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Exploring the Sound Absorption Characteristics of Biodegradable Agricultural Wastes, Coconut Fiber, Groundnut Shell, and Sugarcane Fiber

Nuushuun Archie GBOE[1*], Robert RUŽICKIJ[2], Raimondas GRUBLIAUSKAS[3]

[1–3]*Department of Environmental Protection and Water Engineering, Vilnius Gediminas Technical University, Sauletekio al. 11, Vilnius, Lithuania*

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Abstract **– Noise pollution is a major global health issue, especially in large cities. Its effects go beyond mere annoyance, impacting health, emotions, and behavior. As noise levels rise, researchers are looking for better solutions to address this global issue, with natural fibers emerging as a promising option for sound absorption. Traditional synthetic materials used for sound absorption have negative environmental and health impacts, leading to growing interest in biodegradable natural fibers like coconut fiber, groundnut shell, and sugarcane fiber as safer alternatives. These materials absorb sound well and are environmentally friendly and safe for human health. This study explores the use of biodegradable agricultural waste fibers (coconut fiber, groundnut shell, and sugarcane fiber) for sound absorption. Samples with densities of 75 kg/m³, 100 kg/m³, and 125 kg/m³ were mixed with an equal percentage of non-toxic PVA binder. The sound absorption coefficient was measured according to the ISO 10534-2 standard. The results showed that the 75 kg/m³ sugarcane fiber sample had the highest average sound absorption coefficient of 0.94 at 800 Hz (mid-frequency range: 500–2000 Hz). The 125 kg/m³ coconut fiber sample came next, with the highest average sound absorption coefficient of 0.91 at 1000 Hz (mid-frequency range: 500–2000 Hz). The groundnut shell material showed the lowest sound absorption coefficient, the sample with a density of 125 kg/m³ had the highest average sound absorption coefficient of 0.81 at 3150 Hz (high-frequency range). These findings suggest that these natural materials could be effective for noise reduction in places like classrooms, libraries, and cafes. The approach aligns with global sustainability efforts while addressing the issue of noise pollution in large cities.**

Keywords **– Coconut fiber; groundnut shell; recycling; sound absorption coefficient; sugarcane fiber; waste.**

1. INTRODUCTION

Noise pollution is a worldwide health danger triggering hearing loss, sleep disorders, and heart disease. Expanding transport infrastructure and urbanization along with industrial developments are the main sources of noise pollution; one in five residents experience continuous noise levels [1]. Due to the severe impact of noise pollution on the global population, there is a growing need for environmentally friendly noise barriers [2]. The need for environmentally friendly sound-absorbing materials to improve indoor acoustic and reduce the energy and intensity of sound waves in buildings has taken center stage in the

*Corresponding author.
E-mail address: nuushuun-archie.gboe@vilniustech.lt

building industry due to the environmental and health risks associated with conventional synthetic materials [3]. These conventional synthetic materials have low thermal conductivity and high sound absorption, but the manufacturing process releases harmful gases and its physical surface can cause skin irritation [4].

The sound-absorbing fiber produced from agricultural waste fiber has drawn a lot of interest because of its sustainability and acoustic qualities. These agriculture waste fiber materials are biodegraded consistent with "Green Environment Movement" targets [5]. Sound absorbers may be affordable, biodegradable, and recyclable from agricultural waste fibers like coconut fiber, sugarcane fiber, and groundnut shell [6]. The increasing population and the demand for natural resources have increased efforts for over three decades to enhance sustainable resource management on a global scale. A path to sustainable development emphasizes economic, social, and ecological to improve quality of life. The agricultural industry is among the top industries causing environmental degradation, accounting for 21 % of global GHG emissions which calls for more sustainable agriculture waste management [7].

Air, water, and soil sustainability require Agricultural Waste Management. Agriculture wastes are dumped in open fields without treatment but are increasingly seen as a resource. AWM plans to recycle agricultural waste to minimize environmental impact [8]. This shift in perspective sees agricultural waste as a potential resource instead of a source of air, water, and soil pollution and other hazardous materials [9]. Globally, the sugarcane industry generates 279 metric tons annually with South Africa on the top producing over 1.353 million metric tons [10]. The coconut industry generates approximately 62.5 million tons in over 90 countries worldwide [11]. The large scale and expansion of coconut farming contribute to the production of coconut husks, shells, fronds, fiber, and pulp [12].

Sugarcane wastes are generated in solid, semi-solid, and liquid and are divided into two groups: waste from harvesting activities, including leaves and cane tips, and waste generated from sugarcane processing, including the bagasse, ash from bagasse incineration, press mud (the sludge resulting from the juice settling and waste cake from juice filtration, wastewater, vinasse, along with molasses [13]. Groundnut shells are produced globally in amounts of more or less 11 million tons annually and have a high potential for sustainable production [14]. Reusing agricultural waste materials in the acoustic industry is consistent with the circular economy principle of natural resources being utilized and more ecological products being created [15]. Sugarcane bagasse ash is already being utilized for the generation of energy in cogeneration [16] and coconut fiber has been added to concrete for strength and durability [17]. Groundnut shell ash is also being looked at as a sustainable replacement for cement.

