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QUANTITATIVE ANALYSIS OF SHRINKAGE CHARACTERISTICS OF NEEM (*AZADIRACHTA INDICA A. JUSS.*) WOOD IN NORTH EASTERN ZONE OF NIGERIA.

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ABSTRACT

Quantitative analyses of shrinkage characteristics of neem (*Azadirachta indica* A. Juss.) wood were carried out. Forty five wood specimens were prepared from the three ecological zones of north eastern Nigeria, viz: sahel savanna, sudan savanna and guinea savanna for the research. The results indicated that the wood species has a large coefficient of volumetric shrinkage of 19.17% from green (>30%) moisture content to oven dry moisture content of <<30%. The analysis of variance revealed insignificant differences in shrinkage between the three ecological zones, as well as between the sampled trees. Thus, the shrinkage value of neem wood compares favourably with other local wood species. This confirms the suitability of *Azadirachta indica* A. Juss. for timber production.

KEYWORDS: shrinkage, neemwood, moisture content, ecological zones.

INTRODUCTION

Dry wood is highly hygroscopic. The amount of moisture adsorbed depends mainly on the relative humidity and temperature of the surrounding atmosphere (Haygreen and Bowyer, 1982). Exceptions occur in species with high extractive contents, e.g. red-wood, cedar and teak (Thompson, 1988). Addition of water or other polar liquids to the cell wall substance causes the microfibrillar net to expand in proportion to the amount of liquid which has been added. As the humidity decreases, the wood loses moisture to the environment until the fibre saturation point (FSP) is reached. Addition of water to the wood at above FSP produces no change in volume of the wall substance because additional water above the fibre saturation point is concentrated in the lumen (Rietz and Page, 1991). Conversely, the removal of moisture from the cell wall below the fibre saturation point causes the wood to shrink (Akpan *et al*, 1999). Such dimensional change (shrinkage) is traditionally expressed as a percentage of the maximum dimension of the wood, and since the green size is a condition at which no reduction in dimension has yet occurred, the shrinkage is expressed as a percentage of the green volume (Rowell and Banks, 1985).

During shrinkage, changes in volume or shape of the wood may occur because of the development of moisture gradients and stresses, which result in timber warping. The magnitude of such stresses is minimized by drying wood under carefully controlled and empirically established conditions (Udegbe, 1991). Wood shrinkage is highly anisotropic in line with the three asymmetrical axes of wood, viz: tangential, radial and longitudinal. Tangential shrinkage for air-dried wood is about twice as large as the radial at the same moisture content (Suchsland and Woodson, 1986). The volumetric shrinkage is roughly the sum of the tangential and radial shrinkages since the longitudinal shrinkage from the green to ovendry condition is negligible (Harris *et al*, 1985; Kellog and Wangaard, 1989; Akpan *et al*, 1999)

Shrinkage that occurs in wood is a function not only of the quantity of moisture in the wood, but also of the amount of the cell wall substance (Spielman, 1980). According to Spielman(1980), the greater the amount of material present, the larger the shrinkage that is possible to occur at the same percentage moisture content change. Thus, different wood species will react differently to a particular atmospheric change, depending on the anatomical structure of the species in question. Therefore, the need to understudy the shrinkage characteristics of economic timber species prior to utilisation cannot be over emphasized. The objective of this paper is to determine shrinkage characteristics of *Azadirachta indica* A. Juss. in relation to possible utilisation as timber.

Overview of the wood species under study

Azadirachta indica A. Juss. is a hardwood species of the Meliaceae family. It is native to Eastern India. Its local name in Nigeria is Dogon Yaro or Neem. Although this wood species is not native to Nigeria, it is easily adaptable to the local environmental conditions of Nigeria. Researches carried out by Radwanski (1969) in Sokoto showed that neem is a fast growing tree that can be established without irrigation in many arid regions. It grows well on poor shallow, stony or sandy soils. Its powerful and extensive roots have unique physiological capacity to extract nutritive elements from highly leached sandy soils.

