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DENSITY AND SHRINKAGE PROPERTIES OF APA (AFZELIA AFRICANA SM. EX. PERS.) WOOD IN TARABA STATE, NIGERIA

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Abstract:
This study determines density and shrinkage of Apa (Afzelia africana) wood in Taraba State, Nigeria for utilization as timber. Three study locations were randomly selected from defined zones of Taraba State for the study. These are Ardokola, Bali, Ussa in the Northern, Central and Southern Zones respectively. From each of the study locations 5 matured Apa trees of 20 years and above were randomly selected and felled, from which 45 wood specimens were prepared for the tests using standard procedures. Analysis of variance (ANOVA) was used to test the level of significance of the parameters, between the zones, trees, and tree sections. At an average moisture content of 13.51%, Apa has a density of 718.16kg/m^3, and volumetric shrinkage of 18.70%. There was significant difference of Afzelia wood density across the zones at 1% level of significance ($P<0.01$). Also, significant difference of density was obtained between the trees and their sections ($P<0.05$). However, there was no significant difference of the wood shrinkage across the zones, as well as the trees, and their sections. The density and shrinkage values compare favourably with those of common wood species used for timber in Nigeria. Thus, Afzelia wood could be suitable for timber production.

Key words: *density; shrinkage; Afzelia africana; timber production; Taraba state.*

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INTRODUCTION

As a result of technology advancement and population increase, there has been a phenomenal rise in demand and use of wood in Nigeria. In view of this, wood is gradually becoming scarce and expensive, particularly in northern Nigeria. In northern states of Nigeria, timber for furniture and other building constructions are obtained significantly from southern Nigeria (Opeyemi and Udo 2011), and the procurement and transport arrangements are beset with some obvious difficulties that must be overcome to reduce the escalating price. On this note, wood species that are successfully grown in northern states, with particular reference to Taraba state should be examined with a view of establishing their plantations to supplement the reduced natural forest timber as proposed by Lamb (2012).

Afzelia africana is one of the most successfully grown tree species in Taraba state and it is the species of choice for this research. Despite the wide information on the physical and mechanical properties of the wood in southern Nigeria (Ghelmeziu 1981; Akpan 2006), there is an apparent information gap as to the documentation of its properties in relation to timber utilization in northern states of Nigeria. The objectives of this study are to determine the density and shrinkage properties of Afzelia wood in Taraba state, Nigeria and compare the values with those wood that are commonly used for timber in Nigeria; with a view of ascertaining its suitability for timber utilization.

MATERIALS AND METHODS

Description of the Study Location

This study was carried out in Taraba state, which covers a land area of 59,400km^2 (Ministry of Land and Survey (MLS) 2009). The state currently has sixteen local government areas, namely: Jalingo, Donga, Zing, Lau, Karim Lamido, Sardauna, Bali, Gashaka, Wukari, Takum, Ibi, Yorro, Ardokola, Kurmi, Ussa and Gassol. Taraba State lies between latitude 6^0 30^1 and 9^0 36^1 North and longitude 9^0 10^1 and 11^0 East (Ministry of Land and Survey 2009). Presently, the state is made up of 3 senatorial zones, namely: northern, central, and southern zones. The representative study locations in each of these zones are Ardokola in northern zone, Bali in central zone, and Ussa in southern zone. Variations of climatic conditions across these zones have been documented by Udo and Mamman (1993).

Density Determination

Five (5) matured Afzelia trees of 20 years and above were randomly selected and felled in each of the zones. Each tree was cross cut into three sections from base to top, that is, bottom, middle and top in accordance with the conventional sampling strategy of 0%, 20%, and 40% of the total tree height. Samples were extracted from defects free areas of each of these sections of the trees and labeled for the test. Thus, a total of 45 specimens were collected from the three zones. Each wood specimen was further cut to a standard dimension of 30mm x 20mm x 20mm in accordance with STAS 2682-68. Based on these standard dimensions, their masses were recorded using the electronic weighing balance. In the same vein, the wood specimens' volumes in terms of their lengths, widths and heights were also measured, using the micrometer screw gauge. Densities of the wood samples were then calculated with the relationship.

