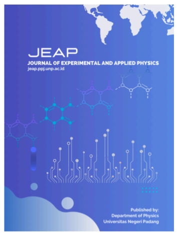
Journal of Experimental and Applied Physics
Journal Homepage: jeap.ppj.unp.ac.id
Vol. 1, No. 1, Juni 2023.
ISSN (Print): 2988-0378 ISSN (Online): 2987-9256



Effect of Variations in Banana Frond Fiber Composition with Polyurethane Matrix on Composite Panels Acoustic Properties and Porosity

Vini Oktavia[1], Yenni Darvina[1,*], Ramli[1], Rahmat Hidayat[1]

[1] *Department of Physics, Universitas Negeri Padang, Padang 25131, Indonesia*

Article History
Received : May, 24th 2023
Revised : June, 7th 2023
Accepted : June, 8th 2023
Published : June, 10th 2023

DOI:
https://doi.org/10.24036/jeap.v1i1.3

Corresponding Author
*Author Name: Yenni Darvina
Email: ydarvina@fmipa.unp.ac.id

Abstract: Noise can damage one's health, affect one's comfort, cause stress, and make activities not run smoothly. Making acoustic materials is one of the efforts made to overcome noise pollution. The material used in this study comes from banana fiber with a polyurethane matrix. This research material is easily and widely available. The advantage of this study is to determine the effect of variations in the composition of banana stem fiber with a polyurethane matrix on the values of the sound reflection coefficient, sound absorption coefficient, sound transmission loss, and porosity. The method used is a hand lay-up with a single microphone tube impedance characterization tool and an analytical balance. In this study, variations in the composition of the composite panels with fiber and matrix variations were carried out, namely 60%:40%, 70%:30%, and 80%:20%. Based on the findings of this study, the higher the sound absorption coefficient, sound transmission loss, and porosity, the lower the sound reflection coefficient. If the frequency used is higher, the values of the sound absorption coefficient and transmission loss increase, while the reflection coefficient decreases for the entire frequency range. If the porosity is higher, the acoustic properties will be better, which is indicated by an increase in the value of the sound absorption coefficient and the value of the sound transmission loss. High porosity will comply with the ISO 11654:1997 standard.

Keywords: Banana Frond Fiber, Polyurethane, Composite Panel, Sound Absorption Coefficient.

Journal of Experimental and Applied Physics is an open access article licensed under a Creative Commons Attribution ShareAlike 4.0 International License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. ©2023 by author.

1. Introduction

In everyday life, humans are often exposed to various pollutants, one of which is noise pollution. Noise pollution comes from several sound sources that meet, causing irregular sound

How to cite:
V. Oktavia, Y. Darvina, Ramli, and R. Hidayat, 2023, Effect of Variations in Banana Frond Fiber Composition with Polyurethane Matrix on Composite Panels Acoustic Properties and Porosity, *Journal of Experimental and Applied Physics,* Vol.1, No.1, page 30-45.

frequencies, disrupting hearing, and causing noise. The occurrence of unwanted sounds that interfere with or endanger health is referred to as noise. Noise occurs at a sound intensity of about 85 dB [1].The ability of humans to hear sounds ranges from a frequency of 20 to 20,000 Hz. Acoustic materials that can suppress sound are required to solve this problem. The technology used is a single microphone impedance tube [2].

Noise is defined as an unwanted sound that is a natural or man-made activity [3]. Noise is one of the environmental aspects that needs to be considered because it is included in disturbing pollution and is sourced from sound. Noise can result in emotional disturbances, anxiety, and stress. Over time, it can lead to a decrease in a person's productivity level [4]. Stress can have an impact on psychological, social, intellectual, and spiritual states [5].One form of effort in noise control is the selection of materials that can absorb sound, or acoustic materials. The quality of the material that can absorb sound can be seen from the value of the sound absorption coefficient (α). Sound has the general wave characteristic that when it encounters a surface, it can be reflected, absorbed, or passed on [6].The greater the value of the sound absorption coefficient (α), the better the material will be as a silencer [7]. Existing soundproofing materials include porous materials, resonators, and panels. Panels or coatings can be made with unused and environmentally friendly materials as composites that can muffle sound so as to reduce noise, have a low cost, and overcome environmental problems [8].

A composite material is a material composed of two or more constituents with different physical and structural properties that are combined to form a bond and become a new material with different properties from its constituents. Composite materials are typically made up of two components: fiber (filler) and a fiber binding material known as matrix. In the composite, the main element is fiber, while the binding material is a polymer that is easy to form using the hand lay-up method [8].

This study is different from the previous study because the matrix used in this study is polyurethane (PU), which is in the form of a liquid, and when it reacts it will be foam and harden [9]. Based on previous research, polyurethane has many advantages, including being not easily worn or resistant enough, not easily damaged, flexible to temperature changes, not easily torn, easily shaped or printed, and resistant to blows and friction [10]. This shows that polyurethane matrix are very suitable for use as adhesives on composite panels. Polyurethane is a polymeric material containing the chemical group urethane (-NH-CO-O-), resulting from the reaction of polyols with isocyanates. Polyurethane can easily stick to fibers [11].

This study used banana frond fibers as reinforcement in composite panels and increased the sound absorption value. Banana frond fiber was chosen because it comes from nature and is still not well utilized. Banana trees in general only bear fruit once, and if they have borne fruit, the banana tree will die. The advantages of banana stem fiber are that it is able to reduce sound, has low density, can be renewed, and overcomes environmental problems as a sound absorber [12]. Banana fronds have cellular tissue with interconnected pores, but if the banana fronds are dried, it will be better because it will become dense, making it a material that has pretty good absorption [13]. A porous, fibrous, and very soft material that is thought to be capable of absorbing the sound of sound energy striking a field surface [14].

