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Comparative Assessment of Selected Acoustic Methods Tested on *Gmelina arborea* (ROXB) Wood

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Abstract— *Wood is among the materials that produce sound, and its excellent sound characteristics has made it one of the suitable materials for acoustic purposes. Many methods have being devised to study the acoustic properties of wood by scholars. However, there has been different acoustic results from these methods and thus leading to conflict of findings. This disparity, if left unchecked can mar the implementation of the resulting acoustic findings. Therefore, there is a need to assess these acoustic methods for existence of significant difference. Three trees of G. arborea were fell, and wood samples of* $20 \times 20 \times 300\ mm^3$*collected axially and radially for acoustic testing using two different methods. Selected acoustic values were obtained from these methods and analysis of variance was done to test for a significant difference. From the analysis done, P-values for the acoustic properties from the two methods were 0.17, 0.27, 0.18, 0.29, and 0.38 for velocity of sound, longitudinal elastic modulus, specific longitudinal elastic modulus, acoustic co-efficient and Impedance respectively. These values revealed that there were no significant difference between the two acoustic methods tested for in this study, and as such the acoustic values obtained are the same. Hence, no conflict of findings.*

Keywords— acoustic, assessment, Gmelina arborea, properties, wood.

I. INTRODUCTION

Acoustic can simply be defined as the science of sound. Many materials can produce sound,and among materials that can produce sound is wood. The study of acoustic thus avail us the opportunity to study the science of sound of these materials, and also for musical instruments.

In spite of recent advances in material science, wood remains the preferred construction material for musical instruments worldwide. Some distinguishing features of wood such as light weight, and workability are easily noticed if wood properties is compared with plastic (acrylic), and metal (aluminum). Woods common in musical instruments (strings, woodwinds, and percussions) are typically (with notable exceptions) softwoods, hardwoods and monocots (Yoshikawa and Waltham, 2014). Furthermore, wood is extensively used in musical instruments because of a significantly low loss of sound energy which occur as a result of friction due to its lightness and structure. Because of such properties, (Turkey, 2005)

For every acoustic material, there exists a natural vibration/frequency (ies) of the material which can be defined as the frequency of a free vibration of that material. Many materials have more than one natural frequency unlike a tuning fork; among such materials is wood, and the first obtained (lowest) natural frequency is referred to as the fundamental frequency. Each of these natural frequencies has its individual amplitude (intensity) when the material is excited or hit. Of all these natural frequencies, the frequency with the highest intensity is known as resonance frequency.

Some acoustic methods such as resonance method and 1st bending natural frequency methodhas been adopted by scholars to determine acoustic properties of wood. Notwithstanding, there has been disparity between results from these methods, and as such may cause conflict of findings.

Since wood is an essential material for acoustic purposes, there is need to test for the acoustic potential of such wood species before recommending it for manufacturing musical instruments, or using such wood species as a musical instrument itself. However, disparity in results of acoustic methods can mar implementation and utilization of recommendations made by scholars. Thus, there is need to test if these methods exhibit significant difference between them.

To this end, this study endeavour to make a comparative assessment of selected acoustic methods tested on *Gmelina arborea* (Roxb) wood in order to check for possible significant difference between results.

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In Nigeria, the wood of *Gmelinaarborea* is considered as one of the most widely cultivated and distributed exotic species, and many people have benefited from the wood. Also, based on indigenous knowledge, *G. arborea* is a choice species for acoustic purpose. Thus, informing the choice of test species for this study.

II. MATERIALS AND METHOD

2.1 Sample Collection and Preparation

Three trees of *G. arborea* with 25 ± 2cm in diameter at breast height (DBH) were fell. From each tree, bolts of 60cm in length were collected from top and base, from which wood samples of $20 \times 20 \times 300\ mm^3$ (R x T x L) were collected from inner and outer of the sampling height for the assessment of selected acoustic properties.

2.2 Acoustic Property test

Samples collected were oven dried to constant weight and then stored at room temperature and relative humidity for one month prior to testing. Hence, selected wood acoustic properties were tested using the longitudinal free vibration test methods. A clue was taken from Mohammad *et al.*, (2014) in setting up this experiment. The wood acoustic parameters tested were: ultrasonic velocity (V), longitudinal elastic modulus (E), specific longitudinal elastic modulus, acoustic coefficient (K), and impedance (Z)

2.2.1 Longitudinal free vibration test

Method 1

The set –up for this technique is shown in Fig. 1. Each sample was tied with a thread on both sides, and suspended from a top with the threads - This is done to ensure no external sound is produced during testing. A wooden hammer was used to hit the wood from one end while the sound resonance frequency was obtained from the other end using a Fast Fourier Transform (FFT) spectrum analyzer, and the response vibrating sound recorded in a wave format file using a recording software (Audacity), thus generating a sound wave. After which equation 1-3 were used to determine longitudinal (dynamic) elastic modulus

$$V = f \times \lambda \qquad (1)$$

$where\ V = velocity, f = resonance\ frequency\ of\ first\ mode\ of\ vibration\ and$

$$\lambda = wavelength \equiv \frac{2L}{n} \qquad (2)$$

$and\ L = length\ of\ the\ sample, n = number\ of\ resonance\ mode$

NB: for the first mode of vibration, n is equal to 1.

