

EFFECT OF VARIATION IN PINEAPPLE LEAF FIBER COMPOSITION WITH POLYURETHANE MATRIX IN COMPOSITE PANELS ON ACOUSTIC PROPERTIES AND POROSITY

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ABSTRACT

Noise can cause medical, psychological, and environmental disturbances. One of the efforts to reduce noise is by using acoustic materials. Acoustic materials can be made using natural fiber composites. This study uses pineapple leaf fiber as fiber and polyurethane as a matrix that will be formed into a sound-absorbing composite panel. This study aims to determine the effect of variations in the composition of pineapple fiber-reinforced composites with polyurethane matrix on acoustic properties and porosity, determine the effect of frequency on acoustic properties, and determine the relationship between porosity and acoustic properties. The method used in this research uses a characterization tool in the form of a one-microphone impedance tube and porosity test equipment. Composite panels are made by varying the composition of pineapple leaf fibers with polyurethane matrix with the ratio of pineapple leaf fiber composition to polyurethane matrix, namely 50%: 50%, 60%: 40%, 70%: 30%, 80%: 20% and 90%: 10%. Based on the research, it was found that the more the amount of pineapple leaf fiber composition is used, the absorption coefficient, sound transmission loss, and porosity will increase while the reflection coefficient decreases. The higher the frequency used, the absorption coefficient and sound transmission loss will increase while the reflection coefficient decreases for all frequencies. The relationship between porosity and acoustic properties is that the higher the porosity, the absorption coefficient and sound transmission loss will increase while the reflection coefficient decreases.

Keywords : Pineapple Leaf Fiber; Polyurethane Matrix; Composite Panel; Acoustic Materials



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I. INTRODUCTION

Noise is sound pollution which is defined as unwanted sound from human activities at a certain level and time that can cause medical, psychological, and environmental problems. Noise that occurs continuously can harm health such as hearing loss [1]. Sounds with an intensity ranging from 50-55 dB(A) are referred to as noises that can disrupt sleep so that when you wake up you become tired, while sounds with an intensity of 90 dB(A) can disturb the autonomic nervous system. Noise with an intensity of 140 dB(A) can cause vibrations in the head, severe pain in the ears, balance disturbances, and vomiting. Apart from having an impact on health factors, noise also has a psychological impact on individuals exposed to it. The impacts include emotional disturbances such as aggravation and confusion, loss of concentration at work, and so on [2]. Noise is an environmental aspect that needs attention because it includes pollution that is disturbing and originates from sound.

Currently, many efforts have been made to be able to reduce the noise that occurs in a room, namely by using sound-absorbing and sound-absorbing materials. The material in a building usually acts as acoustic panels mounted on the dividing wall (partition) and ceiling. A silencer or absorber is a material that can absorb sound energy from a source. Sound-absorbing materials have an important role in room acoustics, recording studio design, office space, schools, and other spaces to reduce noise which is generally very disturbing [3].

The quality of the sound-absorbing material is indicated by the value of the sound absorption coefficient of the material (α), the greater the α , the better it is used as a sound absorber. The value of α ranges from 0 to 1. If α has a value of 0, it means that no sound is absorbed. Meanwhile, if α is 1, it means that 100% of the incoming sound is absorbed by the material [4]. At this time the sound-absorbing material that is often used is made of synthetic materials such as *glasswool* and *rockwool* which are relatively more expensive. Therefore we need an alternative material that functions to absorb sound that is practical, cheap, and abundantly available in nature. One alternative material that can be used as an acoustic material is natural fiber composites. Composite is a combination of two or more different materials, one as a matrix component and the other as a filler component, where the mechanical properties of each of the forming materials are different, and after mixing a material that is different from the forming material will be deposited [5].

Natural fiber composites used as acoustic materials have many advantages such as being easy to obtain, easy to process, lighter in mass, environmentally friendly, having good acoustic properties, and sufficient elastic modulus [6]. The use of natural materials has the advantage of inheriting the chemical composition and structure of the actual raw materials [7]. Natural fibers generally can absorb sound to reduce noise. Usually in the manufacture of acoustic materials, natural fibers containing *segnecellulose* are used as the basic material in the manufacture of dampers' sound [3]. Materials containing *segnecellulose* have a high absorption of sound [8]. One of the natural fibers that contain *segnecellulose* is pineapple leaf fiber which is around 69.5-71.5% [9].

Pineapple leaf fiber is a type of fiber derived from vegetable fiber plants obtained from pineapple plant leaves. The use of pineapple leaf fiber as a composite material is an alternative to making composites scientifically, where pineapple leaf fiber is well known for its strength, where pineapple leaf fiber has good quality with a smooth surface [10]. In utilizing pineapple leaf fiber as a sound-absorbing material, pineapple leaf fiber will later be processed into composite panels, then testing the acoustic properties and porosity testing of the pineapple leaf fiber composite panels, acoustic testing includes testing the absorption coefficient, sound reflection, and sound transmission loss so that it can be seen how much the pineapple leaf fiber composite panel can absorb sound, reflect sound, and reduce sound. Porosity testing is a test by comparing the volume of space or pores possessed by solid material to the volume of the material itself [11].

