalensis* used for this study were felled from a research plantation of the Department of Forestry and Wildlife within the University of Maiduguri, in the North-eastern part of Nigeria, located on latitude 11°30''N and longitude 14° 45''E. The climate is hot and dry for most part of the year. The average annual rainfall is 650mm with a relative humidity of 42-49%. The soil type is generally sandy loam and well drained.

Sampling Technique

Three trees of fairly straight and cylindrical bole with no sign of mechanical damage or attack by fungi and insects were randomly selected from the plantation. The sampled trees were felled approximately 15cm to the ground and neatly de-branched. From each tree, 3 discs of 6cm height and a billet of 30cm were cut from each bole making a total of 9 discs and 3 billets from each stem, and 27 discs were taken at three height levels: base, middle and top of the merchantable height (MH). From the discs obtained, the estimated ages of the trees are 6 years for *A. indica* and *K. senegalensis* while *E. camaldulensis* is 5 years and the following measurements were carried out.

Determination of wood density

The freshly cut sample of 2 cm × 2 cm × 2 cm of about 90 cubes were weighed each with an electronic weighing balance while the volume of each sample were computed based on their dimension. The samples were oven-dried at a temperature of 102±3°C and weighed at an interval until a constant weight was obtained. Thereafter, the oven dried weight was measured together with the dimension of each cube. Density was then determined using this relationship:

$$P = \frac{W_o}{V_o} \quad \text{.......} \quad 1$$

Where;
P = density ($g.cm^{-3}$)
W_o = oven-dry weight (g)
V_0 = volume (cm^3)

Determination of moisture content of wood

The samples were oven-dried until a constant weight was recorded. The moisture
content determination is shown in equation below:

$$MC = \frac{Wm - Wo}{Wo} \times 100 \text{...........} \ 2$$

Where:
MC=Moisture Content
Wm = Weight of the test wood samples before oven-drying (g)
Wo = Weight of the test wood samples after oven-drying (g)

Determination of bark thickness

To obtain the bark thickness of each sampled disc, calibrated ruler was placed on the transverse surface of the disc to measure diameter outside bark of the disc and diameter inside bark which is the xylem (wood). The bark thickness was obtained using the following formula:

BT = DOB – DIB……………… 3

Where:
BT is the bark thickness,
DIB is diameter inside bark (wood),
DOB is diameter outside bark.

Determination of sap and heart wood

There is a visual distinction from sapwood, heartwood to the Pith. The pith is located at the centre of the wood which is darker in colour and well distinct. The heartwood is brownish or yellowish in colour that distinguished from the light colour of sapwood portion.

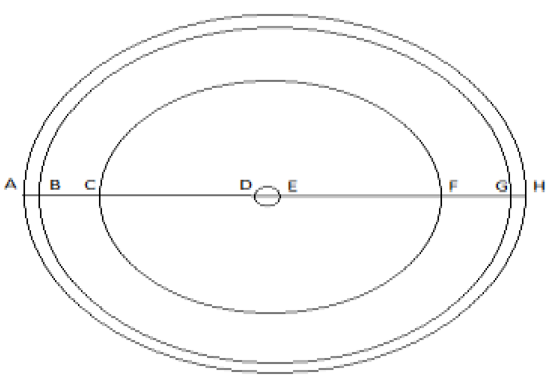

Fig 1: Annotated diagram of a wood cross section AB and GH represent the bark; BC and FG represent the sapwood; CD and EF represent the heartwood; DE represents the pith.

$$Sapwood = \frac{BC + FG}{2} \ldots\ldots\ldots\ldots\ldots \ 4$$

$$Heartwood = \frac{CD + EF}{2} \ldots\ldots\ldots\ldots \ 5$$

Determination of Growth Ring Number

The variations in age of trees as reflected in the number of growth rings were estimated along the main stem corresponding to the base, middle and top of the tree. This involves smoothing one surface of each disc; identify any false ring and counting the number of actual growth ring with the aid of magnifying hand lens.

Ring width Determination (cm)

The ring width determination was estimated by direct measurement on the transverse surface of each disc from the pith towards the bark using a magnifying hand lens over a calibrated transparent ruler. This involved measuring the distance between the transition zone of the late wood of previous years and the early wood of succeeding year.