In this study, it used fibers that had been alkaline treated in order to produce good mechanical interlocking between the fibers and the matrix so that the fibers and matrix could glue well [15]. This alkaline treatment uses NaOH for two hours [16]. In making the banana frond natural fiber silencer material, it needs to be used as a banana frond fiber composite panel. Composites have many advantages compared to other materials; for example, single materials, including composite fibers, have a lighter mass because composites are reinforcements and matrix with different masses [17].

According to a research report conducted previously using banana frond fibers with epoxy resin, banana frond fibers meet the important requirements of the basic characteristics of acoustic materials, namely porous materials that have cellular networks with interconnected pores. The results showed that the highest absorption coefficient was 0.99 at a frequency of 1500 Hz with a thickness of 2 cm [14]. Based on research that has been carried out using banana frond fibers with a polyurethane matrix, the highest absorption coefficient of 0.91 at a frequency of 1000 Hz with a thickness of 2 cm was obtained and met the standard of the absorption coefficient ISO 11654: 1997.

Previous research related to banana frond fibers using a polyester matrix was conducted. The results of the study stated that the highest absorption coefficient was at the highest frequency of 8000 Hz, which was 0.94 with a fiber length of 3 cm. The characteristics of the fibers in banana fronds are often used as silencers, and they have a long shelf life, so banana frond fibers are qualified to be used as acoustic materials. The fibers in banana fronds also have important requirements, namely that they be porous and have cellular tissue with interconnected pores [18]. The impedance tube method, also known as the standing wave method, uses the standing wave ratio to measure sound absorption and reflection in sound waves with a closed surface. The impedance tube allows measurements under specified and well-controlled conditions. The use of this method is based on ISO 11654:1997 standards. The basic principles of the impedance tube method are reflection, absorption, and transmission loss of sound waves by the material surface of a closed space, where the material is used to coat the surface of the wall of an enclosed space [19].

Porosity is defined as a comparison between the amount of free space or pores owned by a solid material and the sum of the material's volumes. Porosity is the air trapped in a composite (void). Voids are caused by uneven pressure, evaporating resins, trapped air at the time of stirring, or inhomogeneous mixing [20]. Therefore, based on this background, the purpose of this study was to determine the effect of variations in the composition of banana stem fiber with a polyurethane matrix on the acoustic properties and porosity of composite panels, as well as the effect of frequency variations on acoustic properties. In this study, the composition of banana stem fiber with a polyurethane matrix used was 60%:40%, 70%:30%, and 80%:20% to obtain data on the values of sound reflection coefficient, sound absorption coefficient, sound transmission loss, and porosity with a single-microphone impedance tube apparatus as well as a digital scale.

2. Materials and Method

Based on the research objectives achieved, the methods used in this study are the hand lay-up method for making composite samples and the single-microphone impedance tube method for testing acoustic properties. Porosity testing has been carried out using digital scales. This research is included in laboratory-based experimental research. Testing was carried out on the basis of ASTM C 384-04 and ISO 5636-5 standards. Several steps were taken, namely preparation of banana frond fiber, mold preparation, sample preparation, and sample characterization. In this study, banana frond fibers were mixed with a polyurethane (PU) matrix that was reacted between polyurethane (polyol compound (A) and polyisocynate (B)) to form a foam. There are three variations of the composition used in the manufacture of composite samples, namely: 40%: 60%, 30%: 70%, and 20%: 80% with a frequency of 250 Hz, 500 Hz, 750 Hz, and 1000 Hz, to find out the best sample that can be used as a silencer. The fiber length used is 3 cm with an alkalization time of 2 hours, and then the printed sample will be pressed with a felt device (hot press) with a pressure of 2 x 10^8 N/m^2 [18].

This research was conducted at the Materials and Biophysics Laboratory, the Electronics and Instrumentation Laboratory, and the Geophysical Laboratory of the Faculty of Mathematics and Natural Sciences, Universitas Negeri Padang. This study discusses the influence of acoustic properties produced in the form of sound reflection coefficient, sound absorption coefficient, sound transmission loss, and porosity. To achieve this research, several tools were used, namely: a microphone impedance tube, digital scales, a sound level meter, a felt device (hot press), a measuring cup, a cleaver, a wire brush, a sample mold, and a grinder. The materials used in this study are renewable and unused materials. The material used is banana frond fiber. Where banana trees bear fruit only once and are thrown away, their concentration needs to be considered again. Other materials are polyurethane matrix, NaOH, and aquades. There are four stages carried out in this test, namely, the preparation stage of materials and sample molds, the stage of making composite samples, the stage of sample characterization, and the stage of analysis and data processing, which can be seen in the form of flowcharts in Figure 1 below, namely:

