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Relationship between Wood Traits and Sound Frequency at Different Pitch Levels of Talking Drums (Gangan) Manufactured from *Aningeria robusta* Wood

K.O. Olaoye | ORCID 0000-0002-9808-2299

Federal College of Forestry, Forestry Research Institute of Nigeria, Ibadan,
Nigeria

snipeskay@gmail.com

A.O. Oluwadare

Department of Forest Production and Products, Faculty of Renewable
Natural Resources, University of Ibadan, Ibadan, Nigeria

aoluwada@gmail.com

Abstract

Wood is a unique material for making musical instruments and is used to make West African talking drums, whose pitch can be regulated depending upon how the player strikes the head of drum and changes its tension. Additionally, talking drum manufacturers have certain wood preferences, and in the absence of preferred species, they use supposedly unsuitable woods. Therefore, there is a need to examine wood traits in relation to the pitch of a talking drum. This study was designed to determine the existing relationship between selected wood traits and the frequency of talking drums made from *A. robusta* wood. Three *A. robusta* trees were obtained from Onigambari Forest Reserve. From each tree, three bolts of 50 cm in length were obtained from the base, middle, and top of the tree to determine selected properties (moisture content (MC), wood basic density (WBD), modulus of elasticity (MOE), modulus of rupture (MOR), and manufacturing of talking drums). A spectrum analyzer was used to analyze the sound frequency of the talking drums at three pitch levels (high, medium, low). A completely randomized block design was used and the data obtained was analyzed using descriptive statistics, ANOVA, and correlation analyses at $\alpha_{0.05}$. Sound frequency was not significant along sampling height, but was significant at pitch levels. Additionally,

the correlation analysis between wood traits and sound frequency was not significant. Thus, wood cannot be recommended for talking drums' optimal acoustic performance based on wood traits alone.

Keywords

talking drum – sound frequency – pitch – *Anningeria robusta* – wood trait

1 Introduction

Africa is the second largest continent in the world, with about one thousand indigenous languages and other foreign languages, and it is a place rich with diverse cultural heritage (Stone 1998), such as its music and musical instruments. One African musical instrument is the talking drum, which is classified by its different shapes and sizes into types, such as Gudugudu, Iya ilu, Dandan, Gangan, Omele gangan, and it has been traced back to the early history of the Yoruba (Abel 1998).

Talking drums are West African drums whose pitch can be regulated depending upon how the player strikes the head of drum and changes its tension (Akere 1995). It is shaped like an hour glass with two faces that are vertically opposite each other with leather string, while the shell is made from carved wood, the main material used in talking drum construction (Wikipedia, 2019). The wood that is usually used for carving these drums are *Afzelia bip-indensis* (Apa), *Tectina grandis* (Teak), *Cordia millennia* (Omo), and *Gmelina arborea*, which are all hardwood species.

Wood is a unique material in the construction of musical instruments and in other acoustic applications because it can produce sound (by direct striking) and can amplify or absorb sound waves originating from other bodies. 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, such as its light weight and intermediate quality factor that are easily noticeable when compared with plastic or metal (Yoshikawa and Waltham 2014). However, an important area of research in wood utilization that has so far been ignored is the production of musical instruments.

Cordia millenii has been the preferred species of wood for manufacturers of talking drums in Nigeria, based on the inherited indigenous knowledge that it has been the standard drum-making wood species for many years without any attempts at domestication. However, the species has become scarce due to its

multiple uses by the carving and other wood-based industries. Additionally, Femi (2019) confirms an increase in the popularity and advancement of African music today due to the utilization of talking drums, which have immensely increased the international popularity of Nigerian culture and its entertainment industry. Thus, the popularity of talking drums added to the mounting pressure on the already threatened species.

Consequently, the shortage of this species has forced the carving industry to employ many unsuitable species for the manufacture of talking drums that eventually render unsatisfactory services to users. The unsuitability of these alternative wood species may be greatly due to the poor relationship between the characteristics of the wood and the respective acoustic properties of the talking drum.

In the quest for finding alternative wood species for making talking drums, Olaoye *et al.* (2016) endeavored to study selected physico-mechanical properties of *A. robusta* wood for the purpose of finding wood with traits similar to the preferred species of wood for making talking drums. However, the study did not look into the fiber traits of the wood nor establish a relationship between these properties and the acoustic properties of the talking drum.

On the other hand, one of the major acoustic properties of a musical instrument is its pitch. The uniqueness of a talking drum is its capacity to be regulated to mimic the tone and prosody of human speech through changes in pitch. Therefore, it is pertinent to consider different pitch levels to be able to establish a relationship between wood traits and the pitch of the sound of a talking drum.

