# Characterization of Sound Properties of Talking Drums Made From Gmelina Arborea Wood

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## Résumé

Le tambour parlant est utile à des fins musicales. Cependant, il produit un timbre sonore complexe, difficile à caractériser. Bien que la géométrie de la coquille de sablier en bois constituant le tambour parlant ait été identifiée comme un facteur influençant la composition du timbre sonore, il reste encore à enquêter sur d'autres facteurs suspectés. Cette étude a caractérisé les propriétés sonores des tambours parlants des housses en cuir, la force et la position de jeu, la tension sur la corde et l'impact de surface excité. Trois boulons du la base des arbres de Gmelina arborea a été utilisée pour produire les tambours parlants, par conséquent, les propriétés sonores ont été mesurées. Les valeurs obtenues ont été soumises à des statistiques descriptives, des graphiques et une ANOVA (α0,005). La fréquence fondamentale, l'amplitude et le temps d'amortissement acoustique (SDT) sans tension sur la corde étaient significativement les plus bas (90,06 ± 27,16, 41,03 ± 4,31 et 380,83 ± 103,58) pour la force de jeu légère et les plus élevés (97,00 ± 29,68, 60,26 ± 3,59 et 474,44 ± 59,48) pour une force lourde, respectivement. A tension maximale sur la corde, SDT de peau de chèvre était significativement plus élevée (478,50 ± 77,04) que la couverture en cuir d'utérus de vache (438,89 ± 97,65), tandis que l'amplitude et le SDT étaient significativement plus élevés (66,61 ± 2,95 et 508,52 ± 51,60) pour une force lourde que pour une force de jeu légère (46,16 ± 7,06 et 408,87 ± 92,46), respectivement. La tension sur la corde était le facteur le plus essentiel nécessaire pour caractériser la propriété sonore de qualité des tambours parlants.

**Mots clefs :** Musique, Culture du bois, Produit du bois, Propriétés sonores

## Abstract

Talking drum is useful for musical purposes. However, it produces a complex sound timbre, difficult to characterize. Although the wooden hourglass-shell geometry making the talking drum was identified as a factor influencing the sound timbre make-up, there is still a need to investigate other suspected factors. This study characterized sound properties of talking drums from Leather covers, force and position of play, the tension on the rope, and excited surface impact. Three bolts from the base of *Gmelina arborea* trees were used to produce the talking drums, hence, sound properties were measured. Values obtained were subjected to descriptive statistics, graphs, and ANOVA ($\alpha_{0.005}$). Fundamental Frequency, Amplitude, and Sound Damping Time (SDT) at no tension on the rope were significantly lowest (90.06±27.16, 41.03±4.31, 380.83±103.58) for the light force of play and highest (97.00±29.68, 60.26±3.59, 474.44±59.48) for heavy force, respectively. At maximum tension on the rope, SDT of goat skin was significantly higher (478.50±77.04) than cow womb leather cover (438.89±97.65), while Amplitude and SDT were significantly higher (66.61±2.95, 508.52±51.60) for heavy force than the light force of play (46.16±7.06, 408.87±92.46), respectively. Tension on the rope was the most essential factor needed in characterizing the quality sound property of the talking drums.

**Keywords:** Music, Wood Culture, Wood Product, Sound Properties

## 1 Introduction

The talking drum (TD) is an hourglass-shaped percussion musical instrument whose two heads (skin surfaces) are vertically opposite to each other with leather string. It is a West African drum that has garnered relevance as a means of communication in Southwestern Nigeria, after human voice. Du-

Definition of some Terms:

**Resonance Frequency (RF)** – The sound frequency having the highest amplitude in a timbre
**Fundamental Frequency (FF)** – The first sound frequency in a timbre
**Sound Damping Time (SDT)** – The time required for a sound of material or musical instrument to return to silence after being excited
**Excited Surface Impact –** The measured response of the skin surface of the talking drum to strike

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rojaye et al. [1] confirm the talking drum to be perfectly fit for linguistic usage, owing to its excellent performance to mimic the human voice. Generally, the use of talking drums is cultural, communication, and music-oriented [1–3].

Furthermore, the major material used for producing talking drums is the wood making its shell. Interestingly, the potentiality of selected wood species for making talking drums have been discussed [4–7], and *Gmelina arborea* wood was confirmed suitably.

Scientifically, the measurement of sound from a musical instrument is characterized by a regular and uniform vibration of the wave propagated. Thus, Pitch, Timbre, Intensity, and Timing are the major properties of sound that distinguish a musical tone [1, 8]. This was also corroborated by Zatorre and Baum [9] who stated that musical sound is characterized by discrete pitches which sustain longer durations.

Pieces of literature have shown the existence of different musical (cultural) systems that define pitch movements, with specific scales and rules [10–13]. Akere [14] pointed out that the pitch of a talking drum can be regulated depending upon how a player strikes the head of the drum and changes its tension. Notwithstanding, this attribute makes the sound from talking drums complex and difficult to characterize. For instance, Figures 1a and 1b show a different sound frequency spectrum (Resonance Frequencies of 81 and 83 Hz) for two strikes made on a single talking drum.

Furthermore, Belcher and Blackman [2] noted the speculation that the sizes and shapes of the various drums, the tension of the drum skins, placement of the strikes, and so on, may hamper the perceived sound frequency. It is, therefore, appropriate to opine that many factors contribute to the properties of sound generated by talking drums. In addressing some of these challenges, Olaoye and Oluwadare [15] characterized the sound properties of talking drums based on the geometry of hourglass shells. However, there is still limited information on the influence of other suspected factors on sound properties of talking drums, thus, it will be difficult to attain optimal performance of talking drum at all times unless adequate characterization is done.

Therefore, there is a need to ascertain if, and how other suspected factors influence the sound properties of talking drums. Hence, this study characterized the sound properties of talking drums made from *G.arborea* wood, with a view of highlighting the influence of selected factors on its sound properties. The factors that were considered in this study were tension on the rope, leather cover, the force of play, position of play, and excited surface impact (ESI).

