SPECIFIC GRAVITY AND MECHANICAL PROPERTIES OF *ANINGERIA ROBUSTA* WOOD FROM NIGERIA

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AJALA OO & OGUNSANWO OY. 2011. Specific gravity and mechanical properties of *Aningeria robusta* wood from Nigeria. Sourcing of choice timber species is becoming increasingly difficult in the forests of West Africa including Nigeria. There is a need to provide alternative species by investigating the technical qualities of species that are hitherto not harvested. Six trees of *Aningeria robusta* were sampled at the base, 10, 30, 50, 70 and 90% of merchantable length and partitioned into the inner, middle and outer wood along the radial plane. Specific gravity (SG) and selected mechanical properties, namely, modulus of rupture (MOR), compressive strength parallel to grain (MCS) and impact bending (IB) were investigated. Data were analysed using analysis of variance. The overall mean SG was 0.44, while the mean values for MOR, MCS and IB were 89.05 N mm^{-2}, 27.45 N mm^{-2} and 0.2 m respectively. Significant variations existed between sampling heights in SG and MOR, while variations in MCS and IB were not significant along the bole. For all properties investigated, no significant variation was found from the inner to the outer wood. The wood properties of this species indicate that it has the potential to substitute some popular species in the market. Its radial and axial uniformity may be exploited in marketing strategy.

Keywords: Axilal and radial variations, lesser-known species, modulus of rupture, modulus of elasticity, compressive strength, impact bending, sampling heights

AJALA OO & OGUNSANWO OY. 2011. Graviti spesifik dan ciri mekanik kayu *Aningeria robusta* dari Nigeria. Pencarian spesies kayu pilihan daripada hutan di Arika Barat termasuk Nigeria semakin sukar. Oleh itu, kita perlu mengkaji kualiti teknikal spesies-spesies yang sehingga kini masih belum dieksplotasi untuk mencari spesies alternatif. Enam pokok *Aningeria robusta* disampel pada dasar, 10%, 30%, 50%, 70% and 90% daripada panjang boleh niaga dan dipotong kepada bahagian luar, tengah dan dalam sepanjang permukaan jejari. Graviti spesifik (SG) dan ciri-ciri mekanik terpilih iaitu modulus kepecahan (MOR), mampatan selari ira (MCS) dan lentur hentaman (IB) dikaji. Data dianalisis menggunakan analisis varians. Purata SG ialah 0.44 manakala purata MOR, MCS dan IB masing-masing 89.05 N mm^{-2}, 27.45 N mm^{-2} dan 0.2 m. Perbezaan signifikan wujud antara ketinggian dengan SG dan MOR tetapi tidak dengan MCS dan IB. Tiada perbezaan signifikan diperhatikan antara kayu bahagian dalam, tengah dan luar untuk kesemua ciri yang dikaji. Ciri-ciri kayu menunjukkan yang spesies tersebut berpotensi menggantikan sesetengah spesies popular dalam pasaran. Keseragaman jejari dan paksi spesies ini boleh dijadikan daya penarik semasa pemasaran.

INTRODUCTION

Due to increasing population and expanding economy, the domestic consumption of processed wood products in Nigeria has increased within the last two decades. Almost all wood products that are produced by the industries are consumed locally. For example, Nigeria's total sawn wood production in 1991 was 1 706 000 m^3. Of this, only 29 000 m^3 representing just 1.8% of the total were exported. The balance 1677 000 m^3 were consumed locally (Owonubi 1999). There is a need, therefore, to produce more sawn wood in order to meet the ever increasing demand for wood and wood products. This will imply that more of the already scarce choice species will have to be harvested leaving them with threat of extinction. To avoid the imminent extinction of these aggressively sought after species, efforts should be made to look for alternatives that could possibly substitute or replace them. The forest of Nigeria, like most tropical forests, is being utilised commercially for a few highly priced timber species which are a mere fraction of the timber

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species that are potentially useful (Chudnoff 1980, Owonubi 1999). Nigerian forests contain over 560 species but only 20% of these species are presently regularly used. Other inferior species which are referred to as lesser-known and are usually left in the forest are gradually becoming relevant all over the West African states including Nigeria. For instance, since the 1970s the lesser-known timbers contributed up to 30% of the annual wood export volumes in Ghana, 40% in Cote d'Ivoire and 5% in Nigeria (Owonubi 1999). These figures give an insight into the potential of the species in contributing to global trade in timber and other related products.

The tropical hardwood trade is conducted on the basis of their known properties and performance. Therefore, research into sourcing and evaluation of the properties of lesser-known tropical species (LKTS) becomes imperative. This will help in efficiently utilising the diverse species available in the tropical forest, thereby, reducing pressure on the popular species.

