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TIMBRE HARMONIC OF SELECTED HARDWOOD SPECIES

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ABSTRACT

One of the limited information about the acoustic characteristics of wood is the timbre harmony. We measure the sound harmony of selected hardwood species using a timbre harmonic model. 324 wood samples of 20 x 20 x 300 mm (R x T x L) were collected axially from 12 trees of *Albizia adianthifolia*, *Gmelina arborea*, *Delonix regia* and *Boscia anguistifolia* for the experiment. Results were subjected to descriptive statistics and analysis of variance. The timbre harmonic model prescribed a scale of 0-1, 0 being the perfect harmonic while 1 represents imperfect harmonic. *G. arborea* wood had the significantly lowest mean timbre harmonic of 0.078 ± 0.006, thus it had the best sound harmony. Meanwhile, *A. adianthifolia* wood had the highest timbre harmonic value (0.120 ± 0.008). Conclusively, this study successfully measured the timbre harmonic of sound from selected hardwood species and information provided revealed the species all performed fairly, owing to their values closer to 0.00.

KEYWORDS: Frequency contents, acoustic, timbre, hardwood, harmonic.

INTRODUCTION

Brémaud (2012) posited wood as a major constitutive material of many musical instruments, because of its role in their design and building process, thus contributing to their behavioral and cultural identity. Many materials and musical instruments contain more than one frequency in their sound when struck, and these frequency contents are referred to as the timbre of the sound. According to Goswami and Makarand (2013), timbre is a property of sound which helps to identify the source of a sound. It is the main attribute that distinguishes musical instruments from each other through sound. The variation in numbers and arrangement of frequencies contained in a sound is one of the parameters that determine the type and quality of the timbre, thereby making such a sound complex.

All complex sounds such as with musical instruments are expected to contain multiple frequencies, with the first frequency as fundamental frequency while other subsequent frequencies are known as overtones (Jeffery 2003, Goswami and Makarand 2013, Zlatintsi and Maragos 2013). More specifically, harmonicity relates to the existence of overtones as integer multiples of the fundamental within a sound's spectrum.

In Africa, wood has found direct usage for musical instruments as wood block, xylophone, balafon, bamboo slit drum, amongst others. In spite of the introduction of other materials (composite, polymer, alloys), wood remains a good and preferred choice for acoustic applications due to its unique acoustic characteristics and aesthetic appeal (Wegst 2006). One of such characteristics that makes wood unique is its damping properties which enable sound waves to be partly absorbed and partly reflected when set into vibration by a strike.

Among scholars who have studied the acoustic characteristics of wood in relation to musical instruments are Yano et al. (1992) who studied the acoustic properties of wood for violin, and Olaoye et al. (2016) who investigated the acoustic potential of *Aningeria robusta* wood for manufacturing talking drum. Also, Sedik et al. (2010) reported the acoustic properties of selected tropical wood species while Olaoye et al. (2019) reported for *Gmelina arborea* wood while Bucur (2006) reported the suitability of various wood species for different musical instruments. Notwithstanding, information about the suitability of wood species for musical or acoustic application based on the harmonicity of its sound timbre has suffered a setback. As such, a further investigation is needed to buttress available information.

Thus, without proper scientific measurement of timbre harmonic from wood species, it will be difficult to identify wood having good harmonic sound pleasant to the ears. Alternatively, practitioners' will continue to rely on listen prowess of supposed experts to determine a pleasant and harmonic sound. Hence, it is important to measure the timbre harmonic of sound generated from wood species. Furthermore, Yano et al. (1994), Obataya et al. (2000), and Haines (2000) reiterate the importance of timbre for wood soundboard of string musical instruments.

Benetos et al. (2006), Pikrakis et al. (2006), Goswami and Makarand (2013), Zlatintsi and Maragos (2013) have identified with MFCC (Mel Frequency Cepstrum Coefficients) as a method for timbre identification in musical instruments. McAdams et al. (1995), Caclin et al. (2005), Aramaki et al. (2007) characterize sounds using timbre descriptors such as attack time, spectral bandwidth, spectral centroid, and spectral flux. These methods though found useful in the classification of timbre into the different musical genre, it is not suitable for measuring harmonicity of timbre, especially for sound of wood species. Nonetheless, Olaoye (2021) successfully designed a model which can be adopted for measuring timbre harmonic of the sound of musical instruments and wood species.