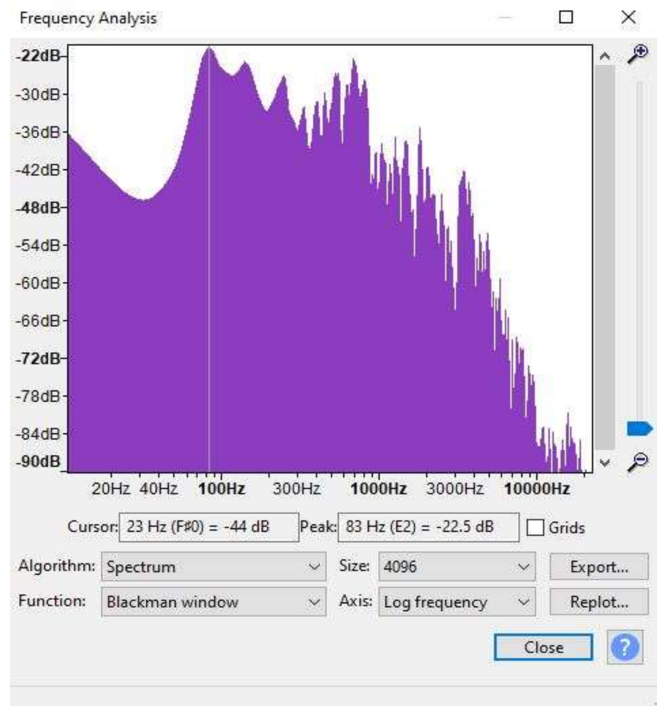


**Figure 1a:** Sound Frequency Sample (1) Obtained from a Talking Drum (A).

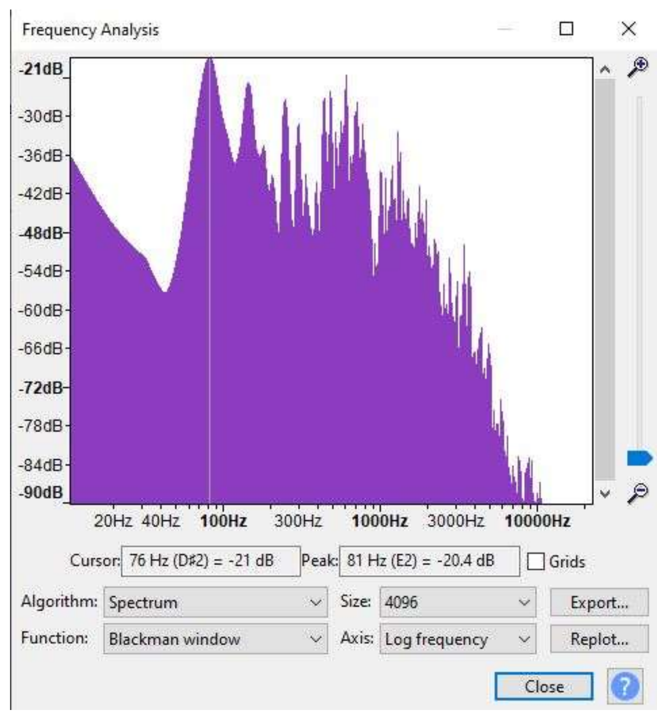


**Figure 1b:** Sound Frequency Sample (2) Obtained from a Talking Drum (A).

## 2 Material and method

Three fifteen years old trees of G. arborea were felled from Gambari Forest Reserve. From each tree, 3 bolts of 60 cm were collected from the base wood of the trees to make the hourglass shells. The bolts were conditioned under atmospheric temperature (30oC) and relative humidity (60%) for a month before carving. The selected acoustic properties of G.arborea wood were reported in Table 1, while Plate 1 shows all the major materials used in producing the talking drums.

### 2.1 Steps in producing the talking drums

Step 1 – The three bolts were manually carved and shaped into a figure of an hourglass shell measuring 28 cm in length, 15 cm in diameter, and a thickness of 0.6 cm. Both ends of the shell were opened since the talking drum is a membranophone percussion instrument.

**Table 1:** Selected Acoustic Properties of *G.arborea* wood.

| **W.D** (gcm$^{-3}$) | **E** (GPa) | **V** (ms$^{-1}$) | **tan δ** | **Es** (GPa) | **Q** | **ACE** (m$^4$/kg/s) |
|---|---|---|---|---|---|---|
| 0.39 | 9.34 | 4848.58 | 0.0039 | 23.57 | 279.64 | 3435.66 |

**W.D** – Wood density; **E** – Dynamic elastic modulus; **V** – Velocity of sound; **tan δ** – Damping factor; **Es** – Specific elastic modulus; **Q** – Sound quality; **ACE** – Acoustic conversion efficiency. Source: [6].


**Plate 1:** Major components used in making the talking drum.


**Plate 2:** Experimental set-up for measuring the excited surface impact of a talking drum.

Step 2 – Goat skin and Cow womb (ole) used as leather covers for the opposite surfaces were prepared by soaking in ordinary water for 45 min and later rubbed and squeezed. Thereafter, the laying of the cover leathers on both ends of the shell was done. It was firmly held in place with leather string by sewing the tension rope and the membrane together. An adhesive was used to hold the tension rope against the shell frame to facilitate the turning of the drum using membrane pegs during production. Three talking drums (TD1, TD2, and TD3) of different cover leathers were produced.

Step 3 – The drums were sundried for two days after which the pegs were removed, and the tension ropes straightened.

## 2.2 Sound property test

The Fundamental Frequency (FF), Resonance Frequency (RF), Amplitude (A), and Sound Damping Time (SDT) were sound properties of the talking drums measured. The experiment was done in an enclosed silent room, as this was to prevent interference of external sounds during recording. A microphone was placed about 20 cm from the talking drums, and the service of a drummer was employed to generate single strikes on the talking drums' surfaces at no extension on the rope (NTR), and at the maximum tension on the rope (MTR), with respect to force of play (light and heavy) and position of play (up, center and down). The sound generated by these strikes was recorded and analyzed using Audacity. The experiment was repeated 108 times.

Additionally, to measure the Excited Surface Impact (ESI) on the leather covers, a piezoelectric crystal was mounted on the talking drums' surface to measure the impact of the drummer's strikes on them. The experiment was set up as shown in Plate 2.

Data obtained were subjected to Descriptive statistics, Pearson correlation, and Analysis of variance at α0.005. Meanwhile, eq. 1 was used to determine the frequency ratio.

$$Fundamental\ Frequency\ Ratio\ (FR) = \frac{Frequency\ at\ No\ Tension\ on\ Rope}{Frequency\ at\ Max.Tension\ on\ Rope} \quad (1)$$

## 3 Results

Tables 2 and 3 documents the means of sound properties of the talking drums to the factors considered for characterization, at NTR and MTR respectively. At NTR, FF, RF, A, and SDT were lowest (90.06 ± 27.16, 242.43 ± 201.53, 41.03 ± 4.31, and 380.83 ± 103.58) at the light force of play and highest (97.00 ± 29.68, 97.00 ± 29.68, 60.26 ± 3.59, and 474.44 ± 59.48) at the large force of play, respectively. Additionally, the amplitude was the only sound property having its value significantly higher at center/down (51.35 ± 10.65/51.46 ± 10.09) than up (49.13 ± 10.67). There were variations in sound properties characterized according to the factors investigated, for TD1, TD2, and TD3.