The study evaluates the sound absorption qualities of agricultural waste fibers (coconut fiber, groundnut shell, and sugarcane fiber) mixed with nontoxic binder (PVA polyvinyl acetate). The aim is to present these materials as a substitute for the production of harmless sound absorption acoustic panels. These materials can make workplaces, libraries, and cafes quieter and more comfortable.

2. Materials and Methods

2.1. Materials Preparation

Groundnut shells were collected from a farm and cleaned with pressurized water to remove dust and contaminants. The shells were then manually crushed into smaller pieces and sieved to achieve a particle size between 0.5–1.0 mm. Sugarcane fibers were gathered from a local "kin juice" production site in Liberia after the juice was extracted from the stalks. The fibers were trimmed to a shorter length. Coconut fibers were obtained from coconut husks at a farm where vendors purchase coconuts to sell. These fibers were cut to a length of 0.5–1.0 mm. All materials were sun-dried for two days (8 hours each day) at 25 °C. After sun drying, they were further dried at a low temperature of 75 °C to remove any remaining moisture. Moisture content was closely monitored by recording the weight of the materials regularly to ensure they were thoroughly dried. As shown in Fig. 1, the dried materials were mixed with PVA D2 glue, known for its strong binding properties. The materials were placed in a mixing container, and PVA D2 glue was added. The materials were manually mixed with a spatula for 1.5 minutes to ensure even binding. The mixture was then placed into a mold with a diameter of 29.9 mm and thicknesses of either 25 or 50 mm, lined with parchment paper to prevent sticking [18]. The samples were left to air-dry at room temperature for 48 hours before being removed from the molds [19].

Fig. 1. Raw agriculture waste materials used in the study: (a) sugarcane fiber; (b) coconut fiber; (c) groundnut shell.

To determine the sound absorption coefficient using the transfer function method with the impedance tube system, six samples were prepared for each type of material: coconut fiber, groundnut shell, and sugarcane fiber. Three specimens were made to check for measurement consistency and accuracy. The preparation of the samples proceeded as shown in Table 1.

TABLE 1. SAMPLE PREPARATION AND COMPOSITION RATIOS

Sample Description	Mass, g	Thickness, mm	Density, kg/m^3	PVA D2 glue Binder, wt %
75 kg/m^3–25	1.2 ± 0.2	25	75	100 ± 0.2
100 kg/m^3–25	1.59 ± 0.2	25	100	100 ± 0.2
125 kg/m^3–25	1.99 ± 0.2	25	125	100 ± 0.2
75 kg/m^3–50	2.39 ± 0.2	50	75	100 ± 0.2
100 kg/m^3–50	3.19 ± 0.2	50	100	100 ± 0.2
125 kg/m^3–50	3.99 ± 0.2	50	125	100 ± 0.2

2.2. Determination Method of Sound Absorption Coefficient in Impedance Tube

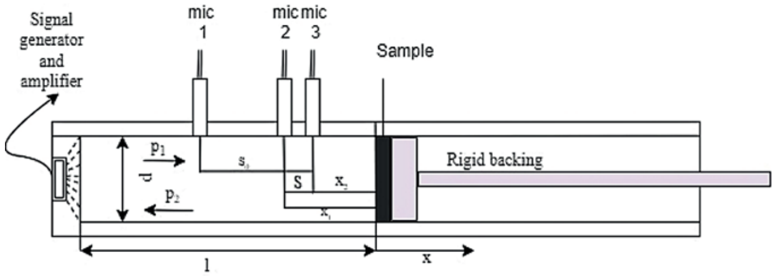

Fig. 2. Schematic diagram of impedance tube.

According to the procedure, the first step is to establish the transfer function. This transfer function, denoted as H_{12} and H_{23}, is obtained by determining the ratio of pressure recorded by microphone pairs No. 1, No. 2, and No. 3, respectively, across the entire frequency range (ISO, 1998) [20]:

$$H_{13} = \frac{P_3(f)}{P_1(f)}, H_{23} = \frac{P_3(f)}{P_2(f)} , \tag{1}$$

$$H_{I\,(160\text{–}1000\,\text{Hz})} = \frac{P_{3I}}{P_{1I}} = e^{-jko\,(x_{12}+x_{23})};\ H_{I\,(1000\text{–}5000\,\text{Hz})} = \frac{P_{3I}}{P_{2I}} = e^{-jko\,(x_{23})} , \tag{2}$$

$$H_{R\,(160\text{–}1000\,\text{Hz})} = \frac{P_{3R}}{P_{1R}} = e^{-jko\,(x_{12}+x_{23})};\ H_{R\,(1000\text{–}5000\,\text{Hz})} = \frac{P_{3R}}{P_{2R}} = e^{-jko\,(x_{23})} . \tag{3}$$

Thereafter, sound reflection coefficient is determined from equation (2) and (3) (ISO 1998):

$$R_{(160\text{–}1000\,\text{Hz})} = \frac{H_{13} - H_{I(160\text{–}1000\,\text{Hz})}}{H_{R(160\text{–}1000\,\text{Hz})} - H_{13}}\ e^{2jko\,(x_{12}+x_{23}+x_{3S})};$$

$$R_{(1000\text{–}5000\,\text{Hz})} = \frac{H_{23} - H_{I(1\text{–}5\,\text{kHz})}}{H_{R(1\text{–}5\,\text{kHz})} - H_{23}}\ e^{2jko\,(x_{23}+x_{3S})} , \tag{4}$$

where:

P_1, P_2, and P_3 represent the pressures captured by the microphones in pascals, Pa;
H_I the incident wave transfer function;
H_R the reflected wave transfer function;
x_{12} the distance between microphones No. 1 and No. 2, mm;
x_{23} the distance between microphones No. 2 and No. 3, mm;
x_{3S} the distance between No. 3 and the sample in mm;
R the sound reflection coefficient;
j the complex number;
ko the wave number.