To calculate longitudinal elastic modulus (E);

$$E = \rho V^2 \, (3)$$

$$where\ \rho = Density = \frac{oven\ dried\ mass}{green\ volume} \qquad (4)$$

Method 2

The experiment was also set up as Fig. 1. However, after generating many sounds by striking the wood, the 1st bending natural frequency (fundamental frequency) was obtained from the FFT. Hence, equation 7 was used to determine the dynamic modulus of elasticity.

$$E = \left(\frac{2f_n}{\gamma_n \pi}\right)^2 \frac{mL^3}{I} \qquad (5a)$$

(Jan *et al.*, 2016)

Where m is the specimen weight, f_n is the 1st bending natural (fundamental) frequency, n is the mode number, L is the length of the sample. γ_n is for the first mode 2.267, and *I* is inertia.

$$I = \frac{(bh^3)}{12} \qquad (5b)$$

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

Having obtained dynamic elastic modulus from method 1 and 2, equation 6-8 were used to calculate other selected acoustic parameters.

Note: the experiment was conducted in an enclosed place at room temperature having ensured a total silence, and the FFT analyzer showing no sign of sound signal.

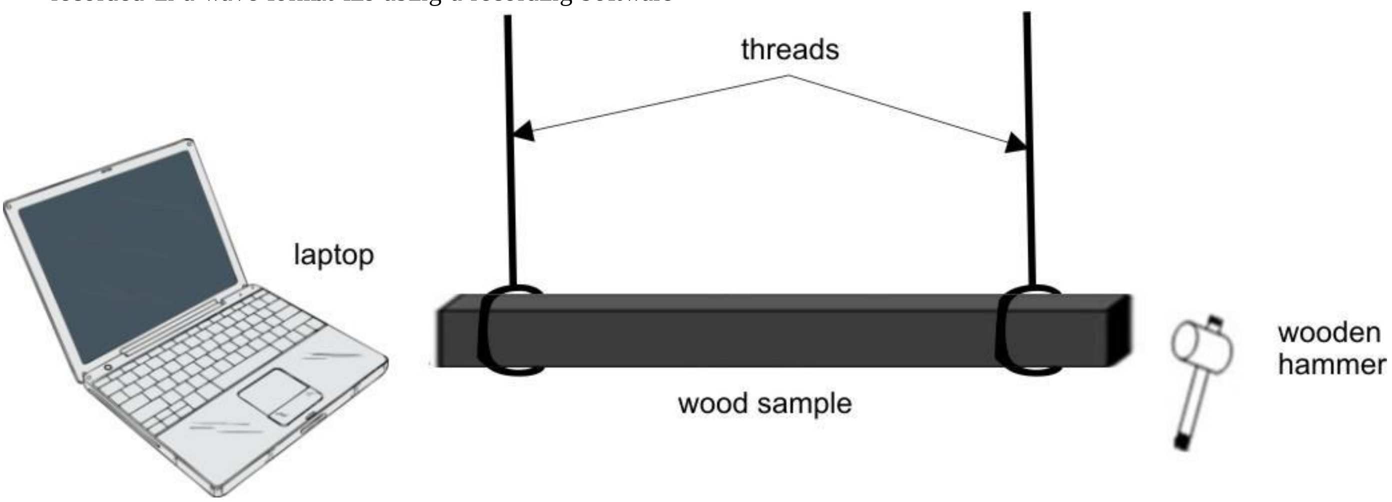

Fig.1: The set-up of longitudinal free vibration test

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Specific longitudinal elastic modulus (S);

$$S = \frac{E}{\rho_s} (6)$$

$$where\ \rho_s = Relative\ Density\ (Specific\ gravity)$$

$$\rho_s = \frac{\frac{oven\ dried\ mass}{green\ volume}}{density\ of\ water} \quad (7)$$

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

$$K = \left(\frac{E}{{\rho_s}^3}\right)^{0.5} \quad (8) \quad \text{(M. Roohnia, 2005)}$$

$$where\ E = longitudinal\ elastic\ modulus, and\ \rho_s = specific\ gravity$$

$$z = c\rho$$

$$z = impedance, c = velocity \quad (9)$$

III. RESULTS AND DISCUSSION

Mean summary of selected acoustic properties and specific gravity of acoustic methods was shown in Table 1, while summary of analysis of variance of these methods was shown in Table 2. Resonance frequency of *G.arborea* wood for method 1 was 7791.84Hz while no record of resonance frequency was recorded for method 2. This is because acoustic method 2 doesn't require finding resonant frequency before it can be utilized. In similar vein, method 1 doesn't require a fundamental frequency before using it, more reason no valueof fundamental frequency was recorded in acoustic method 1 whereas method 2 had a mean of 1095.02Hz.