Hygroscopicity of wood

This was determined based on shrinkage characteristics of the wood samples. The dimension of the freshly cut samples of 2 cm × 2 cm × 2 cm were taken at maximum moisture content (MMC) in the longitudinal, radial and tangential surface, the samples were oven-dried at temperature of 102±3^{o}C until a constant weight was obtained. The dimensions of the oven-dried samples were also taken in longitudinal, radial and tangential direction. The dimensional shrinkage in longitudinal, radial, and tangential direction was obtained using the relationships below:

$$Tgs = \frac{Dt - dt}{dt} \times \frac{100}{1} \ldots\ldots\ldots\ldots \ 6$$

$$Rgs = \frac{Dr - dr}{dr} \times \frac{100}{1} \ldots\ldots\ldots\ldots 7$$

$$Lgs = \frac{Dl - dl}{dl} \times \frac{100}{1} \ldots\ldots\ldots\ldots 8$$

Where:
Tgs =Tangential shrinkage
Rds = Radial shrinkage
Lgs = Longitudinal shrinkage

Dt = Tangential dimension (mm) at MMC
Dr = Radial dimension (mm) at MMC
Dl = Longitudinal dimension (mm) at MMC
dt = Tangential dimension(mm) at oven-dry at MMC
dr = Radial dimension (mm) at oven-dry MMC
dl = Longitudinal dimension (mm) at oven-dry MMC
The volumetric shrinkage (VS) of each sample was computed using the relationship below:

$$VS = 100 - \frac{(100-\mathrm{Lgs})(100-\mathrm{Rds})(100-\mathrm{Tgs})\%}{10^4} \ldots 9$$

RESULTS

Wood Density

The average wood density of the sampled trees stood at 0.88±0.36g/cm^3 for *E. camaldulensis* been the highest followed by 0.63±0.03g/cm^3 in *K. senegalensis* and the least was found in *A. indica* with a mean of 0.54±0.04g/cm^3. *A. indica* decreased from 0.57±0.03 g/cm^3 at the base to 0.50±0.01g/cm3at the top while *E. camaldulensis* decreased from 0.91±0.02 g/cm^3 at the base to 0.85±0.02 g/cm^3 at the top and *K. senegalensis* followed pattern as it decreased from 0.65±0.04 g/cm^3 to 0.61±0.03 g/cm^3 at the base and top accordingly. (Table 2). Table 1 shows that there is significant differences among the species and sampling heights at (P <0.05).

Moisture Content

Table 2 showed that the mean moisture contents for *K. senegalensis*, *A. indica* and *E. camaldulensis* were 86.96±7.32, 57.30±15.46 and 43.21±3.99% respectively (Table 2). There is significant differences among the species and their interactions at (P <0.05) and the all the sampled trees increase in moisture content from base to top except for *A. indica* which decreased from 73.57±2.96% at the base to 39.51±4.98 at the top (Table 2).

Table 1: Anova results of Wood Density and Moisture content among Tree Species and Sampling Height

Source of variation	Df	Density	Moisture Content
Species (S)	2	0.28*	4489.14*
Sampling height (SH)	2	0.01*	59.63 ^{ns}
S*SH	4	0.00^{ns}	512.31*
Error	18	0.00	16.66
Total	26		

* = Significant (P < 0.05), ns = not significant (P ≥ 0.05), df = Degree of freedom

Table 2: Mean Density and Moisture Content of the sampled tree Species

Species	Wood portion	Density (g/cm^3)	Moisture Content (%)
A. indica	Base	0.57±0.03	73.57±2.96
	Middle	0.54±.031	58.83±6.87
	Top	0.50±0.01	39.51±4.98
	Mean	**0.54±0.04[a]**	**57.30±15.46[a]**
E. camaldulensis	Base	0.91±0.02	40.77± 3.83
	Middle	0.86±0.04	42.53±2.15
	Top	0.85±0.02	46.33±4.48
	Mean	**0.88±0.36 [b]**	**43.21±3.99 [b]**
K. senegalensis	Base	0.65±0.04	78.03±3.33
	Middle	0.64±0.00	90.12±3.87
	Top	0.61±0.03	92.74±1.95
	Mean	**0.63±0.03[c]**	**86.96±7.32 [c]**
General Variation in Sampling Height and Radial Position of Moisture content and Density			
	Sampling Height		
	Base	0.71±0.16[a]	64.13±17.86[a]
	Middle	0.68±0.14[b]	63.82±21.34[a]
	Top	0.65±0.15[b]	59.52±25.33[a]
	Mean	**0.68±0.15**	**62.49±20.98**

* Means ± Standard error of mean of 3 replicate samples while, values with the same alphabet on the same column and same section are not significantly different at =0.05.

