Global NEST Journal, Vol 9, No 2, pp 152-158, 2007

HYGROSCOPIC PROPERTY OF NEEM (*Azadirachta indica* A. Juss*)*: AN EXPERIMENTAL DETERMINATION OF THE SHRINKAGE CHARACTERISTICS

M. AKPAN*

Department of Forestry and Wildlife Management
Federal University of Technology, P.M.B.2076
Yola, Adamawa State, Nigeria

Received: 07/08/06
Accepted: 19/09/06

*to whom all correspondence should be addressed:
e-mail: michaelakpn@yahoo.com

ABSTRACT:
A pioneer effort is made in this study to carry out an experimental determination of shrinkage characteristics of neem (*Azadirachta indica* A. Juss) wood on its linear, volumetric, and coefficient values with the hope of ascertaining its utilization potential as timber. Three study locations were randomly selected from defined vegetation zones of north eastern Nigeria for the study. These are Maiduguri (Sahel savanna) Yola (Sudan savanna), and Bauchi (Guinea savanna). Forty five (45) tree samples of neem trees were randomly selected and felled, from which 135 wood specimens were extracted and prepared using Romanian Standard for the research. The analysis of variance (ANOVA) was used to analyze the obtained data. Results showed that the tree species has an average tangential linear shrinkage of 12.74%, radial linear shrinkage of 6.26%, longitudinal linear shrinkage of 1.15%, and volumetric shrinkage of 19.12%. The coefficients of tangential, radial, and longitudinal shrinkage were 0.00674, 0.00339, and 0.00061 respectively. The analysis of variance revealed insignificant differences of shrinkage between the three vegetation zones, the sampled trees, as well as between the tree trunk sections. Since the shrinkage value of neem wood compares favorably with some local wood species used for timber, neem wood could be considered suitable for timber production.

KEYWORDS: linear shrinkage, volumetric shrinkage, coefficient shrinkage, neem wood, moisture content, vegetation zones.

INTRODUCTION

Wood is a hygroscopic substance; that is, it has an affinity for water in both liquid and vapor form. This ability of wood to absorb or to loose water is dependent on the temperature and the humidity of the surrounding atmosphere. As a consequence, the amount of moisture in wood fluctuates with changes in the atmospheric conditions around it. All physical and mechanical properties of wood are greatly affected by the fluctuations of the quantity of water present in wood. In using wood as a raw material, it is therefore essential to be able to evaluate its moisture content, and to understand where the moisture is located and how it moves through the wood.

As with all wood properties, shrinkage is highly anisotropic. Tangential shrinkage (occurring tangential to the rings) is 1.5 to 2.5 times greater than radial shrinkage (occurring along the radius of the rings). Tangential shrinkage from green to dry ranges from 6% to 13%, depending on the species; whereas radial shrinkage ranges from 2% to 8%. Longitudinal shrinkage (occurring in the direction of the tree growth is usually very small, 0.1% to 1.5% (Akpan *et al.*, 1999).

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. This continues until the fiber saturation point is reached. Further addition of water to the wood produces no change in volume of the wall substance. Conversely the removal of moisture from the cell wall below the fiber saturation point causes the wood to shrink. Such dimensional changes are 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). According to Panshin and Dezeeuw (1980), wood shrinkage in general does not begin until the fiber saturation point (25-30%) is reached. The tangential shrinkage is about twice as large as the radial, at the same moisture content. The volumetric shrinkage is roughly the sum of the tangential and radial shrinkages, since the longitudinal shrinkage from the green to oven dry condition is almost negligible (Akpan *et al.*, 1999).

The wood species under study is *Azadirachta indica* A. Juss, which belongs to the *Meliaceae* family. Its local name in Nigeria is Dogon Yaro or Neem. This wood species 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. However, there has been no information on its wood characteristics, particularly shrinkage qualities, in relation to utilization as timber. The objective of this paper is to determine the shrinkage characteristics of neem wood for timber utilization in north eastern Nigeria.

METHODOLOGY

Three vegetation zones of north eastern Nigeria, viz: Sahel savanna, Sudan savanna, and Guinea savanna were chosen for the study. The representative randomly selected study locations in each of these zones are Maiduguri, Sahel savanna; Yola, Sudan savanna; and Bauchi, Guinea savanna. From each of these study locations, thirty three (33) matured neem trees were chosen by block random sampling from free areas using merchantable diameter of at least 60cm as basis for acceptance. Out of this number, 15 tree samples were randomly selected and felled. Thus, a total of 45 neem tree samples were isolated from the three study locations for the research. In determining the ages of the felled trees, their growth rings were counted to ensure that the trees fell into the acceptable merchantable ages of 20 years and above. The species-area curve method as described by Greenwood (1999) was used in determining the tree species' inventory for their isolation.

