

Acoustic Absorption Coefficient of Oil Palm Midrib Composite

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ABSTRACT– Composite from oil palm midrib waste is one of the natural fiber materials that can reduce noise. Its material sample composite with gypsum was placed inside an impedance tube, which fitted with the mass of palm midrib mill, i.e., 0.1 kg, 0.15 kg, and 0.2 kg. Next, sound absorption coefficients were measured based on the two farthest ranges of the sound-receiving microphone, i.e., range A, which was 45 cm from the sample, and range B, which was 55 cm from the sample. Sound source frequencies were used, i.e., 125 Hz, 250 Hz, 500 Hz, 1000 Hz, and 2000 Hz. This research found that the link between sound absorption coefficients and the mass differences of each sample was not significantly affected. The highest sound absorption coefficient is 0.979 in distance A for oil palm midrib sample mass of 0.15 kg, far bigger than gypsums on the same frequency (125 Hz), which is 0.29. In conclusion, sound absorption on oil palm midrib was better because it has higher sound absorption coefficients than gypsum and a minimum sound absorption coefficient standard of 0.15. In the future, oil palm midribs might be widely used as sound-absorbing materials based on their advantages.

KEYWORDS : Oil palm midrib waste; sound absorption coefficient; impedance tube; gypsum

INTRODUCTION

The rapidity of technological development causes many establishments to suffer from noise pollution. Noise pollution is often caused by the rise of urbanization, infrastructure development, transportation, industrial activities, entertainment sources, household noise, and natural phenomena (Hemmat, Hesam, Atifnigar, 2023). Noise is repeated exposure to excessive audible sounds that can harm humans and other living things (Karki et al., 2024). One of the researches for solving noise problems is the experiment with sound-absorbing materials (Ewe et al., 2023). Those materials usually have pores and fibers, such as wool, foam, and glass because they have good sound absorption (Putra et al., 2018). However, materials such as fiberglass and minerals are not good for the environment because they are difficult to recycle, poisonous gas if burned, and produced with huge energy

that generates carbon dioxide, methane, and dinitrogen into the atmosphere (Arenas, et. al., 2020).

One of alternative sound absorption materials is oil palm midrib waste, which is used as livestock feed and compost (Raja et al., 2021). This waste is included as the biggest natural fiber (Momoh & Osofero, 2020). Oil palm midrib is produced after the process of sprouting and harvesting oil palms. The optimal number of 4 to 7-year-old oil palm midribs is around 40-56 midribs, whereas for 8 to 14-year-old oil palm midribs, it is around 40-48 midribs (Senewa, Wirianata, Hartati, 2023). Sprouting midrib in old age aims to maximize midrib's production and minimize its reductions. When it becomes waste, a sound-absorbing material is made, which consists of a mixture of old oil palm midrib and gypsum. Gypsum, which is also called Calcium sulphate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), is a mineral

formed from the deposition of seawater (Martin, 2019) and combined with halite, anhydrite, sulphur, calcite, and dolomite (Sampson, 2011).

A material's sound absorption coefficient can represent how much sound it has absorbed, including at palm midrib (Jang, 2023). Putra (2020) has researched sound absorption coefficient from oil palm midrib waste based on its adhesive and density. That research also used an impedance tube to determine this quantity because it is easy to make, affordable, easy to carry, only small sample required, and provides fast experimental results (Bhattacharya & V Bihola, 2019). The impedance tube must fulfill ISO 10534-2-2003 to get effective sound absorption coefficient result.

MATERIALS AND METHODS

This research aimed to calculate acoustic wall absorption coefficient using the composition of oil palm midrib using an impedance tube fulfilled ISO 10534-2-2003. It was done experimentally at Faculty of Mathematics and Natural Sciences, Universitas Riau. Its process was started by drying palm fronds using hot sunlight, making acoustic wall samples, constructing impedance tubes, measuring oil palm midrib samples' sound intensity, and calculating oil palm midrib samples' absorption coefficient.

Oil palm midribs were cut approximately 40 cm. Then, they were crushed using a

decorticator to become wet fibers. Then, oil palm midribs were dried under the sun until they had a moisture content of around 13.5%. Midrib fibers were cut into small pieces. This process was not carried out until midribs were completely smooth, only oil palm midribs measuring 2-3 cm to make it easier to blend with gypsum.