At MTR, the mean SDT at goat skin was significantly higher (478.50 ± 77.04) than cow womb leather cover (438.89 ± 97.65). Also, A and SDT were significantly higher (66.61 ± 2.95 and 508.52 ± 51.60) at a heavy force of play than a light force of play (46.16 ± 7.06 and 408.87 ± 92.46), respectively.

Meanwhile, Table 4 shows the analysis of variance of sound frequency measured between NTR and MTR. Also, it reported the sound frequency ratio (FR) for fundamental frequencies of the talking drums. SDT was the only sound property not significantly different, for TD2. The FR for TD1 was the highest (3.08) while TD2 had the lowest (1.34). Tables 5 and 6 describe the total count of RF obtained among the talking drums at NTR and MTR, respectively. The highest number of RF (28) was recorded at NTR for TD2, while the least was five (5), at MTR for TD1.

The spectrogram sample of a strike from TD3 was displayed in Figure 2. It describes the sound frequencies in the time domain. As such, the colors differentiate the degree of amplitude (white – red – blue represent high – medium – lower amplitude), while the width interprets the SDT. Figures 4 – 8 showed the histogram distribution of the RF at NTR and MTR for the talking drum. At NTR, TD1 and TD3 had only 33%, and 36% of their RF between 50Hz and 100Hz respectively. Meanwhile, TD2 had 14% of its RF between 100Hz

**Table 2:** The Mean Sound Properties of Talking Drums at NTR.

| **TD 1** | | **Cover leather** | | **Force of play** | | **Position of play** | | |
|---|---|---|---|---|---|---|---|---|
| **TD1** | | goat | Cow | light | heavy | up | center | down |
| | FF(Hz) | 58.44$^{a}$ | 59.33$^{a}$ | 58.28$^{a}$ | 59.50$^{b}$ | 57.58$^{a}$ | 60.00$^{b}$ | 59.08$^{ab}$ |
| | RF(Hz) | 362.56$^{a}$ | 311.56$^{a}$ | 197.61$^{a}$ | 476.50$^{b}$ | 299.75$^{a}$ | 358.42$^{a}$ | 353.00$^{a}$ |
| | A(dB) | 48.72$^{a}$ | 47.61$^{a}$ | 37.27$^{a}$ | 59.06$^{b}$ | 45.97$^{a}$ | 48.55$^{b}$ | 49.97$^{b}$ |
| | SDT(ms) | 464.17$^{a}$ | 450.89$^{a}$ | 440.78$^{a}$ | 474.28$^{b}$ | 446.50$^{a}$ | 475.75$^{a}$ | 450.33$^{a}$ |
| **TD 2** | | | | | | | | |
| | FF(Hz) | 127.67$^{a}$ | 126.06$^{b}$ | 123.78$^{a}$ | 129.94$^{b}$ | 126.50$^{a}$ | 125.92$^{a}$ | 128.17$^{a}$ |
| | RF(Hz) | 383.72$^{a}$ | 428.06$^{a}$ | 367.94$^{a}$ | 443.83$^{b}$ | 396.33$^{a}$ | 422.58$^{a}$ | 398.75$^{a}$ |
| | A(dB) | 51.89$^{a}$ | 51.89$^{a}$ | 39.89$^{a}$ | 63.89$^{b}$ | 50.75$^{a}$ | 52.83$^{b}$ | 52.08$^{b}$ |
| | SDT(ms) | 504.11$^{a}$ | 466.06$^{b}$ | 451.72$^{a}$ | 518.44$^{b}$ | 442.33$^{a}$ | 500.00$^{b}$ | 512.92$^{b}$ |
| **TD 3** | | | | | | | | |
| | FF(Hz) | 93.89$^{a}$ | 95.78$^{a}$ | 88.11$^{a}$ | 101.56$^{b}$ | 97.83$^{b}$ | 89.08$^{a}$ | 97.58$^{b}$ |
| | RF(Hz) | 366.83$^{a}$ | 249.78$^{b}$ | 161.72$^{a}$ | 454.89$^{b}$ | 299.58$^{a}$ | 344.83$^{a}$ | 280.50$^{a}$ |
| | A(dB) | 52.50$^{a}$ | 51.28$^{b}$ | 45.94$^{a}$ | 57.83$^{b}$ | 50.67$^{a}$ | 52.67$^{b}$ | 52.33$^{b}$ |
| | SDT(ms) | 348.94$^{a}$ | 331.67$^{a}$ | 250.00$^{a}$ | 430.61$^{b}$ | 328.92$^{a}$ | 356.00$^{a}$ | 336.00$^{a}$ |
| **Mean** | | | | | | | | |
| | FF(Hz) | 93.33 ± 29.04$^{a}$ | 93.72 ± 28.27$^{a}$ | 90.06 ± 27.16$^{a}$ | 97.00 ± 29.68$^{a}$ | 93.97 ± 29.30$^{a}$ | 91.67 ± 27.79$^{a}$ | 94.94 ± 29.18$^{a}$ |
| | RF(Hz) | 371.04 ± 208.35$^{a}$ | 329.80 ± 202.94$^{a}$ | 242.43 ± 201.53$^{a}$ | 458.41 ± 145.22$^{b}$ | 331.89 ± 220.41$^{a}$ | 375.28 ± 189.03$^{a}$ | 344.08 ± 209.92$^{a}$ |
| | A(dB) | 51.04 ± 9.60$^{a}$ | 50.26 ± 11.30$^{a}$ | 41.03 ± 4.31$^{a}$ | 60.26 ± 3.59$^{b}$ | 49.13 ± 10.67$^{a}$ | 51.35 ± 10.65$^{b}$ | 51.46 ± 10.09$^{b}$ |
| | SDT(ms) | 439.07 ± 97.93$^{a}$ | 416.20 ± 94.20$^{a}$ | 380.83 ± 103.58$^{a}$ | 474.44 ± 59.48$^{b}$ | 405.92 ± 84.66$^{a}$ | 443.92 ± 97.93$^{a}$ | 433.08 ± 104.01$^{a}$ |

Means of the same alphabet between columns are not significantly different

and 150Hz. Contrarily, TD1, TD2, and TD3 had 97%, 97%, and 100% of their RF between 150Hz and 200Hz respectively, at MTR.

