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Selected Physico-Mechanical Properties of *Aningeria Robusta* (A.Chev) Wood for the Manufacture of Talking Drum

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***Abstract**: Wood remains the preferred construction material for talking drum, but the scarcity of the preferred choice of C. millenii for wood carvers has forced them to explore non-suitable species. Hence, need to research into lesser known wood species. This study was aimed to determine selected physico-mechanical properties of Aningeria robusta for the manufacture of talking drum. Three trees of Aningeria robusta were obtained, and samples were collected at the base, middle and top portion of each tree to determine physical and mechanical properties of the wood species. Wood samples were weighed and oven dried to a constant weight at $103^oC \pm 2$ for 24 hours and the weight was recorded thereafter for physical properties. Universal testing machine was used to obtain the mechanical properties whilst using relevant formulars. A complete randomized design was used and data obtained were analysed using descriptive statistics and ANOVA Moisture content, Wood Density, Modulus of Elasticity, Modulus of Rupture for A. robusta were 55.54±2.98%, 429.34±18.91kg/m^3 5876.89±382.82N/mm^2, and 123.91±4.74N/mm^2 respectively. There was no significant difference of the physico-mechanical properties along the bole. Physico-mechanical potential of Aningeria robusta for talking drum manufacturing was explored and compared. Thus: considered a better substitute for the scarce and popularly demanded species.*

***Keywords**: Aningeria robusta, wood density, Modulus of Elasticity, Modulus of Rupture, Moisture content*

I. Introduction

In spite of recent advances in material science, wood remains the preferred construction material for musical instruments worldwide because of some of its distinguishing features (light weight, intermediate quality factor etc.). Wood is common in musical instruments (strings, woodwinds, and percussions) are typically (with notable exceptions) softwoods, hardwoods and monocots (Yoshikawa and Waltham, 2014). The talking drum is an hourglass-shaped drum from West Africa, whose pitch can be regulated to mimic the tone and rhythm of human speech. It has two drumheads connected by leather tension cords, which allow the player to modulate the pitch of the drum by squeezing the cords between his or her arm and body. Similar hourglass-shaped drums are found in Asia (Gravrand, 2012). However, talking drum is prominent among the Yoruba ethnic group but can be found in neighboring Nigerian countries like Togo and Benin republic, and some other ethnic groups like the Hausa (Agun, 2014).

Talking drum manufacture in present day is frequently associated with few known wood species such as *Cordia millenii* and *Gmelina arborea* (Aiyeloja, 2015) and these chosen materials are only sorted after due to the inherited indigenous knowledge of the wood species by wood carvers and talking drum manufacturers through trial and error. However, the scarcity of *C. millenii* and recent overexploitation of *G. arborea* as it is widely used for other purposes has made it not readily available for wood carvers thereby forcing the wood carvers to explore non-suitable species like *Tectona grandis, Alstonia congensis, Celtis zenkeri, Anogeissus leiocarpus* (Aiyeloja, 2015). This implies that more of the already scarce and overexploited wood will have to be harvested, hence, threat of extinction. Iris (2012) stated that sound properties rely greatly on the density of the species used. Also, acoustic property of wood is the function of modulus of elasticity, wood density amongst other factors (Albert *et al.,* 2002). It can therefore be concluded that the unsuitability of the wood species adopted by the carvers to make talking drum may be greatly due to poor physico-mechanical variance. There is need therefore to research into the physico-mechanical properties of lesser known wood species in making effort to look for alternatives that could possibly substitute or replace the overexploited wood species.

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. pseudoracemosa* also occurs in East Africa, principally in Tanzania (TRADA, 1979 cited in Ajala and Ogunsanwo, 2011). 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 3m high. The bark is grayish-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 3cm long, sepals covered with reddish hairs. The fruits are bright red. *Aningeria robusta*, a lesser known tropical species (LKTS), is a hardwood native to West Africa. It is gaining popularity in the local timber market in recent times (Ajala and Ogunsanwo, 2011).