Gypsum was also blended with water, mixed oil palm midribs sample with adhesive material sample according to Table 1. There are three comparisons of mass composition used: 1 kg of gypsum mixed with 0.1 kg of oil palm midribs, 1 kg of gypsum mixed with 0.15 kg of oil palm midribs, and the last composition is 1 kg of gypsum mixed with 0.2 kg of oil palm midribs. Next, that sample was molded with a circular mold with a thickness of 3 cm and a diameter of 6.35 cm according to the size of the impedance tube. The higher the mass of oil palm midribs in the mixture after they were molded, the bigger their density. Finally, wait for that sample until it had $\pm 13\%$ moisture content so that it was ready to be used as an acoustic wall, like the process was shown in Figure 1.

Table 1 Ratio of mixture of oil palm midribs sample and adhesive sample by varying oil palm midribs sample.

No.	Acoustic Materials Ratio (kg)	
	Oil Palm Midrib	Gypsum
1	0.10	1
2	0.15	1
3	0.20	1

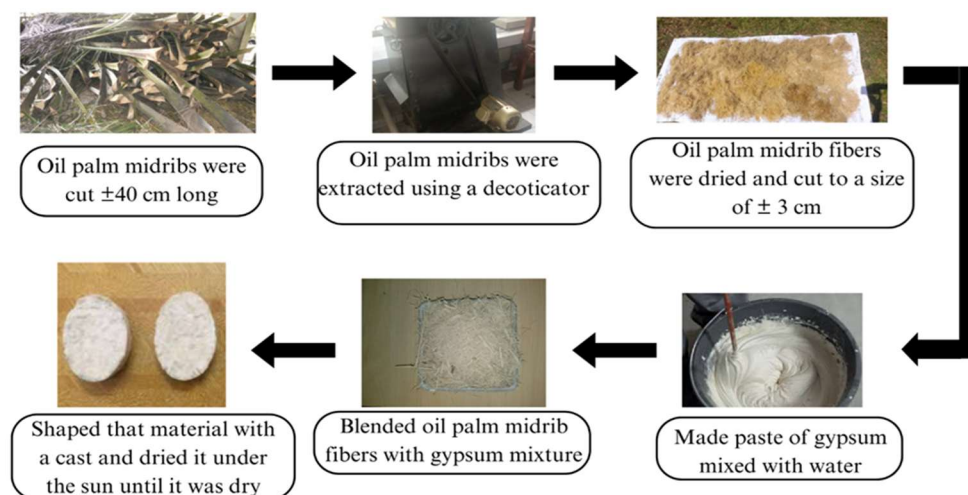


Figure 1 Execution scheme of acoustic walls from oil palm midribs

Constructing Impedance Tube

The impedance tube was made from a pipe with a diameter of 11 cm and a length of 100 cm. At one of its parts, the acoustic wall sample was placed, and there was a speaker as a sound source at the other part, which was connected directly to the signal generator. Two microphones were placed as sound receivers between the sample and the speaker. To facilitate the positioning of the microphones, the impedance tube was perforated at a distance of $x_1 = 45$ cm, designated as sample A, and at a distance of $x_1 = 55$ cm, designated as sample B. Each microphone was connected to the sound level meter. The sound level meter and signal generator used were software that had been installed on the computer.

Measuring Sound Absorption Coefficient

Measuring sound absorption coefficient was first done experimentally. At distance variation A, oil palm midrib sample with a mass of 0.1 kg was placed as in Figure 2 (a), then the signal generator was turned on with five frequency variations of 125 Hz, 250 Hz, 500 Hz, 1000 Hz, and 2000 Hz, respectively. Two microphones were placed according to Figure 2 (a), and a Soundcard Oscilloscope application was used. In order to determine sound absorption coefficients of each

microphone, amplitude magnitude was measured. Also, sound absorption coefficient was determined using transfer function approach mentioned above. Masses of 0.15 kg and 0.2 kg were used for the same process before. Then, each composition of oil palm midrib samples was done with the same process before with distance variation B or Figure 2 (b). In the end, these oil palm midrib mass variations (0.1 kg, 0.15 kg, and 0.2 kg) were used for a total of 10 times repetitions for each frequency (125 Hz, 250 Hz, 500 Hz, 1000 Hz, and 2000 Hz), and each distance variation A ($x_1 = 45$ cm) and B ($x_1 = 55$ cm), respectively.