On the other hand, the ESI bar chart in Figure 9 was used to convey the sensitivity of the leather covers to the impact of force, at NTR and MTR. The mean sensitivity of the cow womb was higher (0.24 ± 0.18v) at MTR. In furtherance, ESI significantly correlated with FF (0.499, at NTR), A (0.799, at MTR), and SDT (0.702, at MTR) for goat skin leather cover. For the cow womb, ESI significantly correlated with A (0.787, at NTR and 0.888, at MTR) and SDT (0.536, at MTR) (Table 7).

## 4 Discussion

The results of this study as presented in tables, figures and plates imply that the talking drums studied had different acoustic properties. This could be caused by variation in cover leather, force of play, position of play, and/or tension applied on the rope while playing the drums. As indicated by Table 4, a talking drum played when tension is applied to the rope had significantly increased acoustic properties. Notwithstanding, a musical instrument with a suitable sound frequency is determined by a high value of frequency ratio (FR), i.e. it must be able to produce low and high frequencies. Thus, TD1 with the highest FR is better suitable where a good sound frequency is desired.

The spectrogram presented showed the anatomy of the sounds generated. The occurrence of the dominance of red colors in 'b and d' implies that more frequencies are generated at MTR, while the positions circled showed evidence of white color (an indication that the highest sounded frequency 'RF' was found at that position). Also, a wider diameter representing SDT at 'b and d' showed that sound excited on the talking drum at MTR took a longer time to return to silence when compared with sound generated at NTR (a and c). As such, a higher value of SDT indicates a better and more desirable acoustic property of the talking drum.

Meanwhile, it should be noted that RF also contributes to the perceived pitch of the sound by a human. Therefore, there was a need to investigate its contribution to the sound frequency of the talking drums found in this study. It should be noted that too much variation of RF from FF is disadvanta-

**Table 3:** The Mean Sound Properties of Talking Drums at Maximum Tension on the Rope (MTR).

| | | Cover leather | | Force of play | | Position of play | | |
|---|---|---|---|---|---|---|---|---|
| **TD1** | | goat | Cow | light | heavy | up | center | down |
| | FF(Hz) | 181.50[a] | 181.17[a] | 181.06[a] | 181.61[a] | 181.33[a] | 181.25[a] | 181.42[a] |
| | RF(Hz) | 206.22[a] | 181.17[a] | 205.78[a] | 181.61[a] | 181.33[a] | 218.33[a] | 181.42[a] |
| | A(dB) | 54.88[a] | 54.50[a] | 41.44[a] | 67.94[b] | 54.73[a] | 54.10[a] | 55.25[a] |
| | SDT(ms) | 505.67[a] | 467.72[b] | 457.33[a] | 516.06[b] | 480.67[a] | 500.83[a] | 478.58[a] |
| **TD 2** | | | | | | | | |
| | FF(Hz) | 170.89[a] | 168.5[a] | 169.44[a] | 169.94[b] | 169.67[a] | 169.58[a] | 169.83[a] |
| | RF(Hz) | 188.78[a] | 168.50[a] | 187.33[a] | 169.94[a] | 169.67[a] | 196.42[a] | 169.83[a] |
| | A(dB) | 53.11[a] | 56.56[b] | 42.78[a] | 66.89[b] | 54.92[a] | 54.33[a] | 55.25[a] |
| | SDT(ms) | 503.61[a] | 507.17[a] | 467.22[a] | 543.56[b] | 499.67[a] | 506.58[a] | 509.92[a] |
| **TD 3** | | | | | | | | |
| | FF(Hz) | 193.72[a] | 194.67[b] | 194.00[a] | 194.39[a] | 193.42[a] | 195.42[b] | 193.75[a] |
| | RF(Hz) | 193.72[a] | 194.67[b] | 194.00[a] | 194.39[a] | 193.42[a] | 195.42[b] | 193.75[a] |
| | A(dB) | 62.67[a] | 56.61[b] | 54.28[a] | 65.00[b] | 60.00[b] | 58.17[a] | 60.75[b] |
| | SDT(ms) | 426.22[a] | 341.78[b] | 302.06[a] | 465.94[b] | 382.17[a] | 387.83[a] | 382.00[a] |
| **Mean** | | | | | | | | |
| | FF(Hz) | 182.04 ± 9.45[a] | 181.44 ± 10.88[a] | 181.50 ± 10.27[a] | 181.98 ± 10.13[a] | 181.47 ± 9.89[a] | 182.08 ± 10.83[a] | 181.67 ± 9.99[a] |
| | RF(Hz) | 196.24 ± 73.65[a] | 181.44 ± 10.88[a] | 195.70 ± 73.87[a] | 181.98 ± 10.13[a] | 181.47 ± 9.89[a] | 203.39 ± 89.66[a] | 181.67 ± 9.99[a] |
| | A(dB) | 56.89 ± 12.58[a] | 55.89 ± 10.62[a] | 46.16 ± 7.06[a] | 66.61 ± 2.95[b] | 56.55 ± 11.65[a] | 55.53 ± 12.68[a] | 57.08 ± 10.65[a] |
| | SDT(ms) | 478.50 ± 77.04[a] | 438.89 ± 97.65[b] | 408.87 ± 92.46[a] | 508.52 ± 51.60[b] | 454.17 ± 92.22[a] | 465.08 ± 87.76[a] | 456.83 ± 91.46[a] |

**Table 4:** ANOVA showing P-values for the Mean Sound Properties of Talking Drums, and Frequency Ratio (FR).

| TD1 | | NTR | MTR | P-value | FR |
|---|---|---|---|---|---|
| | FF(Hz) | 58.89 ± 2.29 | 181.33 ± 0.93 | 0.001* | 3.08 |
| | RF(Hz) | 337.06 ± 249.06 | 193.69 ± 74.11 | 0.001* | |
| | A(dB) | 48.16 ± 11.39 | 54.69 ± 13.77 | 0.001* | |
| | SDT(ms) | 457.53 ± 43.57 | 486.69 ± 47.34 | 0.001* | |
| **TD 2** | | | | | |
| | FF(Hz) | 126.86 ± 4.13 | 169.69 ± 1.35 | 0.001* | 1.34 |
| | RF(Hz) | 405.89 ± 139.99 | 178.64 ± 53.91 | 0.001* | |
| | A(dB) | 51.89 ± 12.36 | 54.83 ± 12.73 | 0.001* | |
| | SDT(ms) | 485.08 ± 65.51 | 505.39 ± 64.99 | 0.092ns | |
| **TD 3** | | | | | |
| | FF(Hz) | 94.83 ± 9.33 | 194.19 ± 1.85 | 0.001* | 2.05 |
| | RF(Hz) | 308.31 ± 206.42 | 194.19 ± 1.85 | 0.001* | |
| | A(dB) | 51.89 ± 6.37 | 59.64 ± 6.59 | 0.001* | |
| | SDT(ms) | 340.31 ± 100.08 | 384.00 ± 96.95 | 0.001* | |