Comparing acoustic method 1 and 2, it was revealed that velocity of sound recorded in method 1 was lower (4675.10m/s) to resulting value in method 2 (4848.58m/s). Similarly, all other acoustic properties tested for in method 1 was lower to findings in method 2. Thus, disparity in the acoustic values of these methods gave rise to analysisin order to ascertain if the differences are significant.

A further analysis of variance done for these two method showed that there was no significant difference between acoustic values obtained from these methods, and as such, values obtained from both methods can be considered the same.

The two methods (method 1 and 2) used in this study were methods adopted by Mohammad *et al.*, (2014) and Jan *et al.*, (2016) in determining acoustic properties of some woodspecies respectively. With a no significant between this methods as shown in this study, it can be concluded that if either of the scholars had used the other's method, they are still bound to achieve a similar results. However, there are still other methods being adopted by scholars in determining the acoustic properties of wood. One of such method is a free-free flexural system (Sedik*et al.*, 2010) which was used by Hamdan*et al.*,(2016) in their study of determining the acoustic properties of wood of *syzygium* sp., *Dialium* sp., *Gymnostoma* sp., and *Sindora* sp. Since the scope of this study did not cover for such methods, more studies should still be done on the comparism of methods for determining the acoustic properties of wood in order to mitigate conflict of findings.

Table.1: Mean summary of selected acoustic properties and specific gravity of G.arboreawood from Method 1 and 2

Acoustic properties tested	Method 1	Method 2
Resonance frequency 'RF' (Hz)	7791.84	-
Fundamental Frequency 'FF' (Hz)	-	1095.02
Velocity of sound 'V' (m/s)	4675.10	4848.58
Specific gravity (γ)	0.39	0.39
Longitudinal elastic modulus 'E' (GPa)	8.71	9.34
Specific longitudinal elastic modulus 'Es' (GPa)	21.96	23.57
Acoustic coefficient 'K'($m^4kg^{-1}s^{-1}$)	11.85	12.30
Impedance 'Z' x10^6($kgm^{-2}s^{-1}$)	1.8520	1.9199

Table.2: Summary of analysis of variance, showing P-values for selected methods used to determine the selected acoustic properties of G.arborea wood.

S of V	Df	V	E	Es	K	Z
Methods	1	0.171ns	0.272ns	0.178ns	0.292ns	0.384ns
Error	22					
Total	23					

ns – not significant

IV. CONCLUSION AND RECOMMENDATION

This study was able to compare selected acoustic properties of *G.arborea* wood done using two different methods. Having assessed the comparism of these methods, it can be concluded that any of the two acoustic methods can be adopted by researchers in testing for acoustic properties of wood since there was no significant difference between these methods. Thus, this study recommends the two methods suitable for determining the selected acoustic properties of wood.

REFERENCES

[1] Hamdan S., Jusoh I., Rahman R and Juan M (2016): "Wood acoustic properties". BioResources 11(3), 5941-5948. Pg. 5941-5948

[2] Jan Baar, Jan Tippner and Vladimir Grye (2016): wood anatomy and acoustic properties of selected hardwoods; IAWA Journal 37(1), 2016:69-83

[3] M. Roohnia (2005): study on some factors affecting coefficient and damping properties of wood using Non-destructive Tests.Ph.D Thesis, Islamic Azad University Campus of Science and Researches, Tehran, Iran

[4] Mohammad Mehdi Jalili, SeyyedYahyaMousavi and Amir SoheilPirayeshfar (2014): Investigating the acoustical properties of carbon fiber-, glass fiber-, and hemp fiber-reinforced polyester composites. Polymer Composites. Vol. 35(11):2103-2111, November 2014. Version of Record online: 17 JAN 2014, DOI: 10.1002/pc.22872

[5] Sedik Y., Hamdan S., Jusoh I. and Hasan M. (2010): Acoustic properties of selected tropical wood species. J. Nondestruct. Eval. 29:38-42. J. Non-destruct. Eval. 29:38-42.

[6] Turkey (2005): wood as a Building Material; It's Benefits and Disadvantage. Republic of Turkey, Ministry of Culture and Tourism.

[7] Yoshikawa, S. and Waltham, C. (2014): wood for wooden instrument; why wood? ISMA 2014, *Le Mans, France*; Pg 282