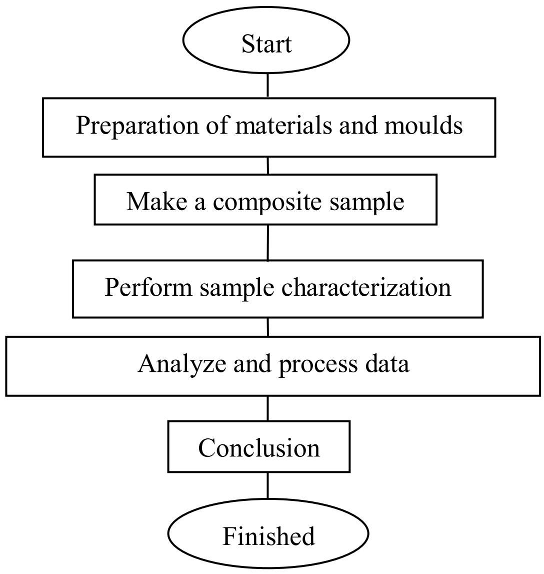


Figure 1. Research stages

The initial stage of making the composite is the preparation of banana fiber. The banana fronds used come from the Sulit Air area, Solok Regency. Banana fronds are taken from banana gardens in Sulit Air. The banana frond is separated from the tree by cutting the banana stem. Then the banana fronds are washed thoroughly using water so that the dirt attached to the banana fronds disappears. Furthermore, the banana frond was scraped using a thin iron plate so that the fibers from the banana frond came out. After that, banana frond fibers are dried in the sun for approximately 2 days. The dried banana frond fibers are brushed with a wire brush to make them more decomposed before being cut into 3 cm lengths. The banana frond fibers measuring 3 cm were then alkalized using NaOH for approximately 2 hours [15]. Banana frond fibers are rinsed again with water and dried. The fibers of the dried banana frond are weighed according to the predetermined weight composition and are ready for use. The ready-to-use banana frond fibers can be seen in Figure 2 below.

Figure 2. Banana frond fibers

Based on Figure 2, it can be seen that the processed banana frond fibers produce good fibers that are thin and smooth. Alkaline treatment makes the fibers look cleaner and smoother. Alkaline treatment is carried out by soaking the fibers in dissolved NaOH. NaOH is one of the chemical substances used to increase the cellulose content of soaked fibers. This alkaline treatment can also reduce fiber surface tension, resulting in good mechanical interlocking [16]. Preparation of mold The sample molds are made according to the diameter of the tube used. The diameter used in the sample mold measures 9.5 cm with a height of 2 cm. The sample mold is made with iron so that when the sample is printed using a press tool, the print is not damaged and remains sturdy. So the resulting sample is good. Before the sample is printed, the mold must be lubricated first so that the sample does not stick when printed and is not difficult to remove from the mold.

The second stage is sample preparation. The composite sample was created from two mixtures of materials: banana frond fibers and a polyurethane matrix. The polyurethane matrix is reacted first between polyurethane (polyol compound (A) and polyisocynate (B)) based on a predetermined composition. After the chemical liquid from the polyurethane reacts and forms foam, the banana fiber measuring 3 cm is mixed with the polyurethane, put into the mold, and pressed with force of 2×10^8 N/m^2 [21]. After the sample is printed. The sample mold is then extracted from the felt device (Hot Press). and the sample is removed from the mold. Samples that have been removed from the mold can be further tested. It can be seen that there are three variations in sample composition, namely 60%:40%, 70%:30%, and 80%:20%, with each diameter measuring 9.5 cm and a thickness of 2 cm. Sample testing was carried out using a characterization tool in the form of a single-microphone impedance tube in accordance with the ASTM C 384-04 standard. The third stage is to characterize the sample using a single-microphone impedance tube made of pipes arranged in such a way. A single microphone impedance tube is connected by several devices, such as LCD, sound level meters, oscilloscopes, and audio generators. The impedance tube of one microphone used can be seen in Figure 3 below.

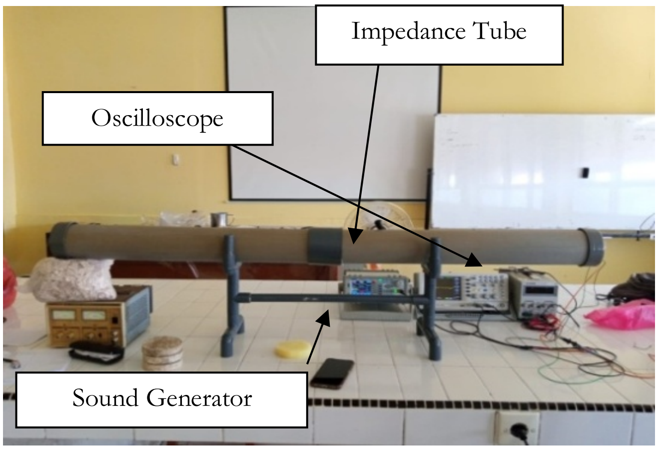


Figure 3. Single microphone impedance tube

Based on Figure 3, an audio generator connected to a sound generator is used to generate acoustic waves that propagate inside the tube and are then reflected by the test object. The phase interference between the coming wave and the reflected wave in the tube of the test sample will result in a standing pattern. The pressure amplitude at the node and antinode is measured using a sliding microphone. The ratio of maximum pressure (antinode) to minimum pressure (node) is the ratio of standing waves and can be viewed using an oscilloscope. Based on the characterization data obtained by the single-microphone impedance tube method, the sound absorption coefficient generated from the sample can be analyzed. Determination of the sound absorption coefficient on the single-microphone impedance tube method by calculating the ratio of the maximum pressure amplitude and the minimum pressure amplitude This pressure amplitude ratio is called the standing wave ratio (SWR) [14]. The porosity test carried out using analytical balance can be seen in Figure 4 below.

Figure 4. Analytical balance ABT 220-5DM

Based on Figure 4, porosity testing is performed by weighing the sample before soaking it in water. Then the weighed sample is soaked with water overnight and re-weighed. The difference between the weight of the sample before soaking and after soaking compared to the weight of the sample dry or before soaking Then it is obtained from the value of porosity.

The fourth stage is the process of analyzing and processing already-characterized sample data. The formula used in acoustic data processing uses a single-microphone impedance tube method and porosity test equipment as follows [14]:

$$\text{SWR} = \frac{A+B}{A-B} \tag{1}$$

Information :
SWR : standing wave ratio.
$(A + B)$: maximum pressure amplitude.
$(A - B)$: minimum pressure amplitude.