Thereafter, each felled tree from the three vegetation zones of north eastern Nigeria was cross cut into three sections from base to top, that is, bottom, middle, and top in line with the conventional sampling strategy of 0%, 20%, and 40% of the total tree height. Thus, 135 test pieces were obtained from defects free areas of the trees and prepared according to STAS 6085:72. Accordingly, the wood species were cut to sizeable samples of 100mm x 60mm x 40mm for the purpose of oven drying to constant weights. Afterwards, each specimen was extracted from the seasoned samples by cutting to a standard dimension of 30mm x 20mm x 20mm. The specimens were sectioned such that the wood rays in the radial axis were parallel to the fibers 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 fiber saturation point (FSP) of wood, at which shrinkage begins to occur. Immediately, by means of a micrometer screw gauge, the initial (maximum) dimensions of the three asymmetrical axes (tangential, radial, and longitudinal) of the specimens were taken. The wood specimens were then oven dried at a temperature of $103^oC \pm 2^oC$ for 24 hours (STAS 6085:72). After the wood samples have dried, at intervals of 15 minutes, the specimens were weighed with the electronic weighing balance, until a constant weight was obtained for each of them. Their final (oven dry) moisture contents were also taken. Similarly, the final (minimum) dimensions 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 shrinkages of the 135 wood specimens were calculated with the respective relationships:

$$TgS = \frac{Dt - dt}{Dt} x100\% \quad (1)$$

$$RdS = \frac{Dr - dr}{Dr} x100\% \quad (2)$$

$$LgS = \frac{Dl - dl}{Dl} x100\% \quad (3)$$

where:

TgS: tangential linear shrinkage (%)
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%
Dl: initial dimension (mm) along the longitudinal axis at green moisture content of ≥ 30%
dt: final dimension (mm) along the tangential axis at oven dry moisture content of <<30%
dr: final dimension (mm) along the radial axis at oven dry moisture content of << 30%.
dl: final dimension (mm) along the longitudinal axis at oven dry moisture content of <<30%

Their mean values were obtained as the linear shrinkages of the three asymmetrical axes of the wood species under study. In the same vein, volumetric shrinkage (VS) of each of the 135 wood specimens was computed with the relationship:

$$VS = 100 - \frac{(100 - LgS)(100 - RdS)(100 - TgS)}{10^4} \% \quad (4)$$

The mean values were also obtained. With the zones as well as the tree samples, and their respective sections being the sources of variation, and volumetric shrinkage as parameter, the analysis of variance (ANOVA) was used to analyze the obtained data, by testing the level of significance of shrinkage between the different vegetation zones, and also between the sampled trees and their respective sections. Relationship between volumetric shrinkage and drying out to oven dry moisture content in the three vegetation zones was also examined. To calculate the coefficients of tangential (άt), radial (άr), and longitudinal (άl) shrinkages respectively, the following equations were used:

$$\dot{\alpha}t = \frac{Dt - dt}{Dt(Mg - Md)} \quad (5)$$

$$\dot{\alpha}r = \frac{Dr - dr}{Dr(Mg - Md)} \quad (6)$$

$$\dot{\alpha}l = \frac{Dl - dl}{Dl(Mg - Md)} \quad (7)$$

where: Mg: green moisture content %
Md: oven dry moisture content %

RESULTS AND DISCUSSION

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 are 21.40 mm (Sahel savanna), 21.41 mm (Sudan savanna), and 21.31 mm (Guinea savanna) along the tangential axes (Dt). The mean initial dimensions of the wood specimens along the radial axes (Dr) in the Sahel, Sudan, and Guinea savannas are 21.21 mm, 21.23 mm, and 21.22 mm respectively. Also, the longitudinal axes (Dl) of the specimens have mean initial dimensions of 30.23 mm in Sahel savanna, 30.25 mm in Sudan savanna, and 30.23 mm in Guinea savanna at the same green moisture contents.

At oven dry 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) are 18.65 mm, 18.62 mm, and 18.63 mm respectively. The average dimensions of the wood samples along the radial axes (dr) in the Sahel, Sudan, and Guinea savannas are 19.84 mm, 19.85 mm, and 19.85 mm respectively. Longitudinally (dl), the mean final dimension of the specimens is 29.90 mm in each of the three vegetation zones.