Significantly different, ns – not significantly different

**Table 5:** Frequency analysis of Resonance Frequency obtained at no Tension on the rope.

| | TD1 | | | TD2 | | | TD3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | RF | Freq. | % | RF | Freq. | % | RF | Freq. | % |
| | 57 | 6 | 16.70 | 122 | 1 | 2.80 | 87 | 1 | 2.80 |
| | 60 | 2 | 5.60 | 123 | 1 | 2.80 | 88 | 4 | 11.10 |
| | 61 | 5 | 13.90 | 124 | 1 | 2.80 | 89 | 1 | 2.80 |
| | 227 | 1 | 2.80 | 130 | 1 | 2.80 | 90 | 3 | 8.30 |
| | 228 | 1 | 2.80 | 132 | 1 | 2.80 | 91 | 3 | 8.30 |
| | 280 | 1 | 2.80 | 338 | 1 | 2.80 | 147 | 1 | 2.80 |
| | 281 | 2 | 5.60 | 339 | 2 | 5.60 | 149 | 1 | 2.80 |
| | 282 | 1 | 2.80 | 387 | 1 | 2.80 | 150 | 1 | 2.80 |
| | 383 | 1 | 2.80 | 388 | 1 | 2.80 | 223 | 1 | 2.80 |
| | 384 | 1 | 2.80 | 389 | 2 | 5.60 | 275 | 2 | 5.60 |
| | 459 | 1 | 2.80 | 390 | 2 | 5.60 | 389 | 1 | 2.80 |
| | 562 | 1 | 2.80 | 391 | 3 | 8.30 | 390 | 1 | 2.80 |
| | 566 | 1 | 2.80 | 405 | 1 | 2.80 | 391 | 3 | 8.30 |
| | 570 | 6 | 16.70 | 407 | 1 | 2.80 | 392 | 3 | 8.30 |
| | 587 | 1 | 2.80 | 409 | 2 | 5.60 | 393 | 2 | 5.60 |
| | 590 | 1 | 2.80 | 410 | 1 | 2.80 | 489 | 1 | 2.80 |
| | 684 | 1 | 2.80 | 413 | 1 | 2.80 | 573 | 1 | 2.80 |
| | 705 | 1 | 2.80 | 428 | 1 | 2.80 | 626 | 1 | 2.80 |
| | 722 | 1 | 2.80 | 430 | 1 | 2.80 | 627 | 1 | 2.80 |
| | 726 | 1 | 2.80 | 502 | 1 | 2.80 | 629 | 1 | 2.80 |
| | | | | 504 | 2 | 5.60 | 634 | 1 | 2.80 |
| | | | | 507 | 1 | 2.80 | 635 | 1 | 2.80 |
| | | | | 574 | 1 | 2.80 | 682 | 1 | 2.80 |
| | | | | 576 | 1 | 2.80 | | | |
| | | | | 582 | 1 | 2.80 | | | |
| | | | | 592 | 1 | 2.80 | | | |
| | | | | 595 | 1 | 2.80 | | | |
| | | | | 598 | 1 | 2.80 | | | |
| | | | | 614 | 1 | 2.80 | | | |
| **Count** | 20 | | | 28 | | | 23 | | |
| **Total** | | 36 | 100 | | 36 | 100 | | 36 | 100 |
| **C.V. (%)** | 54.07 | | | 38.04 | | | 61.36 | | |

C.V. – coefficient of variation

geous as it makes the sound pitch unstable, hence people will perceive the sound more different.

Tables 5 and 6, therefore, presented the analysis of the RF obtained per strike at NTR and MTR respectively. It can then be observed that sound pitch obtained at MTR will be better perceived as stable due to a minimal RF count. It was also evident from the histograms (figures 5-7) that many of the RF obtained at NTR were farther away from the first frequency (FF), an indication that the sound pitch of the talking drums played at NTR was unstable. On the other hand, at MTR a higher percentage of the RF was found closer to its FF thus, the pitches of sound at MTR are more stable and consistent.

Additional pieces of information about the sound properties of the talking drums found in this study were discussed below

## 4.1 Sound frequency

Plack et al. (Plack et al. 2005) described sound frequency as a sensation that refers to the pitch of a sound. Thus, sound frequency measures the degree of sound pitch of material or musical instrument. Similar to other musical instruments, the talking drum contains more than one natural frequency when struck. However, the two prominent frequencies reported for

**Table 6:** Frequency analysis of Resonance Frequency obtained at Maximum Tension on the rope.

| | TD1 | | | TD2 | | | TD3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | RF | Freq. | % | RF | Freq. | % | RF | Freq. | % |
| | 181 | 28 | 77.80 | 168 | 10 | 27.80 | 191 | 1 | 2.80 |
| | 182 | 5 | 13.90 | 169 | 7 | 19.40 | 192 | 2 | 5.60 |
| | 183 | 1 | 2.80 | 170 | 5 | 13.90 | 193 | 9 | 25.00 |
| | 186 | 1 | 2.80 | 171 | 11 | 30.60 | 194 | 15 | 41.70 |
| | 626 | 1 | 2.80 | 172 | 2 | 5.60 | 195 | 5 | 13.90 |
| | | | | 493 | 1 | 2.80 | 196 | 1 | 2.80 |
| | | | | | | | 199 | 2 | 5.60 |
| | | | | | | | 200 | 1 | 2.80 |
| **Count** | 5 | | | 6 | | | 8 | | |
| **Total** | | 36 | 100 | | 36 | 100 | | 36 | 100 |
| **C.V. (%)** | 72.94 | | | 58.92 | | | 1.64 | | |

**Table 7:** Correlation analysis of ESI and Sound Properties of Talking Drum.

| | FF | RF | A | SDT |
|---|---|---|---|---|
| **ESI (at NTR, goat skin)** | 0.499* | -0.071 | 0.3 | -0.118 |
| **ESI (at MTR, goat skin)** | 0.003 | -0.304 | 0.799* | 0.702* |
| **ESI (at NTR, cow womb)** | 0.461 | 0.312 | 0.787* | 0.389 |
| **ESI (at MTR, cow womb)** | -0.059 | -0.059 | 0.888* | 0.536* |