The timbre harmonic model proposed by Olaoye (2021) highlighted that for a sound to be pleasant and harmonious to the ear, the frequency contents of the timbre of that sound must be in perfect arithmetic arrangement. Thus, the model analysis presented a harmonic scale of 0-1, with 0 being the perfectly (strong) harmonic sound and 1 imperfect (weak) harmonic sound. Therefore, this work aims to measure the timbre harmonics of selected hardwood species using the timbre harmonic model, to assess their sound harmony.

The selected wood species considered in this study were *Albizia adianthifolia*, *Gmelina arborea*, *Delonix regia,* and *Boscia anguistifolia*. *A. adianthifolia* is a tall tree (about 36 m) with a few large widely spreading branches. It is widespread in tropical Africa and South Africa, and commonly called 'ayinre bona bona' in Yoruba, Southwestern, Nigeria (Lock and Keay 1991). Also, *G. arborea* is a widely cultivated and distributed exotic wood species in Nigeria. It has found prominence in uses for acoustic application and musical instrument such as the talking drum (Aiyeloja et al. 2015). *D. regia* belongs to the family fabaceae, and is a medium-sized tree found in tropical countries (Shewale et al. 2012). *B. angustifolia* is a shrub or small tree about 6 m high that belongs to the family Capparaceae and it is commonly found across Africa (Burkill 1985).

MATERIALS AND METHOD

Sample collection and preparation

Twelve trees of *A. adianthifolia*, *G. arborea*, *D. regia* and *B. anguistifolia* (3 tree replicates per species) were felled in Oyo State, Nigeria. *G. arborea* and *B. anguistifolia* were felled from Gambari forest reserve while *A. adianthifolia* and *D. regia* were felled from a farm land. Fig. 1 described the sample machining. Bolts were collected from the tree axially using the chain saw, while a band saw was used to covert to the required wood sample dimension. A total of 324 wood samples of 20 x 20 x 300 mm (radial x tangential x longitudinal) were then collected for the timbre harmonic model analysis. The wood samples were oven-dried at 103 ± 2^{o}C for 24 hours, and conditioned at 80% relative humidity and 24^{o}C for one month prior experiment.

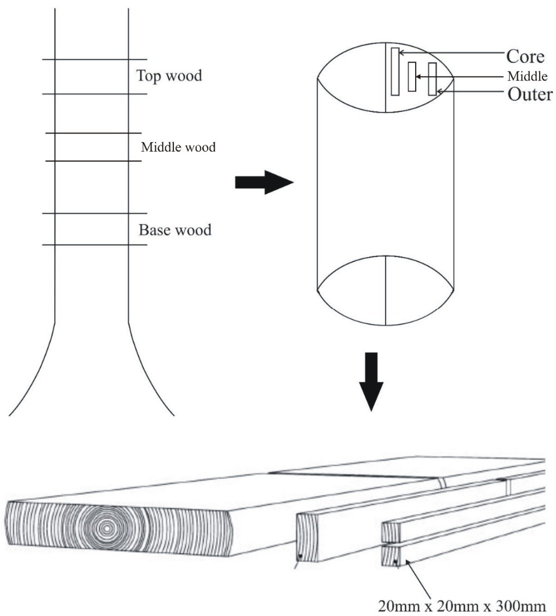


Fig. 1: Sample collection technique.

Timbre harmonic measurement

The experiment was set up as shown in Fig. 2 (Mousavi et al. 2010). This method was used to generate the sound from the wood samples. In order to avoid interference, the experiment was performed in an enclosed silent room, at room temperature. The wood samples were then struck severally with a hammer at one end and sound generated were recorded using Audacity software (version 2.4.2. 2020) at the other end. The average natural frequency contents (timbre) were obtained through the Fast Fourier Transform (FFT) contained in the Audacity. Hence, the timbre harmonic was measured using Eq. 1 (Olaoye 2021). Olaoye (2021) established that the use of six overtones gives a more reliable and accurate results. Thus, the first six frequencies (n = 6) were administered for this experiment.