Accordingly, linear shrinkage along the tangential axes in the Sahel savanna range from 11.32% to 14.08%, with a mean of 12.65%. Similarly, linear shrinkage along the tangential axes in the Sudan savanna range from 12.09% to 13.74 % (mean of 12.88%); while those of the Guinea savanna range from 11.68% to 13.69% (mean of 12.69%). In the same vein, the linear shrinkage along the radial axes in the Sahel savanna range from 5.29% to 7.01% (mean of 6.23%); and those of the Sudan savanna range from 5.29% to 7.04%, having a mean of 6.41%. In the Guinea savanna, the linear shrinkage range from 5.71% to 6.71%, with a mean of 6.22%. Along the longitudinal axes, in the Sahel savanna, the linear shrinkage range from 1.00% to 1.33%, with an average of 1.13%. While the longitudinal linear shrinkage in the Sudan savanna range from 0.66% to 1.35%, having a mean of 1.17%; the longitudinal linear shrinkage in the Guinea savanna range from 1.00% to 1.33%, with a mean of 1.13%.

In the tangential axis, the coefficients of linear shrinkage vary from 0.00576 to 0.00769 in Sahel savanna, and 0.00590 to 0.00769 in Sudan savanna, while Guinea savanna has a range of 0.00604 to 0.00759. The mean coefficient of tangential shrinkage in Sahel savanna is 0.00674, while those of Sudan and Guinea savannas are 0.00668 and 0.00702 respectively. The overall mean coefficient of tangential axis across the study locations is 0.00674. Along the radial direction, the coefficients of linear shrinkage in Sahel savanna vary form 0.00264 to 0.00380, and 0.00270 to 0.00393 in Sudan savanna, while Guinea savanna has a variation of 0.00262 to 0.00398. The mean coefficient of radial shrinkage in Sahel savanna is 0.00334, while those of Sudan and Guinea savannas are 0.00324 and 0.00315 respectively. The overall mean coefficient of radial axis across the study locations is 0.00339. In the longitudinal axis, the coefficients of linear shrinkage vary form 0.00043 to 0.00072 in Sahel savanna and 0.00046 to 0.00084 in Sudan savanna, while Guinea savanna has a range of 0.00048 to 0.00077. The mean coefficient of longitudinal shrinkage in Sahel savanna is 0.00055, while those of Sudan and Guinea savannas are 0.00059 and 0.00052 respectively. The overall mean coefficient of longitudinal axis across the study locations is 0.00061.

The volumetric shrinkage in Sahel savanna ranges from 18.15% to 19.72% with a mean of 19.03%. In the Sudan savanna, it ranges from 18.39% to 19.65%, having a mean of 19.23%; while in the Guinea savanna, it ranges from 18.46% to 19.61%, with a mean of 19.11%. The overall mean volumetric shrinkage across the three zones is 19.12%. Also, the oven dry moisture contents of the wood specimens range from 12.54% to 14.64%, with an average of 13.81% in Sahel savanna. While the oven dry moisture contents range from 12.11% to 14.44% in Sudan savanna, Guinea savanna yielded a range of 12.15% to 14.99%. The mean oven dry moisture contents in Sudan and Guinea savannas are 13.66% and 13.69% respectively. Table 1 contains volumetric shrinkage of neem wood, while Figures 1a, 1b, and 1c show the relationship between drying out to oven dry moisture content and volumetric shrinkage in the various vegetation zones and Table 2 contains the results of the ANOVA of neem shrinkage.

Azadirachta indica at an average volumetric shrinkage of 19.12%, even though compares favorably with some shrinkage values of some locally used timber, is quite high when compared with majority of the Nigerian timber. Examples of locally used timber that neem shrinkage compares favorably with are *Uapaca guineensis* (19.9%), *Strombosia pustulata* (19.7%), *Sterculia rhinopetala* (20.9%), *Distemonanthus benthamianus* (20.6%) and *Lophira alata* (19.8%) (Ghelmeziu, 1981). Those commonly used timber that neem shrinkage does not compare favorably with include *Pericopsis elata* (10.0%), *Terminalia superba* (10.1%), *Khaya ivorensis* (9.1%), *Triplochiton scleroxylon* (9.7%), *Mansonia altissima* (10.3%), and *Afzelia africana* (9.8%). Others are *Ceiba pentandra* (10.4%), *Mitragyna ciliate* (13.1%), *Tectona grandis* (15.0%) *Gossweilerodendron balsamiferum* (7.6%), *Pycnanthus angolensis* (14.5%), *Chlorophora excelsa* (9.4%), *Entandrophragma cylindricum* (12.6%), and *Eribroma oblonga* (18.3%) (Akpan *et al.*, 1999; Ghelmeziu, 1981). However, the NCP 2 (1973) specifies that all woods must be seasoned to equilibrium moisture contents of the surrounding environment before they are subjected to service conditions.