*Significant
FF – Fundamental Frequency RF – Resonance Frequency A – Amplitude SDT – Sound Damping Time

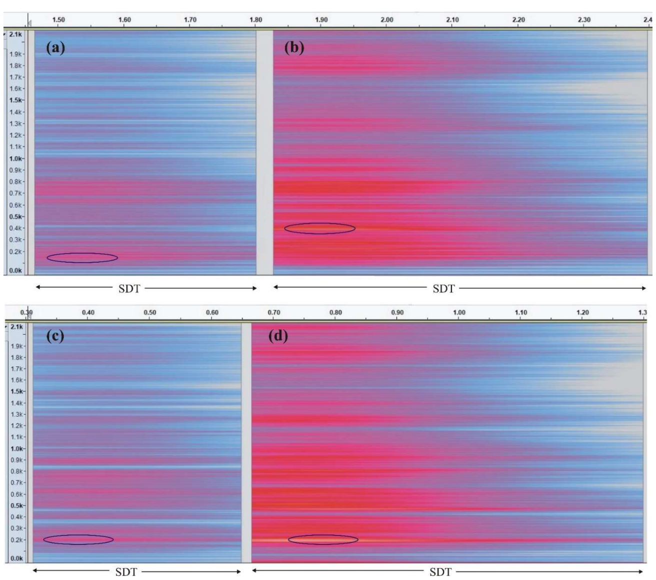


**Figure 2:** Spectrogram sample of sound obtained at (a) light force of play at NTR, (b) heavy force of play at NTR, (c) light force of play at MTR, and (d) heavy force of play at MTR.

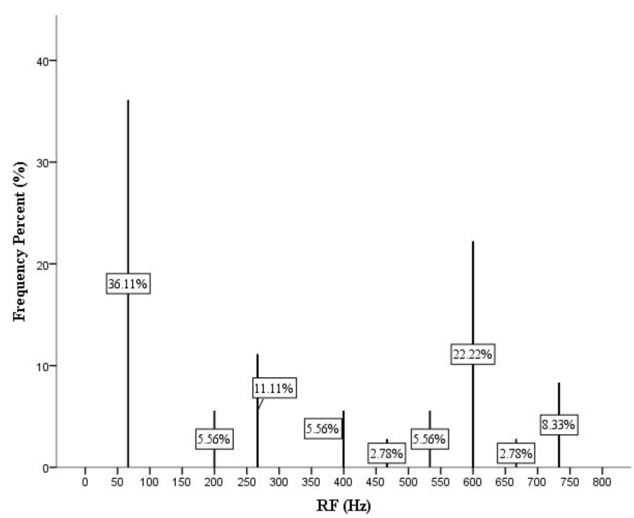


**Figure 3:** Histogram of Resonance Frequency of TD1 Obtained at NTR.

musical instruments are fundamental and resonance frequency [1, 3, 5, 15, 17]. The former measures the first frequency in a given sound, while the latter describes the peak frequency.

Since frequency defines the pitch of a sound, fundamental frequency measures the lowest pitch of a sound while resonance frequency describes the perceived loudness of the sound pitch. Howbeit, this peak frequency is not heard as a separate pitch but is grouped with other frequencies and heard