The reflection coefficient can be determined from the following equation [14]:

$$r_{\Pi} = \left| \frac{B}{A} \right|^2 = \left(\frac{SWR-1}{SWR+1}\right)^2 \tag{2}$$

Information :
r_{Π} = sound reflection coefficient.
A = incident wave impedance.
B = reflected wave impedance.
SWR-1 = minimum standing wave ratio.
SWR+1 = maximum standing wave ratio.

The coefficient of sound absorption (absorption of sounds) at a given frequency can be seen from the following equation [17]:

$$a = 1 - \left(\frac{SWR-1}{SWR+1}\right)^2 = \frac{4}{SWR + \frac{1}{SWR} + 2} \tag{3}$$

Information :
α = sound absorption coefficient.
SWR-1 = minimum standing wave ratio.
SWR+1 = maximum standing wave ratio.

Meanwhile, to obtain the transmission loss of sound from the wave, use the following equation [22]:

$$\text{TL} = \text{NR} + 10 \log \frac{s}{\alpha} \tag{4}$$

Information :
TL = sound transmission loss (dB).
NR = noise reduction (dB).
s = sample surface area (cm^2).
α = sound absorption coefficient.

To determine the value of the porosity test using the equation [20]:

$$P = \frac{w_b - w_k}{w_k} \times 100\ \% \tag{5}$$

Information :
P = material porosity (%).
w_b = gross weight (gram)
w_k = dry weight (gram)

3. Results and Discussion

Samples have been successfully made in the form of composite panels with various types of variations in the composition of banana frond fibers and polyurethane matrix, namely 60%:40%, 70%:30%, and 80%:20%. A single-microphone impedance tube and digital weigh were also used to characterize acoustic properties and porosity. In acoustic testing, the frequency variations used are 250 Hz, 500 Hz, 750 Hz, and 1000 Hz. Testing the sound reflection coefficient, sound absorption coefficient, and sound loss transmission using a single-microphone impedance tube methodwith equations (2), (3), and (4) The test was carried out at the Electronics and Instrumentation Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Negeri Padang. The device is equipped with a one-microphone impedance tube in the form of an oscilloscope, an audio generator, a sound level meter, an LCD, and a microphone. The sample is placed at the end of the tube in a transverse position. Then the sound waves are emitted through the sound generator using an audio generator, from low frequency to high frequency. The measurement of the values of the sound reflection coefficient and the sound absorption coefficient in this study used a standing wave ratio, which is a comparison between the maximum amplitude and the minimum amplitude obtained and viewed on the oscilloscope. and for sound transmission loss by looking at the sound reduction resulting from the difference between the sound source pressure and the sound pressure in the receiving chamber. Testing was performed repeatedly, with three tests for each variation of the sample composition.

Meanwhile, porosity value testing using porosity test equipment in the form of digital scales using equation (5) is carried out at the Geophysical Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Negeri Padang. The measurement of the porosity value is obtained from the ratio of the dry weight of the sample before soaking with water and the wet weight of the sample after soaking with water. Porosity testing was performed three times for each variation in sample composition.

Based on the results of characterization, the results of the study were obtained as follows:

3.1. Sound Reflection Coefficient

Here is the data from the test results of each sample, with variations in composition and frequency used. The results of the analysis of the sound reflection coefficient can be seen in Table 1.

Table 1. Sound Reflection Coefficient on Composition and Frequency Variations

Sound Reflection Coefficient (r_{Π})				
Composition (Fiber:Matrix)	Frequency			
	250 Hz	500 Hz	750 Hz	1000 Hz
60%:40%	0,36	0,36	0,36	0,25
	0,44	0,36	0,36	0,25
	0,44	0,44	0,25	0,36
Average (r_{Π})	0,41	0,39	0,32	0,29
70%:30%	0,44	0,25	0,36	0,11
	0,44	0,44	0,25	0,11
	0,19	0,25	0,11	0,36
Average (r_{Π})	0,36	0,31	0,24	0,19
80%:20%	0,44	0,25	0,11	0,11
	0,25	0,36	0,11	0,11
	0,25	0,25	0,25	0,04
Average (r_{Π})	0,31	0,29	0,16	0,09

Based on Table 1, the data obtained shows that the value of the highest sound reflection coefficient is 0.41 at a frequency of 250 Hz with a composition of 60%:40%. The lowest value of the sound reflection coefficient is 0.09 at a frequency of 1000 Hz with a composition of 80%:20%. This happens because the less fiber composition used, the higher the reflection coefficient value produced, and vice versa. The following can be seen as a graph of the influence of composition on the sound reflection coefficient in Figure 5.

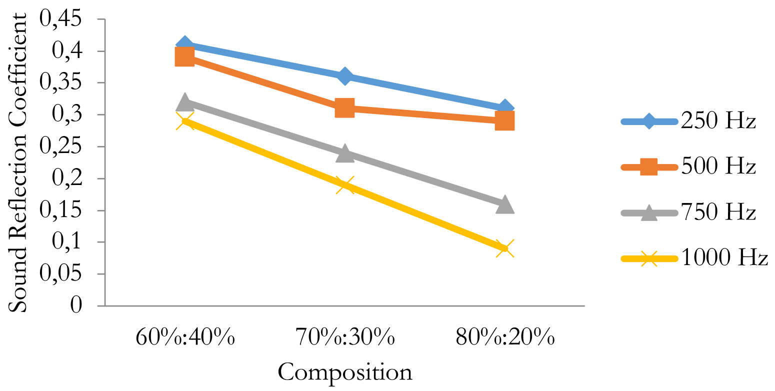


Figure 5. Effect of variations in composition and frequency of banana frond fibers with polyurethane matrix on composite panels on sound reflection coefficients

Based on Figure 5, it can be seen that the value of the sound reflection coefficient decreases further with the addition of the fiber composition used for all types of frequencies. So the relationship between the addition of variations in the composition of fibers and the coefficient of reflection of sounds is inversely proportional. The more fibers used, the less sound will be reflected. This is due to the fact that more pores are formed in the sample, so more sound is absorbed and less reflected [19]. So that the highest reflection coefficient is produced from a small fiber composition.