$$Density = \frac{Mass\ of\ ovendry\ wood}{Volume\ of\ ovendry\ wood}\ \text{Kg/m}^3 \qquad (1)$$

Prior to density determination, the moisture contents of the test pieces were determined by recording the samples' wet weight, and thereafter drying the wood samples at a temperature of 103^0C ± 2^0C for 24 hours. At intervals of 30 minutes, each sample was removed and weighed, using the electronic weighing balance until a constant weight was obtained for each of the wood samples. The moisture content of the wood samples was then calculated using the equation.

$$Moisture\ Content = \frac{Wet\ Weight - Dry\ Weight}{\textbf{Dry Weight}} \times 100\% \qquad (2)$$

Mean densities of the 45 wood samples were obtained from the three zones. The obtained data were analysed with the Analysis of variance (ANOVA) statistics, by testing the level of significance of density between the different zones, sampled trees and their respective sections. The Fisher's Least Significant Difference (LSD) was used to analyze the established variation. Relationship between density, mass, and moisture content were examined.

Shrinkage Determination

Fifteen (15) tree samples were used for this experiment by randomly selecting 5 trees from each of the 3 zones. Each felled tree was cross cut into three sections from base to top that is, bottom, middle, and top. Thus, 45 test pieces were selected from defects free areas of the trees and prepared according to STAS 2682-68. Accordingly, the wood specimens were cut to standard dimensions of 100mm x 20mm x 20mm. The specimens were cut in such a way that the wood rays in the radial axis were parallel to the fibres in the tangential and longitudinal axes.

Thereafter, the test pieces were completely immersed in water for 60 minutes. Subsequently, at regular intervals of 15 minutes, their moisture contents were determined with the moisture meter until initial (Green) moisture content of at least 30% was attained for each test piece. Immediately, by means of a micrometer screw gauge, the initial (maximum) dimensions of the three axes of the wood were taken. The wood specimens were then dried at a temperature of $103^0C \pm 20^0C$ for 24 hours. At intervals of 30 minutes, the specimens were weighed with the electronic weighing balance, until a constant weight was obtained for each of them. Their final (dry) moisture content was also calculated. Similarly, the final (minimum) dimensions, viz: longitudinal, radial and tangential of the three axes of the specimens were recorded using the micrometer screw gauge. On the bases of these dimensions, tangential, radial and longitudinal linear shrinkage of the 45 wood specimens were calculated with the respective relationships:

$$Tgs = \frac{Dt - dt}{Dt} \times 100\%$$
$$Rds = \frac{Dr - dr}{Dr} \times 100\% \qquad (3)$$
$$Lgs = \frac{Dl - dl}{Dl} \times 100\%$$

where:
Tgs - Tangential Linear shrinkages (%)
Rds - Radial linear shrinkage (%)
Lgs - Longitudinal linear shrinkage (%)
Dt - Initial dimension (mm) along the tangential axis at green moisture content of ≥ 30%
Dr - Initial dimension (mm) along the radial axis at green moisture content of ≥ 30%
D1 - Initial dimension (mm) along the longitudinal axis at green moisture content of ≥ 30%
dt - Final dimension (mm) along the tangential axis at dry moisture content of << 30%
dr - Final dimension (mm) along the radial axis at dry moisture content of << 30%
dl - Final dimension (mm) along the longitudinal axis at dry moisture content of << 30%.

The mean values were obtained as the linear shrinkages of the three asymmetrical axes of the wood samples. In the same vein, volumetric shrinkage (VS) of each of the 45 wood specimens was computed with the relationship:

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

ANOVA was used to analyse the obtained data, by testing the level of significance of shrinkage between the different zones, sampled trees, and tree sections. Relationship between volumetric shrinkage and drying (at 15 minutes interval of drying) in the three zones were examined.