This study work was aimed at determining selected physico-mechanical properties of *A. robusta* wood with the view of exploring its suitability for the manufacture of talking drum. It is believed that exploring *A. robusta* will reduce pressure on the overexploited and scarce wood species.

II. Materials And Method

Materials: oven, weighing balance, circular sawing machining, planning machine, venier caliper, and wood samples of *Aningeria robusta*.

Sample collection and preparation

Three trees of *Aningeria robusta* with at least 25cm DBH obtained from Gambari Forest Reserve were selected which lies between latitude 7° 25' N and longitude 3° 53' E in Oluyole Local Government Area of Oyo State, Nigeria. From each tree, bolt of 50cm in length was collected at the base, middle and top portion to determine the physical and mechanical properties of the wood species. The wood samples was processed using circular machine and planning machine to a dimension of 20x20x300mm for modulus of elasticity and modulus of rupture (mechanical property), 20x20x60mm for wood density and moisture content according to ASTM, 1991.

Determination of wood density

The 20x20x60mm wood samples collected were oven dried to a constant weight at 103^{o}C ± 2 for 24 hours and the weight afterward was recorded. The volume of samples at green weight was recorded and the following formula was adopted for the calculation of wood density.

$$D = \frac{m}{v}(kg/m^3) \quad \text{……………… 1}$$

D = Density
m = oven-dried mass
v = green volume

Determination of moisture content

The samples were weighed when wet (original weight), it was then dried to a constant weight at 103^{o}c ± 2 in an oven for 24 hours, after which it was re-weighed. The loss of weight of the wood samples on drying to a constant weight was noted. Calculation of the loss in weight as a percentage of the samples weight after drying was done by using the formula below

$$MC = \frac{ww - ow}{ow} \times 100 \quad \text{……………… 2}$$

MC = Moisture Content
ww = wet weight
ow = oven dry weight

Determination of modulus of rupture (MOR)

This involved the use of standard test specimen (10 x 10 x 300mm), in a universal testing, the peak and breaking force were recorded; hence “MOR” was calculated as thus;

$$MOR = \frac{3PL}{2bd^2}(N/mm^2) \quad \text{………………………… 3}$$

MOR = modulus of rupture
P = load needed for failure
L = span of the material between support (length)
b = width of the material
d = thickness of the material

Determination of modulus of elasticity

Universal testing machine was used to obtain the force needed to reach elastic limit and its displacement. The modulus of elasticity was calculated from these values. Thus,

$$MOE = \frac{PL^3}{4\Delta bd^3}(N/mm^2)$$

……………………….. 4

Where:

P = load in Newton (N)
L = span / length (mm)
B = width (mm)
D = depth (mm)
Δ = the displacement at beam centre at proportional load

Comparison of wood species

Data of selected physico-mechanical properties of wood species considered acceptable for construction of talking drum in southwestern Nigeria, Africa was sourced from literature review and comparison were made with resulting data from *Aningeria robusta* species.

Data Analysis

The design was of three treatments (top, middle and base) with three replicates in a completely randomized design; Analysis of variance (ANOVA) was used to test for significance difference at 5% probability level.

$$\mathrm{Yij} = \mu + \mathrm{Ti} + \mathrm{Eij}$$

Yij = Observation
μ = Mean
Ti = Treatment effect (sampling height)
Eij = Error term

III. Results

Moisture Content

Table 1 shows that the base wood of tree 1 had the highest moisture content of (65.88%) and lowest moisture content (48.44%) was obtained at the middle wood of tree 2, while the mean total moisture content for *A. robusta* was (55.54±2.98%).