Table 3: Anova results of the variations of the wood proportions along the sampling heights of the selected species

Sources of Variation	DF	BKP (%)	BSTP (%)	SWP (%)	HWP (%)	PTP (%)
Species (S)	2	32.51*	2.86*	5408.13*	4361.23*	33.41 [ns]
Sampling Height (SH)	2	3.69 [ns]	1.90*	11.76 [ns]	16.65 [ns]	105.13 [ns]
S*SH	4	1.80 [ns]	0.20 [ns]	36.86 [ns]	42.76 [ns]	14.37 [ns]
Error	18	3.72	0.17	41.86	28.12	11.56
Total	**26**					

* = significant ($P < 0.05$), ns = not significant ($P \geq 0.05$), Df = Degree of freedom.

Wood Properties of the Selected Species

Bark Proportion

As shown in Table 3, the bark proportion varies considerably among the sample species ($P < 0.05$). The bark proportion decreased from 6.66±0.60% at the base to 6.11±1.02% at the top in *A. indica*, while *E. camaldulensis* decreased from 11.16±3.94% at the base to 9.32±2.29% at the top and *K. senegalensis* followed same pattern by decreasing from 10.02±0.87% at the base to 8.57±2.77 at the top. Averagely bark accounted for 8.67±2.37% of the stem cross section of all the selected species (Table 4). Among the species, *E. camaldulensis* has the highest bark proportion of 10.47±2.45% while *A. indica* had the least with 6.68±1.00% (Table 4).

Bast Proportion (%)

There is a marked effect on the bast proportion of the selected species and sampling heights ($P < 0.05$) as shown in Table 3. The bast proportion followed the same pattern as it increased from the base to top with 0.99±0.05% and 2.04±0. 42% respectively in *A. indica*, *E. camaldulensis* increased from 2.11±0.29% at the base to 2.19±0.41% at the top while *K. senegalensis* also increased from 2.38±0.59% to 2.90±0.10% at the base and top accordingly (Table 4). Among the species sampled, *K. senegalensis* had the highest bark proportion with a mean value of 2.46±0.49% while *A. indica* had the least with a mean value of 1.33±0. 61% (Table 4).

Sapwood Proportion

There is significant difference in sapwood proportion among the tree samples (P < 0.05) (Table 3). The sapwood proportion increased from the base to the top for all species as *E. camaldulensis* increased from 11.91±4.56% at the base to 16.45±8.64% at the top, *K. senegalensis* recorded 42.87±2.65% and 48.10±12.10% for base and top respectively while *A. indica* followed different pattern as in decreased from 64.71±2.75% at to 61.52±1.88% at the top. *A. indica* had the widest sapwood proportion (64.71±2.75%) while *E. camaldulensis* had the least 15.31±6.03% (Table 4).

Heartwood proportion

As shows in Table 3, significant differences existed in the heartwood proportion of the sampled Species (P < 0.05). The heartwood proportion increased from 27.64±2.70% at the base to 30.32±1.26% at the top in *A. indica* and decreased from 44.99±0.64% to 40.15±10.73 at base and top of *E. camaldulensis* accordingly while *K. senegalensis* followed same pattern as its decreased from 74.83±1.38% at the base to 69.13±4.65% at the top. Overall, heartwood proportion accounted for 48.06±19.05% of the stem (Table 4). Among trees, *K. senegalensis* had the largest heartwood averaged 71.54±4.03 % while *A. indica* had the least averaged 27.89±2.30% of the total stem (Table 4).

Pith proportion

Sapwood proportion of the pith also increased from the base of the stem to the top with average values of 4.48±0.50% obtained at the base and 13.98±6.80 % at the top of the stem height of *A. indica*, *E. camaldulensis* increased from 4.53±0.61% at the base to 6.48±0.70% at the top and *K. senegalensis* also adopted same pattern as it increased from 5.28±0.68 to 14.09±7.35% of the base and top respectively. Averagely, pith proportion accounted for 7.84±4.57% of the total stem (Table 4). Meanwhile, among trees, *K. senegalensis* had the largest pith with mean value of 9.06±5.41% while *A. indica* had the least, 8.84±5.38 % (Table 4). There is no marked effect among the species and sampling heights (P > 0.05) as shown in Table 3.