Based on Figure 5, it can also be seen that the higher the frequency used, the smaller the value of the sound reflection coefficient produced. This happens because when the emitted sound hits the surface of the sample with a high frequency, it will be absorbed more and reflected less. so that the relationship between the frequency and the value of the sound reflection coefficient is inversely proportional. It can be concluded that the more fiber composition used and the higher the frequency used, the smaller the value of the sound reflection coefficient [18].

3.2. Sound Absorption Coefficient

Based on the data obtained, the value of sound absorption coefficient can be seen in Table 2.

Table 2. Sound Absorption Coefficient at Composition and Frequency Variations

Sound Absorption Coefficient (α)				
Compositon (Fiber:Matrix)	Frequency			
	250 Hz	500 Hz	750 Hz	1000 Hz
	0,64	0,64	0,64	0,75
60%:40%	0,56	0,64	0,64	0,75
	0,56	0,56	0,75	0,64
Average (α)	0,59	0,61	0,68	0,71
	0,56	0,75	0,64	0,89
70%:30%	0,56	0,56	0,75	0,89
	0,81	0,75	0,89	0,64
Average (α)	0,64	0,69	0,76	0,81
	0,56	0,75	0,89	0,89
80%:20%	0,75	0,64	0,89	0,89
	0,75	0,75	0,75	0,96
Average (α)	0,69	0,71	0,84	0,91

Based on the data obtained in Table 2, the value of the highest sound absorption coefficient is 0.91 at a frequency of 1000 Hz with a composition of 80%:20%. The lowest value of the sound absorption coefficient is 0.59 at a frequency of 250 Hz with a composition of 60%:40%. The following can be seen in the graph of the sound absorption coefficient in Figure 6.

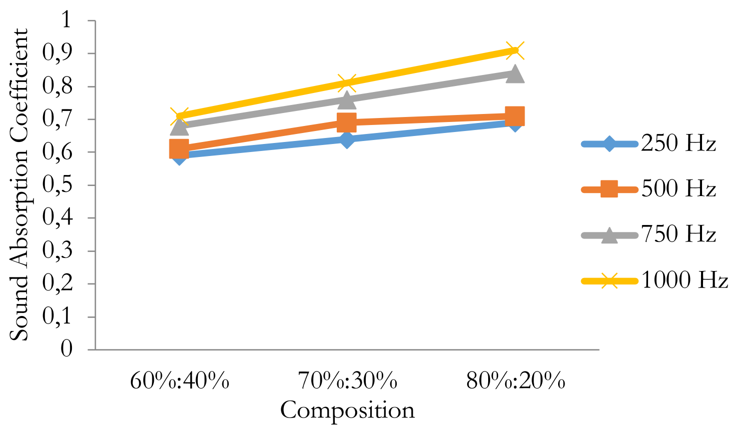


Figure 6. Effect of variations in composition and frequency of banana frond fibers with polyurethane matrix on sound absorption coefficient

Based on Figure 6, it is seen that the value of the sound absorption coefficient increases with the addition of the fiber composition used for all types of frequencies. So, the relationship between the sound absorption coefficient and the addition of variations in the composition of fibers is directly proportional. According to the graph, the more fiber used, the more sound absorbed by the material. The sound absorption coefficient increases because the material has many cavities, so waves easily enter and are absorbed in the acoustic material. Therefore, banana frond fibers have the potential to be used as silencers [14]. And banana frond fibers meet ISO 11654:1997 standards [23]. The more fiber used, the greater the value of the sound absorption coefficient. This affects the number of pores formed on the sample. Based on Figure 6, it can also be seen that the higher the frequency used, the greater the value of the sound absorption coefficient produced. This happens because when the emitted high frequency hits the surface of the sample, it will be absorbed a lot by the pores on the sample. So it can be concluded that the more compositions and the higher the frequency used, the larger the sound absorption coefficientie. The following is a classification of the sound absorption coefficient standard based on ISO 11654:1997, as seen in Table 3 .

Table 3. Sound Absorption Coefficient Value Classification

Sound Absorption Class	α_w
A	0,90; 0,95; 1,00
B	0,80; 0,85
C	0,60; 0,65; 0,70; 0,75
D	0,30; 0,35; 0,40; 0,45; 0,50; 0,55
E	0,25; 0,20; 0,15
Not Classfield	0,10; 0,005; 0,00

(Source: ISO 11654, 1997 [24])

Based on Table 3, all sample variations that have been studied have a sound absorption coefficient value above 0.50 and meet the ISO 11654:1997 standard [18]. The lowest sound absorption coefficient value is at 60%:40%, which is 0.59 at a frequency of 250 Hz, and the highest value is at a composition of 80%:20%, which is 0.91 at a frequency of 1000 Hz.

3.3. Sound Transmission Loss

Based on the data obtained, the value of sound transmission loss can be seen in Table 4.