However, this wood species is far more than a tree that grows vigorously in difficult sites. According to Khalid *et al* (1989) and Saxena *et al* (1987), its leaves are used in treating malaria and in the control of farm and household pests, while its oil is used in the prevention of tooth decay. Khalid *et al* (1989) also reported that neem seeds and leaves contain compounds with antifungal activities. However, there has been no information on its wood characteristics, particularly shrinkage qualities, in relation to utilisation as timber.

METHODOLOGY

Three study areas were randomly picked from three ecological zones of north eastern zone of Nigeria as classified by Ileoje, (1982) and Dabi (2000) for the research. In each of the study areas, viz: Maiduguri, in sahel savanna; Yola, in sudan savanna; and Bauchi, in guinea savanna, five mature tree samples of neem wood were isolated by selective random sampling from a plot of $5km^2$ (Greenwood, 1999), using

.meter of at least 60cm as basis. In each of these plots, sixteen neem trees, each having a minimum diameter of 60cm were numbered. Replica numbers were placed in a container, and vigorously shaken before numbers were picked from it. The picked number for a particular tree in each of the study

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Table 1: Coefficients of Linear Shrinkage of *Azadirachta indica* A. Juss.

No. of Specimens	Dimensions of Specimens (mm)						MC %		Coefficients of Linear Shrinkage (%)		
	Initial			Final							
	Dt	Dr	Dl	Dt	Dr	Dl	Green	o.d	άt	άr	άl
1	21.61	21.33	30.42	18.90	20.01	30.00	34.01	15.00	12.50	6.10	1.32
2	21.40	21.22	30.22	18.52	19.94	29.92	33.62	14.11	13.55	6.12	1.00
3.	21.52	21.41	30.33	18.92	19.93	29.92	33.90	14.56	12.09	7.01	1.32
4.	21.23	21.03	30.12	18.44	19.94	29.94	32.05	13.50	13.21	6.19	1.00
5	21.32	21.12	30.23	18.33	19.85	29.93	32.41	13.55	14.08	6.16	1.00
6	21.51	21.33	30.30	18.81	20.00	30.02	33.96	14.84	12.56	6.10	1.00
7	21.33	21.22	30.22	18.83	19.83	29.93	33.51	13.24	11.74	6.60	1.00
8	21.33	21.25	30.23	18.52	19.80	29.93	33.44	13.12	13.15	6.60	1.00
9	21.52	21.34	30.34	18.74	19.91	29.91	32.61	13.00	13.02	6.57	1.32
10	21.44	21.25	30.34	18.93	19.85	29.92	32.99	13.00	11.68	6.60	1.32
11	21.24	21.13	30.22	18.80	19.85	29.92	31.04	12.33	11.32	6.16	1.00
12.	21.12	20.82	30.13	18.42	19.74	29.85	31.96	12.00	12.80	5.29	1.00
13.	21.22	21.03	30.13	18.41	19.82	29.85	31.46	12.11	13.21	5.71	1.00

No. of Specimens	Dimensions of Specimens (mm)						MC %		Coefficients of Linear Shrinkage (%)		
	Initial			Final							
	Dt	Dr	Dl	Dt	Dr	dl	Green	o.d	ά t	άr	άl
14	21.33	21.13	30.23	18.60	19.85	29.84	32.09	13.60	12.68	6.16	1.33
15	21.43	21.23	30.34	18.80	19.93	29.94	33.75	13.98	12.15	6.13	1.32
Sahel Mean	21.40	21.21	30.23	18.65	19.84	29.90	32.86	13.46	12.65	6.23	1.13
16	21.63	21.40	30.42	18.92	20.02	30.00	34.05	15.00	12.50	6.54	1.32
17	21.44	21.22	30.34	18.63	19.83	29.90	33.71	14.30	13.04	6.60	1.32
18	21.33	21.23	30.30	18.71	19.82	29.93	32.45	13.50	12.2	6.60	1.32
19	21.52	21.31	30.33	18.84	20.00	30.02	33.55	14.20	12.56	6.10	1.00
20	21.22	21.00	30.23	18.44	19.75	29.85	31.96	13.36	13.21	6.19	1.32
21	21.61	21.44	30.44	18.93	20.03	30.03	33.99	14.81	12.50	6.54	1.32
22	21.40	21.32	30.34	18.85	19.82	29.82	33.08	13.75	12.15	7.04	1.65
23	21.31	21.12	30.24	18.55	19.84	29.83	33.08	13.75	12.15	6.16	1.32
24	21.22	21.13	30.13	18.42	19.84	29.82	31.73	12.99	13.21	6.16	1.00
25	21.33	21.21	30.20	18.52	19.83	29.81	32.52	13.00	13.15	6.60	1.33
26	21.11	20.84	30.12	18.23	19.72	29.83	31.33	12.00	13.74	5.29	1.00
27	21.51	21.42	30.33	18.94	19.90	30.00	33.87	14.80	12.09	7.01	1.00