To improve the compatibility of fibers as reinforcement in composites, alkali treatment can be carried out on fibers. Alkali treatment is one of the chemical treatments, namely immersion of fiber into an alkaline base to increase the *segnecellulose* content through the removal of hemicellulose, lignin, wax, and oil covering the outer surface of the fiber cell wall. The addition of NaOH to the fiber can promote ionization from hydroxyl groups to alkoxides. Alkali treatment effects on the fiber, which can clean and modify the fiber surface to reduce surface tension and increase the interface adhesion between natural fibers and polymer matrices resulting in better mechanical interlocking [12].

Making acoustic materials from pineapple fiber composites as sound absorbers requires a good adhesive that functions as a matrix. The matrix is the material that binds the fibers together into a structural unit so that the fibers and the matrix are interrelated. The matrix used is generally more elastic but has lower strength and stiffness so that the fibers can adhere to the matrix properly. One of the good materials to be used as a matrix with high adhesion and flexibility is polyurethane. Polyurethane is formed when two reactive chemicals are mixed, namely polyol and diisocyanate after mixing it will form a foam that has high adhesive power when it hardens so polyurethane is very suitable to be used as a fiber binding matrix [13].

Manufacture of acoustic panels from pineapple leaf fiber and polyurethane matrix using the hand lay-up method because this method only uses a small amount of printing equipment, is easy to print, and can adjust the variations and composite compositions easily. The mold used is in the form of an iron plate and the pressure used in the printing process is 200 Mpa or 2×10^8 N/m² [14]. Using emphasis when printing aims to make the resulting sample denser.

Several studies have been conducted related to the sound absorption coefficient of composite materials and natural fibers. One of them was conducted by Hafifah 2022, has researched "Utilization of Pineapple Leaf Waste (Ananas Comosus) for Acoustic Panels as Noise Absorption" which is research to make acoustic materials using pineapple leaf fiber with epoxy resin matrix with a comparison of variations in the ratio of pineapple leaf fiber material with polyurethane matrix is 70: 30, 72.50: 27.50, 75: 25, 77.50: 22.50, and 80:20 tests conducted are sound absorption coefficient test and acoustic impedance test. The results obtained are the value of the sound absorption coefficient and the highest acoustic impedance found in the sample with a ratio of 80: 20 with a frequency of 8000 Hz, which is 0.87 and 1.35 dyne.sec / cm⁵. In general, the more fiber composition is given to the acoustic material, the sound absorption coefficient and acoustic impedance will also increase [15].

Arafah 2021, has researched "Utilization of Flax Fiber (*Boehmeria Nivea*) as a Sound Absorbing Material for House Buildings", namely research using flax fiber, flax fiber waste, and polyurethane matrix as a sound absorbing material for house buildings with variations in the ratio of reinforcing material and matrix of 85:15, 90:10, and 95:5. Evaluation of hemp fiber composites and hemp fiber waste composites includes: tensile strength, density, and sound absorption coefficient tests. The results obtained are the highest tensile strength achieved in the hemp fiber-based composite specimen of 235.2 N at a ratio of 95:5, while in the hemp fiber waste-based composite specimen is 166.6 N at a ratio of 95:5. The highest density value was achieved by the jute fiber composite at 95:5 ratio of 1.7 gr/cm³. The highest sound absorption coefficient at various frequency ranges was achieved by the jute fiber composite at a ratio of 95:5 of 0.988 [16].

From several previous studies, this study developed an acoustic material from pineapple leaf fiber raw materials and polyurethane matrix by varying the composition of the two. Research on the manufacture of acoustic materials from pineapple leaf fibers and polyurethane matrices that are used as sound-absorbing composite panels are chosen because none of the previous studies have conducted research on the manufacture of acoustic materials from pineapple leaf fibers and polyurethane matrices and these two materials after being made into composite panels are very potential to be made into good sound-absorbing materials. Pineapple leaf fiber was chosen because it has the characteristics of high cellulose content, a soft surface, and also has high storage capacity, so this fiber meets the requirements as an acoustic material for sound absorption [17]. The polyurethane matrix was chosen because it has the advantages of being easy to shape and print, flexible, and resistant to friction and impact, not easily damaged, and has a fairly good level of hardness [18]. In this study, the one-microphone impedance tube method and analytical balance scales were used to determine the value of the sound reflection coefficient, sound absorption coefficient, sound transmission loss value, and porosity value.