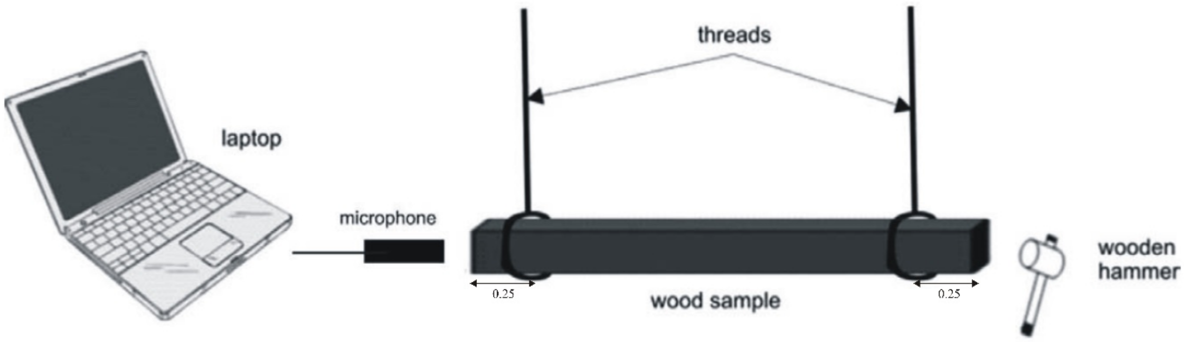


Fig. 2: The set-up of longitudinal free vibration test.

$$\sum_{\substack{i=1\\j=2}}^{n-1}\left|\frac{f_j - f_i}{\sum_{\substack{i=1\\j=2}}^{n}(f_j - f_i)} - \frac{1}{n-1}\right| \div K_n \qquad (1)$$

where: i = 1, 2… n, j = 2, 3…n, f - natural frequency, n - number of frequency observation, K_n - Kay's constant = 1.6 (n = 6).

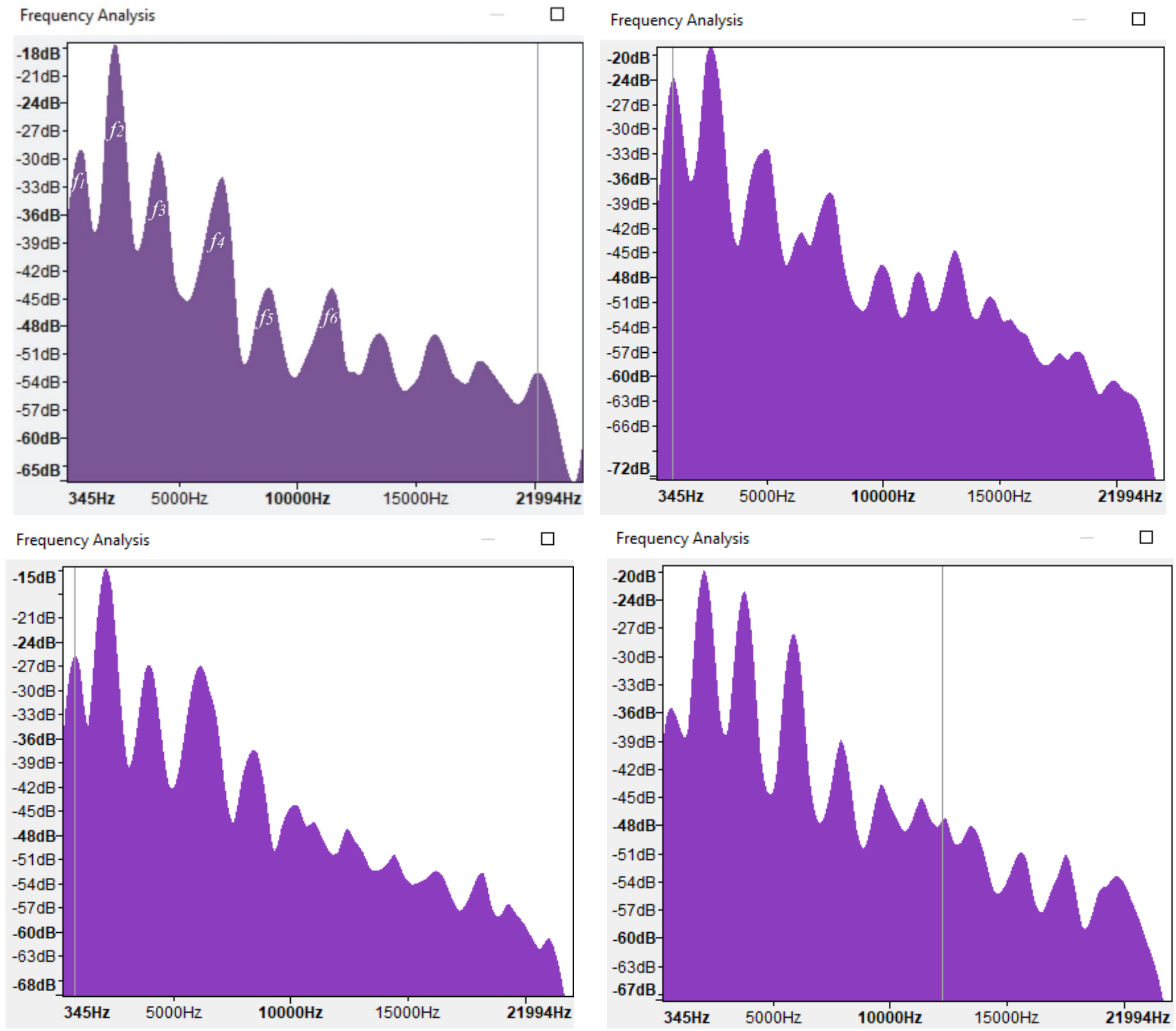
The experiment was set up in a completely randomized design while descriptive statistics, charts, and analysis of variance were used to test for significance:

$$Yij = \mu + Ti + Eij \qquad (2)$$

where: Yij - observation, μ - mean, Ti - treatment (hardwood species), Eij - error term.

RESULTS AND DISCUSSION

The Fig. 3 shows the FFT spectrum analysis for one of the wood samples measured. The first frequency labeled f_1 is the fundamental frequency while $f_2 - f_6$ represents the first five overtones. Additionally, the mean timbre harmonic of sound from all the wood species studied were presented in Fig. 4, while radar diagrams in Fig. 5 represent the harmonic values per species. The radars consist of circles with 0.05 difference to each other, and the first circles identified with red represent timbre harmonic values ≤ 0.05. Furthermore, Tab. 1 shows post-hoc analysis of variance of timbre harmonic of the species studied.



f_1- fundamental frequency, f_2-f_6 – overtones.

Fig. 3: FFT spectrum analysis of the sound frequencies of: a) A. adianthifolia wood, b) G. arborea wood, c) D. regia wood, d) B. anguistifolia wood.

G. arborea wood had the lowest mean timbre harmonic of 0.078 ± 0.006 thus making it significantly different from the other wood species, while the highest mean timbre harmonic value was obtained for *A. adianthifolia* wood at 0.120 ± 0.008.

The results in Fig. 5 interpret that only *A. adianthifolia* wood had its timbre harmonic value in the 6th radar circle (0.25-0.30). An implication that the poorest timbre harmony was found with *A. adianthifolia* wood. Also, no timbre harmonic values were observed in the 1st radar circle of *A. adianthifolia*, whereas *G. arborea* shows that more of its values were contained in its 1st radar circle; a situation which thus implies that more harmonious sounds were associated with *G.arborea* wood.

In the 2nd radar circles (0.05-0.10), only *G. arborea* and *B. anguistifolia* wood had the most populous harmonic values present. Since the 1st and 2nd circles represent values closest to 0.00 (perfect harmonic sound), it can thus be insinuated that these two wood species have performed better owing to more harmonic values present in their first two circles. However, there is a need to present an analysis of variance to confirm this insinuation.

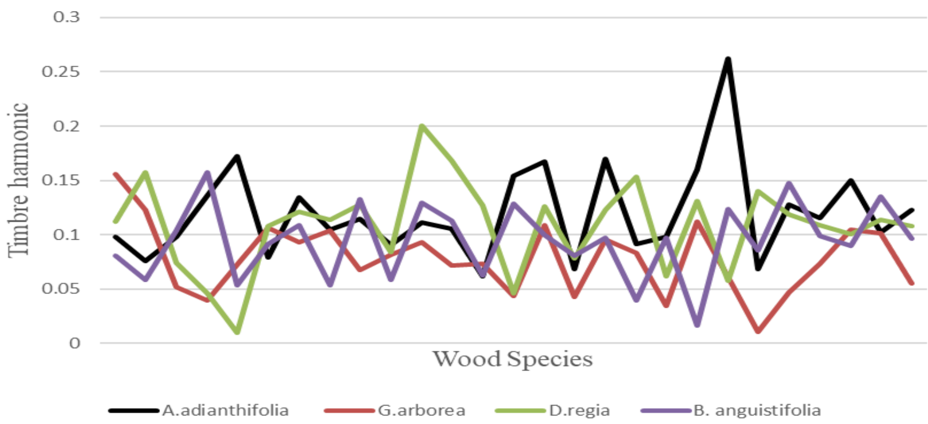


Fig. 4: Mean harmonic values obtained for the selected hardwood species.