Of the lesser-known species in Nigeria, *Aningeria robusta* is fast becoming popular due to its excellent performance in structural applications especially in roofing, and in recent times, door frames and furniture. *Aningeria robusta* belongs to the family Sapotaceae, a hardwood. It is referred to as 'agengre' in Cote d'Ivoire, 'landosan' in Nigeria and 'osan' in Uganda (TRADA 1979), 'mukali' in Angola, 'mukangu' in Kenya (Chudnoff 1980) and 'asafonia' in Ghana (Okai 2003). Four species of *Aningeria* occur in tropical Africa: *A. robusta* is found in West Africa, *A. altissima* occurs in both West and East Africa, *A. adolfi-friederici* is widely distributed throughout East Africa and *A. pseudo-racemosa* also occurs in East Africa, principally in Tanzania (TRADA 1979). It can be found in lowland rainforest, sometimes along river bank.

The tree grows up to 36 m; the bole is clear and straight with buttress up to 3 m high. The bark is greyish-white with dark brown streaks inside, exuding white latex. The leaves have 8–20 pairs of lateral orange-coloured nerves. The lower leaf surface is hairy. The flowers are about six together in the axils of the leaves; pedicels stout 3 cm long, sepals covered with reddish hairs. The fruits are bright red.

Aningeria robusta, a LKTS, is a hardwood native to West Africa. It is gaining popularity in the local timber market in recent times. However, marketability of the species depends on the properties that are inherent in the species for users to exploit. It is believed that exploring the species will not only reduce pressure on the popular and scarce species but also help in the efficient management of the ecosystem. This study was, therefore, aimed at assessing the variability in specific gravity and some strength properties of the wood of *A. robusta* along and across the bole. This is to evaluate its potential for structural and other applications.

MATERIALS AND METHODS

Location

The study area is Gambari Forest Reserve, formally known as Ibadan District Native Authority Forest Reserve. The Reserve lies between latitude 7° 25' N and longitude 3° 53' E. It is situated between River Ona on the west and the main motor road from Ibadan to Ijebu-Ode on the east. Gambari Forest Reserve is presently located in Oluyole Local Government Area of Oyo State. It is bordered in the north and south by Mamu and Abatan settlements respectively near Ijebu-Ode Local Government Area of Ogun State.

Geology and soil

The parent rock is crystalline and is part of the pre-Cambrian series shown as basement complex rocks which are quite variable in grain size and mineral composition, ranging from very coarse-grained pegmatite to fine-grained schist (Smyth & Montgomery 1962). The soil varies in depth and consists of brown loam overlying the red sandy earth. McGregor (1934) refers to it as light sandy soil, 457 mm deep, overlying limestone concentration, below which is found clay soil.

Topography

The gently undulating character of the area is due to the alternation of hardy quartz and granite schist, and the soft biotic schist and gneiss and grained by a number of rivers and streams. The reserve is located 152 m above sea level (Shomade 2000).

Climate

The forest reserve has typical humid climate with two distinct seasons a year. The two seasons are the rainy season, which starts from April till September and the dry season, which falls between November and March. The annual rainfall is 1257 mm. The relative humidity ranges between 84.5 (June till September) and 78.8% (December till January). The mean annual temperature ranges from 21.0 to 31.3 °C (Shomade 2000).

Vegetation

Presently, the reserve is divided into two: natural and plantation forests. The natural forest is made up of indigenous species such as *Terminalia* sp. *Triplochiton scleroxylon* and *Irvingia garbonensis,* while the plantation forest is made up of exotic species such as *Gmelina arborea* and *Tectona grandis*. The most commonly planted species in the reserve is *T. grandis*, which has been self-regenerating since 1958 in virtually all parts of the reserve. The second major plantation species is *G. arborea,* planted mainly for providing raw materials for pulp and paper production.

Sample selection and preparation

Six trees of *A. robusta* were harvested from Gambari Forest Reserve, south-west Nigeria. They were converted to six bolts of 50 cm long collected at the base (50 cm above the ground), 10, 30, 50, 70 and 90% of the merchantable height. The bolts were partitioned into three equal zones, namely, inner wood, middle wood and outer wood along the radial plane as in Onilude and Ogunsanwo (2002). A total of 216 test samples of dimensions 20 × 20 × 500 mm were collected from each tree to give a total of 1080 test samples.