No. of Specimens	Dimensions of Specimens (mm)						MC %		Coefficients of Linear Shrinkage (%)		
	Initial			Final							
	Dt	Dr	Dl	Dt	Dr	Dl	Green	o.d	át	ár	ál
28	21.43	21.22	30.33	18.72	19.93	29.93	32.66	13.58	12.62	**6.13**	**1.32**
29	21.33	21.22	30.14	18.44	19.83	29.93	31.54	13.66	13.62	**6.60**	**0.66**
30	21.52	21.32	30.23	18.62	19.92	30.01	33.60	14.33	13.49	**6.57**	**0.66**
Sudan Mean	21.41	21.23	30.25	18.62	19.85	29.92	32.83	12.55	12.88	**6.41**	**1.17**
31	21.41	21.22	30.32	18.94	19.94	29.93	32.41	13.50	11.68	**6.13**	**1.32**
32	21.21	21.03	30.23	18.42	19.84	29.84	31.34	12.04	13.21	**5.71**	**1.33**
34	21.52	21.24	30.32	18.84	19.91	30.00	33.77	14.22	12.56	**6.57**	**1.00**
35	21.23	21.12	30.12	18.34	19.82	29.84	31.34	13.29	13.68	**6.16**	**1.00**
35	21.12	20.93	30.10	18.24	19.74	29.83	31.11	12.00	13.74	**5.74**	**1.00**
36	21.42	21.22	30.31	18.82	19.93	29.92	33.35	13.52	12.15	**6.13**	**1.32**
37	21.33	21.23	30.23	18.63	19.84	29.92	32.24	12.66	12.68	**6.60**	**1.00**
38	21.25	21.12	30.22	18.42	19.72	29.83	31.48	12.21	13.21	**6.64**	**1.33**
39	21.53	21.40	30.33	18.73	20.02	30.03	33.17	14.60	12.02	**6.54**	**1.00**
40	21.62	21.42	30.44	19.00	20.00	30.00	33.94	15.00	12.04	**6.54**	**1.32**

No. of Specimens	Dimensions of Specimens (mm)						MC %		Coefficients of Linear Shrinkage (%)		
	Initial			Final							
	Dt	Dr	Dl	Dt	Dr	Dl	Green	o.d	át	ár	ál
41	21.42	21.33	30.33	18.92	19.94	29.93	33.30	13.00	11.68	6.71	1.32
42	21.40	21.23	30.22	18.93	19.93	29.92	33.36	13.11	11.68	6.13	1.00
43	21.33	21.23	30.22	18.83	19.82	29.93	31.91	12.68	11.74	6.60	1.00
44	21.21	21.00	30.12	18.32	19.82	29.84	31.42	12.12	13.69	5.71	1.00
45	21.32	21.22	30.21	18.44	19.93	29.92	31.84	13.32	13.62	6.13	1.00
Guinea Mean	21.31	21.22	30.23	18.63	19.85	29.92	32.40	13.15	12.69	6.22	1.13
Overall Mean	21.37	21.22	30.24	18.63	19.85	29.90	32.70	13.05	12.74	6.29	1.14