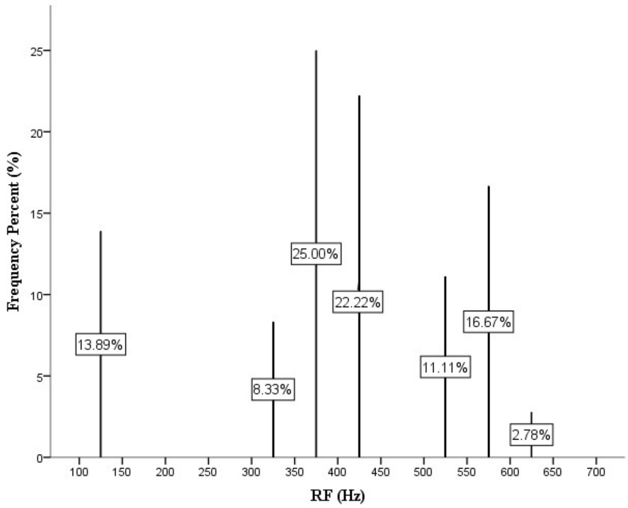


**Figure 4:** Histogram of Resonance Frequency of TD2 Obtained at NTR.

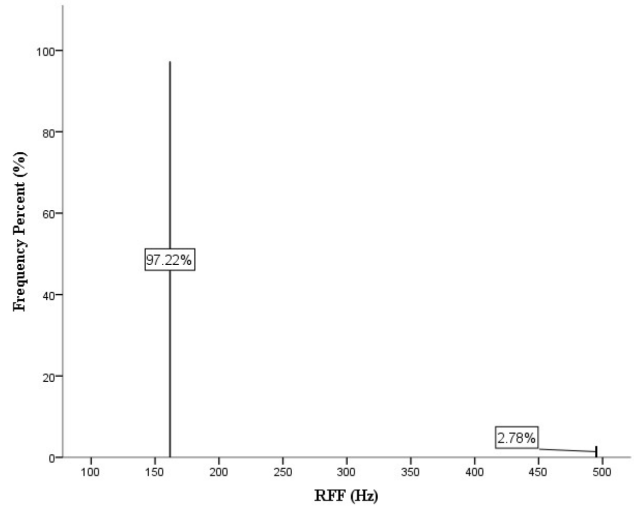


**Figure 7:** Histogram of Resonance Frequency of TD2 Obtained at MTR.

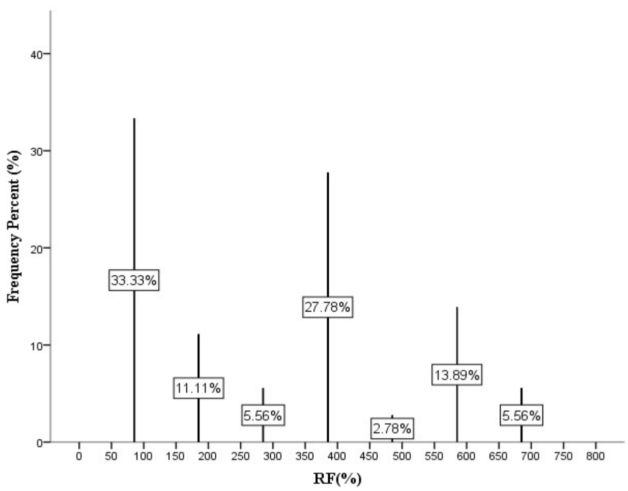


**Figure 5:** Histogram of Resonance Frequency of TD3 Obtained at NTR.

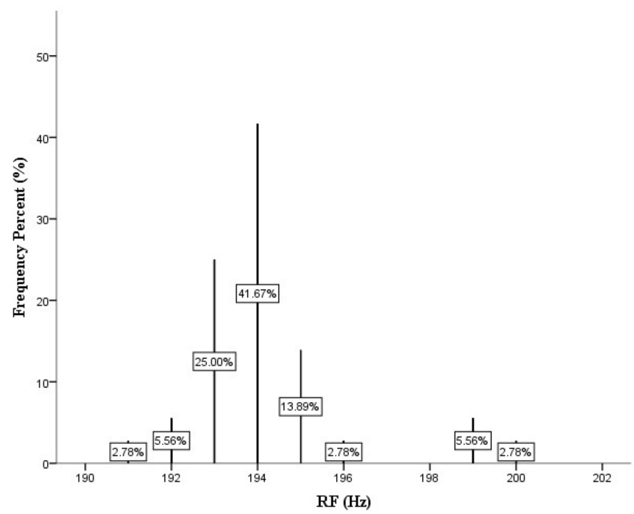


**Figure 8:** Histogram of Resonance Frequency of TD3 Obtained at MTR.

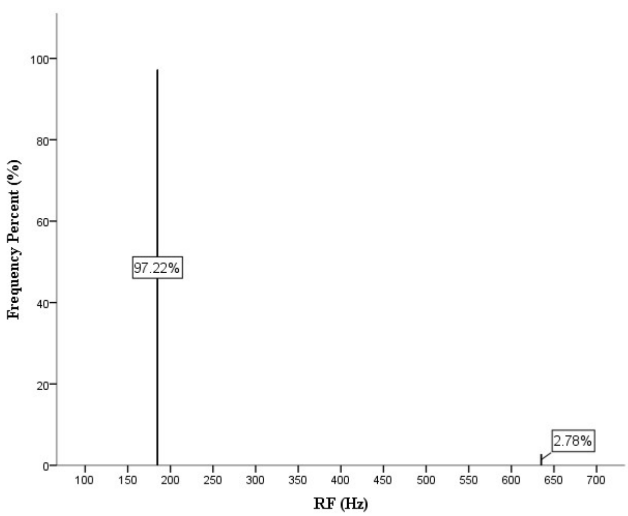


**Figure 6:** Histogram of Resonance Frequency of TD1 Obtained at MTR.

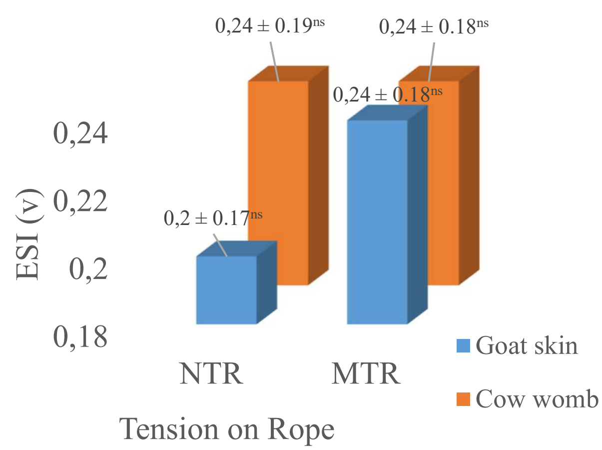


**Figure 9:** The Excited Surface Impact (ESI) on the Drums at NTR and MTR.

as a single coherent entity, that is, the auditory system automatically binds together frequency components that are integer multiples of a common fundamental frequency [18].

Therefore, the mean fundamental frequencies obtained in this study for talking drums characterized at NTR implies that TD1 and TD2 had the lowest and highest pitch of the sound, respectively, while at MTR, TD2, and TD3 had the lowest and highest pitch, respectively. A good index to characterize a talking drum as musically suitable is its ability to have a wider range of frequency, that is - it should be able to produce the lowest pitch at NTR and still have a high pitch at MTR. Following [19], the FR ($\geq 2$) of TD1 and TD3 imply that they completed an octave of a musical note. Thus, TD1 with the highest frequency range can be considered the most suitable.

Also, this study found that the fundamental frequency did not at all times sound the loudest, meaning there were occasions where the fundamental frequencies were not the resonance frequencies. In such an instance, the loudest frequency is expected to influence the perceived pitch of the sound. Hence, there was a need to determine the degree of variation and contribution of resonance frequencies to the general pitch of sound obtained at NTR and MTR.

At NTR, TD2 had the highest numbers (28) of obtainable RFs despite the lowest coefficient of variation. This thus explains that though multiple RF were obtained, they were still closer to the average value for its RF. However, the suitability of talking drum based on the frequency at NTR is best characterized by the minimum frequency value. Therefore, TD1 having the highest RF percentage (36%) closest to the minimum (i.e. FF), and TD3 which had 33% are more stable and better than TD2. Inferentially, the presence of multiple RF had a negative influence on the sound pitch of the talking drums at NTR, and caution should be taken to minimize its occurrence.

At MTR, TD3 had the highest number of RF and the lowest CV. The RF Values in TD3 were found to have the least deviation from each other, compared with TD1 and TD2. Regardless of the CV derived from all the TDs, not less than 97% of all RF obtained were closer to the FF. this means that nearly all of the resonance frequencies were also fundamental frequencies. This is an indication that all talking drums characterized based on sound frequency were stable and reliable at MTR. Therefore, this study deduced that there is no major effect of the RF on the pitch of sound at MTR.

On the other hand, FF at NTR was significantly different with respect to leather covers for TD2 only. This suggests that the cow womb with lower FF at NTR is better as a leather cover for making talking drums, especially where a lower pitch of a sound is to be ensured. However, at MTR, values of FF and RF obtained at cow womb were significantly higher than goat skin, for TD3 only. Since a higher sound frequency at MTR depict a better pitch and aids a wider frequency range, cow womb was better than goat skin.

Meanwhile, there were no significant differences in the effect of cover leather on the mean total sound frequency (FF and RF) for all the talking drums at NTR and MTR. Hence, the cow womb has not adequately shown an edge over goat skin. Therefore, this study did not confirm in generality the superiority of cow womb leather cover over goat skin, for obtaining a better pitch of sound in a talking drum. Notwithstanding, it exhibited a greater potential for preferential usage.