RESULTS

Wood Density

Based on the specimen's masses (Kg) (Table 1) and constant volume of $6.75 \times 10^{-5} m^3$, their densities were computed at an average of 14.48% moisture content. The density results in the three study locations are contained in Table 2. In the northern zone of the state, the mean density is $695.77 kg/m^3$. In the central zone, the mean density is $701.32 kg/m^3$, while the southern zone has a mean density value of $757.38 kg/m^3$. The overall mean density of the wood species across the three zones is $718.16 kg/m^3$. This value agrees with the general range of wood densities as published by Desch (1992), who recorded a density variation of $160 kg/m^3$ to $1250 kg/m^3$ among tree species. Afzelia density value compares favourably with some economic trees commonly used for timber in Nigeria. Examples of these tree species according to Ghelmeziu (1981), Desch (1992), and Akpan (2010) include *Eribroma ablonga* (670kg/m^3), *Khaya ivorensis* (485kg/m^3), *Chlorophora excelsa* (660kg/m^3), *Mitragyna ciliata* (560kg/m^3), *Tectona grandis* (660kg/m^3), *Triplochiton scleroxylon* (368kg/m^3),*Mansonia altissima* (615kg/m^3), *Terminalia ivorensis* (550kg/m^3), and *Terminalia superba* (580kg/m^3). Thus, Afzelia wood will be a promising tree species for timber utilization.

The result of the analysis of variance (ANOVA) shows that there is significant difference between density of the trees and their sections at 5% level of probability (P<0.05), while the zones showed highly significant difference of density at 1% level of probability (P<0.01) (Table 3). The Fisher's Least Significant Difference analysis reveals that there is significant difference between means of the zones, the trees, and the tree sections, as each mean difference is greater than the LSD value (Table 4). These results agree with the works of Desch (1992) and Akpan (2010), who recorded considerable variation in wood density between and within tree species. Figure 1 shows the graphical relationship between density and mass of the sampled trees, and Figure 2 shows the relationship between density and moisture content of the trees. The results show that density increases both with mass and moisture content of the wood samples.

Table 1

Mass (kg) of Afzelia Wood in the Three Zones of Taraba State

Tree Samples	Northern Zone Wood Specimens			Central Zone Wood Specimens			Southern Zone Specimens		
	1*	2*	3*	1*	2*	3*	1*	2*	3*
1	0.04927	0.04843	0.04357	0.04966	0.04851	0.04422	0.05200	0.05192	0.05124
2	0.04643	0.04562	0.04317	0.04720	0.04651	0.04443	0.05175	0.05155	0.05120
3	0.04677	0.04628	0.04528	0.04700	0.04672	0.04582	0.04975	0.04822	0.04755
4	0.04923	0.04815	0.04732	0.04941	0.04879	0.04772	0.05196	0.05190	0.05182
5	0.04835	0.04878	0.04782	0.04892	0.04822	0.04699	0.05223	0.05200	0.05175

*1– bottom, 2 – Middle, 3 – top

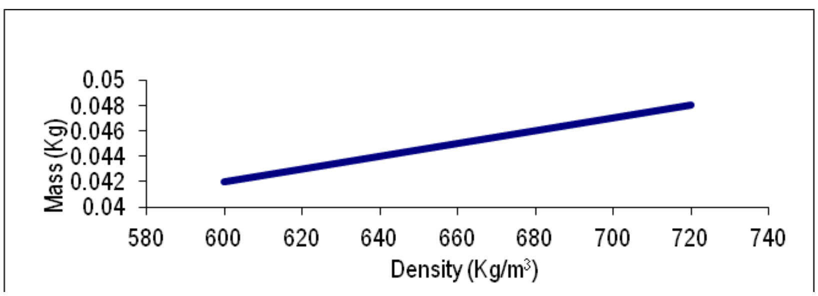

Fig. 1
Relationship between density and mass of Afzelia wood in Taraba State.

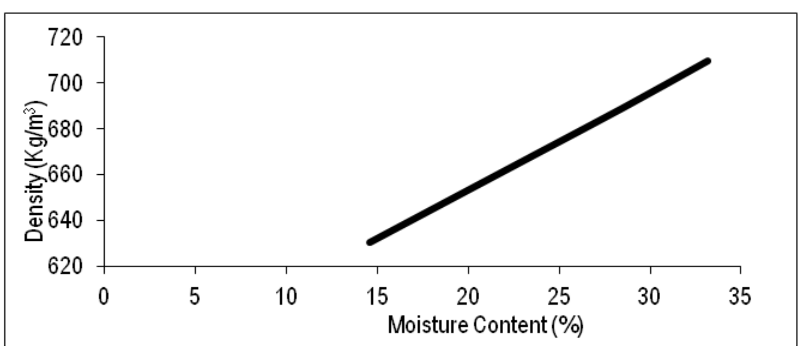

Fig. 2
Relationship between density and Moisture Content of Afzelia wood in Taraba State.

