



## POTENTIAL SUITABILITY OF *ALBIZIA ADIANTHIFOLIA* WOOD FOR ACOUSTIC APPLICATION

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**ABSTRACT:** The dearth of scientific information on utilization potential of some wood species has rendered them lesser-used. As such, wood species used for acoustic applications in Nigeria were borne out of indigenous knowledge through trial and error. Studying properties of lesser used wood species such as *Albizia adianthifolia* wood will help to provide adequate information on its potential usage. This paper aimed at investigating the potentiality of *Albizia adianthifolia* wood for acoustic application. Three trees of *A. adianthifolia* were felled, and 45 wood samples of  $20 \times 20 \times 300 \text{ mm}^3$  each were collected from each tree. The samples were conditioned prior to acoustic measurement. The mean fundamental frequency, resonant frequency, Velocity of sound, dynamic elastic modulus, specific dynamic elastic modulus, sound quality, internal friction, radiation ratio, acoustic conversion efficiency, impedance, and specific gravity were 807.94 Hz, 2051.20 Hz, 3542.66 m/s, 7.92 GPa, 12.65 GPa, 126.01, 0.009, 5.76, 731.75  $\text{m}^4\text{kg}^{-1}\text{s}^{-1}$ ,  $2.21 \times 10^6 \text{ kgm}^{-2}\text{s}^{-1}$ , and 0.62 respectively. Conclusively, values obtained in this study did not perform favourably with acoustic standards for wood species, and as such was not considered suitable for making soundboards but frame boards of musical instrument.

Keywords: sound, frequency, wood, variation

Received: February 25, 2020 • Returned in Revised form: August 11, 2020 • Accepted: August 15, 2020

### 1. INTRODUCTION

The ability and uniqueness of wood to produce sound effect when set into vibration by an external body has made it considerable for acoustic applications, especially for making musical instruments. Acoustic simply describes the study of sound, and wood has been used to produce a number of musical instruments such as guitar,

violin, piano, xylophone and percussion (Tsoumis, 1991) because of its excellent sound effect.

*A. adianthifolia* is one of the lesser used wood species available in Nigeria. Its tree is tall, having a few large widely spreading branches and more or less horizontal branchlets producing flat crown. The wood can be found in tropical Africa and S. Africa. It is commonly called ‘ayinre bona bona’ in Yoruba, Southwestern, Nigeria.

The tree grows to about 36m high (Lock & Keay, 1991). It has been useful in folk medicine for the treatment of cough, diarrhoea, insomnia, irritability, rheumatism, stomach ache, tuberculosis, and wounds (Bahgat D, 2015), and occasionally used for timber purposes

The dearth of scientific information on utilization potential of some wood species has rendered them lesser-used. As such, wood species used for acoustic applications in Nigeria were borne out of indigenous knowledge through trial and error. Unfortunately, species such as *Tectona grandis*, *Cordia millenii*, *Gmelina arborea* identified as suitable for acoustic application have also been found useful in other wood utilization areas, thus putting pressure on this selected wood species so much that *Cordia millenii* is in extinction.

Therefore, to avoid unnecessary pressure on supposed suitable wood species used for acoustic application, there is need to scientifically investigate the potentiality of lesser used wood species to be able to infer its suitability for acoustic applications. This procedure involves measuring the acoustic properties (sound frequency, velocity of sound, damping factor etc.) of a wood before a logical and scientific conclusion can be made.

Olaoye and Okanlawon, (2019) had studied the acoustic properties of *A. adianthifolia* in relation to moisture, however, the study was not total enough to highlight the potentiality of the species for acoustic application. It is therefore appropriate to investigate the possibility of using *A. adianthifolia* for acoustic application.

Thus, this paper aimed at investigating the potentiality of *A. adianthifolia* wood for acoustic application.

## 2. MATERIALS AND METHOD

Three trees of *A. Adianthifolia* wood having  $25 \pm 2$ cm diameter at breast height (DBH) were fell. From each tree, bolts of 60cm in length were collected axially (top, middle and base), and wood samples of  $20\text{ mm} \times 20\text{ mm} \times 300\text{ mm}$  (Radial x Tangential x Longitudinal) were obtained for the acoustic property test from the radial section (core, middle and outer) of the bolt using circular machine and planing machine (Fig. 1). 45 samples were taken from each tree (i.e. 5 samples from each position), thus making a total of 135 samples. The samples were oven dried at  $103 \pm 2^\circ\text{C}$  for 24 hours after which they were stored at ambient temperature of  $25^\circ\text{C}$  and 60% relative humidity for one month prior to acoustic testing.