Table 4: Mean Variations in wood properties of the selected species along the Sampling Heights

Species	BKP (%)	BSTP (%)	SWP (%)	HWP (%)	PTP (%)
A. indica					
Base	6.66±0.60	0.99±0.05	64.71±2.75	27.64±2.70	4.48±0.50
Middle	7.26±1.28	0.97±0.40	66.06±3.31	25.713.29	8.07±0.60
Top	6.11±1.02	2.04±0. 42	61.52±1.88	30.32±1.26	13.98±6.80
Mean	**6.68±1.00[a]**	**1.33±0. 61 [a]**	**64.10±3.10[a]**	**27.89±2.30 [a]**	**8.84±5.38 [a]**
E. camaldulensis					
Base	11.16±3.94	2.11±0.29	11.91±4.56	44.99±0.64	4.53±0.61
Middle	10.92±1.00	1.33±0.68	17.58±4.82	49.08±8.88	5.84±1.10
Top	9.32±2.29	2.19±0.41	16.45±8.64	40.15±10.73	6.48±0.70
Mean	**10.47±2.45[b]**	**1.87±0.59 [b]**	**15.31±6.03[b]**	**44.74±7.98 [a]**	**5.62±1.12 [a]**
K. senegalensis					
Base	10.02±0.87	2.38±0.59	42.87±2.65	74.83±1.38	5.28±0.68
Middle	7.98±1.03	2.09±0.35	40.83±7.76	70.66±3.91	7.80±0.80
Top	8.57±2.77	2.90±0.10	48.10±12.10	69.13±4.65	14.09±7.35
Mean	**8.86±1.79bc**	**2.46±0.49c**	**43.91±8.34[c]**	**71.54±4.03[a]**	**9.06±5.41[a]**
General Variations in Sampling Height of wood properties					
Sampling Height					
Base	9.28±2.87 [a]	1.83±0.72 [a]	39.83 [a]	49.15±20.73 [a]	4.76±0.65 [a]
Middle	8.72±1.89 [a]	1.46±0.70 [a]	41.49 [a]	48.48±20.13 [a]	7.24±1.29 [a]
Top	8.00±2.37 [a]	2.38±0.50 [b]	42.02 [a]	46.53±18.44 [a]	11.52±6.28 [a]
Mean	**8.67±2.37**	**1.89±0.72**	**41.11**	**48.06±19.05 [a]**	**7.84±4.57 [a]**

*Means ± Standard error of 3 replicate samples. **Note:** BKP = Bark proportion, BSTP = Bast proportion, SW P= sapwood proportion, HWP = Heartwood proportion, PTP = Pith proportion.

Hygroscopic Properties of the Wood Samples

Longitudinal shrinkage

Longitudinally, the shrinkage decreased from 2.20±0.41% at the base to 0. 45±0.08% at the top of *A. indica*, *E. camaldulensis* reduced from 1.30±0.46 to 0.81±0.55% at the base and top respectively while *K. senegalensis* increased from 0.61±0.30% at the base to 0.64±0.13% at the top. Overall, shrinkage in longitudinal direction accounted for 0.890.65% of the volumetric shrinkage of the wood samples (Table 6). Among the Trees, *A. indica* had the highest longitudinal shrinkage with a mean of 1.30±0.82% while *K. senegalensis* had the least with a mean of 0.55±0.27% (Table 6). There is also a marked effect among the species ($P < 0.05$) as presented in Table 5.

Radial Shrinkage

Radially, shrinkage accounted for 3.99±1.06% of the total shrinkage of the wood. It decreased from the base to with 3.99±1.77% to 3.94±1.34% at the top in *A. indica*, *E. camaldulensis* also decreased from 3.82±0.30 to 3.21±1.19% at the base and top accordingly but *K. senegalensis* followed different pattern by increasing from 4.39±0.83% at the base to 5.23±0.42% at the top. Among the trees, *K. senegalensis* had the highest radial shrinkage with average value of 4.56±0.79 % while *A. indica* had the least with 3.66±1.24% (Table 8). The result presented in Table 5, shows that there is no significant difference among tree species ($P > 0.05$).