The contribution of the force of play on FF and RF was significantly noticed among all the talking drums, at NTR. The FF & RF values obtained at a heavy force of play were significantly higher than at a light force of play. As earlier mentioned, the occurrence of lower sound frequency at NTR is more beneficial than higher sound frequency – this is because only a low pitch is required to render the quality of the talking drum at NTR.

Furthermore, the predominance of red lines at (b) and (d) as displayed in the spectrogram confirms that more frequencies were produced and were louder when heavy force was used to play the talking drum. Since a significant difference occurred for RF with respect to the force of play at NTR, it can be argued that heavy force of play resulted in the turnout of multiple RFs, causing inconsistency in the sound frequency of the talking drums. Consequently, the resulting higher FF and RF from the heavy force of play is disadvantageous. Therefore, a heavy force of play at NTR is to be discouraged.

Contrarily, there were no significant differences between the mean total of FF and RF obtained at the light and heavy force of play respectively, at MTR. As such, the force of play does not affect the pitch of the sound generated from a talking drum when played at MTR.

Furthermore, the intersperse significant variations in FF obtained for the position of play at NTR indicate that TD1 highlighted up to be significantly lowest, and performed best, while it can be deduced from TD3 that FF obtained at the center was significantly best. For TD2, FF from up, center, and down were not significantly different from each other. Also, the mean total of FF & RF were not significantly different from each other. This showed that the influence of the position of play on sound frequency is not significant at all times. However, this intersperse variation may have been caused by the drummer's discomfort to play at the desired positions and/or the instability of the talking drums at NTR, as reported above.

At MTR, FF and RF were significantly better at the center position for TD3, but the position of play did not generally affect the sound frequencies. As a result, this study cannot confirm that position of play significantly influence the sound frequency of a talking drum at MTR. However, it is still appropriate to suggest that drummers should ensure playing at the center position since it contributed to the best performance of FF for TD3 at NTR and MTR.

The sound frequencies obtained in this study was lower to [15] for talking drum made from the same wood species but performed within the range reported by [5, 7] for talking drums made from G.arborea, Brachystegia eurycoma, Aningeria robusta, and Cordia mellina wood. The better frequency in the work of [15] could be associated with the different types of hourglass shell shapes used in their study. Also, the sound frequency recorded in this study at NTR was similar to what was obtained in the work of Olaoye and Oluwadare [20] at the lowest pitch of the talking. Whereas, the higher pitch of sound obtained at MTR confirms the report of [14, 15, 21, 22] - that a higher pitch will be attained with respect to tension on the rope.

### 4.2 Amplitude

Abokhalil [23] described the amplitude (A) of a wave with intensity and loudness as the maximum displacement of the medium elements from its equilibrium position. Similarly, the amplitude of a sound wave was defined as the loudness or the amount of maximum displacement of vibrating particles of the medium from their mean position when the sound is produced [24]. Therefore, a higher amplitude value means a louder sound.

The results obtained at NTR and MTR showed that while a heavy force of play resulted in a significantly louder sound, leather covers (goat skin/cow womb) did not. A closer look at the spectrogram revealed that louder sound frequencies were produced with heavy force, owing to the predominance of red lines. Also, the distinct white line at (d) distinguished the loudest RF.

On the other hand, at NTR, the sound produced from the center and down positions were significantly louder than up, while there was no significant loudness at MTR along with the positions of play. The inconsistency of sound frequency at NTR may be responsible for amplitude variation which occurred along with the positions of play.

This study thus opined that drummers are compelled to play the talking drum with a heavy force of play to generate louder sound. Just as this is tenable, a large force of play at NTR needs to be discouraged as it will also introduce an unwanted frequency, as earlier discussed. Alternatively, the use of an amplifier may be adopted to improve the sound intensity and in turn, a louder sound.

### 4.3 Sound damping time (SDT)

The sustainability of sound for a longer duration has been identified as an important property for sound characterization [9]. The SDT measures the time taken for a sound emanating from a talking drum to go into silence or loss its vibration energy after striking [15]. Hence, a higher SDT value describes a longer sound.

Of the factors examined at NTR, only force of play had a significant effect on SDT, with a heavy force of play contributing to a higher SDT and in turn a longer sound. At MTR, there was intersperse variation of SDT across the talking drums with respect to leather covers, however, the mean result showed that goat skin was better for SDT. Similar to what was obtained at NTR, heavy force of play was confirmed to produce a longer sound, at MTR.

In congruence, the longer SDT shown at (b) and (d) of the spectrogram implies that the longest SDT was found at MTR, and also confirms that a longer duration of sound was attained at a heavy force of play. Inferentially, a heavy force of play at MTR is essential where a longer duration of sound is required.

### 4.4 Excited surface impact

The ESI which measures the impact of force on the leather covers revealed that cow womb is more sensitive and responsive to force impact than goat skin, owing to its higher value of ESI. As such, it is expected to be less deformed when force is applied and consequently vibrate better than goat skin cover. However, since the values were insignificantly different, it can be assumed that both leather covers performed similarly.

It should be recalled that it is a lower sound pitch at NTR that qualifies a good talking drum. Therefore, the significant correlation between FF and ESI (at NTR) for goat skin is disadvantageous, as it shows that goat skin leather cover aid high pitch of sound with increasing force impact. However, other significant relationships recorded in Table 7 are beneficiary, thus cow womb leather cover is preferential.

## 5 Conclusion

The sound properties of talking drums made from G.arborea wood were successfully characterized from the surface leather covers, force of play, position of play, and excited surface impact, at no tension and maximum tension on the rope. The sound properties obtained compared favorably with what has been recorded in literature. Notwithstanding, the influence of leather covers on the sound properties was not generally established, but cow womb leather cover was a preference. Similarly, general variation in properties of sound generated at the up, center, and down positions was not found. Meanwhile, a heavy force of play contributed a major role in the characterization of the sound properties, thus, careful consideration must be given to the force used in playing the talking drums. Most importantly, adequate tension on the rope was essential in rendering a quality sound property of the talking drums. Hence, materials and factors that can enhance tension on the rope should be stimulated.

## Declaration

**Conflicts of interest or competing interests:** No conflicts of interest or competing interests
**Data and code availability:** Secondary data have been referenced
**Supplementary information:** No supplementary information applicable
**Ethical approval:** No ethical approval was required
**Role of funding source:** No funding was provided for this study

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