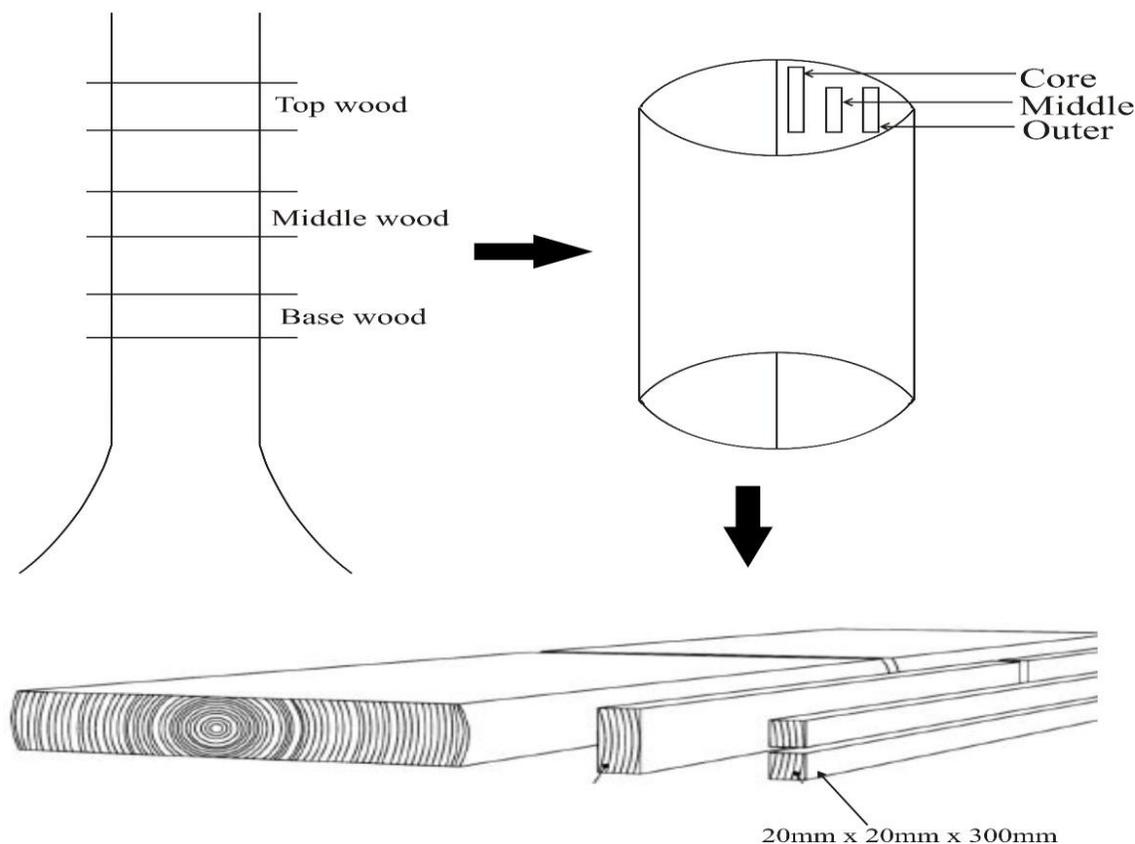


Fig. 1: Sample collection positions

2.1 Acoustic Property test

Selected acoustic properties of the wood were measured using the longitudinal free vibration acoustic test method. The experiment was set up according to Jalili *et al.*, (2014) (Fig. 2). The wood acoustic parameters measured were: fundamental frequency (FF), resonance frequency (RF), sound velocity (V), dynamic elastic modulus (E), specific dynamic elastic modulus (Es), acoustic coefficient (K), damping factor ( $\tan\delta$ ), sound quality (Q), impedance (Z) and acoustic conversion efficiency (ACE). The experiment was conducted in an enclosed laboratory having ensured a total silence, and the FFT analyzer showing no sign of a sound signal.

The wood was struck at one end while the sound obtained was recorded at the other end with the aid of a computer laptop, using audacity software. The fundamental frequency and resonance frequency were obtained from

the sound generated using Fast Fourier Transform (FFT). Hence, equation 1 (Görlacher, 1984) was used to determine the dynamic modulus of elasticity (E).

$$E = \left(\frac{2f_n}{\gamma_n\pi}\right)^2 \frac{mL^3}{I} \dots \dots \dots \text{eq. 1a}$$

Where m is the specimen weight,  $f_n$  is the fundamental frequency, n is the mode number, L is the length of the sample.  $\gamma_n$  is for the first mode 2.267, and I is inertia.

$$I = \frac{(bh^3)}{12} \dots \dots \dots \text{eq. 1b}$$

Where b is the width and h is the thickness of the specimens

Meanwhile, equation 2-10 were used to calculate other selected acoustic parameters.