Table 1. Volumetric Shrinkage of *Azadirachta indica* in the Three Vegetation zones of North Eastern Nigeria

Tree Sample	Volumetric Shrinkage of *Azadirachta indica* (%)												
	Sahel Savanna				Sudan Savanna				Guinea Savanna				Over-all Shrin-kage Mean
	Wood Specimens			Mean Shrin-kage Value	Wood Specimens			Mean Shrin-kage Value	Wood Specimens			Mean Shrin-kage Value	
	1*	2*	3*		1*	2*	3*		1*	2*	3*		
1	18.42	19.06	19.15	18.88	19.03	19.25	19.09	19.12	18.19	19.25	19.12	18.85	18.95
2	18.95	18.92	18.93	18.93	18.71	18.36	19.03	18.70	19.50	19.50	18.65	19.22	18.95
3	18.89	19.69	19.81	19.46	19.68	19.58	19.37	19.54	19.26	19.44	19.52	19.41	19.47
4	18.80	18.22	18.94	18.66	19.96	19.52	19.17	19.59	18.88	18.57	17.92	18.46	18.90
5	18.98	19.15	18.46	18.86	19.06	19.15	19.71	19.24	18.39	19.43	19.73	19.18	19.09
6	19.39	17.62	18.92	18.65	18.20	18.60	19.15	18.65	19.05	18.80	19.67	19.17	18.83
7	19.32	20.16	19.65	19.71	19.71	19.05	18.78	19.21	18.71	18.60	19.09	18.80	19.24
8	19.40	19.42	18.39	19.07	19.06	19.18	19.33	19.18	19.18	19.70	19.50	19.46	19.23
9	19.66	19.69	19.81	19.72	18.92	20.08	18.39	19.13	19.50	19.27	18.90	19.22	19.36
10	18.82	18.63	18.92	18.79	19.32	18.80	19.88	19.33	18.66	20.00	18.21	18.96	18.78
11	18.83	19.38	18.39	18.87	18.60	18.98	17.60	18.39	18.41	19.94	18.96	19.10	18.79
12	19.69	19.82	17.62	19.04	19.60	19.80	19.15	19.52	19.53	19.51	19.54	19.53	19.36
13	18.34	19.35	18.62	18.77	18.20	19.35	18.60	18.72	19.85	17.93	18.55	18.79	18.72
14	19.66	18.98	18.71	19.12	19.37	19.30	19.85	19.51	19.30	19.30	18.88	19.16	19.26
15	19.70	18.60	18.97	19.09	19.67	19.56	19.71	19.65	19.07	19.09	19.11	19.09	19.28
Mean	19.12	19.11	18.88	19.03	19.14	19.24	19.12	19.23	19.03	19.22	19.02	19.11	19.12

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

Table 2. Results of ANOVA for Neem Shrinkage in the Three Vegetation Zones

SV	SS	Df	MS	F	P-Value
Trees	5.58864148	14	0.39918868	1.45^{ns}	0.1504
Vegetation 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	84	0.27596989		
Total	29.716338	102			

ns- not significant (P<0.05)

The purpose being to subject timber to the same moisture conditions it is likely to attain in service. In the case of neem, the air seasoning technique may be suitable to minimize any defect that could arise from excessive drying stresses and associated shrinkage.