Calculation of this quantity started by measuring sound pressure p_1 at a specific position x_1 and sound pressure p_2 at a different specific position x_2 in the following impedance tube:

$$p_1 = Ae^{-jkx_1} + Be^{-jkx_1} \quad (1)$$

$$p_2 = Ae^{-jkx_2} + Be^{-jkx_2} \quad (2)$$

In the two equations above, A and B are voltage amplitudes. The wave number is k (m^{-1}). The distance from the sample to the farthest distant microphone is x_1 , while the distance to the nearest microphone is x_2 . The significance of Equations (1) and Equation (2) was elucidated more fully in Figure 3.

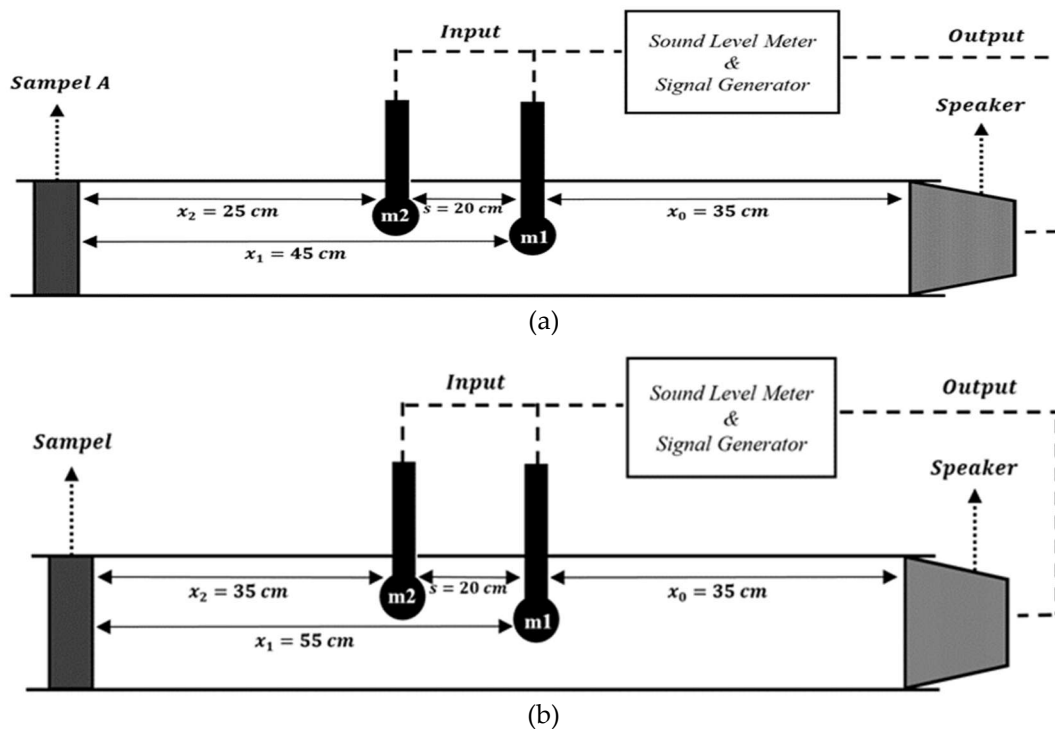


Figure 2 The impedance tube with distance variation (a) A and (b) B

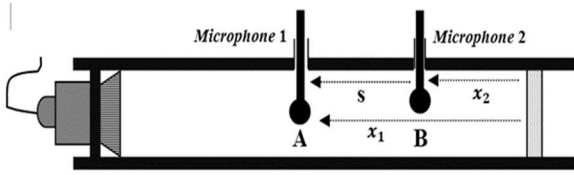


Figure 3 Impedance tube with general x_1 and x_2 range.