Table 4. Sound Transmission Loss at Composition and Frequency Variations

Sound Transmission Loss/TL (dB)				
Composition (Fiber:Matrix)	Frequency			
	250 Hz	500 Hz	750 Hz	1000 Hz
	32,1 dB	26,7 dB	27,4 dB	31,5 dB
60%:40%	31,7 dB	27 dB	27,4 dB	31,7 dB
	31,5 dB	27,5 dB	26,9 dB	32,3 dB
Average TL	31,43 dB	27,06 dB	27,23 dB	31,8 dB
	32,5 dB	29,1 dB	28,9 dB	31,8 dB
70%:30%	32,8 dB	30,3 dB	28,1 dB	32 dB
	30,6 dB	29,2 dB	27,6 dB	33,3 dB

AverageTL	31,97 dB	29,5 dB	28,2 dB	32,37 dB
	33,1 dB	29,5 dB	26,4 dB	34,7 dB
80%:20%	33,1 dB	30,2 dB	26,5 dB	34,3 dB
	31,7 dB	29,4 dB	27,2 dB	33,8 dB
AverageTL	32,16 dB	29,7 dB	26,7 dB	34.26 dB

Based on Table 4, the highest sound transmission loss value obtained is 34.26 dB at a frequency of 1000 Hz with a composition of 80%:20%. The lowest sound transmission loss value is 26.70 dB at a frequency of 750 Hz with a composition of 80%:20%. The following can be seen in a graph of the sound transmission loss in Figure 7.

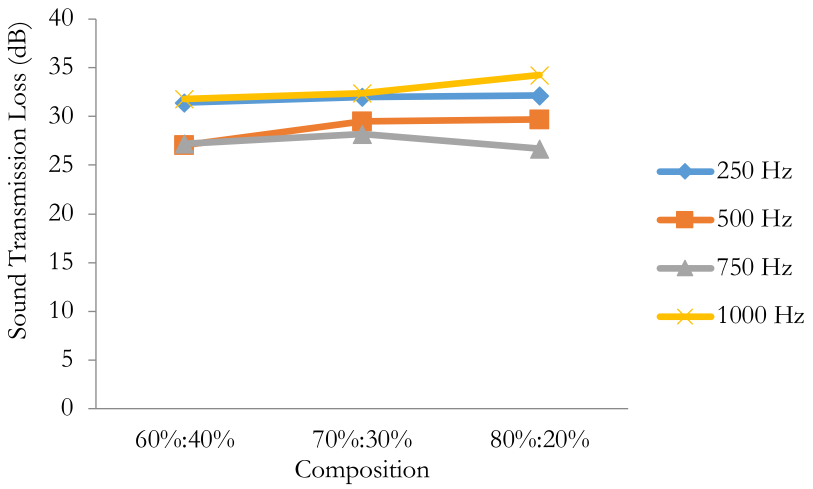


Figure 7. Effect of variations in composition and frequency of banana frond fibers with polyurethane matrix on composite panels on sound transmission loss

Based on Figure 7, it can be seen that the transmission loss value of the sound increases with the addition of the fiber composition used. So, the relationship between sound transmission loss and the addition of variations in fiber composition is directly proportional. Based on the picture above, the more fiber composition used, the greater the transmission loss value of the sound [25]. Based on Figure 7, theoretically, the higher the frequency used, the greater the transmission loss value of the sound produced [25]. But in this study, the lowest sound transmission loss value produced was at a frequency of 750 Hz. This was caused when testing with a sound level meter connected to an impedance tube. The position of the connected sound level meter still has a cavity, so that the incoming sound does not only come from the frequency emitted but also from the outside. This is also at the time of making the impedance tube device, when deciding where to put the sound level meter beyond the circle of the sound level meter microphone so that there is still a cavity.

3.4. *Porosity*

Based on the data obtained, the porosity test values can be seen in Table 5.

Table 5. Porosity Test Results Data on Samples

Composition (Fiber : Matrix)	Dry Weight (gr)	Gross Weight (gr)	Wet And Dry Weight Difference (gr)	Porosity (%)	Average Porosity (%)
	74	90	16	21,62	
60% : 40 %	74	90	16	21,62	22,07
	74	91	17	22,97	
	65	84	19	29,23	
70% : 30%	65	84	19	29,23	28,72
	65	83	18	27,69	
	69	93	24	34,78	
80% : 20%	69	93	24	34,78	35,26
	69	94	25	36,23	

According to Table 5, the highest porosity test value was 35.26% with an 80%:20% composition. The lowest porosity value is 22.07% with a composition of 60%:40%. The following can be seen in a graph of the porosity values in Figure 8.

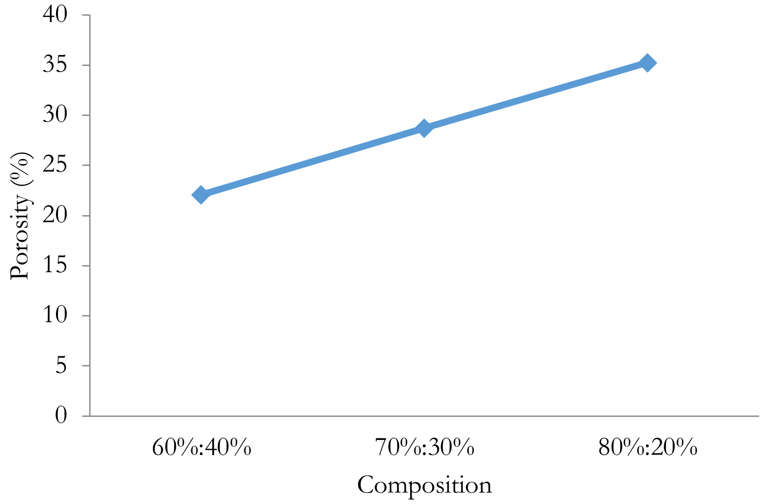


Figure 8. Effect of variations in the composition of banana frond fibers with polyurethane matrix on composite panels on porosity

Based on Figure 8, it can be seen that the porosity test value increases with the addition of the fiber composition used. So, the relationship between porosity and the addition of variations in the composition of fibers is directly proportional. Based on the picture above, the more fiber composition used, the greater the porosity value. This happens because of the large number of pores formed on the sample if more fiber is used so that it is easier to absorb. It can be said that banana frond fibers are very suitable for use as silencers based on the ISO 5636-5:2011 standard [26]. The following can be seen in the classification of porosity values based on the ISO 5636-5 standard in Table 6 [26].