Tangential shrinkage

There are marked effects in the tangential shrinkage of the selected species ($P < 0.05$). *A. indica* increased from the base to the top with a mean value of 6.91±2.34% obtained at the base and 8.13±2.64% at the top, similarly it increased from 6.09±1.21 to 6.85±1.78% at the base and top in *E.* .
camaldulensis respectively while *K. senegalensis* increased from 12.73±1.50% at the base to 16.01±1.65% at the top. Averagely the tangential shrinkage accounted for 7.58±2.18% of the total volumetric shrinkage (Table 6). Among the tree samples, *K. senegalensis* had the highest tangential shrinkage of 13.75±2.28% while *A. indica* had the least with 6.74±2.23% (Table 6).

Volumetric shrinkage

The volumetric shrinkage is the total shrinkage in wood volume and it amounted to 12.03±2.10% of the stem wood volume of the all selected species. *A. indica* increased from 11.67±2.57% at the base to 13.00±5.13% at top, of the stem height in *A. indica*, *E. camaldulensis* also increased from 10.85±1.05 at the base to 9.89±3.25% at top while *K. senegalensis* increased from 12.73±1.50 to 13.75±2.28% respectively following the same pattern. *K. senegalensis* had the highest volumetric shrinkage with a mean value of 13.75±2.28% and the least with a mean value of 11.05±2.70% in *E. camaldulensis* (Table 6). There are no significant differences both among species and sampling heights of the selected species ($P > 0.05$) seen in Table 5.

Ring Width (RGW)

The result in Table 5 showed that there are marked differences among the tree species and interaction of the selected species ($P < 0.05$). The highest ring width was found in *K. senegalensis* with averaged value of 0.67±0.42cm followed by 0.63±0.42cm in A. *indica* while *G. sepium* had the least with 0.54±0.20cm (Table 6). The sampled species all followed a particular pattern as they all decreased from base to top.

Table 5: ANOVA results of the variations in shrinkage properties and Ring Width of the selected species

Sources of Variation	Df	Lgs	Rds	Tgs	Vs	Df	RGW
Species (S)	2	1.29 *	2.19 ns	16.56 *	20.16 ns	2	0.19*
Sampling Height (SH)	2	1.80 ns	0.30 ns	5.89 ns	6.13 ns	2	0.74 ns
S*SH	4	0.60 ns	1.23 ns	4.80 ns	10.61 ns	4	0.16*
Error	18	0.14	1.09	3.33	7.59 ns	139	0.12
Total	**26**					**147**	

* = significant (P < 0.05), ns = not significant (P ≥ 0.05), Df = Degree of freedom

Table 6: Mean Variations in Wood shrinkage properties and Ring Width

Species	Lgs	Rds	Tgs	Vs	RGW
A. indica					
Base	2.20±0.41	3.99±1.77	6.91±2.34	11.67±2.57	0. .86±0.49
Middle	1.24±0.50	3.05±0.60	5.18±0.92	9.20±1.35	0.54±0.39
Top	0. 45±0.08	3.94±1.34	8.13±2.64	13.00±5.13	0.47±0.22
Mean	**1.30±0.82 a**	**3.66±1.24 a**	**6.74±2.23a**	**11.28±3.38a**	**0.63±0.42 a**
E. camaldulensis					
Base	1.30±0.46	3.82±0.30	6.09±1.21	10.85±1.05	1.00±0.23
Middle	0.75±0.57	4.25±1.27	7.87±2.03	12.42±3.57	0.52±0.17
Top	0.38±0.12	3.21±1.19	6.58±2.06	9.89±3.25	0.51±0.21
Mean	**0.81±0.55 b**	**3.76±0.99 a**	**6.85±1.78a**	**11.05±2.70a**	**0.54±0.20b**
K. senegalensis					
Base	0.61±0.30	4.39±0.83	8.16±1.04	12.73±1.50	0.76±0.53
Middle	0.40±0.37	4.06±0.72	8.45±1.90	12.51±2.10	0.72±0.38
Top	0.64±0.13	5.23±0.42	10.81±1.48	16.01±1.65	0.50±0.26
Mean	**0.55±0.27**	**4.56±0.79 a**	**9.14±1.48 b**	**13.75±2.28a**	**0.67±0.42c**
General Variations in Sampling Height of wood Shrinkage properties and Ring Width					
Sampling Height					
Base	1.370.77 a	4.07±1.02 a	7.05±1.68 a	11.75±1.77a	0.74±0.44 a
Middle	0.790.56 a	3.79±1.00 a	7.17±2.10 a	11.38±2.72 a	0.58±0.32 a
Top	0.490.15 a	4.13±1.28 a	8.51±2.60 a	12.96±4.11 a	1.00±0.23 a
Mean	**0.890.65**	**3.99±1.06 a**	**7.58±2.18a**	**12.03±2.10 a**	**0.61±0.36**

*Means ± Standard error of 3 replicate samples. **Note:** Lgs = Longitudinal shrinkage, Rds = Radial Shrinkage, Tgs = Tangential Shrinkage, Vs = Volumetric shrinkage and RGW = Ring Width.