That impedance tube must fulfil ISO 10534-2-2003 by determining its diameter d in the Equation 3.

$$d = K \frac{c}{f_u} \quad (3)$$

where upper frequency in tube f_u multiplies range between two microphones s must be under 0.45 from the speed of sound c . K is the cut-off mode constant, valued at 0.58 (International Organization for Standardization, 2023). Spacing between two microphones s is determined by the Equation (4).

$$f_u \cdot s < 0.45c \quad (4)$$

Meanwhile, measuring transfer function of complex acoustic between two microphones H_{21} uses this Equation ((5).

$$H_{21} = \frac{p_1}{p_2} \quad (5)$$

and reflection factor r is:

$$r = \frac{H_{21}H_1}{H_R H_{21}} e^{2jkx_1} \quad (6)$$

$$H_1 = e^{-jks} \quad (7)$$

$$H_R = e^{jks} \quad (8)$$

$$s = x_1 - x_2 \quad (9)$$

where H_1 is a propagation factor denoting the phase shift and attenuation of the wave traversing from the reference point to first microphone. Then, H_R is the same factor but works with second microphone. In the end, sound absorption coefficient α is stated with Equation (10).

$$\alpha = 1 - |r|^2 \quad (10)$$

RESULTS AND DISCUSSION

Sound absorption coefficient values for each mass variation are conducted to ascertain the impact of frequency on the acoustic wall mass. Sound absorption coefficient values are illustrated in Figure 4 to Figure 6. Figure 4 is a graph of results of three mass samples. This

figure explains that samples with masses of 0.1 kg and 0.2 kg have identical sound absorption coefficients for frequencies of 125 Hz, 500 Hz, and 1000 Hz. However, those three samples experience the same thing when they are at frequencies of 250 Hz and 2000 Hz, decreasing of sound absorption coefficient. On the other hand, at frequencies of 500 Hz and 1000 Hz, their sound absorption coefficient increase. In this experiment with mass variations, those three samples got the highest value at a frequency of 1000 Hz.

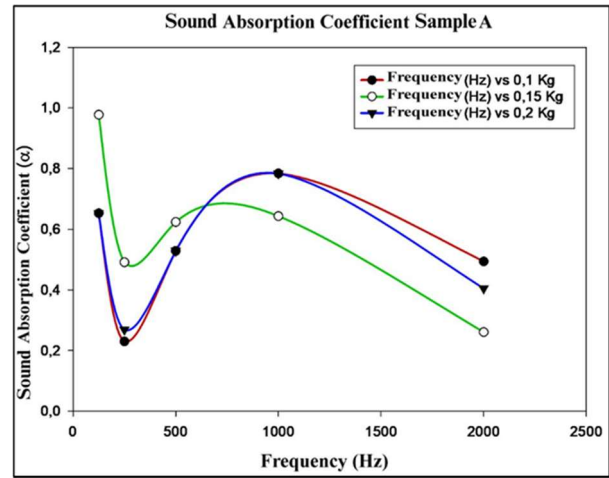


Figure 4 Sound absorption coefficient of sample A

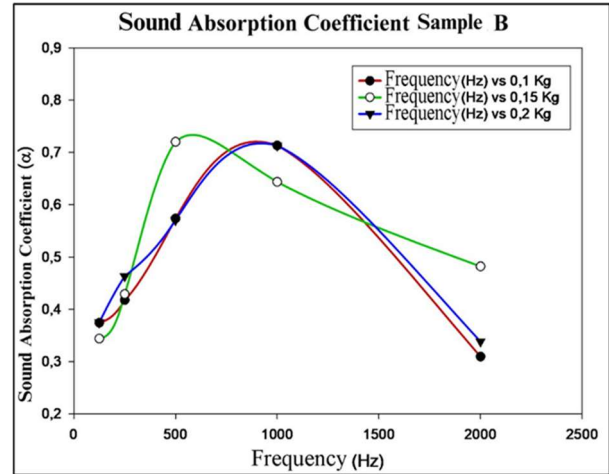


Figure 5 Sound absorption coefficient of sample B.

Figure 5 differentiates sound absorption coefficient for each mass variation that occurs at distance variation B. The graph illustrates an increase in sound absorption coefficient of three samples at frequencies of 250 Hz and 500 Hz. In contrast, their decline occurs at a frequency of 2000 Hz. The highest sound absorption coefficient is from 0.15 kg sample at

a frequency of 500 Hz compared to other frequencies. Samples with masses of 0.1 kg and 0.2 kg have the same sound absorption coefficient at several frequencies, the same as the experimental results at distance A.