Table 6. Classification of Porosity Values

Porosity (%)	Quality
0-5	Very Bad Porosity
5-10	Bad Porosity
10-15	Medium Porosity
15-20	Good Porosity
Over 20	Very Good Porosity

(Source: ISO 5636-5, 2011 [26])

Based on Table 6, it can be seen that if the porosity value exceeds 20%, then the composite sample that has been made meets the ISO 5636-5 standard. From the studies that have been carried out, all variations in the composition of composite samples exceed 20%, with the highest porosity value being at a variation of 80%:20% and meeting the ISO 5636-5 standard. In the composition of 80%:20%, all samples experienced an increase in the values of the sound absorption coefficient, sound transmission loss, and porosity, while the sound reflection coefficient decreased. At 60%:40% of all samples, a decrease was observed in the values of the sound absorption coefficient, sound transmission loss, and porosity, while the sound reflection coefficient increased. This happens if the more fiber composition is used, the more pores are formed on the acoustic material, so that the sample easily absorbs sounds. If more fiber composition is used, the greater the values of the sound absorption coefficient, sound transmission loss, and porosity [19].

At a frequency of 1000 Hz, all samples experienced an increase in the values of the sound absorption coefficient and sound transmission loss, while the sound reflection coefficient decreased. At a frequency of 250 Hz, all samples experienced a decrease in the value of the sound absorption coefficient while the sound reflection coefficient increased. Theoretically, the higher the frequency used, the greater the value of the sound absorption coefficient and sound transmission loss, while the sound reflection coefficient is smaller [25]. But in this study, transmission loss decreased at a frequency of 750 Hz. This happened because the impedance tube device where the sound level meter was connected exceeded the microphone at the sound level meter, so that there was still a cavity that caused outside sound to enter and influence the result of the transmission loss value of the sound. The sound absorption coefficient, sound transmission loss, and porosity increase as fiber composition increases, while the sound reflection coefficient decreases. When the frequency is increased, the sound absorption coefficient and sound transmission loss increase, while the sound reflection coefficient decreases. Then, if the porosity value is higher, the better the acoustic properties will be, as evidenced by the increase in the sound absorption value and sound transmission loss. So the best composition for silencers in this study was 80%:20% and met ISO 5636-5:2011 standards [26]. Therefore, all variations of banana fiber composite samples with a polyurethane matrix have the best sound absorption coefficient at high frequencies and meet ISO 11654:1997 standards [24].

4. Conclusion

Based on the research that has been carried out on the effect of variations in the composition of banana frond fibers with polyurethane matrix on composite panels' acoustic properties and porosity, there are three conclusions in this study. First, if more banana frond fiber composition is used in the composite panel, the higher the value of the sound absorption coefficient, transmission loss of sound, and porosity, while the coefficient of sound reflection decreases. Second, the higher the frequency used, the greater the value of the sound absorption coefficient and sound transmission loss, while the sound reflection coefficient is smaller. Third, higher porosity values indicate better acoustic properties, as evidenced by increases in sound absorption coefficient and sound transmission loss values. Therefore, the best composition for silencers using banana frond fibers and polyurethane matrix is found in variations of 80%:20%, which meet the requirements for silencers in accordance with ISO 11654:1997 and ISO 5636-5:2011 standards.

Acknowledgments

This research can be carried out properly thanks to the help of various parties. For this reason, the researcher would like to thank the author, the head of the physics department, the head of the physics department study program, the administrative staff and laboratory assistants of the physics department who have provided collaboration in this research, as well as the research team who participated in this research.

References

[1] B. Cessar Bimara, A. Rahma Azizah, T. Anita Wulansari, U. Nurbaiti, F. Jurusan Fisika, and F. Matematika dan Ilmu Pengetahuan Alam, "Analisis Material Serat Alam Tebu Sebagai Bahan Peredam Suara," *Fis. Sains dan Apl.*, vol. 6, no. 2, pp. 2657–1900, 2021.

[2] K. Hariprasad, K. Ravichandran, V. Jayaseelan, and T. Muthuramalingam, "Acoustic and mechanical characterisation of polypropylene composites reinforced by natural fibres for automotive applications," *J. Mater. Res. Technol.*, vol. 9, no. 6, pp. 14029–14035, 2020, doi: 10.1016/j.jmrt.2020.09.112.

[3] Dewanty.R.A.Sudarmaji, "Analisis Dampak Intensitas Kebisingan Terhadap Gangguan Pendengaran Petugas Laundry Worker," *J. Kesehat. Lngkungan*, vol. 8 (02), pp. 229–237, 2015.

[4] S. Sumardiyono, R. Wijayanti, H. Hartono, and A. H. Sutomo, "Noise Industrial Pollution: Health Vulnerabilities on Textile Industry Workers," *J. Kesehat. Lingkung.*, vol. 11, no. 4, p. 267, 2019, doi: 10.20473/jkl.v11i4.2019.267-275.

[5] D. & Sugiharto, "Kebisingan Dan Gangguan Psikologis Pekerja Weaving Loom Dan Inspection Pt. Primatexco Indonesia," *JHE (Journal Heal. Educ.*, vol. 2, no. 2, pp. 130–137, 2017.

[6] R. Eriningsih, M. Widodo, and R. Marlina, "Pembuatan Dan Karakterisasi Peredam Suara Dari Bahan Baku Serat Alam," *Arena Tekst.*, vol. 29, no. 1, pp. 1–8, 2014, doi: 10.31266/at.v29i1.838.