Inferentially, results presented in Tab. 1 confirm that timbre harmonic values obtained for *G. arborea* and *B. anguistifolia* wood were significantly different from other wood species. However, *G. arborea* wood was significantly better. This further explains the reason *G. arborea* wood was considered suitable (Olaoye et al. 2019) and sort after (Aiyeloja et al. 2015) for musical and acoustic applications.

Tab. 1: Post-hoc analysis of variance for mean timbre harmonic of sound from the selected hardwood species.

Hardwood species	**Mean ± standard error**	**Subsets**		
		a	b	c
G. arborea	0.078 ± 0.006^{a}	0.078		
B. anguistifolia	0.094 ± 0.006^{ab}	0.094	0.094	
D. regia	0.108 ± 0.008^{bc}		0.108	0.108
A. adianthifolia	0.120 ± 0.008^{c}			0.120
Sig. (P-values)	0.0007*	0.125	0.177	0.250

* - Significant. Mean values with a different alphabet in the same column are significantly different from each other.

The mean timbre harmonic (0.078 ± 0.006) obtained for *G. arborea* wood in this study was similar to what was found in (Olaoye 2021) (0.07) for the same wood species, at the same number of frequency observations (n = 6). Going by the scale prescription (0-1) of the timbre harmonic model, it can be shown that all the wood species considered in this study performed and compared fairly, owing to their mean values (0.078, 0.094, 0.108, 0.120) and highest recorded value (0.26) relatively closer to 0.00. This could be another major reason wood is preferred for musical applications.

On the other hand, (Baar et al. 2016) opined that anatomical properties of hardwood species can influence acoustic traits of wood. Similarly, Brancheriau et al. (2006) confirmed the importance of the regularity and homogeneity of the anatomical structures of wood species, thus suggesting that. The axial parenchyma and rays as the key trait for good timbre. Thus, different anatomical properties of these wood species may have influenced the timbre harmonic values obtained in this study. This study, therefore, highlights the need to investigate the relationship between anatomical traits and timbre harmonic of hardwood species.

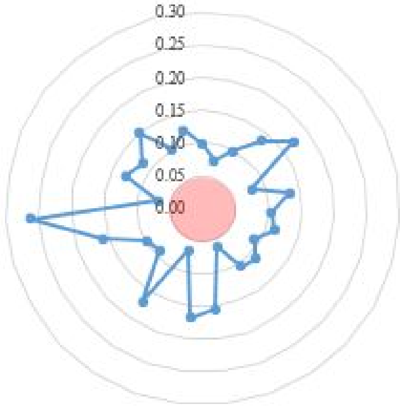


Fig. 5a

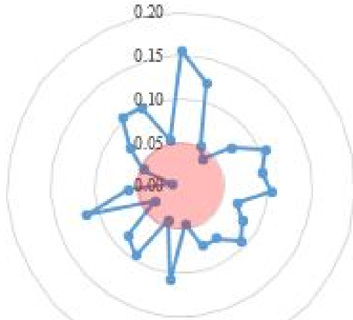


Fig. 5b

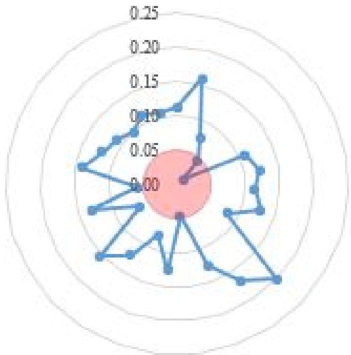


Fig. 5c

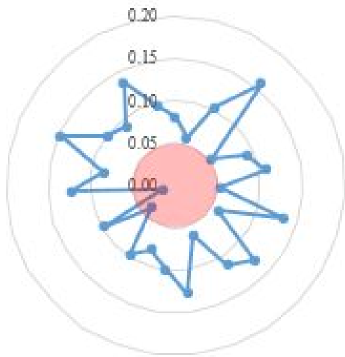


Fig. 5d

Fig. 5: Radar representation of the mean timbre harmonics of: a) A. adianthifolia wood, b) G. arborea wood, c) D. regia wood, d) B. anguistifolia wood.

CONCLUSIONS

This study measured the timbre harmonics of selected hardwood species using the timbre harmonic model, and relevant information was provided. *G. arborea* wood had the lowest timbre harmonic value, which thus signifies that it has the best sound harmony, followed by *B. anguistifolia* and *D. regia*, while *A. adianthifolia* had the highest value. Meanwhile, the influence of anatomical properties was suspected to cause variation in values of the timbre harmonic obtained for different species in this study. Notwithstanding, all the wood species performed fairly, owing to their mean timbre harmonic values closer to 0.00.

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