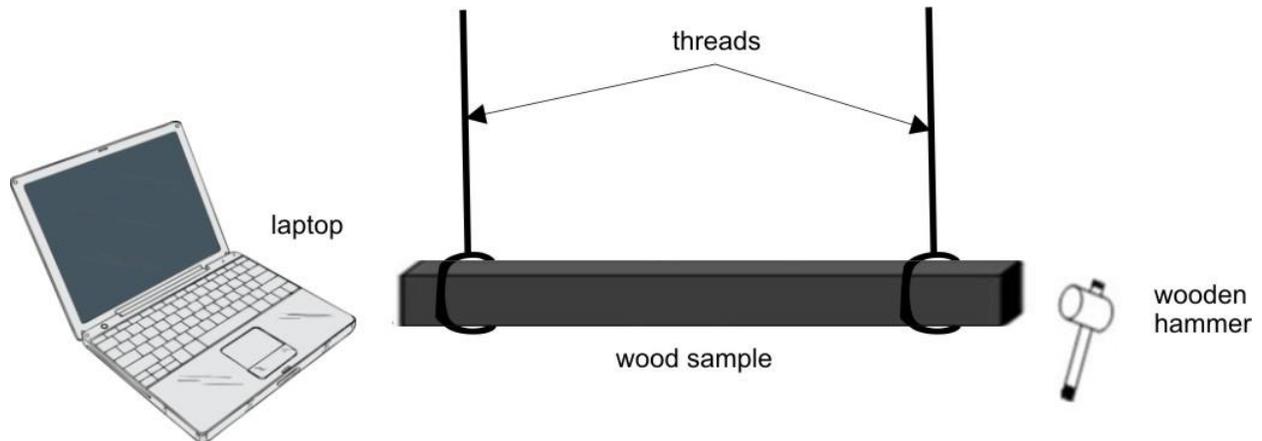


Fig. 2: The set-up of the longitudinal free vibration test

Specific longitudinal elastic modulus (Es);

$$Es = \frac{E}{\gamma} \dots \dots \dots \text{eq. 2}$$

$\gamma = \text{Specific gravity}$

$$\gamma = \frac{\text{oven dried mass}}{\frac{\text{green volume}}{\text{density of water}}} \dots \dots \dots \text{eq. 3}$$

Velocity of sound (V) (Akitsu *et al.*, 1993; Ono & Norimoto, 1983);

$$v = \sqrt{\frac{E}{\gamma}} \dots \dots \dots \text{eq. 4}$$

Acoustic co-efficient of the vibrating body (K);

$$K = \left(\frac{E}{\gamma^3}\right)^{0.5} \dots \dots \dots \text{eq. 5}$$

Damping factor due to internal friction ( $\tan\delta$ );

$$\tan\delta = \frac{\lambda'}{\pi} \dots \dots \dots \text{eq. 6}$$

$\lambda^1 = \text{logarithmic vibrating decrement factor}$



friction is related to sound damping factor while ACE is related to the ratio of acoustic energy radiated from a musical instrument to the energy given by the string (Tanaka, 1987).

Therefore, a better acoustic wood species is associated with lower value of  $\tan \delta$ . However, Brémaud, (2012) stated that an acoustically suitable species should have its average value of  $\tan \delta$  to be 0.006, thus implying that wood species having  $\leq 0.006$  can only be considered as acoustically suitable species. Consequently, wood of *A. adianthifolia* can't be regarded as having acoustic potential, owing to a mean damping factor higher than 0.006.

Tanaka, (1987); Yano, Matsuoka and Mukudai, (1992); Yano *et al.*, (1995); Matsunaga *et al.*, (1996) reported that higher Es and lower  $\tan \delta$  are essential for wood