In the last step, the sound absorption coefficient is determined by Eq. (5) (ISO 1998):

$$\alpha = 1 - |R|^2 . \quad (5)$$

3. Experimental Results and Discussion

The experiment produced a comprehensive report containing data on sound absorption coefficients of various raw materials, including details such as density, thickness, and frequency range. An analysis of these results was performed to explore the relationship between these factors and the sound absorption capabilities of natural composite fiber materials. The result presents the connection between material composition, physical attributes, and sound-absorbing behavior, providing a valuable understanding of what influences the sound-absorption properties of natural fibers.

3.1. Coconut Fiber (CF)

Fig. 3 shows experimental results for coconut fiber samples at three densities: 75 kg/m^3, 100 kg/m^3, and 125 kg/m^3 in 25 mm mold. For the 75 kg/m^3 sample, in lower frequencies (160–500 Hz), the highest sound absorption is 0.14 at 500 Hz, in mid-range frequencies (500–2000 Hz), the highest sound absorption is 0.50 at 2000 Hz, in higher frequencies (2000–5000 Hz), the highest sound absorption is 0.53 at 2500 Hz. In the 75 kg/m^3 sample in 25 mm mold the peak sound absorption occurs in higher frequencies at 2500 Hz, with a maximum value of 0.53. For the 100 kg/m^3 sample, in lower frequencies, the highest sound absorption is 0.14 at 500 Hz, in the mid-range frequencies, the highest sound absorption is 0.74 at 2000 Hz, in higher frequencies, the highest sound absorption is 0.67 at 2500 Hz. The 100 kg/m^3 sample shows a significant improvement in sound absorption at mid-range frequencies, with a peak sound absorption of 0.74 at 2000 Hz, which is higher than the 75 kg/m^3 sample. The sound absorption at higher frequencies is also improved compared to the low-density sample.

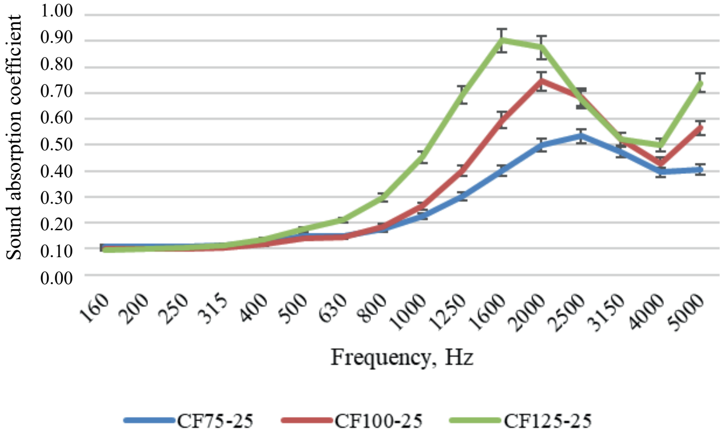

Fig. 3. Results of experimental sound absorption coefficients measurements using impedance tube for coconut fiber (75 kg/m^3, 100 kg/m^3, and 125 kg/m^3) in 25 mm mold.

For the 125 kg/m^3 sample, in lower frequencies, the highest sound absorption is 0.17 at 500 Hz, in mid-range frequencies, the highest sound absorption is 0.90 at 1600 Hz, in higher frequencies, the highest sound is 0.87 at 2000 Hz. The 125 kg/m^3 sample in 25 mm mold the peak sound absorption occurs in mid-frequencies at 1600 Hz, with a maximum value of 0.90. The 125 kg/m^3 sample provides the best sound absorption in the mid-range frequencies, with a peak sound absorption of 0.90 at 1600 Hz. It also offers high absorption in the high frequencies with 0.87 at 2000 Hz. This sample absorbs sound much better in both mid-range and higher frequencies compared to the 75 kg/m^3 and 100 kg/m^3 samples.