Table 1: Moisture content (%) of Aningeria robusta along the bole

	TREE 1	TREE 2	TREE 3	MEAN
MC (%)				
TOP	58.02	62.65	65.12	61.93±2.08
MIDDLE	38.79	48.44	57.65	48.29±5.44
BASE	65.88	48.49	54.77	56.38±5.08
MEAN	54.23±8.04	53.19±4.72	59.18±3.08	55.54±2.98

Wood density

Table 2 shows that mean wood density at the middle wood of tree 1 was lowest (361.67 kg/m^3) and highest at the middle wood of tree 2 (517.67 kg/m^3). The wood density for *A. robusta* was (429.34±18.91kg/m^3).

Table 2: Wood density (kg/m^3) of Aningeria robusta along the bole

	TREE 1	TREE 2	TREE 3	MEAN
WOOD DENSITY				
TOP	380.42	407.5	434.50	407.47±15.61
MIDDLE	361.67	517.67	452.92	444.08±45.24
BASE	412.25	515.25	381.92	436.472±40.35
MEAN	384.77±14.76	480.14±36.32	423.11±21.2	429.34±18.91

Modulus of Rupture (MOR) and Modulus of Elasticity (MOE)

The Middle wood of tree 3 had the highest modulus of rupture (145N/mm^2) and lowest MOR at the middle wood of tree 1 (95.04N/mm^2) as presented in Table 3. The MOR for *A. robusta* was (123.91±4.74N/mm^2) while the mean modulus of elasticity at the base wood of tree 3 (7008.62N/mm^2) had the highest modulus of elasticity value and lowest at the base wood of tree 2 (3176.22N/mm^2). The MOE for *A. robusta* was (5876.89±382.82N/mm^2).

Table 3: Modulus of rupture (N/mm^2) and Modulus of Elasticity (N/mm^2) of Aningeria robusta along the bole

	TREE 1	TREE 2	TREE 3	MEAN
MOR				
TOP	122.1	129.51	129.56	127.06±2.47
MIDDLE	95.04	116.33	145	118.79±14.47

BASE	116.73	136.87	124.08	125.893±5.88
MEAN	111.29±8.27	127.57±6.0	132.88±6.26	123.91±4.74
MOE				
TOP	5807.8	6435.92	6609.44	6284.39±243.50
MIDDLE	5754.87	5576.14	5660.49	5663.83±51.62
BASE	6862.52	3176.22	7008.62	5682.45±1253.82
MEAN	6141.73±360.71	5062.76±975.37	6426.18±399.81	5876.89±382.82

Table 4 shows that there were no significant difference of the physico-mechanical properties tested for along the bole of *Aningeria robusta* wood.

Table 4: ANOVA for determined physico-mechanical properties of *A. robusta*

Source of Variation	SS	Df	MS	Fcal
MOISTURE CONTENT				
Sampling height	282.27	2	141.13	2.36ns
Error	358.72	6	59.79	
Total	640.99	8		
WOOD DENSITY				
Sampling height	2239.302	2	1119.65	0.29ns
Error	23516.51	6	3919.41	
Total	25755.81	8		
MOR				
Sampling height	120.15	2	60.07	0.24ns
Error	1501.68	6	250.28	
Total	1621.82	8		
MOE				
Sampling height	747756.9	2	373878.4	0.23ns
Error	9804227	6	1634038	
Total	10551984	8		

* Significant ns = not significant MOR – Modulus of rupture MOE – Modulus of elasticity
($P>0.05$)

Comparison OF WOOD SPECIES

From Table 5, the MC of *G. arborea* (30.79%) (Noah et al., 2012) is slightly lower than the mean MC of *A. robusta* (55.54%). Also, wood density of *A. robusta* compared favourably with *G. arborea* and *C. millenii* in that it all have a wood density range (407 – 476 kg/m^3) that can be considered to be classified under low wood density. Modulus of rupture which may also be defined as the crushing strength of a wood is highest at *A. robusta* (127.06 N/mm^2, 118.79 N/mm^2, and 125.89 N/mm^2) for top, middle and base wood respectively. *G, arborea* and *C. millenii* have a MOR of 14 N/mm^2 and 76.10 N/mm^2 as recorded by Adeniyi et al., (2013) and CIRAD (2009) respectively.