areas qualified the tree bearing that number for final selection. Thus, a total of fifteen trees were isolated and felled at breast height. The felled trees were afterward sawn into three sections: top, middle, and bottom. The bottom part started at diameter at breast height (dbh). Thus, forty five test pieces were prepared according to STAS 6085:72 as published by Pescarus and Cismaru (1979), and Desch (1992). Accordingly, the wood species were cut to pieces of 50.00mmx50.00mmx60.00mm for the purpose of oven drying to equilibrium moisture content (EMC) of 12-15%. From each of these oven-dried pieces, standard dimensions of 20.00mm x 20.00mm x 30.00mm were extracted. The selected wood specimens were from defects free zones of the sampled timber. They were also machined to provide for highly smooth surfaces. The specimens were sectioned such 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 30 minutes. Subsequently, at regular intervals of 15 minutes, their moisture contents were measured with the moisture meter, until an initial (green) moisture content of at least 30% was attained for each test piece. This is the fibre saturation point (FSP) of wood. This is the moisture content at which shrinkage begins to occur. At this moisture content level, the initial (maximum) dimensions of the three asymmetrical axes (tangential, radial and longitudinal) of the specimens were taken with a micrometer screw gauge. The wood specimens were then oven dried at a temperature of 103°C ± 2°C for 30 minutes (AOAC, 1980). At intervals of 15 minutes, the specimens were weighed with the electric weighing balance, until a constant mass was obtained for each of them. Their final (ovendry) moisture contents were also taken. Similarly, the final (minimum) dimensions of the specimens were recorded.

The coefficients of tangential, radial and longitudinal linear shrinkages of the forty five wood specimens were calculated with the following relationships, according to

Table 2: Coefficients of Volumetric Shrinkage of *Azadirachta indica* A. Juss.

Tree Sample	Coefficients of Volumetric Shrinkage (%)													
	Sahel Savanna				Sudan Savanna				Guinea Savanna					
	Specimens			Mean Value	Specimens			Mean Value	Specimens			Mean Value	Mean (x)
	1	2	3		1	2	3		1	2	3		
I	18.92	19.66	19.33	19.30	19.30	19.85	19.09	19.41	18.19	19.25	19.12	18.85	19.19
II	19.40	20.18	18.71	19.43	18.71	17.67	19.30	19.23	19.50	19.50	18.65	19.22	19.29
III	18.39	19.69	19.81	19.30	19.68	19.58	19.37	19.54	19.26	20.05	19.52	19.61	19.48
IV	18.60	17.62	18.24	18.15	19.96	19.12	19.07	19.38	18.88	18.57	17.92	18.46	18.66
V	18.98	19.15	18.62	18.92	19.06	19.85	19.71	19.54	18.39	19.43	19.73	19.18	19.21
Mean				19.02				19.42				19.06	19.17

Table 3: ANOVA

SV	SS	df	MS	F	Fcrit (0.05)
Trees	1.116707	4	0.279177	2.833514 [ns]	3.837854479
Ecozone	0.48112	2	0.24056	2.441573 [ns]	4.458968306
Error	0.788213	8	0.098527		
Total	2.38604	14			

ns - not significant

Pescarus and Cismaru (1979):

$$\alpha t = \frac{Dt - dt}{Dt} \times 100\% \text{ --------(1)}$$

$$\alpha r = \frac{Dr - dr}{Dr} \times 100\% \text{ --------(2)}$$

$$\alpha l = \frac{Dl - dl}{Dl} \times 100\% \text{ ---------(3)}$$

Where:

αt - coefficient of tangential linear shrinkage (%)
αr - coefficient of radial linear shrinkage (%)
αl - coefficient of longitudinal linear shrinkage (%)
D - initial dimensions (mm) as applied to any of the three asymmetrical axes (t- tangential, r – radial, l – longitudinal) of the specimens at M.C. ≥ 30% (green M.C.)
d - final dimensions (mm) as applied to any of the three asymmetrical axes (t – tangential, r – radial, l – longitudinal) of the wood specimens at M.C. <<30% (ovendry moisture contents).

Their mean values were the linear shrinkages of the three asymmetrical axes of the wood species under study. The coefficient of volumetric shrinkage (αv) of each of the forty five wood specimens was calculated using the formula:

$$\alpha v = 100 - \frac{(100 - \alpha l)\ (100 - \alpha r)\ (100 - \alpha t)}{10^4}\ \% \text{ ------(4)}$$

(Pescarus and Cismaru, 1979).

To test for the level of significance of shrinkage between the different ecological zones and the sampled trees, the ANOVA was used to analyse the data obtained. Fisher's least significant difference (LSD) was used to validate the analysed data as a follow-up analysis.