Although, scholars such as Albert *et al.* (2002) and Bremaud (2012) have established a relationship between a selected wood trait and the acoustic properties of wood, little or no information is available about the influence of this relationship on the musical instrument itself.

There is therefore a need to research lesser-known wood species for the manufacture of talking drums and to establish a possible relationship between wood traits and the drum's pitch. Research into lesser-known wood species, like *Aningeria robusta* wood from Nigeria, to determine their suitability for making talking drums and to establish a possible relationship between wood traits and the pitch of the drum will not only help to reduce pressure on the scarce yet popular *Cordia millenii* species, but also contribute to the social, cultural, and economic lifestyle of the population of Nigeria.

Furthermore, it should be noted that pitch is positively correlated with sound frequency (Plack *et al.* 2005). As such, sound frequency is the measure of pitch. In addition, Tsoumis (1991) stated that the pitch produced depends on the frequency of vibration, which is affected by the dimensions, density,

moisture content, and modulus of elasticity of the wood. Smaller dimensions, lower moisture content, and higher density and elasticity produce sounds of a higher pitch.

Aningeria robusta belongs to the family Sapotaceae, a hardwood. It is called “agengre” in Cote d’Ivoire, “landosan” in Nigeria, and “osan” in Uganda (TRADA 1979, cited in Ajala and Ogunsanwo (2011)), “mukali” in Angola, “mukangu” in Kenya (Chudnoff 1980, cited in Ajala and Ogunsanwo 2011), and “asafonia” in Ghana (Okai 2003).

The aim of this study was to determine the relationship between wood traits and sound frequency at different pitch levels for talking drums manufactured from *Aningeria robusta*, with the view of exploring the suitability of this type of wood for manufacturing talking drums and providing relevant information.

2 Materials and Methods

2.1 Sample Collection and Preparation

Three trees of *Aningeria robusta* with at least 25 cm DBH obtained from Onigambari Forest Reserve were selected. Bolts 50 cm in length were collected at the base, middle, and top of each tree to determine the physical and mechanical properties of the species as well as its viability for the manufacturing of talking drums.

The wood samples were processed using a circular machine and planing machine to 20 × 20 × 300 mm for modulus of elasticity and modulus of rupture (mechanical property), 20 × 20 × 20 mm for fiber characteristics, and 20 × 20 × 60 mm for wood density and moisture content according to ASTM 1991.

2.2 Determination of Wood Traits

2.2.1 Moisture Content

The samples were weighed when wet (original weight), and then dried to a constant weight at 103 ± 2°C in an oven for 24 hours, after which they were re-weighed. The wood samples’ reduction in weight during the drying process was noted. The loss in weight as a percentage of the samples’ weight after drying was calculated using the formula below:

$$MC = \frac{WW - OW}{OW} \times 100 \quad 1$$

where MC = moisture content, ww = wet weight and ow oven dry weight.

2.2.2 Wood Density

The 20 × 20 × 60 mm wood samples collected were oven dried to a constant weight at 103 ± 2°C for 24 hours, and their weight recorded afterward. The volume of samples at green weight was recorded and the following formula was adopted for the calculation of wood density.

$$D = \frac{m}{v} (\text{kg} / \text{m}^3) \quad 2$$

where D = density, m = oven-dried mass and v = green volume.

2.2.3 Modulus of Rupture (MOR)

Analyzing this characteristic involved the use of a standard test specimen (10 × 10 × 300 mm) in a universal testing machine. The test sample was prepared in such a way that growth rings will be made parallel to one edge. Load was applied at the rate of 0.2mm/sec with the growth rings parallel to the direction of loading, that is, the specimen was loaded on the radial face. From the graph generated by the universal testing machine, the peak and breaking forces were recorded; hence, "MOR" was calculated as thus:

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

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

2.2.4 Modulus of Elasticity

The graph generated from the universal testing machine was used to obtain the force needed to reach the wood's elastic limit and its displacement. The modulus of elasticity was calculated from these values. Thus,

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

where P = load (N), L = span/length (mm), B = width (mm), D = depth (mm) and Δ = the displacement at beam center at proportional load.

2.2.5 Speed/Velocity of Sound

$$c = \sqrt{\frac{E}{\rho}} \quad 5$$

where c = speed of sound, E = modulus of elasticity and ρ = density.