[7] L. . A. D. L. E. D. Maryanti, "Pengaruh Fraksi Volume Komposit Polyester Berpenguat Limbah Serbuk Kayu Bangkirai Terhadap Sifat MAterial Akustik," *Rekayasa Mesin*, p. ISSN 2477-6041,277-285, 2019.

[8] A. Nasution, A. Wahab, and D. Nuari, "Analisis Pengaruh Benang Wol Dan Limbah Batang Pisang Dalam Rancangan Produk Komposit Peredam Bunyi Ruang Akustik," *J. Sist. Tek. Ind.*, vol. 20, no. 2, pp. 53–62, 2018, doi: 10.32734/jsti.v20i2.490.

[9] C. Buratti, E. Belloni, E. Lascaro, F. Merli, and P. Ricciardi, "Rice husk panels for building applications: Thermal, acoustic and environmental characterization and comparison with other innovative recycled waste materials," *Constr. Build. Mater.*, vol. 171, pp. 338–349,

2018, doi: 10.1016/j.conbuildmat.2018.03.089.
[10] S. Komariyah, M. Farid, J. Teknik, and F. T. Industri, "Karakterisasi Sifat Fisik dan Sifat Mekanik Komposit Polyurethane / Serbuk Bambu Sebagai Aplikasi Panel Pintu Mobil," vol. 5, no. 2, pp. 2015–2017, 2016.
[11] E. E. Ahaddin, M. Farid, and V. M. Pratiwi, "Analisa Pengaruh Fraksi Massa Terhadap Kekuatan Komposit Polyurethane / Serat Bambu Betung dengan Metode Hand Lay-up Untuk Aplikasi Door Panel Mobil," *J. Tek. ITS*, vol. 5, no. 2, pp. 32–35, 2016.
[12] R. D. Pratama, M. Farid, H. Nurdiansah, D. Teknik, F. T. Industri, and I. T. Sepuluh, "Pengaruh Proses Alkalisasi terhadap Morfologi Serat Tandan Kosong Kelapa Sawit untuk," vol. 6, no. 2, pp. 250–254, 2017.
[13] R. Bhatnagar, G. Gupta, and S. Yadav, "A Review on Composition and Properties of Banana Fibers," *Int. J. Sci. Eng. Res.*, vol. 6, no. 5, pp. 49–52, 2015, [Online]. Available: http://www.ijser.org
[14] N. Nabila and A. Mahyudin, "Pengaruh Ketebalan Pelepah Pisang terhadap Koefisien Absorpsi Material Akustik," *J. Fis. Unand*, vol. 9, no. 2, pp. 244–249, 2020, doi: 10.25077/jfu.9.2.244-249.2020.
[15] M. K. Bin Bakri, E. Jayamani, and S. Hamdan, "Processing and Characterization of Banana Fiber/Epoxy Composites: Effect of Alkaline Treatment," *Mater. Today Proc.*, vol. 4, no. 2, pp. 2871–2878, 2017, doi: 10.1016/j.matpr.2017.02.167.
[16] S. . M. Khumar.A. P Mishra, "Effect Of Surface Treatment On The Mechanical Propeties Of Bagasse Fiber Reinforced Polymer Composite," *Bio Resour.*, vol. 6(3), pp. 3155–3165, 2011.
[17] F. Ridhola and E. Elvaswer, "Pengukuran Koefisien Absorbsi Material Akustik dari Serat Alam Ampas Tebu Sebagai Pengendali Kebisingan," *J. Ilmu Fis. | Univ. Andalas*, vol. 7, no. 1, pp. 1–6, 2015, doi: 10.25077/jif.7.1.1-6.2015.
[18] R. Fauziah and Y. Darvina, "Effect of the Volume of Banana Fiber As a Polymer Composite Amplifier With Polyester Resin Matrix on the Sound Absorption of Acoustic Materials," vol. 15, no. 1, pp. 44–51, 2022.
[19] K. Syirpia, R. Jonuarti, and Y. Darvina, "the Effect of Variations of Bagasse Sugarcane Fiber Composition With Plastic / Polypropylene Waste Matrix and Paper Sludge Filler on Acoustic Testing on Composite Panels," *Pillar Phys.*, vol. 15, no. 1, pp. 1–9, 2022.
[20] A. F. Firdaus, C. Kencanawati, and I. G. N. Priambadi, "Pengaruh Variasi Fraksi Volume Serat Kulit Buah Pinang dengan Getah Pinus sebagai Biocomposite terhadap Kekuatan Tarik dan Porositas," *J. Ilm. Tek. Desain Mek.*, vol. 8, no. 2, pp. 529–532, 2019.
[21] Fajriyanto and F. Firdaus, "Komposit Limbah Pabrik Kertas (Sludge), Sabut Kelapa Dan Sampah Plastik : Pengaruh Komposisi Bahan Dan Beban Pengempaan Terhadap Kuat Lentur (Bending)," *Semin. Nas. Telknoin 2008*, pp. 55–62, 2008.
[22] E. D. Nurcahya *et al.*, "ANALISA AKUSTIK SEBAGAI DASAR PERANCANGAN RUANGAN STUDIO (Studi Kasus studio Audio Video Recording Akademi Komunitas Negeri Pacitan) Akademi Komunitas Negeri Pacitan PENDAHULUAN Dalam pembelajaran audio video diperlukan sarana berupa ruang kedap suara u," vol. 3, no. 1, pp. 19–28, 2021.
[24] S. ISO, *11654 Acoustical Sound Absorbers For Use in Building Rating of Sound Aabsorption*. 1997.
[25] Lindawati, "KARAKTERISTIK AKUSTIK PANEL SERAT AREN DENGAN BAHAN PEREKAT LATEX Lindawati," *J. Inotera*, vol. 2, no. 1, 2017.
[26] S. ISO, *5636-5 Klasifikasi Nilai Porositas*. 2011.