The impedance tube method, also known as the standing wave tube method, uses the ratio of standing waves to measure the absorption of sound waves by a material surface in an enclosed space. Tube impedance allows measurement under defined and well-controlled conditions, this method is convenient and inexpensive as only a small sample is required and is suitable for testing new samples. The use of this method is based on two standards, namely ISO 10534-2:1998 and American Standard for Testing Materials (ASTM) E1050-98 [19].

II. METHOD

The method used in this research is the Hand lay-up method. It is the simplest method and is a process with an open method of the composite fabrication process. The process of making with this method is by pouring the matrix into woven, knitted, or fabric-shaped fibers, then applying pressure while manually leveling it and then printing it. The process is repeated until the desired thickness is achieved. Some molds that can be used in this method include wood, plaster, or sheet plate. In this process, the matrix is in direct contact with air, and the molding process is usually done at room temperature. The advantages of this method are the little equipment used during molding, the easy molding process, and can easily adjust the variation and composition of the composite [20], and the method using a characterization tool in the form of a single microphone impedance tube for testing acoustic properties and analytical balance scales for porosity testing. This research is included in laboratory-based experimental research. The tests were carried out according to ASTM C 384-4 and ISO 536-5 standards. The material used for the manufacture of composite samples was pineapple leaf fiber with a polyurethane matrix, the composition ratio of pineapple leaf fiber and polyurethane matrix used was 50%:50%, 60%:40%, 70%:30%, 80%:20%, and 90%:10%. The pineapple leaf fiber used has been alkalinized beforehand thereby increasing the interfacial adhesion between the pineapple leaf fiber and the polyurethane matrix resulting in better mechanical interlocking [12].

There are four stages carried out in this study, namely the preparation of materials and sample molds, the stage of making composite samples using the Hand lay-up method, the sample characterization stage using the one-microphone impedance tube method to characterize acoustic properties and analytical balance scales to characterize porosity properties, and the data analysis and processing stage.

The first stage was the manufacture of pineapple leaf fiber. First, the pineapple leaves that will be used as fiber are taken from the pineapple garden in Payakumbuh. Then the pineapple leaves that have been taken are then cleaned using water to remove the dirt that sticks and then soaked for 5 minutes in water. Furthermore, the pineapple leaves are scraped using a thin iron plate so that the pineapple fibers are separated from the pineapple leaves. The leaves that have become fibers are then cleaned using water. After the fiber is cleaned, the fiber is then dried in the sun for 1 day. After drying, the fiber is cut into 3 cm lengths [21]. Pineapple leaf fibers that are 3 cm in size are then soaked in a 5% NaOH solution for 2 hours [22]. Pineapple leaf fibers that are ready to be

soaked and then dried. Finally, the pineapple leaf fiber is ready to use and weighed according to the required dose. Pineapple leaf fibers that are ready to use can be seen in Figure 1:



Fig 1. Pineapple leaf fibers

Based on Figure 1, it can be seen that pineapple leaf processing can produce smooth and clean fibers. Alkali treatment of pineapple leaf fibers affects the fiber, which can clean and modify the fiber surface to reduce surface tension and increase the interface adhesion between natural fibers and the matrix to produce better mechanical interlocking [12].

Sample mold making. The diameter of the sample mold is adjusted to the diameter of the impedance tube of one microphone, which is 9.5 cm with a mold height of 2 cm. The mold used for making samples can be seen in Figure 2:



Fig 2. Composite sample print

It can be seen from Figure 2 that the mold is made of iron with a lid made of wood so that when the sample printing process uses a press tool the sample mold is not damaged and does not change size so that the resulting sample is good and according to size. Making the lid of the wood aims to facilitate the process of removing the sample from the mold, the inside of the mold will also be given a lubricant so that the sample does not stick. after printing the mold must be cleaned immediately from the remaining polyurethane matrix that is still attached to the mold after cleaning the mold can be reused. The printing results can be seen in Figure 3.

The second stage is sample preparation. Composite samples are made from a mixture of pineapple leaf fibers with polyurethane matrices. First weighing Polyisocyanate (A) and Polyol compound (B) according to the dose. Then mix Polyisocyanate (A) and Polyol compound (B). After mixing it will form foam, pineapple leaf fiber mixed with polyurethane that has formed foam then put into the mold. The mold is placed in a felt machine and then pressed with a pressure of $2 \times 10^8 \text{ N/M}^2$ [13]. After the sample is pressed using a felt tool, the sample is removed from the mold and then the sample can be tested further. Samples that have been printed into composite panels with the ratio between pineapple leaf fibers and polyurethane matrices, namely 50%: 50%, 60%: 40%, 70%: 30%, 80%: 20%, and 90%: 10% can be seen in Figure 3:



Fig 3. Composite sample

It can be seen in Figure 3 that the planned sample composition is 50%:50%, 60%:40%, 70%:30%, 80%:20%, and 90%:10%. After making samples, only samples with compositions of 50%:50%, 60%:40%, 70%:30%, and 80%:20% are printed perfectly and can be tested, samples with composition variations of 90%:10% no can be printed perfectly and cannot be tested because the composition of the polyurethane matrix is too little, namely 10% and the composition of pineapple leaf fibers is too much, namely 90% so that the polyurethane matrix is not able to bind and unite all the fibers so that the sample is not formed. Sample testing was carried out using a characterization tool in the form of 1 microphone impedance tube and analytical balance scales.