Figure 4 shows experimental results for coconut fiber samples at three densities: 75 kg/m^3, 100 kg/m^3, and 125 kg/m^3 in 50 mm mold. For the 75 kg/m^3 sample, in lower frequencies, the highest sound absorption is 0.21 at 500 Hz, in mid-range frequencies, the highest sound absorption is 0.61 at 1250 Hz, in higher frequencies, the highest sound absorption is 0.75 at 4000 Hz. The 75 kg/m^3 sample in 50 mm mold the peak sound absorption occurs in high frequencies at 4000 Hz, with a maximum value of 0.75. The 50 mm mold significantly improves the sound absorption of the 75 kg/m^3 sample, especially at higher frequencies, with a peak sound absorption of 0.75 at 4000 Hz, the sound absorption at lower frequencies is also enhanced compared to the 25 mm mold. For the 100 kg/m^3 sample, in lower frequencies, the highest sound absorption is 0.28 at 500 Hz, in the mid-range frequencies, the highest sound absorption is 0.82 at 1250 Hz, in higher frequencies, the highest sound absorption is 0.89 at 4000 Hz. The 100 kg/m^3 sample in the 50 mm mold shows significant improvement in sound absorption across all frequency ranges. The peak sound absorption shifts to higher frequencies (4000 Hz), where it reaches 0.89, making it more effective in higher frequency ranges compared to the 25 mm mold. For the 125 kg/m^3 sample, in lower frequencies, the highest sound absorption is 0.39 at 500 Hz, in mid-range frequencies, the highest sound absorption is 0.91 at 1000 Hz, in higher frequencies, the highest sound is 0.84 at 3150 Hz. The 125 kg/m^3 sample in the 50 mm mold performs well in mid-range frequencies, with a peak sound absorption of 0.91 at 1000 Hz. The sound absorption in lower frequencies is significantly enhanced compared to the 25 mm mold, making it the most effective sample in lower to mid frequencies among all the configurations.

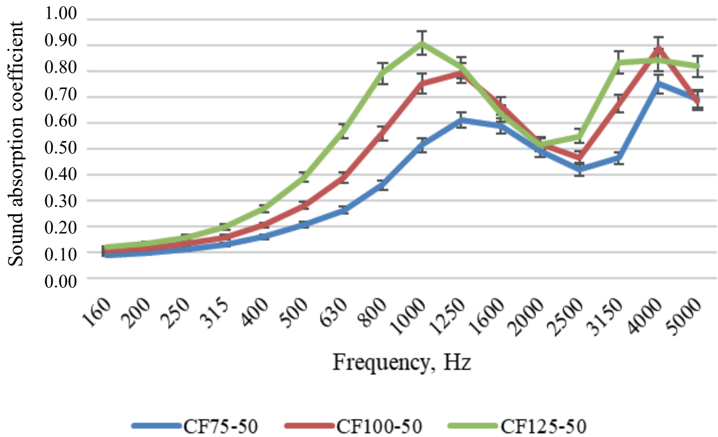

Fig. 4. Results of experimental sound absorption coefficients measurements using impedance tube for coconut fiber (75 kg/m^3, 100 kg/m^3, and 125 kg/m^3) in 50 mm mold.

The researchers [21] utilized coconut fiber panels treated with latex during the forming process to apply a coating to the fibers and uphold the structure of the resulting sheets. The samples tested had a diameter of 100 mm for low frequency and 28 mm for high frequency. They assessed the noise absorption coefficient values when coconut fiber sheets, lacking a porous layer backing, were installed in front of a rigid wall. Among the samples with a thickness of 20 mm, the noise absorption coefficient reached its peak within the frequency range of 3680–3860 Hz, with a maximum value of approximately 0.83 occurring at 3784 Hz. For samples with a thickness of 100 mm, the sound absorption coefficient peaked at 0.39 observed at a frequency of 5000 Hz.

3.2. Sugarcane Fiber (SF)

Fig. 5 shows experimental results for sugarcane fiber samples at three densities: 75 kg/m^3, 100 kg/m^3, and 125 kg/m^3 in 25 mm mold. For the sample with a density of 75 kg/m^3, the sound absorption coefficient reaches its peak value within the frequency range of 1600 Hz to 5000 Hz. The peak sound absorption value is 0.91, occurring at a frequency of 5000 Hz. At lower frequencies, the highest sound absorption, at 0.19, occurred at 500 Hz. In the mid-range frequencies, the highest sound absorption of 0.90 occurred at 1600 Hz. The highest sound absorption occurs at high frequencies, making this sample more effective at absorbing high-frequency sounds. For the sample with a density of 100 kg/m^3, the sound absorption coefficient reaches its peak value within the frequency range of 1000 to 1600 Hz. The peak sound absorption value of 0.79, occurring at a frequency of 1250 Hz. At the lower frequency range, the highest sound absorption, at 0.25, occurred at 500 Hz. In the mid-range frequencies, the highest sound absorption of 0.79 occurred at 1250 Hz. In the higher frequency range, the highest sound absorption of 0.70, occurred at 5000 Hz. This sample performs best in the mid-range but is less effective at higher frequencies compared to the 75 kg/m^3 sample.