Determination of specific gravity

The specimen for specific gravity (SG) was obtained by removing cubes of 20 × 20 × 20 mm from the upper part of each test specimen. They were subjected to a gravimetric procedure developed by Smith (1954) in which specimens were completely saturated with water by boiling from initial moisture content of 17%. Each cube was removed from the water, blotted to remove excess water, weighed and oven dried to a constant weight at 103 °C. Specific gravity was determined using the formula:

$$SG = \frac{1}{\frac{Wo - Ws}{Wo} + \frac{1}{1.53}}$$

where

SG = specific gravity
Ws = saturated weight of wood
Wo = oven-dry weight of wood
1.53 = constant developed by Stamm (1929) as the actual weight of wood substance

Determination of strength properties

Test samples of dimensions 20 × 20 × 300 mm were collected from each bolt to give a total of 1080 test samples. They were divided into 360 samples each for modulus of rupture (MOR), impact bending (IB) and maximum compressive strength parallel to grain (MCS) tests. Samples for MCS was further reduced to 20 × 20 × 60 mm as recommended in BS 373 (BS 1957). Hounsfield tensometer was used on the test samples loaded on the radial face at the rate of 0.01 mm s^{-1}. MOR was calculated as

$$MOR = \frac{3PL}{2bd^2}$$

where

P = maximum load at failure (N)
L = span of the material between supports (mm)
b = width of the material (mm)
d = thickness of the material (mm)

Samples for MCS were compressed to failure at the rate of 0.01 mm s^{-1} and MCS was calculated as

$$MCS = \frac{Pmax}{ab}$$

where

MCS = compressive strength (N mm^{-2})
Pmax = maximum load (N)
a = length of sample (mm)
b = width of sample (mm)

For the impact bending test, the Hatt-Turner impact testing machine was used in accordance with BS 373, where specimens were supported over a span of 240 mm on supporting radius 15 mm, and subjected to repeated blows from a weight 1.5 kg at increasing height until complete failure occurred at which point the height was recorded (m) as the height of maximum hammer drop. Specimens were placed in such a way that the ring was parallel to the direction of hammer drop. This was done to ensure uniformity of standard as position of test specimen with respect to the direction of growth rings affects the ultimate strength of wood.

Data analysis

Analysis of variance (ANOVA) was used to test the significance of the variability in the properties examined at 5% probability level.

RESULTS AND DISCUSSION

Specific gravity

The mean specific gravities for sampled species along and across the bole are presented in Table 1. Chudnoff (1980) obtained similar values (0.40–0.48), while Okai (2003) recorded a higher value of 0.50 on the same species from Ghana. Age and location could have contributed to the differences. There were significant variations between SG along sampling height ($p < 0.05$). However, an inconsistent pattern of variation was noticed. The trend is in line with the type C pattern propounded by Panshin and deZeeuw (1980) and supported by previous studies (Akachuku (1982) and Awoyemi (1997) on *Gmelina arborea*, Poku et al. (2001) on some lesser-used hardwood species from Ghana and Gillah et al. (2007) on some lesser-known timber species from Tanzania).

Along the radial plain there was a general increase in SG from 0.43 in the inner wood to a constant value of 0.44 in the middle and outer wood. At the radial view, the pattern of variation was in line with the type 3 specific gravity radial variation described by Panshin and deZeeuw (1980). Similar trend has also been reported by Ogunsanwo and Onilude (2000), Josue (2004) and Veenin et al. (2005).

The mean value for MOR was 89.05 N mm^{-2}, ranging from 75.69 to 101.83 N mm^{-2} axially and 82.65 to 92.86 N mm^{-2} along the radial plane (Table 2). Significant variation was found from base to 90% of merchantable height but variation along the radial plane was not significant. The overall mean value obtained in this study was in agreement with the value obtained for the same species in Ghana (Okai 2003) and higher

Table 1 Specific gravity values of *Aningeria robusta* along and across the bole

Wood type	Sampling height						
	Base	10%	30%	50%	70%	90%	Mean
Inner	0.43 ± 0.04	0.43 ± 0.05	0.46 ± 0.03	0.39 ± 0.041	0.43 ± 0.01	0.45 ± 0.015	0.43 ± 0.043
Middle	0.45 ± 0.021	0.42 ± 0.006	0.46 ± 0.014	0.41 ± 1.018	0.43 ± 0.041	0.43 ± 0.017	0.44 ± 0.036
Outer	0.45 ± 0.004	0.44 ± 0.044	0.44 ± 0.035	0.42 ± 0.024	0.44 ± 0.033	0.44 ± 0.021	0.44 ± 0.023
Mean	0.44 ± 0.047	0.43 ± 0.032	0.45 ± 0.008	0.41 ± 0.056	0.43 ± 0.036	0.45 ± 0.024	0.43