The third step is to characterize the sample using a single-microphone impedance tube. The impedance tube is very good for characterizing new samples because the acoustic material to be tested using the impedance tube requires only a small amount of material and the operation of the impedance tube is easy. The one-microphone impedance tube used to characterize the acoustic properties of the sample can be seen in Figure 4:



Fig 4. Single microphone impedance tube

It can be seen in Figure 4 that in operation this impedance tube is connected to several devices including amplifiers, oscilloscopes, signal generators, power supplies, microphones, Arduino, and loudspeakers. The loudspeaker is used to generate waves that propagate in the pipe and are then reflected by the test sample. Phase interference between waves in the pipe that are incident and reflected from the test sample will produce a standing pattern in the pipe. Pressure amplitudes at nodes and antinodes are measured using a sliding microphone. The ratio of the maximum pressure (antinode) to the minimum pressure (node) is the Standing Wave Ratio (SWR).

The porosity test is carried out using analytical balance scales which can be seen in Figure 5:



Fig 5. ABT 220-5DM analytical balance scales

It can be seen in Figure 5 that analytical balance scales have an accuracy level of 0.0001 g. To carry out the porosity test, first, the dry sample is weighed, then the sample is soaked in water overnight after soaking the wet sample is weighed. The difference between the wet sample weight and the dry sample weight divided by the dry sample weight will get the porosity value.

The fourth stage is the process of analysis and processing of sample data that has been characterized. The formula used in processing acoustic data using the one-microphone impedance tube method and processing porosity data using analytical balance scales is as follows:

The ratio of standing waves can be found by the equation [23] :

$$SWR = \frac{A+B}{A-B} \quad (1)$$

SWR : Standing Wave Ratio
 $(A + B)$: maximum pressure amplitude
 $(A - B)$: Minimum pressure amplitude

Adjustment can be determined from the following equation [14] :

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

R_{Π} : Reflection coefficient.
 A : Impedance of the incident wave (m).
 B : Impedance of reflected wave (m).
 $SWR-1$: Minimum standing wave ratio (m).
 $SWR+1$: Maximum standing wave ratio (m)

The sound absorption coefficient at certain frequencies can be seen from the following equation [15]:

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

α : Absorption coefficient

The sound transmission loss (TL) can be found using the equation [24] :

$$NR = L1 - L2 \quad (4)$$

$$TL = NR + \log_{10} \frac{S}{A_2} \quad (5)$$

NR : noise reduction (dB)
 $L1$: average sound pressure level in the sound source room (dB)
 $L2$: the average sound pressure level in the receiving room (dB).
 TL : sound transmission loss (dB)
 S : surface area between the sound source room and the receiving room (m²)
 A_2 : total absorption of receiving space

To determine the value of the porosity test using the equation [25] :

$$P = \frac{W_b - W_k}{W_k} \times 100 \quad (6)$$

P : Porosity (%)
 W_b : wet sample weight
 W_k : dry sample weight

III. RESULTS AND DISCUSSION

Samples were made in the form of composite panels by varying the composition of pineapple leaf fiber with a polyurethane matrix, the planned sample compositions were 50%:50%, 60%:40%, 70%:30%, 80%:20%, and 90%:10%. After making samples, only samples with compositions of 50%:50%, 60%:40%, 70%:30%, and 80%:20% are printed perfectly and can be tested, samples with composition variations of 90%:10% no can be printed perfectly and cannot be tested because the composition of the polyurethane matrix is too little, namely 10% and the composition of pineapple leaf fibers is too much, namely 90% so that the polyurethane matrix is not able to bind and unite all the fibers so that the sample is not formed. The tool used to characterize acoustic samples and porosity is the tube impedance of one microphone and the analytical balance scales. In the acoustic test, the frequency variations used are 250 Hz, 500 Hz, 750 Hz, and 1000 Hz. For testing the reflection coefficient, absorption coefficient, and sound transmission loss testing using the impedance tube method with equations (2), (3), (4), and (5), for porosity testing using analytical balance scales with equation (6). Tests were carried out at the Electronics and Instrumentation Laboratory, Faculty of Mathematics and Natural Sciences, Padang State University. The impedance tube is equipped with an amplifier, oscilloscope, signal generator, power supply, microphone, Arduino, and loudspeaker. The sample is placed at the end of the impedance tube and then sound waves are emitted through the sound generator using the audio generator from low to high frequencies. Measurement of the value of the reflection coefficient and absorption coefficient using the standing wave ratio (SWR), namely the ratio of the maximum pressure amplitude to the minimum pressure amplitude which can be seen on an oscilloscope. The sound transmission loss is the difference between the average sound pressure level in the sound source space and the average sound pressure level in the receiving room. The test was carried out with three repetitions. For porosity testing, use analytical balance scales at the Geophysics Laboratory, Faculty of Mathematics and Natural Sciences, Padang State University. The porosity value is obtained by obtaining the difference between the dry sample weight and the wet sample weight then divided by the dry sample weight by equation (8). Porosity testing was carried out three times for each variation of sample composition.