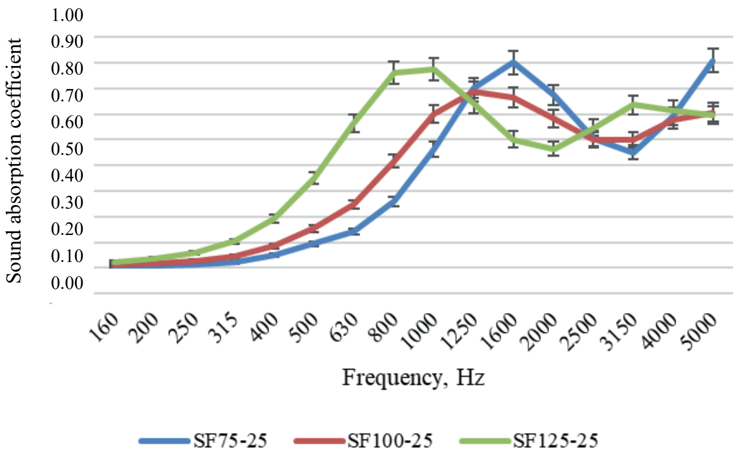

Fig. 5. Results of experimental sound absorption coefficients measurements using impedance tube for sugarcane fiber (75 kg/m^3, 100 kg/m^3, and 125 kg/m^3) in 25 mm mold.

For the sample with a density of 125 kg/m^3, the sound absorption coefficient reaches its peak value within the frequency range of 800 Hz to 1250 Hz. The peak sound absorption value of 0.88, occurring at a frequency of 1000 Hz. In the lower frequency range, the highest sound absorption of 0.45, occurred at 500 Hz. In the mid-range frequencies, the highest sound absorption of 0.88 occurred at 1000 Hz. In the higher frequency range, the sound absorption is at its highest, reaching 0.74, occurring at 3150 Hz. The 125 kg/m^3 sample performs best in the mid-frequency range but also shows strong sound absorption in the low-frequency range compared to the 75 kg/m^3 and 100 kg/m^3.

Figure 6 shows experimental results for sugarcane fiber samples at three densities: 75 kg/m^3, 100 kg/m^3, and 125 kg/m^3 in 50 mm mold.

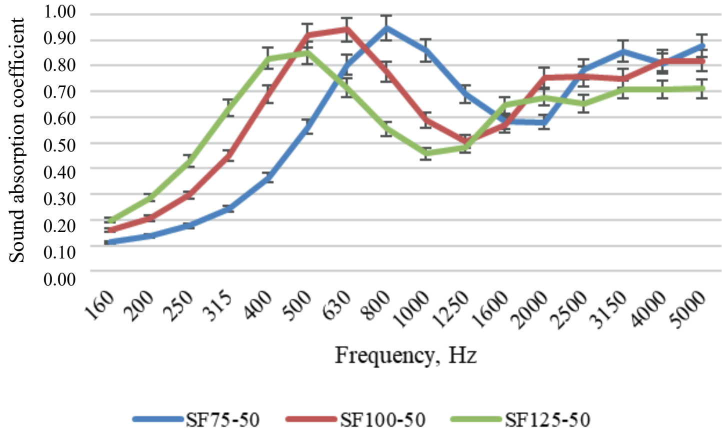

Fig. 6. Results of experimental sound absorption coefficients measurements using impedance tube for sugarcane fiber (75 kg/m^3, 100 kg/m^3, and 125 kg/m^3) in 50 mm mold.

For the sample with a density of 75 kg/m^3, the sound absorption coefficient reaches its peak value within the frequency range of 630 Hz to 1000 Hz. The peak sound absorption value is 0.94, occurring at a frequency of 800 Hz. At lower frequencies, the highest absorption, at 0.56, occurred at 500 Hz. In the mid-range frequencies, the highest absorption of 0.94 occurred at 800 Hz. At higher frequencies, absorption peaks at 0.88 occurred at 5000 Hz. This sample shows improved sound absorption across all frequencies, with good performance in mid and high frequencies. For the sample with a density of 100 kg/m^3, the sound absorption coefficient reaches its peak value within the frequency range of 500 Hz to 800 Hz. The peak sound absorption value of 0.94, occurring at a frequency of 630 Hz. At the lower frequency range, the highest sound absorption, at 0.92 occurred at 500 Hz. In the mid-range frequencies, the highest sound absorption of 0.94 occurred at 630 Hz. In the higher frequency range, the sound absorption is highest at 0.82 occurring between 4000 to 5000 Hz. This sample shows strong sound absorption in both low and mid-frequency ranges, with a slight high-frequency performance.

For the sample with a density of 125 kg/m^3, the sound absorption coefficient reaches its peak value within the frequency range of 400 Hz to 630 Hz. The peak sound absorption value of 0.85, occurring at a frequency of 500 Hz. In the lower frequency range, the highest sound absorption, at 0.85 occurred at 500 Hz. In the mid-range frequencies, the highest sound absorption of 0.71 occurred at 630 Hz. In the higher frequency range, the sound absorption is at its highest, reaching 0.71, occurring between 4000 to 5000 Hz. This sample shows stronger performance at low frequencies, with consistent absorption in both mid and high ranges.

The researchers [22] investigated the sound absorption coefficient of sugarcane fiber, sugarcane fiber samples were prepared in two stages: pre-treatment and fabrication. During the pre-treatment stage, the raw material was initially cut into lengths ranging from 1 to 3 mm, then left to sun-dry for a week before being subjected to a 5-minute heating process in an 80 °C oven to remove excess moisture from the fiber. The raw materials were cut into lengths of 5 to 10 mm and then mixed with varying compositions of polyurethane and polyester binders. The acoustic absorption of one gram of sugarcane fiber mixed with polyurethane and polyester binders, with a thickness of 12.7 mm. The result shows that the composition of binder (up to 40 %) does not significantly affect the performance of sound absorption. Good performance of sound absorption coefficient of more than a half ($\alpha > 0.5$) is shown for frequency above 3.5 kHz and the absorption coefficient increases until it reaches the value of 4.5 kHz at 0.78.