DISCUSSION

Wood density

Wood density is widely regarded as one of the most influential properties affecting the strength and several wood characteristics. Savidge (2003), opined that basic wood density is the prime wood quality consideration for industry as higher wood values yield stronger and more pulp wood density has been the focus of many researchers in the past and has traditionally been the factor on which the utilization potential of timber species are based (Oyagade and Fabiyi, 2002; Akpan, 2007; Poku *et al.,* 2001; Oluwadare and Somorin, 2007). This could be attributed to the fact that density has been very good indication of wood strength, stiffness and stability (Josue, 2004). The average value of 0.63±0.03g/cm^3 in *K. senegalensis* was lower than the previous finding by Sotannde *et al.,* (2015), which reported the density to be 0.732±0.12g/cm^3 but followed same trend for the species along the sampling height as it decreased from base to top (Sotannde *et al*., 2010; Sotannde *et al*., 2015).

Moisture content

Moisture content is the ratio of oven-dry weight of a given volume of wood to the weight of an equal volume of water (Baker *et al.,* 2009) is considered to be a good indicator of wood quality. The moisture content of 86.96±7.32% was obtained in *K. senegalensis,* 57.30±15.46% in *A. indica* and 43.21±3.99% was found in *E. camaldulensis* along the sampling heights were all high. This is an indication that moisture is one of the major components of wood.

In this study, the axial pattern of variation of moisture content increased from base to the top following a similar trend as reported by Sotannde *et al.,* (2015) except for *A. indica* which decreased from base to top. The mean value of all the woods studied is greater than 12% often reported in literature for most hardwood species (Ogunsanwo, 2000). The high moisture content could be as a result of wood anatomy, tree age and specie hence, the need to dry wood before use for efficient handling, transportation and storage.

Bark Proportion (%)

Wood bark protects wood from extreme temperature, drought, provides mechanical protection to the softer inner bark and also help to limit evaporative water loss (Raven *et al.,* 1999). It is rich in chemical substances such as tannin and dyes derived plant metabolism. In all the sampled species, bark thickness decreased from the base to the top and accounted for an average 8.67±2.37% of the stem cross section of the selected species. This perhaps explains the juvenility of the sampled trees. Being dry zone species, it is expected that wood bark values could be higher as an adaptive feature of the species to cope with water stress and high temperature (Sotannde *et al.,* 2015).

Bast Proportion (%)

Bast Proportion is important in that bast fibre as found in many non-wood fibre sources is an additional source of fibre. Averagely, bark accounted for 1.89±0.72% of the stem cross section of the selected species. Depending on the quality of the fibre, it could furnish additional fibre material in addition to the woody portion, this need further investigation because the total bast might be an indication of relative growth rate of the tree because bast is made of mostly cambium cell. Bast fibre, could furnish additional fibre material in addition to the woody portion (Oluwadare and Egbewole, 2008).

Sapwood Proportion (%)

Sapwood is the outer portion of a wood stems, trunk or log usually distinguishable from the core or heartwood by its lighter colour. In the living tree, the sapwood is responsible not only for the conduction of sap, but also for the storage and synthesis of biochemicals. Starch grains are stored in the parenchyma cells, and can be easily seen using a microscope. The starch content of sapwood can have important ramifications in the wood industry (Wiedenhoeft and Miller, 2005). To wood workers, the most significant aspect of sapwood is the colour which ranges from whitish to yellowish or light (Hoadley, 2000).

Heartwood Proportion (%)

Heartwood is the area of extractive-impregnated dead cells at the centre of the tree. Heartwood functions in the long-term storage of biochemicals of many varieties depending on the species. These chemicals are known collectively as extractives. In the past it was thought that the heartwood was a disposal site for harmful by-products of cellular metabolism, the so-called secondary metabolites (Wiedenhoeft and Miller, 2005).