Based on the research, the reflection coefficient value, absorption coefficient value, sound transmission loss value, and porosity value are obtained as follows:

Based on the data obtained, the following results show the average value of the sound reflection coefficient of each variation of the sample composition used, which can be seen in Table 1:

Table 1. The Value of the Sound Reflection Coefficient for Each Variation of the Sample Composition

Frequency (Hz)	Sound Reflection Coefficient Value			
	Pineapple Leaf Fiber Composition Variations: Polyurethane Matrix			
	Composition 50%:50%	Composition 60%:40%	Composition 70%:30%	Composition 80%:20%
250	0,43	0,41	0,38	0,35
500	0,40	0,38	0,36	0,28
750	0,35	0,32	0,31	0,20
1000	0,31	0,28	0,25	0,13

Based on Table 1, it can be seen that the sound reflection coefficient value is the lowest, namely 0.13 at a frequency of 1000 Hz in samples with a composition variation of 80%:20%, while the sound reflection coefficient value is the highest, namely 0.43 at a frequency of 250 Hz in samples with variations composition 50%:50%. The effect of variations in the composition of pineapple leaf fiber with a polyurethane matrix on the value of the sound reflection coefficient in each sample used can be seen in Figure 6:

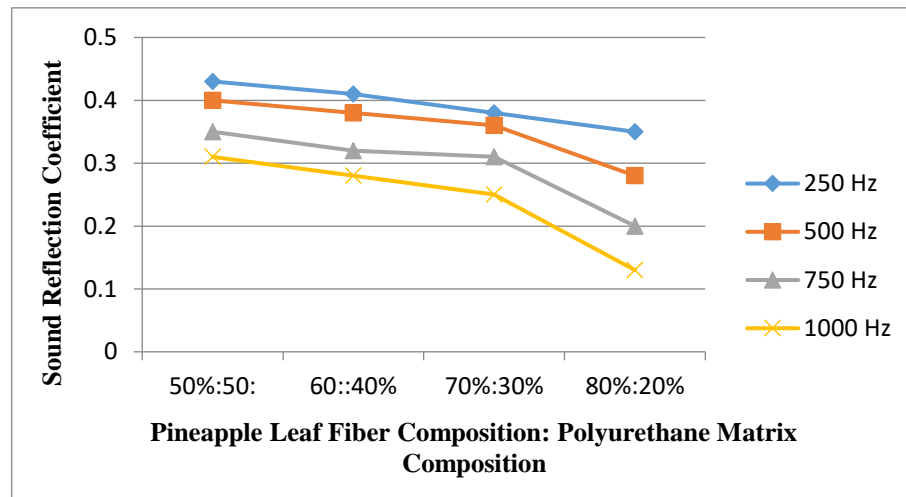


Fig 6. The relationship between variations in the composition of pineapple leaf fiber and the polyurethane matrix on the value of the sound reflection coefficient

Based on Figure 6, When the amount of pineapple leaf fiber is 50%, the reflection coefficient value is very high but after adding pineapple leaf fiber to 80%, the coefficient value decreases and reaches the lowest point, this proves that the more pineapple leaf fiber composition used, the reflection coefficient value will decrease. So the relationship between the sound reflection coefficient value and the addition of pineapple leaf fiber composition is inversely proportional. The addition of fiber can cause a decrease in the coefficient of sound reflection in the composite sample, this is because the fiber added to the composite material matrix can increase the number of pores contained in the sample resulting in more sound absorbed than reflected. Fiber can function as a barrier to reflect sound waves by muffling or absorbing sound, so the reflection coefficient will decrease as the number of fibers used increases [14]. The addition of fiber can cause a decrease in the value of the sound reflection coefficient in the composite sample because the fiber added to the composite material matrix can improve the acoustic properties of the material by increasing the material's ability to dampen or absorb sound. Fiber can function as a barrier to reflect sound waves by muffling or absorbing sound, so the reflection coefficient will decrease as the number of fibers used increases [26].