3.3. Groundnut Shell (GS)

Fig. 7 shows experimental results for groundnut shell samples at three densities: 75 kg/m^3, 100 kg/m^3, and 125 kg/m^3 in 25 mm mold.

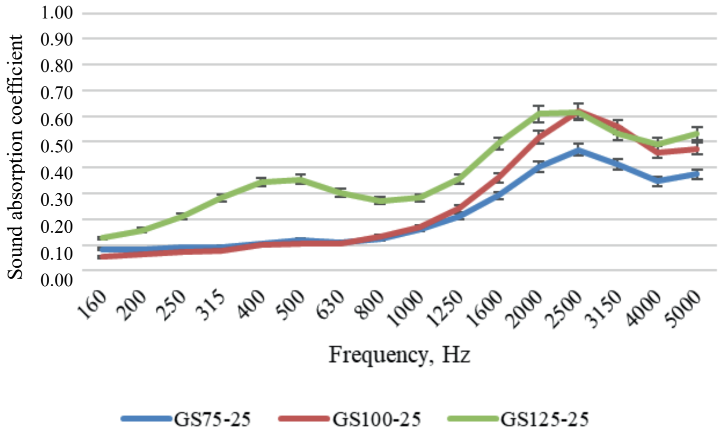

Fig. 7. Results of experimental sound absorption coefficients measurements using impedance tube for groundnut shell (75 kg/m^3, 100 kg/m^3, and 125 kg/m^3) in 25 mm mold.

For the sample with a density of 75 kg/m^3, the sound absorption coefficient reaches its peak value within the frequency range of 2000 Hz to 3150 Hz. The peak sound absorption value is 0.47, occurring at a frequency of 2500 Hz. At lower frequencies, the highest sound absorption, at 0.12, occurred at 500 Hz. In the mid-range frequencies, the highest sound absorption of 0.40 occurred at 2000 Hz. At higher frequencies, the highest sound absorption of 0.47, occurred at 2500 Hz. The sample performs better at higher frequencies, though the overall absorption values are relatively low compared to denser samples. For the sample with a density of 100 kg/m^3, the sound absorption coefficient reaches its peak value within the frequency range of 1600 Hz to 5000 Hz. The peak sound absorption value of 0.62, occurring at a frequency of 2500 Hz. At the lower frequency range, the highest sound absorption, at 0.11, occurred at 500 Hz. In the mid-range frequencies, the highest sound absorption of 0.52 occurred at 2000 Hz. In the higher frequency range, the highest sound absorption of 0.62, occurred at 2500 Hz. The sample shows a noticeable improvement in mid and high-frequency absorption compared to the 75 kg/m^3.

For the sample with a density of 125 kg/m^3, the sound absorption coefficient reaches its peak value within the frequency range of 2000 Hz to 5000 Hz. The peak sound absorption value of 0.62, occurring at a frequency of 2500 Hz. In the lower frequency range, the highest sound absorption of 0.35, occurred at 500 Hz. In the mid-range frequencies, the highest sound absorption of 0.61 occurred at 2000 Hz. In the higher frequency range, the sound absorption is at its highest, reaching 0.62, occurring at 2500 Hz. The sample performs better than the lower-density samples, especially in the lower and mid-frequency ranges, where absorption is significantly higher.

Fig. 8 shows experimental results for groundnut shell samples at three densities: 75 kg/m^3, 100 kg/m^3, and 125 kg/m^3 in 50 mm mold. For the sample with a density of 75 kg/m^3, the sound absorption coefficient reaches its peak value within the frequency range of 1250 Hz to 5000 Hz. The peak sound absorption value is 0.67, occurring at a frequency of 4000 Hz. At lower frequencies (160–500 Hz), the highest absorption, at 0.16, occurred at 500 Hz. In the mid-range frequencies (500 Hz to 2000 Hz), the highest absorption of 0.46 occurred at 1250 Hz. At higher frequencies (2000 Hz to 5000 Hz), absorption peaks at 0.67 occurred at 4000 Hz. The sample shows improved absorption across all frequency ranges compared to the 25 mm mold, especially in the higher frequencies. For the sample with a density of 100 kg/m^3, the sound absorption coefficient reaches its peak value within the frequency range of 3150 Hz to 5000 Hz. The peak sound absorption value of 0.83, occurring at a frequency of 4000 Hz. At the lower frequency range, the highest sound absorption, at 0.23 occurred at 500 Hz. In the mid-range frequencies, the highest sound absorption of 0.68 occurred at 1250 Hz. In the higher frequency range, the sound absorption is highest at 0.83 occurring between 4000 Hz. The sample shows significantly better performance in both mid and high frequencies with the 50 mm mold, making it more effective than the lower-density sample.