Table 2 Modulus of rupture values (N mm^{-2}) of *Aningeria robusta* along and across the bole

Wood type	Sampling height						
	Base	10%	30%	50%	70%	90%	Mean
Inner	87.38 ± 17.6	92.10 ± 20.34	110.14 ± 10.83	67.40 ± 6.22	90.99 ± 31.52	101.90 ± 0.16	91.65 ± 8.34
Middle	89.64 ± 14.45	85.95 ± 21.67	82.49 ± 19.86	79.38 ± 41.03	71.60 ± 2.11	86.89 ± 1.80	82.65 ± 22.1
Outer	98.85 ± 10.79	80.99 ± 1.19	90.21 ± 3.11	80.28 ± 2.32	90.19 ± 32.20	116.68 ± 7.23	92.86 ± 5.3
Mean	91.95 ± 26.38	86.34 ± 13.54	94.28 ± 13.98	75.69 ± 21.29	84.26 ± 22.63	101.83 ± 4.71	89.05

when compared with choice timber species such as *Milicia excelsa, Khaya senegalensis* and *Cordia millenii* as shown in Table 3. This suggests that *A. robusta* can possibly substitute these species where stiffness of wood is important.

Modulus of elasticity (MOE)

The mean MOE was 6297.40 N mm^{-2} (Table 4). This value was lower than that reported by Okai (2003) for *A. robusta* from Ghana (12 783 N mm^{-2}). Panshin and deZeeuw (1980) opined that the extent of wood maturity played a major role in magnitude and pattern of wood property variability. Therefore, this could have caused the big difference in value obtained from Ghana. The mean age of trees sampled from this study was 24 years. The older the wood the more mature it is (Panshin & deZeeuw 1980). However, the MOE value in this study is very close to 7910 N mm^{-2} which CIRAD (2009) recorded for *M. excelsa* and *Daniellia oliveri* (5530 N mm^{-2}) which are widely used in structural applications. MOE varied inconsistently along the bole. The exceptionally high MOE noted at 70% sampling height is an indication of the unpredictable nature of the crown region of trees. The crown region is usually critical for lumber because wood obtained from this zone is knotty. Since it is also the region of photosynthetic activity, its properties are influenced more compared with wood from the lower bole. This was also noted by Sanwo (1983) in his study on plantation-grown *T. grandis* in Nigeria. Across the radial plane, sharp decrease in MOE from inner to outer wood was noted. This trend was reported by Ogunsanwo and Onilude (2000). It was also reported by Panshin and deZeeuw (1980) in C*ryptomeria japonica and Pseudotsuga menziesii.* It is believed to be influenced by the extent of cell wall development. Panshin and deZeeuw (1980) reported decreasing fibril angle and increasing proportion of cellulose as factors responsible for the trend. Similar trend has been observed in other hardwoods (Poku et al. 2001, Onilude & Ogunsanwo 2002).

The results of MCS are presented in Table 5. The overall means were 28.00, 26.75, 27.69, 27.04, 26.78 and 28.44 N mm^{-2} respectively for the base, 10, 30, 50, 70 and 90% of sampling

Table 3 Selected wood properties of *Aningeria robusta* compared with other choice timber species

Species	Wood property				
	SG	MOR (N mm^{-2})	MOE (N mm^{-2})	MCS (N mm^{-2})	IB (m)
Aningeria robusta	0.44	89.05	6297	27.45	0.22
Milicia excelsa [a]	0.60	83.30	7910	55.09	NA
Cordia millenii [b]	0.40	76.10	NA	39.10	NA
Mansonia altissima [a]	0.66	110.00	NA	60.00	NA
Khaya senegalensis [a]	0.78	86.00	8120	54.00	NA

[a] CIRAD (2009), [b] Chudnoff (1980); SG = specific gravity, MOR = modulus of rupture, MOE = modulus of elasticity, MCS = maximum compression strength parallel to grain, IB = impact bending

Table 4 Modulus of elasticity values (N mm^{-2}) of *Aningeria robusta* along and across the bole