Based on Figure 6 it can also be seen that the greater the frequency that hits the sample, the reflection coefficient value will decrease for all frequencies. So the relationship between the increase in frequency with the value of the sound reflection coefficient is inversely proportional. An increase in frequency can cause the sound reflection coefficient to decrease because at higher frequencies sound waves have shorter wavelengths. The energy reflected by the surface will be less at higher frequencies because the number of reflections that occur will be reduced. More sound reflection occurs at low frequencies while at high frequencies more sound is absorbed than reflected [26].

Based on the data obtained, the following results show the average value of the sound absorption coefficient for each variation of the sample composition used, which can be seen in Table 2:

Table 2. The Value of the Sound Absorption Coefficient for Each Variation of the Sample Composition

Frequency (Hz)	Sound Absorption Coefficient Value			
	Pineapple Leaf Fiber Composition Variations: Polyurethane Matrix			
	Composition 50%:50%	Composition 60%:40%	Composition 70%:30%	Composition 80%:20%
250	0,56	0,58	0,61	0,65
500	0,60	0,61	0,63	0,71
750	0,65	0,67	0,69	0,80
1000	0,69	0,71	0,75	0,87

Based on Table 2, it can be seen that the lowest sound absorption coefficient value is 0.56 at a frequency of 250 Hz in samples with 50%: 50% composition variation, while the highest sound absorption coefficient value is

0.87 at a frequency of 1000 Hz in samples with 80%: 20% composition variation. The value of the sound absorption coefficient has met the requirements as a sound-absorbing material by ISO 11654 standards. the effect of variations in the composition of pineapple leaf fiber with polyurethane matrix on the value of the sound absorption coefficient in each sample used can be seen in Figure 7:

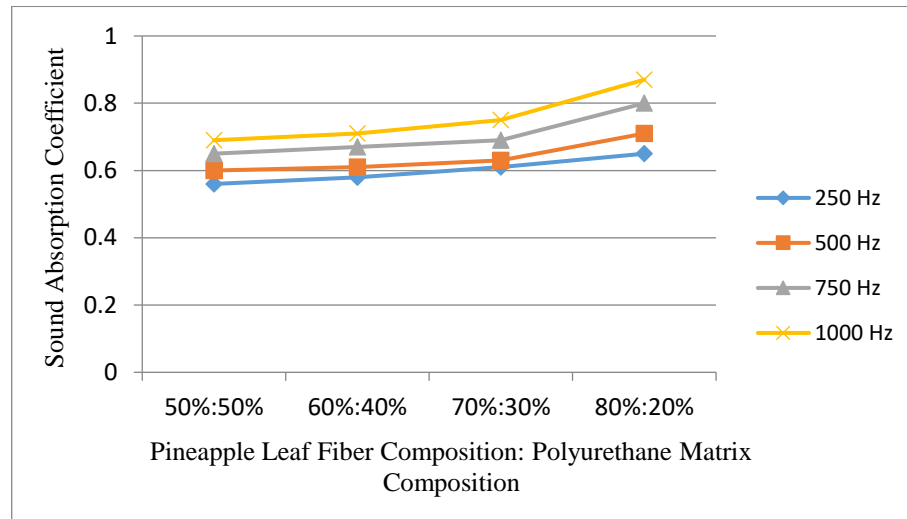


Fig 7. The relationship between pineapple leaf fiber composition variation and polyurethane matrix on the value of the sound absorption coefficient

Based on Figure 7, it can be seen that if more pineapple leaf fiber composition is used, the value of the sound absorption coefficient will increase. So the relationship between the value of the coefficient of sound absorption with the addition of fiber composition is directly proportional. The addition of fiber can cause an increase in the value of the coefficient of sound absorption in the composite sample, this is influenced by the number of pore cavities formed in the sample and the resistance of airflow on the surface of the sample so that the sound waves are absorbed more than reflected. The fiber in the composite material will provide pores in the composite sample. Porous soft materials vibrate easily and the presence of pores causes sound waves to enter the material [17].

Based on Figure 7, it can also be seen that the greater the frequency that hits the sample, the value of the absorption coefficient will increase for all frequencies. So that the relationship between the increase in frequency and the value of the sound absorption coefficient is directly proportional. The higher the frequency used, the value of the sound absorption coefficient will increase because higher frequencies have shorter wavelengths. This means that sound waves can spread and dock more easily through materials or materials that absorb sound. When sound waves propagate through the material some of the sound energy will be absorbed and converted into heat energy, so that the sound will not be reflected, and the higher the frequency fired at the sample, the more sound is absorbed by the pores contained in the sample [26].

The following is a standard classification of sound absorption coefficient based on ISO 11654:1997, as shown in Table 3:

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 Classified	0,10; 0,005; 0,00

(Source: ISO 11654, 1997 [27])

Based on Table 3, all sample variations that have been studied have sound absorption coefficient values above 0.50 and meet ISO 11654:1997 standards as sound-absorbing materials.