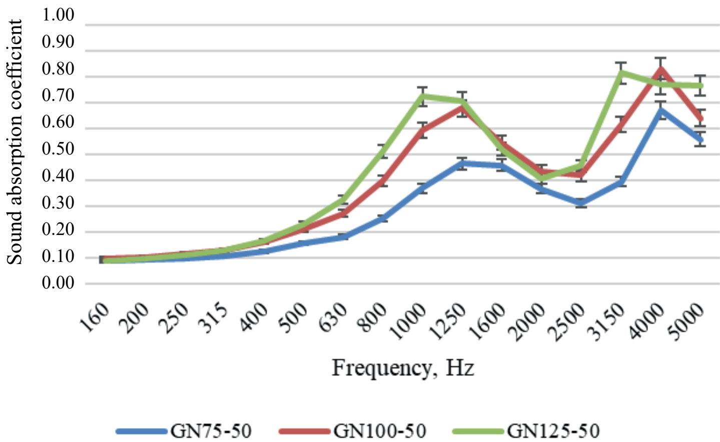

Fig. 8. Results of experimental sound absorption coefficients measurements using impedance tube for groundnut shell (75 kg/m^3, 100 kg/m^3, and 125 kg/m^3) in 50 mm mold.

For the sample with a density of 125 kg/m^3, the sound absorption coefficient reaches its peak value within the frequency range of 1350 Hz to 5000 Hz. The peak sound absorption value of 0.81, occurring at a frequency of 3150 Hz. In the lower frequency range, the highest sound absorption, at 0.23 occurred at 500 Hz. In the mid-range frequencies, the highest sound absorption of 0.72 occurred at 1000 Hz. In the higher frequency range, the sound absorption is at its highest, reaching 0.81, occurring between 4000 Hz. The sample exhibits the best overall performance, with strong absorption values across all frequencies, particularly in the mid-range.

Authors [23] examined the sound absorption coefficient of groundnut shells through experiments conducted with three different thicknesses: 10 mm, 20 mm, and 30 mm, also considering the inclusion of an air gap. The sound absorption coefficient was assessed using the transfer impedance tube method across a frequency range of 100 to 4000 Hz. Results show that for the 10mm sample, the peak sound absorption coefficient reached 0.96 at a frequency of 3250 Hz, while for the 20 mm sample, it peaked at 0.95 at 2000 Hz, and for the 30 mm sample, it peaked at 0.95 at 1250 Hz. Consequently, as the thickness of the sample increased, the maximum sound absorption coefficient shifted towards lower frequencies.

4. CONCLUSION

The study presents an investigation into the sound absorption capabilities of natural agricultural waste fiber materials (coconut fiber, groundnut shell, and sugarcane fiber). The experimental results show that the material is potentially a viable alternative to the synthetic materials used for sound absorption purposes. The sound absorption performance of natural fiber-based materials (coconut, sugarcane, and groundnut shells) demonstrates a strong correlation with density, thickness, and frequency. Higher-density samples (100–125 kg/m^3) consistently exhibit better sound absorption across mid and high-frequency ranges compared to lower-density ones (75 kg/m^3), especially when thickness increases. A thicker sample enhances absorption, particularly at lower frequencies, shifting the peak absorption to lower ranges. For example, the 125 kg/m^3 sample in a 50 mm mold achieved a peak sound absorption of 0.91 at 1000 Hz, while thinner samples (25 mm) showed lower overall sound absorption. Meanwhile, groundnut shell shows comparatively lower sound absorption, with the highest coefficient recorded at 0.81, with a sample density of 125 kg/m^3 in a 50 mm mold at a frequency of 3150. Sound absorption at lower frequencies is critical in environments like classrooms and libraries where the dominant frequency content ranges from 20 to 200 Hz. Lower frequencies have better propagation characteristics and can pass through obstacles more easily without losing their integrity. This demonstrates the need to use materials that can dampen low-frequency noise to provide good auditory environments.

These results are a starting point for further research highlighting the immense potential for using these organic agricultural waste fibers in acoustic soundproofing applications in libraries, cafes, and classrooms. By reducing noise pollution, these materials help create productive and comfortable working environments. But to fully assess the environmentally friendly impact of using such materials a thorough Life Cycle Assessment (LCA) is necessary for further studies. This kind of evaluation would offer useful information on the overall ecological footprint related to the production, disposal, and use of such materials. With this information, stakeholders can make informed choices on the usage of these materials to attain sustainability and environmental responsibility in different applications.

REFERENCES

[1] Malawade U. A., Malgaonkar V. V., Badadhe A. M., Jadhav M. G. Utilization and Study of Raw Groundnut Shell as a Source of Sound Absorbing Material. *Journal of Natural Fibers* 2022:19(13):6335–6347. https://doi.org/10.1080/15440478.2021.1916673

[2] Samsudin E. M., Ismail L. H., Kadir K. A. A. A review on physical factors influencing absorption performance of fibrous sound absorption material from natural fibers. *ARPN Journal of Engineering and Applied Sciences* 2016:11(6):3703–3710.

[3] Jariwala H. J., Syed H. S., Pandya M. J., Gajera Y. M. Noise Pollution & Human Health : A Review. *Conference: Noise and Air Pollution: Challenges and Opportunities* 2017.