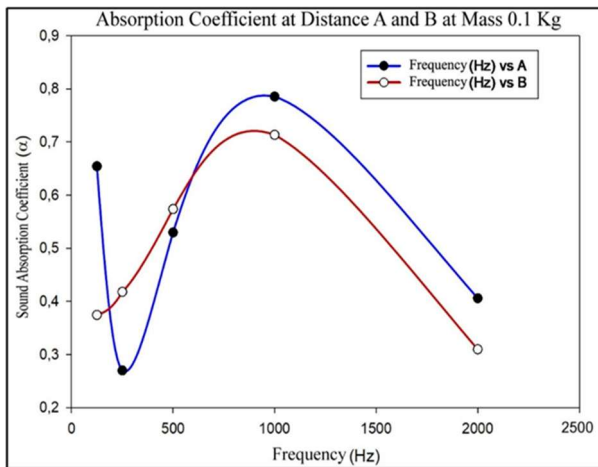


Figure 6 Sound absorption coefficients for distances A and B with a mass of 0.1 kg.

The variation in distances A and B for each mass (0.1 kg, 0.15 kg, and 0.2 kg) influenced the magnitude of sound absorption coefficient. Figure 6 shows a difference of sound absorption coefficient at distances A and B for a mass of 0.1 kg. At a frequency of 125 Hz, sound absorption coefficient is greater at distance A compared than distance B. Sound absorption coefficient increases at frequencies of 500 Hz and 1000 Hz, but decreases at a frequency of 2000 Hz, at both distances. The greatest sound coefficient values for both distances are at a frequency of 1000 Hz. At these two distances, a sample with a mass of 0.1 kg has the best coefficient value at distance A.

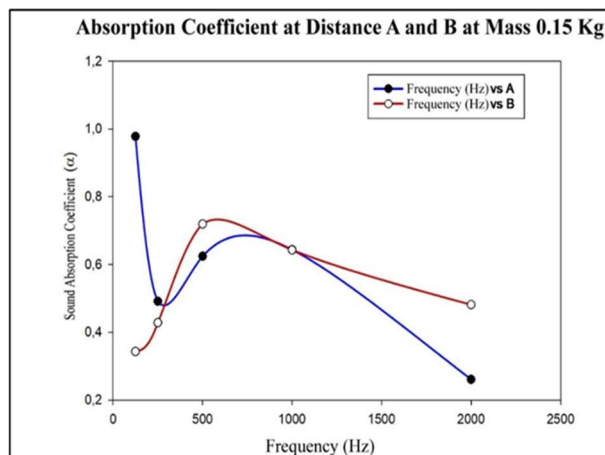


Figure 7 Sound absorption coefficients for distances A and B with a mass of 0.15 kg.

Figure 7 shows the sound absorption coefficients for a mass of 0.15 kg at distances A and B. Sound absorption coefficient at distance A is markedly greater than at distance B at a frequency of 125 Hz; but, at 250 Hz, sound absorption coefficient at distance A decreases and becomes comparable to that at distance B. Sound absorption coefficient at distances A and B increases to 500 Hz. Sound absorption coefficient decreases at both distances, except at a frequency of 1000 Hz at distance A, where it remains stable at frequencies of 1000 Hz and 2000 Hz. At the starting frequency of 125 Hz, these two distances on this mass yield contradictory outcomes. Distance A yields the highest coefficient value in comparison to others. The sample with a mass of 0.15 kg achieves the highest sound absorption coefficient value at distance A.

Figure 8 shows sound absorption coefficient from distances A and B at a mass of 0.2 kg which has different results. Sound absorption coefficient at distance A is greater than at distance B at a frequency of 125 Hz. However, when the frequency is 250 Hz, distance B has a larger sound absorption coefficient than distance A. Next, it increases at both distances for frequencies of 500 Hz and 1000 Hz. At a frequency of 2000 Hz, sound absorption coefficient at both distances decreases. This sample with a mass of 0.2 kg also gave good results at distance A.