Based on the data obtained, the results of the average sound transmission loss for each variation of the sample composition used can be seen in Table 4:

Table 4. Value of Sound Transmission Loss for Each Variation of Sample Composition

Frequency (Hz)	Sound Transmission Loss Value			
	Pineapple Leaf Fiber Composition Variations: Polyurethane Matrix			
	Composition 50%:50%	Composition 60%:40%	Composition 70%:30%	Composition 80%:20%
250	28,03	29,23	31,86	32,46
500	27	28,26	30,13	31,23
750	25,53	26,86	29,76	30,03
1000	30,76	32,33	33,53	34,60

Based on Table 4, the value of sound transmission loss is different for each frequency. It can be seen that the lowest sound transmission loss value is 25.53 dB at a frequency of 750 Hz in samples with a composition variation of 50%: 50%, while the highest sound transmission loss value is 34.60 dB at a frequency of 1000 Hz in samples with a composition variation of 80%: 20%. This proves that composite samples with a composition ratio of (80%: 20%) are good for reducing sound at a frequency of 1000 Hz and composite samples with a composition ratio of (50%: 50%) are less good for reducing sound at a frequency of 750 Hz. The effect of variations in the composition of pineapple leaf fiber with polyurethane matrix on the value of sound transmission loss in each sample used can be seen in Figure 8:

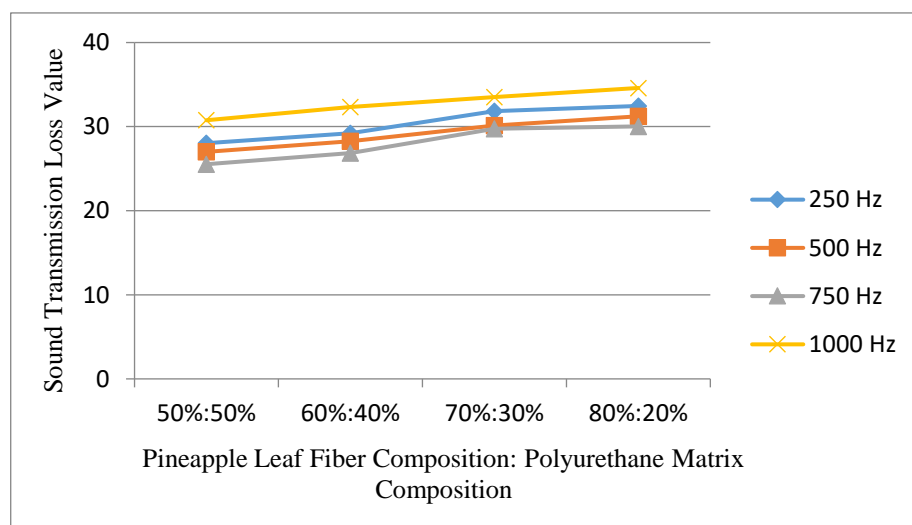


Fig 8. Graph of the relationship between variations in pineapple leaf fiber composition and polyurethane matrix on the value of sound transmission loss

Based on Figure 8, it can be seen that if more pineapple leaf fiber composition is used, the value of the sound transmission loss will increase. So that the relationship between the value of sound transmission loss with the addition of pineapple leaf fiber composition is directly proportional. The addition of fiber can cause an increase in the value of the sound transmission loss in composite samples, this is caused by the addition of the number of fibers resulting in more sound being absorbed and reduced than transmitted so that the value of the transmission loss also increases [28].

Based on Figure 8, theoretically the higher the frequency used, the greater the transmission loss value of the sound produced. However, in this study, the lowest sound transmission loss value produced is at a frequency of 750 Hz. This is caused when testing with a sound level meter connected to the 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 emitted frequency but also from outside. Each frequency is unique in reducing sound energy which states that the reduction in sound energy for each frequency is logarithmic so that it is not always directly proportional to

other frequencies, this is what causes certain frequency points to decrease or increase in sound transmission loss (STL) values and cause inconsistent graphics [29].

Based on the data obtained, the following is the porosity value of each variation in the sample composition which can be seen in Table 5:

Table 5. Porosity Value for Each Variation of Sample Composition

Composition (Fiber : Matrix)	Dry Sample Weight (gr)	Wet Sample Weight (gr)	Difference between Wet and Dry Sample Weight (gr)	Porosity (%)	Average Porosity (%)
50%:50%	71,47	93,07	21,6	30,22	30,20
	71,49	93,07	21,58	30,18	
	71,47	93,06	21,59	30,20	
60%:40%	72,72	103,25	30,53	41,98	41,97
	72,72	103,26	30,54	41,99	
	72,73	103,25	30,52	41,96	
70%:30%	75,02	112,63	37,61	50,13	50,12
	75,04	112,63	37,59	50,09	
	75,02	112,65	37,63	50,16	
80%:20%	74,11	116,34	42,23	56,98	56,95
	74,11	116,32	42,21	56,95	
	74,11	116,31	42,2	56,94	