Table 5: Selected physico-mechanical properties of Aningeria robusta wood compared with other choice of talking drum wood species

Species	Wood properties			
	MC (%)	WBD (kg/m^3)	MOR (N/mm^2)	MOE (N/mm^2)
Aningeria robusta				
Top	61.93	407.47	127.06	6284.39
Middle	48.29	444.08	118.79	5663.83
Base	56.38	436.47	125.89	5682.45
Gmelina aborea	30.79	476	14	7500
Cordia millenii	NA	436	76.10	5316.54

Ajala and Ogunsanwo (2011), Arowosoge et al., (2008), (Aiyeloja, 2015), Noah et al., (2012) Adeniyi et al., (2013), MC – Moisture Content, WBD – Wood Basic Density, MOR – Modulus of Rupture, MOE – Modulus of Elasticity, NA – Not Available

IV. Discussion

Moisture Content

The amount of moisture in a wood may be due to the available sorption site in the wood. Therefore, the top wood having highest mean value of moisture content may have resulted from larger and/or more sorption site present as a result of larger lumen width in the top wood. However, there was inconsistency in the mean value of moisture content obtained along the sampling height; this supports the findings of Okon (2014) and Noah *et al.*, (2012), stating the inconsistency of moisture content in *G. arborea*. Typically, there is less sapwood than heartwood in any given stem (Michael, 2007), the highest value of moisture content at the top wood may therefore be due to youngest portions of stem wood at the top wood being dominated by sapwood which therefore supports (Michael, 2007).

Furthermore, Okai (2003) recorded high heartwood to softwood moisture content ratio for *Aningeria robusta*. This could also imply that, inconsistency in moisture content may not have been due to more sapwood at the top wood; rather, inconsideration of values along the radial position may have been a cause.

Wood Density

The findings of this work shows a wood density of (429.34 ± 19.91kg/m^3) which is similar to Chudnoff (1980) who obtained wood density values of (400–480kg/m^3) for *A. robusta*. Also, Ajala and Ogunsanwo (2011) recorded a mean specific gravity of (430 kg/m^3) while Arowosoge *et al.*, (2008) recorded a specific gravity value of (510kg/m^3)on the same species.

Also, Okai (2003) obtained a higher mean value of (500 kg/m^3) for *A. robusta* from Ghana, while Falemara *et al.*, (2012) recorded a wood density value of (436 kg/m^3) for *Cordia millenii*. The resulting wood density can therefore be said to be lower compared to Arowosoge et al., (2008). Age and location could have contributed to the differences (Arowosoge et al., 2008).

In addition, an inconsistent pattern of axial variation in density was noticed. This trend was in line with the type C pattern propounded by Panshin and deZeeuw (1980) as reported by Ajala and Ogunsanwo (2011) and supported by previous studies of Akachuku (1982) and Awoyemi (1997) on *G. arborea*. Also, 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).

Modulus of Rupture (MOR) and Modulus of Elasticity (MOE)

According to Ajala and Ogunsanwo (2011); the mean recorded MOR value for *A. robusta* was (89.05 N mm^{-2}), ranging from (75.69 to 101.83 N/mm^{-2}) axially and (82.65 to 92.86N mm^{-2}) along the radial plane. The resulting intersperse increase in the mean value of MOR in the course of this study may be due to wood maturity, inconsideration of values along radial pattern, or the universal testing machine used to carry out this test.

The mean Modulus of elasticity (MOE) was lower than what was reported by Okai (2003) for A. robusta from Ghana (12 783 N mm^{-2}). Ajala and Ogunsanwo (2011) reported that Panshin and deZeeuw (1980) opined that the extent of wood maturity played a major role in magnitude and pattern of wood property variability. Therefore, wood maturity could have caused the difference in value obtained from Ghana.