TABLE 1 Mean values of selected wood traits determined for *A. robusta*

	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	513 ± 8.04	53.19 ± 4.72	59.18 ± 3.08	55.54 ± 2.98
Wood density (kg/m ³)				
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
MOR (N/mm ²)				
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 (N/mm ²)				
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
Speed (m/s)				
Top	3907.29	3974.12	3900.2	3927.2 ± 23.54
Middle	3988.99	3282.02	4363.87	3591.63 ± 208.74
Base	4080.01	2482.82	4283.83	3615.55 ± 569.41
Mean	3992.1 ± 49.88	3246.32 ± 430.87	3895.97 ± 225.16	3711.46 ± 183.35
Z (kg/m ² s)				
Top	1486398	1619454	1694637	1600163 ± 60882.23
Middle	1442685	1698992	1586961	1576213 ± 74184.56
Base	1681984	1279273	1636066	1532441 ± 127276.2
Mean	1537022 ± 73171.17	1532573 ± 128714.5	1639221 ± 31123.33	1569606 ± 47017.33

2.2.6 Impedance

$$z = c\rho \quad (\text{Wegst 2006})$$

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2.3 Fiber Characteristics

For the determination of the fiber dimensions, small slivers were obtained at each of the different sampling heights. The slivers were placed in an equal volume (1:1) of 30% hydrogen peroxide and 10% glacial acetic acid, boiled until soft, and bleached white (Franklin 1945). The slivers were then washed, placed in 30 ml test tubes with 20 ml of distilled water, and shaken vigorously to separate the fiber bundles into individual fibers. The macerated fiber suspension

TABLE 1 Mean values of selected wood traits determined for *A. robusta* (cont.)

	Tree 1	Tree 2	Tree 3	Mean
FL (mm)				
Top	1.73	1.37	1.51	1.54 ± 0.10
Base	2.04	1.34	1.51	1.63 ± 0.21
Mean	1.44	1.43	1.54	1.47 ± 0.35
	1.74 ± 0.17	1.38 ± 0.03	1.52 ± 0.01	1.55 ± 0.10
FD (µm)				
Top	11.83	10.67	11.48	11.33 ± 0.34
Middle	12.21	10.99	12.43	11.88 ± 0.44
Base	12.64	11.41	11.73	11.93 ± 0.37
Mean	12.23 ± 0.23	11.02 ± 0.21	11.88 ± 0.28	11.71 ± 0.36
LW (µm)				
Top	10.13	8.16	10.45	9.58 ± 0.73
Middle	8.43	6.67	9.60	8.23 ± 0.85
Base	9.12	8.00	8.59	8.57 ± 0.32
Mean	9.23 ± 0.49	7.61 ± 0.57	9.55 ± 0.54	8.79 ± 0.60
CWT (µm)				
Top	0.85	1.25	0.56	0.89 ± 0.20
Middle	1.89	2.16	1.41	1.82 ± 0.22
Base	1.76	1.71	1.57	1.68 ± 0.06
Mean	1.50 ± 0.33	1.71 ± 0.26	1.18 ± 0.31	1.46 ± 0.15

MOR, modulus of rupture; MOE, modulus of elasticity; Z, impedance; FL, fiber length; FD, fiber diameter; CWT, cell wall thickness.

was carefully aligned on a slide using a rubber teat. The resulting image on a Rheichert visopan microscope screen was measured for fiber length, diameter, lumen width, and cell wall thickness, and were calculated using equation 7:

$$CWT = \frac{FD - LW}{2}$$

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Where FD = fiber diameter and LW = lumen width.

2.4 Sound Frequency Test

The talking drums produced were taken to the musical studio of the Department of Music, The Polytechnic, Ibadan, Nigeria for testing. A professional talking drummer made several strikes on the talking drum for 8 seconds while sounds generated and time taken were recorded, after which this data was analyzed using spectrum analyzer to obtain its sound frequencies. The sound frequencies, which are also a measure of the pitch of a sound, were categorized into high, medium, and low frequency levels.

2.5 *Experimental Design*

The design was comprised of three treatments (top, middle, and base) with three replicates in a completely randomized block design, and significance difference was tested at a 5% probability level. The variables were analyzed using descriptive analysis of variance (ANOVA) and correlation statistics.

3 Results and Discussion

3.1 *Selected Wood Traits Determined*

Table 1 shows the mean value of selected wood traits at different sampling heights and among trees.

3.1.1 Moisture Content

The base wood of tree 1 had the highest moisture content at 65.88%, and the lowest moisture content (48.44%) was obtained from the middle wood of tree 2. The moisture content for *A. robusta* was $55.54 \pm 2.98\%$.