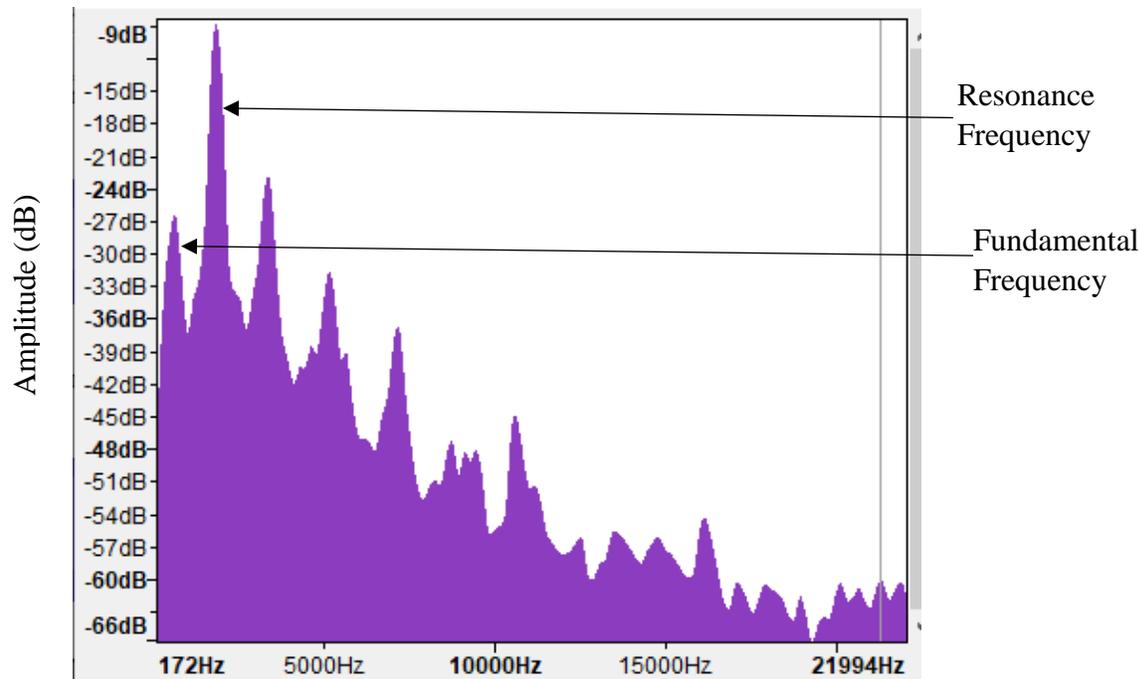
suitable for making soundboards of musical instruments. Also, Hamdan *et al.*, (2016) highlighted a high ACE value for excellent soundboards, while lower ACE and higher  $\tan \delta$  is identifiable with making frame boards.

Since higher ACE, Es and lower  $\tan \delta$  have been highlighted as an essential parameter for acoustic suitability, it is thus appropriate to determine the potentiality of *A. adianthifolia* for acoustic application base on these essential parameters. As such, the mean value of ACE and Es in this study compared lower with *G. arborea* wood (Olaoye *et al.*, 2019); *Dialium* sp. (Hamdan *et al.*, 2016); *Endospermum diadenum* (Sedik *et al.*, 2010). Also,  $\tan \delta$  was higher than the average recommended value. Therefore, the wood of *A. adianthifolia* has no potential use for making sound board for acoustic applications, but can still be considered for making frame boards.

Table 1: Physico-acoustic properties of *Albizia adianthifolia* wood

	Mean	Minimum	Maximum	S.D.	CV (%)
<b>FF (Hz)</b>	807.94	708.50	887.33	56.49	6.99
<b>RF (Hz)</b>	2051.20	1623.00	2430.33	241.01	11.75
<b>V (m/s)</b>	3542.66	3106.62	3890.76	247.69	6.99
<b>E (GPa)</b>	7.92	5.63	10.59	1.67	21.11
<b>Es (GPa)</b>	12.65	9.66	15.15	1.73	13.64
<b>Q</b>	126.01	75.09	155.95	26.85	21.31
<b><math>\tan \delta</math></b>	0.009	0.007	0.0113	0.002	24.59
<b>K</b>	5.76	4.28	7.07	0.65	11.31
<b>ACE (<math>m^4kg^{-1}s^{-1}</math>)</b>	731.75	456.51	1090.33	209.38	28.61
<b>Z (<math>x106</math>) (<math>kgm^{-2}s^{-1}</math>)</b>	2.21	1.80	2.72	3.51	15.84
<b><math>\Gamma</math></b>	0.62	0.52	0.73	0.07	11.70

FF – Fundamental Frequency, RF – Resonance Frequency, V – Velocity of sound, E - Dynamic modulus of elasticity, Es – Specific dynamic modulus of elasticity, Q – Quality factor,  $\tan \delta$  – damping factor, K – Radiation coefficient, ACE – Acoustic Conversion Efficiency, Z – Impedance,  $\gamma$  – specific gravity, S.D. – Standard Deviation, CV – Coefficient of Variation



**Fig. 4** Fundamental frequency Sound Frequency (Hz) measured in frequency domain

#### 4. CONCLUSION

It can be concluded that *A. adianthifolia* is not potentially suitable for general acoustic applications. However, it is potentially suitable for making frame boards of musical instruments.