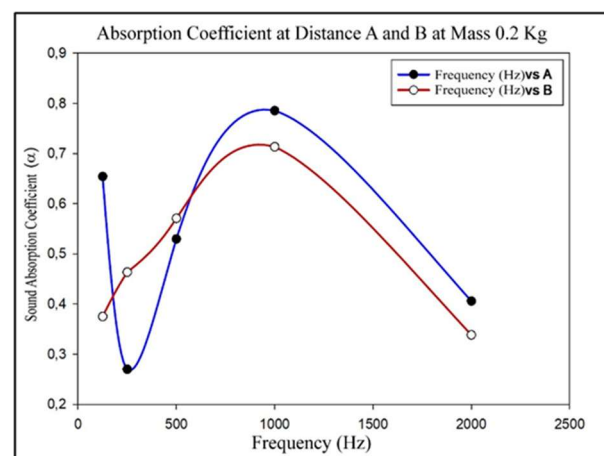


Figure 8 Sound absorption coefficients for A and B samples at 0.2 kg for distances A and B with a mass of 0.2 kg.

Table 2 Sound absorption coefficients of samples

Frequency	Sound Absorption Coefficient (α)						
	<i>gypsum</i>	Sample A			Sample B		
		0.1 kg	0.15 kg	0.2 kg	0.1 kg	0.15 kg	0.2 kg
125	0,29	0.655	0.979	0.655	0.376	0.346	0.376
250	0,10	0.233	0.494	0.271	0.419	0.430	0.465
500	0,05	0.531	0.626	0.531	0.575	0.721	0.572
1000	0,04	0.786	0.645	0.786	0.714	0.645	0.714
2000	0,07	0.496	0.263	0.407	0.311	0.483	0.340

This subchapter uses sound absorption coefficient of gypsum adhesive material as a benchmark to evaluate the influence of oil palm midrib on sound absorption coefficient. The authors' research findings are integrated with sound absorption coefficient values for gypsum as published by Asade & Isranuri (2013) in Table 2. Table 2 presents the sound absorption coefficients of oil palm midrib and gypsum. The maximum sound absorption coefficient is 0.979 at distance A for an oil palm midrib sample weighing 0.15 kg. Sound absorption coefficient at 125 Hz is lower for gypsum than for oil palm midrib. This effect occurs within the frequency range of 250 Hz to 2000 Hz, when sound absorption coefficient of oil palm midrib exceeds that of gypsum. A material is categorized as sound-absorbing if its sound absorption coefficient is a minimum of 0.15 (British Standards Institution., 1997).

Sound absorption coefficient of oil palm midrib is more excellent than gypsum because oil palm midribs have more fibers than gypsum for sound waves to interact (Ewe et al., 2023). In addition, gypsum is a mineral that does not naturally contain natural fibers, but its structure can be strengthened if it is added natural fibers (Mutuk et al., 2023). Also, sound absorption coefficient of oil palm midrib exceeds 0.15, surpassing the absorption coefficient of adhesive material. These findings demonstrate the effectiveness of oil palm midrib as a sound absorber.

In this research, frequency is an important variable in acoustic wall measurements. Each sample was taken at a frequency humans can still hear, namely 20 Hz – 20,000 Hz (Jacewicz,

Alexander, & Fox, 2023). The frequency that has the maximum sound absorption coefficient value at both distances is always in the range 500 – 1000 Hz. However, in Table 2 which was carried out on three different masses, distance A has a better sound absorption coefficient value than distance B. This is because distance A has a shorter range over the sample. Thus, the frequency that is best absorbed by acoustic walls made from oil palm midrib is in the range 500 – 1000 Hz (medium) at distance A.

CONCLUSION

According to the conducted research, it can be inferred that the variation in the mass of each sample does not substantially impact the sound absorption coefficient. Furthermore, it suggests that sound absorption coefficient remains rather consistent across different frequencies and distances for each variation of mass. At low frequencies (125 Hz and 250 Hz), distances A and B in each sample have very different sound absorption coefficients. However, there is little difference between two distances in terms of sound absorption coefficient at the following frequency. Sound absorption coefficient of oil palm midrib is superior to that of gypsum due to its higher value, with the highest result being 0.979 in distance A for oil palm midrib sample mass of 0.15 kg.

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