[4] ALRahman L. A., Raja R. I., Rahman R. A. Experimental study on natural fibers for green acoustic absorption materials. *American Journal of Applied Sciences* 2013:10(10):1307–1314. https://doi.org/10.3844/ajassp.2013.1307.1314

[5] Liang M., Wu H., Liu J., Shen Y., Wu G. Improved sound absorption performance of synthetic fiber materials for industrial noise reduction: a review. *Journal of Porous Materials* 2022:29(3):869–892. https://doi.org/10.1007/s10934-022-01219-z

[6] Gboe N. A., Grubliauskas R. Agriculture Waste As Sound-Absorbing Material : Case Study Liberia. *Darni Aplinka Sustainable Environment* 2023. https://doi.org/10.3846/da.2023.003

[7] Duque-Acevedo M., Belmonte-Ureña L. J., Cortés-García F. J., Camacho-Ferre F. Agricultural waste: Review of the evolution, approaches and perspectives on alternative uses. *Global Ecology and Conservation* 2020:22:e00902. https://doi.org/10.1016/j.gecco.2020.e00902

[8] Fauzi N. S., Ali N. E. H. Agricultural Waste Management (Awm) System in Mukim Ulu Telom, Cameron Highlands. 2018:121–127. [Online]. Available: https://ir.uitm.edu.my/id/eprint/40229/1/40229.pdf

[9] Obi F., Ugwuishiwu B., Nwakaire J. Agricultural Waste Concept, Generation, Utilization and Management. *Nigerian Journal of Technology* 2016:35(4):957. http://doi.org/10.4314/njt.v35i4.34

[10] Putra A., Abdullah Y., Efendy H., Farid W. M., Ayob M. R., Py M. S. Utilizing Sugarcane Wasted Fibers As A Sustainable Acoustic Absorber. *Procedia Engineering* 2013:53:632–638. https://doi.org/10.1016/j.proeng.2013.02.081

[11] Hosseini Fouladi M., Nor M. J. M., Ayub M., Leman Z. A. Utilization of coir fiber in multilayer acoustic absorption panel. *Applied Acoustics* 2010:71(3):241–249. https://doi.org/10.1016/j.apacoust.2009.09.003

[12] Azeta O., Ayeni A. O., Agboola O., Elehinafe F. B. A review on the sustainable energy generation from the pyrolysis of coconut biomass. *Scientific African* 2021:13:e00909. https://doi.org/10.1016/j.sciaf.2021.e00909

[13] Sustainable Valorization of Sugarcane Waste from Sugarcane Processing. Brazil, 2019.

[14] Mandala R., Hegde G., Kodali D., Kode V. R. From Waste to Strength : Unveiling the Mechanical Properties of Peanut-Shell-Based Polymer Composites. *Journal of Composites Science* 2023:7(8):1–22. https://doi.org/10.3390/jcs7080307

[15] Rubino C., Gisbert-pay J., Liuzzi S., Stefanizzi P., Zamorano M., Martellotta F. Composite Eco-Friendly Sound Absorbing Materials Made of Recycled Textile Waste and Biopolymers. *Materials* 2019:12(23). https://doi.org/10.3390/ma12234020

[16] Xu Q., Ji T., Gao S. J., Yang Z., Wu N. Characteristics and applications of sugar cane bagasse ash waste in cementitious materials. *Materials (Basel)* 2018:12(1):1–19. https://doi.org/10.3390/ma12010039

[17] Rima B., Nadir B. Thermal and physiochemical characterization of bricks incorporating date palm fiber for use as insulation materials in buildings. *Journal of Engineered Fibers and Fabrics* 2024:19. https://doi.org/10.1177/15589250241276842

[18] Bhingare N. H., Prakash S. Effect of Polyurethane Resin Addition on Acoustic Performance of Natural Coconut Coir Fiber. *Journal of Natural Fibers* 2022:19(8):2902–2913. https://doi.org/10.1080/15440478.2020.1836545

[19] Liu X., Xiong X., Pang J., Wu L., Zhang H. Airflow resistivity measurement and sound absorption performance analysis of sound-absorb cotton. *Applied Acoustics* 2021:179:108060. https://doi.org/10.1016/j.apacoust.2021.108060

[20] Ružickij R., Grubliauskas R. Prediction of sound absorption of waste tyre textile fibre composite material. *12th International Conference "Environmental Engineering"* (ICEE-2023), 2023. https://doi.org/10.3846/enviro.2023.841

[21] Zulkifli R., Zulkarnain, Nor M. J. M. Noise control using coconut coir fiber sound absorber with porous layer backing and perforated panel. *American Journal of Applied Sciences* 2010:7(2):260–264. https://doi.org/10.3844/ajassp.2010.260.264

[22] Putra A., Abdullah Y., Efendy H., Farid W. M., Ayob M. R., Py M. S. Utilizing sugarcane wasted fibers as a sustainable acoustic absorber. *Procedia Engineering* 2013:53:623–638. http://dx.doi.org/10.1016/j.proeng.2013.02.081

[23] Malawade U. A., Malgaonkar V. V., Badadhe A. M., Jadhav M. G. Utilization and Study of Raw Groundnut Shell as a Source of Sound Absorbing Material. *Journal of Natural Fibers* 2021:19(13):1–13. https://doi.org/10.1080/15440478.2021.1916673