3.1.2 Wood Density

Mean wood density for the middle wood of tree 1 was the lowest (361.67 kg/m³), and the highest was the middle wood of tree 2 (517.67 kg/m³). The wood density for *A. robusta* was $(429.34 \pm 18.91 \text{ kg/m}^3)$.

3.1.3 MOR and MOE

The middle wood of tree 3 had the highest modulus of rupture (145 N/mm²), and the lowest MOR was the middle wood of tree 1 (95.04 N/mm²). The MOR for *A. robusta* was $123.91 \pm 4.74 \text{ N/mm}^2$, while the mean modulus of elasticity for the base wood of tree 3 (7008.62 N/mm²) had the highest modulus of elasticity value and lowest was from the base wood of tree 2 (3176.22 N/mm²). The MOE for *A. robusta* was $5876.89 \pm 382.82 \text{ N/mm}^2$.

3.1.4 Speed of Sound and Acoustic Impedance

The speed of sound was highest in the middle wood of tree 3 (4363.87 m/s) and lowest in the base wood of tree 2 (2482.82 m/s). The mean speed of sound in *A. robusta* wood was $3711.46 \pm 183.35 \text{ m/s}$. Meanwhile, the middle wood of tree 2 had the highest acoustic impedance (1 698 992 kg/m²s), while the lowest acoustic impedance was in the base wood of tree 2 (1 279 273 kg/m²s). The mean acoustic impedance for *A. robusta* was $1 569 606 \pm 47 071.33 \text{ kg/m}^2\text{s}$.

3.1.5 Fiber Characteristics

The mean fiber length, fiber diameter, lumen width, and cell wall thickness were 1.55 ± 0.10 mm, 11.71 ± 0.36 μ m, 8.79 ± 0.60 μ m, and 1.46 ± 0.15 μ m, respectively.

3.2 Sound Frequency Determined

Figure 1 shows the manufactured talking drums while Figure 2 shows the sound frequency in respect to pitch obtained from the talking drum produced from top, middle, and base of *A. robusta* trees. Middle wood produced the highest frequency (331 ± 86.31 Hz) at its highest pitch level, while the lowest frequency (50 ± 11.26 Hz) was obtained from base wood. The mean frequencies of sound at high, medium, and low pitch levels are as follows: 248.77 ± 44.58 , 134.11 ± 12.02 , and 64.77 ± 8.01 Hz, respectively.

Meanwhile, Table 2 presents the analysis of variance of the talking drums' pitch with respect to sampling height and pitch variation. No significant difference was recorded for sampling height, while a significant difference existed within the pitch variation.

FIGURE 1 Nine manufactured talking drums from the top, middle, and base of *Aningeria robusta*.

FIGURE 2 Variation in sound frequency (Hz) at different pitch levels in talking drums made from *A. robusta* wood with respect to sampling heights.

TABLE 2 Analysis of variance of the pitch of talking drums made from *A. robusta* wood with respect to sampling height

Source	Type III sum of squares	df	Mean square	<i>F</i>	Sig.
SH	19448.074	2	9724.037	1.560	0.237
SPL	155235.630	2	77617.815	12.449	0.001*
SH * SPV	26582.370	4	6645.593	1.066	0.402
Error	112230.000	18	6235.000		
Corrected Total	313496.074	26			

SH, sampling height; SPL, sound pitch levels.

* Significant at 5% probability level.

3.3 Relationships between Selected Wood Traits and Sound Pitch

Table 3 shows the respective correlation between wood traits and sound frequency at different pitch levels. The relationships with an existing association of 50% and above were highlighted, such as impedance and cell wall thickness that had a negative relationship of 50.7% and 57.6%, respectively, with sound frequency at a low pitch, while fiber diameter had a positive relationship of 54.9% with high pitch frequency and lumen width had a positive relationship of 57.8% with low pitch frequency.

TABLE 3 Correlation analysis between selected wood traits and the pitch of talking drums from *A. robusta* wood

	<i>F</i> (Hz) at High pitch	<i>F</i> (Hz) at Medium pitch	<i>F</i> (Hz) at Low pitch
Wood density	0.294	0.025	-0.309
Speed	-0.113	-0.134	-0.045
MC	0.202	-0.271	-0.023
MOR	0.189	-0.147	0.298
Impedance	0.302	-0.135	-0.507*
MOE	0.049	-0.192	-0.249
Fiber length	-0.253	0.381	0.448
Fiber diameter	0.549*	0.382	0.045
Lumen width	-0.024	0.060	0.578*
CWT	0.310	0.220	-0.576*

MOR, modulus of rupture; MOE, modulus of elasticity; *F*, frequency of sound.