From Table 5 it can be seen that the lowest average porosity percentage value is 30.20 for the 50%:50% composition variation and the highest porosity average percentage value is 56.95 for the 80%:20% composition variation. This is by the ISO 5636-5 standard which states that a material will have good porosity if the porosity value is above 20%. This indicates that the composite panel sample with a combination of pineapple leaf fiber and a polyurethane matrix has good porosity. The effect of variations in the composition of pineapple leaf fiber with a polyurethane matrix on the porosity value of each sample used can be seen in Figure 9:

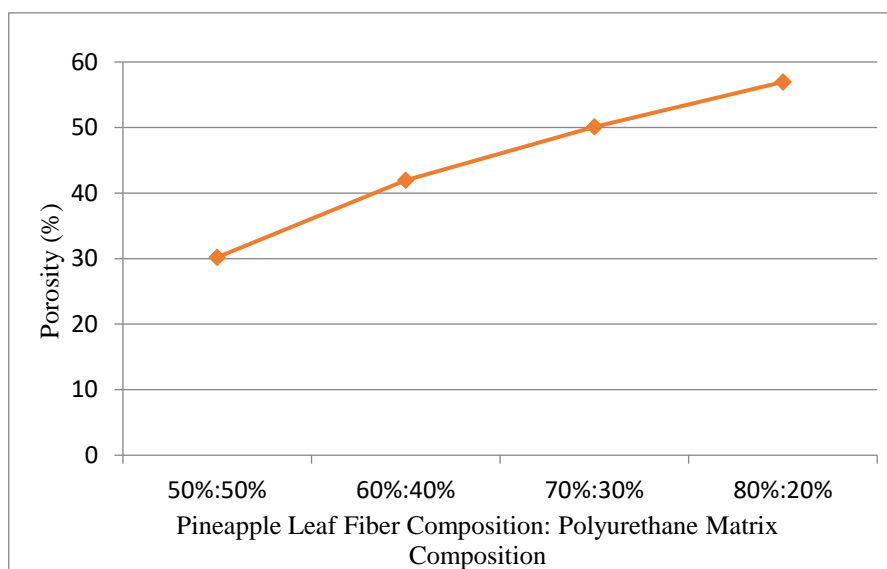


Fig 9. The relationship between pineapple leaf fiber variation and polyurethane matrix on porosity values

Based on Figure 9, it can be seen that if more pineapple leaf fiber composition is used, the porosity value will increase. So the relationship between the porosity value and the increase in fiber composition is directly proportional. This is caused by the more fibers added to a material, the more space or pores will be formed between the fibers. This mainly occurs in fibers that have an irregular arrangement, thus forming cavities between the fiber fibers, besides that the more fibers added to a material can also improve the drainage properties

for the permeability of the material, which can allow liquid or air to flow through the pores of the material more easily [30].

The following can be seen as the standard classification of porosity values based on the ISO 5636-5 standard in Table 6:

Table 6. Classification Standard Porosity Value

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, 2013 [31])

Based on Table 6, all sample variations that have been examined have porosity values above 20% and meet ISO 5636-5 standards as porous materials.

The relationship between porosity value and acoustic properties is that the higher the porosity value, the value of the sound absorption coefficient and the sound transmission loss value will increase while the sound reflection coefficient value will decrease so that the increase in porosity value is directly proportional to the sound absorption coefficient and sound transmission loss value and inversely proportional to the sound reflection coefficient value. This is due to the higher porosity value, the more space there will be in a material to accommodate more sound energy so that more sound is absorbed and reduced than reflected [25]. It is also influenced by the amount of mixing between the resin and the fiber formed, so that the incident sound easily enters the pores if the surface porosity is high, then in the pores, a resonance occurs which causes the incident sound to be converted into heat energy, the remaining energy that has been reduced is reflected by the surface of the material. The pores in the sample are largely determined by the mass ratio between fiber and matrix. A small matrix composition will absorb sound better than a matrix with a large composition because the incident sound waves will be absorbed by materials that contain many pores or materials with high porosity so that the sound waves are absorbed more than reflected.[32]

IV. CONCLUSION

Based on the research that has been conducted on the effect of variations in the composition of pineapple leaf fiber with polyurethane matrix on composite panels on acoustic properties and porosity, there are four conclusions, namely First, if the amount of pineapple leaf fiber composition is higher, the value of the absorption coefficient and the value of sound transmission loss will increase but the value of the reflection coefficient decreases. Second, if the greater the frequency that hits the sample, the value of the absorption coefficient and the value of sound transmission loss will increase but the value of the reflection coefficient decreases. Third, if the amount of pineapple leaf fiber composition is higher, the porosity value will increase. Fourth, if the higher the porosity value, the sound absorption coefficient and sound transmission loss value will increase but the sound reflection coefficient value will decrease.

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