Pith proportion (%)

Pith is the central core of the wood. It is formed by epical meristem of the growing tip which is found in the stems and sometimes in the root. The shape and diameter help in the identification of plant species producing the wood. Usually it does not increase in diameter it decreases in its diameter. It contains water in some species, although it believed to be functionless. The pith proportion increases from the base to the top along the sampling height in all the selected species. This shows that more mature wood at the base had lower proportion of pith and juvenile wood at the top had greater proportion.

Longitudinal shrinkage

Longitudinal shrinkage occurs in the direction of the growth. Longitudinal shrinkage is the defect that is most frequently associated with juvenile wood (Philip *et al.*, 2001). This values fall between 0.1% - 1.5% and further confirmed that longitudinal shrinkage of the wood usually very small and less than one Akpan (1999). The mean value of 0.55±0.27% gotten in *K. senegalensis* is higher than the value reported by Sotannde *et al.*, (2015) and this may be due to age differences in the sampled species. This shows that lumber from this specie can exhibit minimum dimensional changes after drying. This might be an advantage for the stability of the wood for structural work.

Radial shrinkage

The radial shrinkage runs from the pith to bark direction, provides lateral support for biochemical and in many cases performs a fraction in the storage of function in wood (Wiedenhoeft and Miller, 2005). Along the sampling height of all the sampled trees, radial shrinkage increased from the base to the top of the stem. The observed trends in the relationship between sampling heights might be due to the decreased wood content with height (Oyagade and Fasulu, 2005).

Tangential shrinkage

On tangential shrinkage, growth rings appear as a series of cones, one within the other and with the apices of the cone point toward the top of the tree. The tangential planes are at right angle to the radial planes. The tangential plane of section does not provide any information about features that vary in the radial direction, but it does not provide information about the tangential dimension of feature (Wiedenhoeft and Miller, 2005). Generally shrinkage along the principal direction slightly increased with increase in sampling height (Oyagade and Fasulu, 2005).

Volumetric shrinkage

In all the samples, volumetric shrinkage increased from the base to the top which is inconsonance with the report of Sotannde *et al.*, (2015) The high radial and tangential shrinkage might be due to the alignment of wood cells in those axes (Josue, 2004).

Ring Width (RGW)

The width of the growth ring indicates the rate of growth of tree. When there is fast growth, wider growth rings will be produced than when there is slow growth. In many woods in the tropics growth rings are not evident. However, continuing research in this area has uncovered several characteristics whereby growth rings can be correlated with seasonality changes (Callado *et al.*, 2001). Along the sampling height there is a general reduction in ring width from the base to the top. The common trend in most wood whether hardwood or softwood has being gradually decreased from pith to bark (Osadare, 2001: Sotannde *et al.*, 2015).

CONCLUSION AND RECOMMENDATIONS

Conclusion

Based on this study the following conclusions were made.

The thickness of the bark of the selected species are small (6.68±1.00 - 10.47±2.45%), probably due to the young ages of the trees. The high values of bast proportion of *E. camaldulensis (*1.87±0.59%*) and K. senegalensis* (2.46±0.49%) shows that they can be used as an additional fibre material in pulp and paper industry. The sapwood formed about 64% in *A. indica*, *E. camaldulensis* 15% and 43% *K. senegalensis* of the total stem cross section while the heartwood of *A. indica* constituted only 27% almost disappeared towards the top of the stem. The average annual ring of the selected species is estimated to be 6 *A. indica*, 5 in *E. camaldulensis* and 6 in *K. senegalensis*, this showed that the trees are still at the juvenile sap stage. The density of the wood species shows that strength of a timber depends on its species as it varies from specie to specie and hence different wood species have different strength characteristics. The results obtained in this study have provided quantitative information on the density of selected wood species which can be used as alternative to the economical wood species for construction and structural purposes. The high moisture content could be as a result of wood anatomy, tree age and specie hence, the need to dry wood before use for efficient handling, transportation and storage. The shrinkage behaviour of the selected species is low and indicates that the problems of cracking, splitting, opening of joint and warping in service will be minimal.

Recommendations

Silvicultural practices are needed to increase the merchantable height of the stem, likewise more details are required for the strength characterization of the wood since their densities shows that they can be used as alternative to the economical wood species. Closer sampling should be carried out along the stem height to understand the uniformity of wood properties. There would be need to investigate the chemical properties of the wood and how this relate to strength properties.