RESULTS AND DISCUSSION

The results of the experiment showed that, at average green moisture contents of 32.86% in sahel savanna, 32.83% in sudan savanna, and 32.40% in guinea savanna, the mean initial dimensions of the specimens were 21.40mm (sahel savanna), 21.41mm (sudan savanna), and 21.31mm (guinea savanna) along the tangential axes (Dt) (Table 1). At the same green moisture contents, the mean initial dimensions of the specimens along the radial axes (Dr) in the sahel, sudan, and guinea savannas were 21.21mm, 21.23mm and 21.22mm respectively (Table 1). Also from Table 1, the longitudinal axes (Dl) of the specimens had mean initial dimensions of 30.23mm in sahel savanna, 30.25mm in sudan savanna, and 30.23mm in guinea savanna at the same green moisture contents.

At oven dried (o.d.) moisture contents of 13.46% in sahel savanna, 12.55% in sudan savanna, and 13.15% in guinea savanna, the average final dimensions of the test pieces along the tangential axes (dt) were 18.65mm, 18.62mm, and 18.63mm respectively (Table 1). At the same oven dried moisture contents, the average final dimensions of the wood samples along the radial axes (dr) in the sahel, sudan and guinea savanna zones were 19.84mm, 19.85mm, and 19.85mm respectively (Table 1). Longitudinally (dl), at o.d. moisture contents, the mean final dimensions of the specimens measured 29.90mm in each of the three ecological zones (Table 1).

The estimated mean coefficients of linear shrinkage in the tangential axes (αt) were 12.65% (sahel savanna), 12.88% (sudan savanna), and 12.69% (guinea savanna). Mean values of the coefficients of linear shrinkage along the radial axes were as follows: 6.23% (sahel savanna), 6.41%

Table 4: Fisher's Least Significant Difference (LSD) Analysis

Alpha (∝)	0.05
Error degree of freedom	8
Error mean square	0.098527
Critical value of t	2.30600
Least Significant Difference	0.45779%

Means with the same letter are not significantly different.

t Grouping	Mean	N	Ecozone
A	19.42%	15	Sudan
A	19.06%	15	Guinea
A	19.02%	15	Sahel

(sudan savanna), and 6.22% (guinea savanna); while those of the longitudinal axes were: 1.13%, 1.17%, and 1.13% respectively (Table1). Mean values of the coefficient of volumetric shrinkage were 19.02% in sahel savanna, 19.42% in sudan savanna, and 19.06% in guinea savanna, with an overall mean (of the volumetric shrinkage) of 19.17% (Table 2). As shown in Tables 1 and 2, the tangential shrinkage was about twice as large as the radial shrinkage at the same moisture content. The volumetric shrinkage was approximately the sum of the two (tangential and radial), since the longitudinal shrinkage from green to oven dry condition was almost negligible. This observation is in line with the works of Suchsland and Woodson (1986), Harris *et al* (1985), Kellog and Wangaard (1989), and Akpan *et al* (1999).

These data, as applied to shrinkage characteristics of neem, indicate that the wood species falls into the class of tree species with large shrinkage. This classification is based on the work of Woldstein and Nicholas (1993), which classified wood species into five categories, viz: negligible (≤ 9.00%), small (>9.00%-11.00%), moderate (>11.00%-14.00%), large (>14.00%-19.50%), and very large (>19.50%), depending on their shrinkage values. This large shrinkage value of neem makes the wood species to be largely applicable as timber for interior utilization. This is specially so, as there is little fluctuation of relative humidity and temperature in the interior, than in the ambient. If used in the ambient in its fresh stage, (due to the high variation of humidity and temperature) the wood will exhibit considerable shrinkage, resulting in warping; with a corresponding high degree of

stage. In order to circumvent this possibility, the wood species should, immediately after conversion, be subjected to carefully controlled seasoning conditions (Udegbe, 1991) to bring the moisture content to equilibrium moisture content.