The high MOE noted at top wood sampling height is an indication of the unpredictable nature of the crown region of trees (Ajala and Ogunsanwo, 2011). Also noted is an intersperse increase in MOE from base to top was recorded in this research study. A similar inconsistent trend along the bole was also obtained by Ajala and Ogunsanwo (2011) on *Aningeria robusta*.

Furthermore, a mean MOE value of (5316.54 N/mm^2)and (8023.55N/mm^2) for *Cordia millenii* and *A. robusta* respectively was recorded by Arowosoge et al., (2008), and 6297N/mm^2 for *A. robusta* was recorded by Ajala and Ogunsanwo (2011). The mean MOE value obtained in the course of this study is slightly lower (5876.89 N/mm^2) to the findings of Ajala and Ogunsanwo (2011); this may be due to extent of wood maturity, inconsideration of radial pattern, or the universal testing machine used to carry out this test.

Comparison of wood species

It has been established that the higher the temperature of a medium, the faster a sound will travel in the medium, and that moisture contribute to faster damping of sound (George, 2014). This therefore means that sound will travel slower in high humid (moisture) medium than lower humid medium. Thus, *A. robusta* which compared favourably with *G. arborea* in term of its MC value will contribute to faster damping of sound than *G. arborea*. However, where lower MC is required, talking drum manufactured from *A. robusta* can be sundried to attain a lower MC before being played.

Also, wood density of *A. robusta* compared favourably with *G. arborea* and *C. millenii* in that it all have a wood density range (407 – 476 kg/m^3) that can be considered to be classified under low wood density. NDT (2015), stated that the closer the molecules are to each other (wood density) the tighter their bonds, then the less time it takes for medium (wood) to pass the sound to each other and the faster sound can travel, but also noted that a denser medium will transmit sound slower if the medium is denser as a result of larger molecules in it. Consequently, density of a wood is one of the determining properties to consider for sound production.

In addition, sound waves are made up of kinetic energy and it takes more energy to make large molecule vibrate than it does to make smaller molecules vibrate. Thus; sound will travel at a slower rate in the more dense material if the material is made up of larger molecules. According to Integrated Publishing (2015) on acoustic of sound quality, it highlighted that a denser material may pass sound slower. Therefore, this may be the major reason wood species classified under lower wood density (less dense) are more considered and suitable for the manufacture of talking drum.

Furthermore, the resulting values of modulus of rupture as compared above is an indication that other species (*G. arborea and C.millenii*) considered acceptable for manufacture of talking drum may have lesser resistance to crushing when force of strikes of sound is being propagated through its talking drum. Thus, a higher value of MOR of *A. robusta* is an added advantage over other acceptable species. Nevertheless, a research work is recommended to ascertain this finding.

An elastic property as related to material is the tendency of a material to maintain its shape and not deform when a force is applied to it. NDT (2015) described MOE as forces that can be thought of as springs that control how quickly particles return to their original position, and particles that return to their resting position quickly are ready to move again more quickly, and thus they can vibrate at high speed. The statement above highlight the importance of modulus of elasticity of wood on the speed of sound, this therefore means that a high MOE is an essential property to enhance speed of sound. The top wood of *A.robusta* (6284.39 N/mm^2) in this research work compared favourably with *G.arborea* (7500 N/mm^2) and *C.millenii* (5316.54 N/mm^2); the popularly known and used species for manufacture of talking drum.

V. Conclusion

Selected physico-mechanical properties of *A.robusta*, a lesser known wood species along the sampling height was determined, and differences among properties tested along sampling height were not significant. Comparison of *A.robusta* with *G. arborea* and *C. millenii* (acceptable species) was made based on their physico-mechanical properties, and its potential for manufacture of talking drum was explored. Thus, *A.robusta* can be considered a better substitute thereby reducing pressure on the scarce and popularly demanded species. However, top wood of *A.robusta* wood is highly recommended for the manufacture of talking drum.

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