#### REFERENCE

- Akitsu, H., Norimoto, M., Morooka, T., & Rowell, R. (1993). Effect of humidity on vibrational properties of chemically modified wood. *Wood and Fiber Science*.
- Bahgat D, S. A. (2015). Saponins from Genus Albizia: Phytochemical and Biological Review. *Medicinal & Aromatic Plants*. <https://doi.org/10.4172/2167-0412.s3-001>
- Brémaud, I. (2012). Acoustical properties of wood in string instruments soundboards and tuned idiophones: Biological and cultural diversity. *The Journal of the Acoustical Society of America*. <https://doi.org/10.1121/1.3651233>
- EngineeringToolbox. (2018). *Speed of Sound in common Solids and Metals*. [https://www.engineeringtoolbox.com/sound-speed-solids-d\\_713.html](https://www.engineeringtoolbox.com/sound-speed-solids-d_713.html)
- Görlacher, R. (1984). Ein neues Meßverfahren zur Bestimmung des Elastizitätsmoduls von Holz. *Holz Als Roh- Und Werkstoff: European Journal of Wood and Wood Industries*. <https://doi.org/10.1007/BF02607231>
- Hamdan, S., Jusoh, I., Rahman, M. R., & de Juan, M. (2016). Acoustic properties of *Syzygium* sp., *Dialium* sp., *Gymnostoma* sp., and *Sindora* sp. wood. *BioResources*. <https://doi.org/10.15376/biores.11.3.5941-5948>
- Jalili, M. M., Mousavi, S. Y., & Pirayeshfar, A. S. (2014). Investigating the acoustical properties of carbon fiber-, glass fiber-, and hemp fiber-reinforced polyester composites. *Polymer Composites*. <https://doi.org/10.1002/pc.22872>
- Lock, J. M., & Keay, R. W. J. (1991). Trees of Nigeria. *Kew Bulletin*. <https://doi.org/10.2307/4110619>
- Matsunaga, M., Sugiyama, M., Minato, K., & Norimoto, M. (1996). Physical and mechanical properties required for violin bow materials. *Holzforschung*. <https://doi.org/10.1515/hfsg.1996.50.6.511>
- Olaoye, K.O., Oluwadare, A. ., Kolapo, M. ., & Akala, A. . (2016). Acoustic potential of *Aningeria robusta* (A. chev) wood for manufacturing talking drum. *Proceeding of the 5th Biennial Conference of the Forest and Forest Products Society, Nigeria*, 466–470.
- Olaoye, K O, Oluwadare, A. O., Adelusi, E. A., & Abiola, J. K. (2019). *Acoustic Properties of Gmelina arborea* ( Roxb .). 4(1), 1–9.
- Olaoye, Kayode Oladayo, & Okanlawon, F. B. (2019). Acoustic Properties of *Albizia Adianthifolia* (schum.) Wood in Relation to Moisture. *American Journal of Agriculture and Forestry*, 7(3), 119. <https://doi.org/10.11648/j.ajaf.20190703.15>
- Ono, T., & Norimoto, M. (1983). Study on young's modulus and internal friction of wood in relation to the

- evaluation of wood for musical instruments. *Japanese Journal of Applied Physics*. <https://doi.org/10.1143/JJAP.22.611>
- Plack, C. J., Oxenham, A. J., & Fay, R. R. (2005). Pitch: neural coding and perception. In *Springer handbook of auditory research*.
- Ross, R. J., & Pellerin, R. F. (1994). *US General Technical Reports*. 70(1).
- Sedik, Y., Hamdan, S., Jusoh, I., & Hasan, M. (2010). Acoustic properties of selected tropical wood species. *Journal of Nondestructive Evaluation*, 29(1), 38–42. <https://doi.org/10.1007/s10921-010-0063-7>
- Tanaka, C. (1987). Acoustic property of wood. *Mokuzai Gakkaishi*, 33, 811–817. <http://ci.nii.ac.jp/naid/10010682936/en/>
- Tsoumis, G. (1991). Science and technology of wood. Structure, properties, utilization. *Science and Technology of Wood. Structure, Properties, Utilization*.
- Yano, H., Kyou, K., Furuta, Y., & Kajita, H. (1995). Acoustic properties of brazilian rosewood [*Dalbergia nigra*] used for guitar back plates. *Mokuzai Gakkaishi*, 41, 17–24.
- Yano, H., Matsuoka, I., & Mukudai, J. (1992). Acoustic Properties of Wood for Violins. *Mokuzai Gakkaishi*.
- Yoshikawa, S., & Waltham, C. (2014). Woods for Wooden Musical Instruments. *The Journal of the Acoustical Society of America*.