The analysis of variance (ANOVA) revealed that none of the three different ecological zones showed significant difference in shrinkage values of neem, as F calculated was less than the critical value of F (F tabulated) at 95% (ά = 0.05) confidence limit (Table 3). Also, there was no significant difference in shrinkage between the tree samples at the same 5% level of probability (Table 3). Furthermore, the Fisher's least significant difference (LSD) analysis confirmed that the means of the coefficients of volumetric shrinkage from the three different ecological zones did not show significant difference, as each of their mean differences was found to be less than the least significant difference (LSD) value (Table 4).

CONCLUSION

From the results of the research, *Azadirachta indica* A. Juss. falls under the category of timber with large shrinkage value (Woldstein and Nicholas, 1993). Similar wood species under this class of shrinkage, according to Ghelmeziu (1981) are *Lophira alata*, *Daniellia klainei*, *Nesogordonia papaverifera*, *Terminalia ivorensis*, *Uapaca guineensis*; as well as *Eribroma oblonga* (Akpan *et al*, 1999), which are widely used for timber production. Thus, the tree species is considered suitable for timber production.

REFERENCES

Akpan, M., Anametemfiok, V. and Ijomah, J. U., 1999. Dimensional changes of wood in service: potential of *Eribroma oblonga* for interor decorations. *Journal of Scientific and Technological Research* (in press).

A .O. A. C (Association of Official Analytical Chemist) ,1980. Official methods of analysis, 13th edition, Washington, D.C., pp. 170.

Dabi, D. D., 2000. Rural water resources management problems in Katarko, a semi-arid village in northern Nigeria, Journal of Environmental Sciences, 4: (1):103-111.

Desch, H. E., 1992. Timber: its structure, properties and utilization. Macmillan Educational Publications, London, pp. 410.

Ghelmeziu, N. G., 1981. African wood. Technical Publications, Bucharest, pp. 426.

Greenwood, J. D., 1999. Basic techniques; in: The Handbook on Ecological Census Techniques. Cambridge University Press, U.K., PP. 109.

Harris, J. F., Baker, A. J., Conner, A. H., 1985. General Technical Report FPL 45, USDA Forest Service, Forest Products Laboratory, Madison, pp. 17.

Haygreen, J. G. and Bowyer, J. L., 1982. Forest Products and Wood Science: an Introduction, 1st edition. Iowa State University Press, Ames.

Iloeje N. P., 1982. A new geography of Nigeria, new revised edition. Longman Nigeria Limited, Ikeja, pp. 201.

Kellog, R. W. and Wangaard, F. F., 1989. Wood Fibre, Bulletin No. 180, Vol. 1, No. 3, USDA, Forest Products Laboratory, Madison.

Khalid, S.A., Duddeck, H and Gonzaler, M., 1989. Isolation and characterization of an antimalarial agent of the neem tree. Journal of Natural Products, 52 (2): 922-926.

Pescarus, P. and Cismaru, N., 1979. Wood anatomy and properties: a guide manual for laboratory work. University of Brasov Publications, Brasov, pp. 240.

Radwanski, S. A., 1969. Improvement of red acid sands by neem tree in Sokoto, north-western Nigeria. Journal of Applied Ecology, 6: 507 – 511.

Rietz, R. C. and Page, R. H., 1991. Agricultural Handbook No. 402. U.S. Department of Agriculture, Washington, D.C.

Rowell, R. M. and Banks, W. B., 1985. General technical report FPL 50 USDA Forest Service, Forest Products Laboratory, Madsion.

Saxena, R. C., Khan, Z . R., and Bajet, N. B., 1987. Reduction of tungro virus transmission by *Nephotettix virescens* in neem cake-treated rice seedlings. *Journal of Economic Entomology*, Vol. 80, PP. 1079-1082.

Spielman, P., 1980. Working green wood with PEG. Sterling Press, New York.

Suchsland, O. and Woodson, G. E., 1986. Agricultural Handbook 640. U. S. Department of Agriculture, Washington, D. C.

Thompson, W. S., 1988. Research report No. 6. Forest Products Utilization Laboratories, Mississipi State University, Mississipi.

Udegbe, J., 1991. Design and construction of a solar-heated wood kiln. M.Sc. Thesis, University of Ibadan, Ibadan.

Woldstein, T. S. and Nicholas, D. D., 1993. Degradation, protection and seasoning of wood. Syracuse University Press, Syracuse, pp. 307