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Table 2

Density (kg/m^3) of Afzelia africana Wood in the Three Zones of Taraba State

Tree Samples	Northern Zone Wood Specimens				Central Zone Wood Specimens				Southern Zone Wood Specimens				
	1*	2*	3*	Mean	1*	2*	3*	Mean	1*	2*	3*	Mean	Overall Mean
1	729.93	717.48	645.48	697.63	735.70	718.66	655.11	703.16	770.37	769.19	759.11	766.22	722.34
2	687.85	675.85	639.56	667.75	699.30	689.04	658.22	682.19	766.76	763.70	758.52	762.99	704.31
3	692.88	685.63	570.82	683.11	696.30	692.15	678.82	689.09	737.04	714.87	704.44	718.62	696.94
4	729.33	713.33	701.04	714.57	732.00	722.82	706.96	720.59	769.77	768.88	767.70	768.78	734.65
5	716.30	722.66	708.44	715.80	724.24	714.37	696.15	711.59	773.77	770.37	766.76	770.30	732.56
Mean	711.26	702.99	673.07	**695.77**	717.51	707.41	679.05	**701.32**	763.54	757.30	751.31	**757.38**	**718.16**

*1-bottom, 2-middle, 3-top

Table 3

ANOVA Result of Afzelia africana Wood Density

SV	SS	Df	MS	F	P-Value
Trees	298872.60	4	285671.30	1.03*	0.0496
Zones	468287.78	2	283686.89	1.02**	0.0036
Tree Sections	4564576.63	2	278818.88	1.00*	0.0251
Error	18402550.84	14	269514.44		
Total	22316287.85	22			

* - Significant (P<0.05) **- Highly significant (P< 0.01)

Table 4

Fisher's Least Significant Difference for Density

Least Significant Difference		2.21Kg/m^3
Zone	Sample Size	Mean Density (kg/m^3)
Northern Zone	45	695.77 **a**
Central Zone	45	701.32 **b**
Southern Zone	45	757.38 **c**
Tree Sections	Sample Size	Mean Density (kg/m^3)
Bottom	45	730.77 **a**
Middle	45	722.56 **b**
Top	45	701.14 **c**

N.B. Means with the same letter are not significantly different.

Wood shrinkage

Results of the volumetric shrinkage as contained in Table 5 show that in the northern zone the property has a mean value of 18.77%. In the central zone, the mean value is 18.85%, while in the southern zone, the mean value is 18.49%. The overall mean volumetric shrinkage across the three zones is 18.70%. This value tends to be on the high side when compared with some Nigerian timber (Ghelmeziu 1981, Akpan *et al.* 2001). However, it still compares favourably with shrinkage values of some locally used timber. Examples of such timber are *Uapaca guineensis* (19.9%), *Strombosia pustulata* (19.7%), *Terminalia ivorensis* (18.8%), *Sterculia rhinopetala* (20.9%), *Distemonanthus benthamianus* (20.6%), and *Lophira alata* (19.8%) (Ghelmeziu 1981).

Findings also indicate that the tangential shrinkage at 12.74% is about twice as large as the radial shrinkage with a value of 6.26% at the same moisture content of 13.05%. In addition, the volumetric shrinkage is approximately the sum of the tangential and radial shrinkages, since the longitudinal shrinkage from green to oven dry condition is almost negligible. These observations are in accordance with the work of Akpan (2007). It was also observed that shrinkage did not occur when the wood samples were fully saturated with water. However, as the moisture content in the wood samples reduces from green to dry condition, the volumetric shrinkage increases (Figure 3). This scientific concept is explained by the fact that wood begins to shrink only when it attains fibre saturation point; and the more moisture that leaves the wood, the higher the volume of shrinkage. The shrinkage finally ceases when the wood is completely dried, attaining equilibrium moisture content (EMC), because the wood moisture content decreased towards the air moisture content (Sova 2006). Results of the analysis of variance (ANOVA) (Table 6) and the Fisher's Least Significant Difference (Table 7) of volumetric shrinkage indicate that none of the three different zones, as well as the trees and their sections showed significant difference of shrinkage values at 5% probability level (P>0.05).