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%. Also observed from the shrinkage results is the fact that 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. It was also observed that coefficient of tangential shrinkage at 0.00674 is almost twice that of radial shrinkage at 0.00339 at oven dry moisture content of 13.05%. This agrees with the principle that the tangential shrinkage is higher than those of the radial and longitudinal shrinkages (Suchsland and Woodson, 1986; Harris *et al.,* 1995; Kellog and Wangaard, 1989; Akpan *et al.,* 1999; Wagenfuhr and Steiger, 1972). Also discovered in the course of the neem shrinkage experiment is the concept that shrinkage of the wood samples did not begin until the fiber saturation point was attained. This observation also agrees with the works of Panshin and Dezeeuw (1980), and Akpan *et al.* (1999) that shrinkage only occurs at moisture contents equals to fiber saturation point. With regard to the relationship between moisture content and volumetric shrinkage, it was found 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 (Figures 1a, 1b, and 1c). This concept is explained by the fact that wood begins to shrink only when it attains fiber 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. These findings agree with similar works conducted by Rowell and Banks (1985), Akpan *et al.* (1999), as well as Suchsland and Woodson (1986).

It is important to note that this large shrinkage value of *Azadirachta indica* restricts the tree species to be particularly applicable as timber for interior utilization, as there is less fluctuation of relative humidity and temperature in the interior, than outside. If, however, the wood species is to be used outside in its fresh stage (due to the high variation of humidity and temperature), the wood will, exhibit considerable shrinkage, resulting into warping; with a corresponding high degree of wastage. In order to circumvent this disadvantage, neem wood, on account of its large shrinkage characteristics, should be immediately subjected to carefully controlled seasoning conditions after conversion; just like all other timber with large shrinkage, as recommended by NCP 2 (1973). The purpose is to minimize excessive drying stresses resulting into warping. The results of the analysis of variance (ANOVA) reveals that none of the three different vegetation zones showed significant difference in shrinkage values at 5% probability level (P<0.05). In the same vein, significant difference of shrinkage was not attained between the neem tree samples and the sections at 5% level of probability (P<0.05) (Table 2).

CONCLUSION

Azadirachta indica even though has a relatively high volumetric shrinkage, it however compares favourably with shrinkage values of some locally used wood species for timber production, and therefore could be considered suitable for timber utilization. In view of this large shrinkage, the wood species should be subjected to controlled air seasoning technique to reduce possible drying stresses associated with the high shrinkage. On account of the higher moisture loss along tangential axes of the wood which is almost twice that of the radial axes, the tangential axes could be treated by applying a thick coat of oil paint to prevent too rapid loss of moisture, thus reducing the volume of shrinkage. Wooden cleats can also be nailed on the tangential axes of the wood to seal the end green from excess moisture loss.

ACKNOWLEDGEMENT
I wish to acknowledge the Department of Forestry and Wildlife Management, Federal University of Technology, Yola, Adamawa State, Nigeria for providing the facilities for me to carry out the research.

REFERENCES
Akpan M., Anametemfiok V. and Ijomah J.U., (1999), Dimensional changes of wood in service: potential of *Eribroma oblonga* for interior decorations. *Journal of Technology and Development*, **7**, 6-11.
Desch H.E., (1992), Timber: its structure, properties and utilization, Sixth Edition, Macmillan Education Ltd, London.
Ghelmeziu N.G., (1981), Lemnul exotic- Lemnul African: proprietatii si utilisari.Editura Tehnica, Bucuresti.
Greenwood J.D., (1999), Basic techniques, In: The Handbook on Ecological Census Techniques. Cambridge University Press, U.K.
Harris J.F., Baker A.J. and Conner A.H., (1985), General Technical Report No 45, USDA Forest Service, Forest Products Laboratory, Madison.
Kellog R.W. and Wangaard F.F., (1989), Wood Fiber, Bulletin No. 180, Vol. 1, No. 3, USDA, Forest Products Laboratory, Madison.
NCP2 (Nigerian Code of Practice 2) (1973), Timber Design Manual, Nigerian Society of Engineers (NSE), Lagos.
Panshin J.A. and Dezeeuw, C., (1980), Textbook of wood technology: structure, identification, uses, and properties of the commercial woods of the United States, Fourth Edition, McGraw -Hill, New York.
Radwanski S.A., (1969), Improvement of red acid sands by neem tree in Sokoto, North-Western Nigeria. *Journal of Applied Ecology*, **6**, 507 – 511.
Romanian Standards Institution (1972), STAS 6085: 72.Anatomica si proprietatea lemnului, Bucuresti.
Rowell R.M. and Banks W.B., (1985), General technical report No 50, USDA Forest Service, Forest Products Laboratory, Madison.
Suchsland O. and Woodson G.E., (1986), Agricultural Handbook No 640, U.S. Department of Agriculture, Washington, D.C.
Wagenfuhr R. and Steiger A., (1972), African species, Holz Technology Bulletin No 3, FPL, Washington D.C.