REFERENCES

Akpan, M. (1999). Dimensional changes of wood in service; potential of *Eribroma oblanga* for interior decoration. *Journal of technology and development*, 7: 6-11.

Akpan, M., (2007): Hygroscopic properties of neem (*Azadirachta indica*): An experimental determination of the shrinkage characteristics. *Global nest Journal*, 9(2): 152-158.

Brain Bond and Peter Hammer (1998): Wood identification for hardwood and softwood species native to Tennessee. Research Associate Department of Forestry, Wildlife and Fisheries, The University of Tennessee, Tennessee, USA: pp 16.

Falemara, B. C., Owoyemi, J.M., and Olufemi B. (2012): Physical Properties of Ten Selected Indigenous Wood Species in Akure, Ondo State, Nigeria. *Journal of Sustainable Environmental Management* (JSEM) 4:16 – 23.

Fuwape, J. A (2000): Wood utilization: From cradle to the grave. Inaugural lecture delivered at Federal University of Technology, Akure. Nigeria. 1-33pp.

Hoadley, R. B. (2000): Understanding Wood: A Craftman s Guide to Wood Technology.

John. P (2004):Tree growth, foresting and their implications for wood quality. PMW 576 September 2004. A pacific NorthWest Extension Publication Oregan State University, Washington DC.

Josue, J. 2004. Some wood properties of *Xylia xylocarpa* planted in Sabah. *Sepilok Bulletin* 1: 1-15.

Ogunsanwo, O. Y. 2000. Effects of pulp blending and beating on selected strength properties of Pine- *Gmelina* hand sheets in Nigeria. *Journal of Tropical Forest Resources,*16 (58 – 65).

Oluwadare, A. O. and Somorin, O. A. (2007): Preliminary report on utilization potential of *Gliricidia sepium* (Jacg.). steud for timber. *Research journal of forestry*, (2): 80-85.

Oluwadare, A. O. and Egbewole, Z. T. 2008. Wood quality studies in plantation-grown Sterculia (*Sterculia setigera* Del.) in the Guinea savanna, Nigeria. *Research Journal of Forestry*, 2 (1): 22-23.

Osadare, A. O. (2001): Basic wood and pulp properties of Nigeria grown Caribbean pine (Pinus Caribbean) and their relationship with tree growth indics. Ph.D thesis, University of Ibadan, Ibadan.

Oyagade, A. O. and Fasulu, S. A. (2005): Physical and Mechanical properties of *Trilepisiummadaga scariensis* and *Funtumia elastica* wood. *Journal.of Tropical Forestry Science* 7(2):258-264.

Oyagade, A. O. and Fabiyi, J. S. 2002. Density variation in plantation grown *Nauclea diderrichii*. J. Trop. For. Resources., 18(1): 26-34.

Philip, R. L., David, E.K., Alexander, C. and Isebrand, J. G (2001): Formation and properties of juvenile wood in sourthern pines. Pp 245.

Poku, K., Qinglin, W. and Vlosky, R. (2001): Wood properties and their variations within tree stem of lesser-used species of tropical hardwood from Ghana. *Wood and Fiber Science,* 33 (2): 284-291.

Raven, P., Evert, R., and Eichhorn, S. (1999): Biology of plants (6thed.). W.H. Freeman, New York.Rijkaert,

Savidge, R. A. (2003): Tree Growth and Wood Quality. Wood Quality and its Biological Basis. Author: Jeronimidis JR and Barnett G. Blackwell Publishing, CRC Press. Pp. 226.

Sotannde, O. A., Oluyege, A. O., Adeogun P. F. and Maina S. B. (2010): Determination in wood Density, Grain Orientation and Anisotropic Shrinkage of Plantation Grown *Azadirachta indica*. *Journal of Applied Sciences Research,* 6(11): 1855-1861.

Sotannde A. O., Anguruwa, G. T. and Ishaya, D. (2015): Wood Quality Study of 9-Year Old Plantation Grown *Khaya senegalensis* in Sudano-Sahelian Environment of Borno State Nigeria. *Journal of Forestry Research and Management*. 12, 95-112.

Wiedenhoeft, A. C. and Miller, R. B. (2005): USDA, Forest Service, Forest Products Laboratory, Madison, WI.Pp 12.