* Significant at 5% probability level.

Except for materials such as a tuning fork, every other material that produces sound has more than one sound frequency per hit/strike. The most audible frequency is often used to judge the overall pitch of the sound. This most audible frequency is known as the resonance frequency of the sound. Hence, the sound frequency recorded in this study is known as the resonance sound frequency. As a result, the mean sound frequency obtained for talking drums in this study was higher than what was reported by Noah *et al.* (2014), who used other wood species to make talking drums. Therefore, it can be assumed that this variation in values of sound frequency is because different wood species were used, highlighting the possibility of a significant relationship between wood traits and the drums' sound frequency. Notwithstanding, adequate analysis is still needed.

Furthermore, it was evident that the frequency obtained from the middle wood of the tree was highest among the sampled tree heights. However, these values were not significantly different among the sampled heights, implying that the major reason for differences in the pitch of the talking drums is not connected to the position of the wood used to make them. Therefore, despite recording the highest sound frequency (at a high pitch) in the middle wood, the pitch of the talking drums manufactured in this study are assumed to be the same.

Meanwhile, the classification of the values for sound frequency into different pitch levels was significant, hence this study affirms that the pitch of the sound generated from a talking drum can be different depending on the different strikes made while being played.

Notwithstanding, the need to ascertain the influence of the wood used to make these talking drums on the significant variation in pitch levels is pertinent. As such, the relationship between the wood traits and sound frequency of these drums examined in this study revealed that no significant relationship existed. Therefore, this could mean that any wood species can be used for making talking drums without concern about variation in pitch levels.

However, Aiyeloja *et al.* (2015) stated that wood carvers have preferences for a certain type of wood for making talking drums, thus challenging the findings of this study mentioned above. Consequently, it can be concluded that there are other reasons for wood carvers' and talking drum manufacturers' preferences. These reasons may include the workability of the wood, availability of the wood species, and other acoustic properties of talking drums not examined in this study, among others.

In addition, Stack Exchange (2017) defines frequency as an intrinsic property of a vibrating source that does not depend on the medium through which it travels. Rather, it is a function of its source of propagation. This clearly explains the reason that the correlation analysis between wood traits and frequency in Table 3 had a low to average degree of association. This therefore means that the frequencies generated by the talking drums manufactured from the top, middle, and base wood of *A. robusta* do not depend on any individual wood trait examined in this study, but rather they may be dependent on sources of propagation such as the force of play/strike, tension rope, and skin cover of the talking drum, among others, thus supporting Akere (1995).

Nevertheless, wood traits such as impedance, fiber diameter, lumen width, and cell wall thickness all had a good correlation of 50% and above with the sound frequency of the talking drums. This implies that the influence of wood traits on the general acoustic properties of talking drums should not be underestimated. Subsequently, more studies should be carried out to determine the causes of wood preference in the manufacture of talking drums.

The decreased impedance value from positive (+) to negative (-) in degree of association from high pitch to low pitch indicates that wood does not restrict lower frequency sounds from passing through it, but tends to reduce higher frequency sounds. This implies that impedance reflects higher pitch sounds than lower pitch sounds, and when a high level of reflection occurs it either results in a constructive or destructive interference of the wave, giving

rise to high intensity (Berg 2019). Hence, louder sound will be generated. As such, careful consideration should also be given to geometrical shape when making a talking drum.

On the other hand, this study goes against the opinion of Noah *et al.* (2014), who proposed that the sound frequency obtained from a talking drum is dependent on the MOE of the wood used. Although Ouis (2002) established a relationship between MOE and frequency, the study only revealed a relationship between MOE and the sound frequency of the wood, not the sound frequency of a musical instrument. Apparently, Noah *et al.* (2014) are mistaken. Thus, relationships such as these should not be confused with each other.

4 Conclusion

Having successfully established a relationship between wood traits and the sound frequency of talking drums made from *A. robusta* wood with respect to pitch levels, it can thus be concluded that it is not enough to recommend a wood suitable for manufacturing a talking drum of optimal performance without considering other non-wood factors that can also influence the pitch of the talking drum.

4.1 Recommendation

In further studies, careful consideration should be given to sources of sound propagation such as the tension rope, skin surface to be used, and force applied by the player, among others, as these will all determine the pitch of the sound the talking drum will generate.

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