Wood type	Sampling height						
	Base	10%	30%	50%	70%	90%	Mean
Inner	7249.49 ± 3922.6	6488.88 ± 612.8	5755.75 ± 249.4	7072.25 ± 1167	7163.56 ± 22.53	6604.35 ± 2810	6722.38 ± 1013.4
Middle	4922.86 ± 1101.8	6738.91 ± 3402.9	5619.89 ± 5764	6844.13 ± 1108	6914.35 ± 1275	7111.69 ± 2447	6358.64 ± 214.1
Outer	5587.05 ± 285.4	6671.26 ± 592.7	5791.76 ± 963	5025.35 ± 1972	5821.24 ± 1641	5970.53 ± 699	5811.20 ± 549
Mean	5919.80 ± 2282.3	6633.30 ± 2200.3	5722.24 ± 1461	6313.91 ± 1376	6633.05 ± 1301	6562.19 ± 1906	6297.40

height. Although the values obtained in this study were lower than those reported for choice species, lower SG might be suggesting fair comparison in individual specific strength. While MCS varied inconsistently along the vertical axis of tree, variation along the radial plane increased consistently from inner to outer wood. The variations were, however, not statistically significant. This non-significant variation pattern was also observed in black locust *Robinia pseudoacacia* (Adamopoulos et al. 2007). Similar trend was observed across the radial plane in *Xylia xylocarpa* (Josue 2004).

Impact bending was 0.20 m, ranging from 0.14 to 0.25 m along the vertical axis and from 0.19 to 0.21 m radially (Table 6). Like all other strength properties, inconsistent variations were found along the axial plane. On the other hand, IB was 0.19 m at the inner and middle wood but increased slightly to 0.21 m in the outer wood, giving an indication of increasing impact strength from inner to outer wood. ANOVA test showed that IB variations along and across the bole were not significant (Table 7). It should be noted that the variation patterns shown by SG were also similar to the patterns exhibited by most strength properties evaluated. Gillah et al. (2007) predicted the coefficients of determination of MOR and MCS from SG as 0.73 and 0.74 respectively along the radial plane and 0.02 and 0.69 respectively on the axial direction in *Uapaca kirkiana,* another lesser-known species from Tanzania. The trend observed in this study was, therefore, an indication that strength properties could be estimated from SG.

Table 5 Maximum compressive strength parallel to grain values (N mm^{-2}) of *Aningeria robusta* along and across the bole

Wood type	Sampling height						
	Base	10%	30%	50%	70%	90%	Mean
Inner	26.89 ± 0.09	27.10 ± 1.23	27.28 ± 0.08	26.50 ± 5.83	26.10 ± 1.32	28.26 ± 0.33	27.03 ± 0.12
Middle	28.40 ± 0.01	25.70 ± 0.53	28.06 ± 0.88	26.90 ± 5.48	27.33 ± 0.44	28.96 ± 0.71	27.56 ± 0.51
Outer	28.73 ± 0.96	27.44 ± 0.09	27.74 ± 0.35	27.72 ± 2.07	26.89 ± 0.43	28.08 ± 1.06	27.76 ± 0.32
Mean	28.00 ± 0.79	26.75 ± 0.67	27.69 ± 0.58	27.04 ± 3.98	26.78 ± 1.25	28.44 ± 0.73	27.45

Table 6 Impact bending values (m) of *Aningeria robusta* along and across the bole

Wood type	Sampling height						
	Base	10%	30%	50%	70%	90%	Mean
Inner	0.18 ± 0.14	0.19 ± 0.11	0.21 ± 0.07	0.14 ± 0.001	0.18 ± 0.001	0.20 ± 0.05	0.19 ± 0.002
Middle	0.19 ± 0.04	0.18 ± 0.02	0.20 ± 0.04	0.14 ± 0.001	0.14 ± 0.001	0.25 ± 0.02	0.19 ± 0.04
Outer	0.19 ± 0.13	0.20 ± 0.04	0.25 ± 0.05	0.14 ± 0.001	0.18 ± 0.001	0.29 ± 0.04	0.21 ± 0.13
Mean	0.19 ± 0.09	0.19 ± 0.06	0.23 ± 0.06	0.14 ± 0.0003	0.16 ± 0.0003	0.25 ± 0.13	0.20

Table 7 ANOVA for the mechanical properties of *Aningeria robusta* from Nigeria

Source of variation	F-value				
	SG	MOR	MOE	MCS	IB
Tree	29.00 *	3.39 *	1.73 ns	7.97 *	18.67 *
Sampling height	6.00 *	3.07 *	0.87 ns	1.99 ns	0.50 ns
Radial position	1.00 ns	1.68 ns	3.54 ns	1.33 ns	1.67 ns

ns = not significant, * = significant at $p \leq 0.05$; SG = specific gravity, MOR = modulus of rupture, MOE = modulus of elasticity, MCS = maximum compression strength parallel to grain, IB = impact bending

CONCLUSIONS

The study provided baseline data on the suitability of *A. robusta,* a lesser-known species, as a possible substitute for some choice species. The study showed in particular that variations along and across the bole of the species were not significant for most of the properties studied, indicating wood uniformity along and across the bole.

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