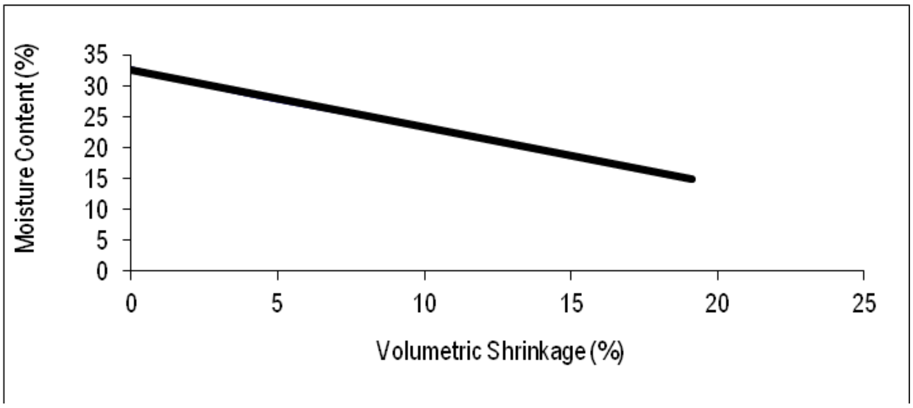

Fig. 3
Relationship between volumetric shrinkage of Afzelia wood and drying from green to oven dry moisture content.

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Table 5

Volumetric Shrinkage (%) of Afzelia africana in the Three Zones of Taraba State

Tree Sample	Northern Zone Wood Specimens 1*	2*	3*	Mean	Central Zone Wood Specimens 1*	2*	3*	Mean	Southern Zone Wood Specimens 1*	2*	3*	Mean	Overall Mean
1	18.52	18.40	18.06	18.33	18.66	19.21	19.20	19.02	18.24	18.20	18.22	18.22	18.52
2	18.89	19.05	19.00	18.98	18.86	19.06	19.01	18.96	18.55	18.57	18.20	18.44	18.80
3	18.83	19.30	18.39	18.84	18.20	18.60	19.15	17.65	19.13	18.71	18.70	18.85	18.78
4	19.06	18.98	18.71	18.92	19.02	18.80	18.50	18.77	18.21	18.96	18.78	18.65	18.78
5	18.70	18.60	18.97	18.76	18.60	18.98	18.90	18.83	18.50	18.15	18.21	18.29	18.63
Mean	18.80	18.87	18.63	**18.77**	18.67	18.93	18.95	**18.85**	18.53	18.52	18.42	**18.49**	**18.70**

*1 – bottom, 2 – middle, 3 – Top

Table 6

Results of ANOVA of Afzelia africana Wood Shrinkage

SV	SS	Df	MS	F	P-Value
Trees	5.58864148	4	0.39918868	1.45 ^{ns}	0.1504
Zones	0.38864148	2	0.19432074	0.70^{ns}	0.4974
Tree Sections	0.55758370	2	0.27879185	1.01^{ns}	0.3685
Error	23.18147111	14	0.27596989		
Total	29.716338	22			

ns- not significant (P>0.05)

Table 7

Fisher's Least Significant Difference for Volumetric Shrinkage

Least Significant Difference		0.1 %
Zone	Sample Size	Mean Shrinkage (%)
Northern Zone	45	18.77 **a**
Central Zone	45	18.85 **a**
Southern Zone	45	18.49 **a**
Tree Sections	Sample Size	Mean Shrinkage (%)
Bottom	45	18.66 **a**
Middle	45	18.77 **a**
Top	45	18.66 **a**

N.B. Means with the same letter are not significantly different.

CONCLUSION AND RECOMMENDATION

Findings from the research revealed that density and shrinkage properties of Afzelia wood compare favourably with some tree species used for timber in Nigeria. Therefore, *Afzelia africana* grown in Taraba state, Nigeria could be a promising tree species for timber utilization. Thus, establishment of Afzelia plantations in Taraba state of Nigeria is therefore recommended. This will provide the state and indeed the entire northern Nigeria with the much needed wooden raw-material for timber.

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