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Acoustic Material Capability of Pineapple (*Ananaa comosus*) Leaf Fibre with PVA (Polyvinyl Alcohol) Ahesive as Noise Absorbent

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Abstract

Noise pollution can harm health if its intensity exceeds the hearing threshold. This research explores pineapple (Ananas comosus) leaf fiber with Polyvinyl Alcohol (PVA) adhesive as an acoustic material to reduce noise. The study measures the sound absorption coefficient using the impedance tube method, varying composition and thickness. For fiber-to-PVA ratios of 7:3, 3:1, 8:2, and 6.5:3.5 at 800 Hz, the absorption coefficients were 0.18, 0.17, 0.37, and 0.18, respectively. Thickness variations of 1 cm, 1.5 cm, and 2 cm produced absorption coefficients of 0.47, 0.65, and 0.73, respectively. Results show that increasing thickness improves sound absorption. Both composition and thickness variations meet ISO 11654 standards, demonstrating the material's effectiveness and eco-friendliness. This study highlights the potential of pineapple leaf fiber as an innovative acoustic material for reducing noise pollution while promoting sustainable solutions.

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1. INTRODUCTION

Sound is a longitudinal wave that propagates through a medium. Sound is created by a vibration that creates a sound system that makes the sound audible to the human sense of hearing [1]. Sound is transmitted through water and air by longitudinal waves, and through solid objects by longitudinal and transverse waves. In longitudinal waves, the particles oscillate along the direction of propagation, while in transverse waves the direction of particle oscillation is perpendicular to the direction of propagation [2]. Sound has two definitions [3]:

1. Physically, sound is the deviation of pressure, the displacement of particles in an elastic medium such as air. This definition is called objective sound.
2. Physiologically, sound is an auditory sensation caused by physical deviations.

There are two main causes that determine the quality of the sound itself, namely frequency and intensity [1]:

1. Frequency is a wave received by humans per second, expressed in units of Hertz (Hz), and every living creature has the ability to receive sound at different frequency levels. Humans can only receive sound in the frequency range of 16-20,000 Hz and most commonly for communication in the range of 250-3,000 Hz.
2. Sound intensity is an energy from the pressure of the sound source in units of decibels (dB) with a range of 0-140 dB.

Noise is a problem that is often found in various areas, such as offices, industries, schools, highways that can disturb human comfort. Noise control is one of the right solutions to overcome noise [4]. Noise control can be in the form of muffling the noise source, creating barriers, or using damping materials. From the various ways that mentioned above to control noise, the right noise control is to use a damping material [5]. The conditions for obtaining good acoustic quality are required as follows [6]:

1. Sound reflectors: For sound reflection used sheets characterized by a hard, firm and flat surface: for example, gypsum board, plywood, plexiglas, fiber and hard plastic.
2. Sound Absorption: Absorption of porous materials is more efficient for high frequencies, the thicker the better for low frequencies. In porous materials there are three types:
   a. Porous materials for acoustics that are available on the market and ready to use.
   b. Acoustic plastic-plastering porous material.
   c. Porous fabric and carpet
3. Sound dampening: By paying attention to the properties of acoustic materials, it is hoped that it can help get clear

sound like the original.

a. Panel absorption: It is positive because it produces evenly distributed reverberation characteristics and functions as an evenly distributed reverberation absorption and functions as a low frequency absorber, suitable for small rooms. The negative aspect of the material is that it is less resistant to scratches.
b. Space Absorbers: The material is easy to install and move using a hanging system.
c. Variable Absorption: used for rooms that require variable Reverbation Time, its function as a reflector and absorber. Variable absorption is widely used in TV studios, radio and media partners because the sound can be adjusted according to the arrangement.
d. Cavity resonator Serves for maximum absorption of sound energy in a narrow frequency region. The noise control measure for continuous noise without a significant sound source appearing is not to exceed 40 dB

Damping materials can use natural fibers made in composite form [5]. In developing countries, sound absorbing materials that widely developed are made from natural and recycled materials [7]. One of the natural fibres that can be used as a sound absorbing composite is pineapple *(Ananas comosus)* leaf fibre because it has a porous structure and is able to absorb sound waves. Pineapple leaf fibre also has environmentally friendly characteristics and abundantly available as agricultural waste [8]. Pineapple is a fruit that is produced in large quantities in several countries around the world, and therefore generates a lot of agro-industrial waste, such as its natural fibers found in its leaves [9].

To produce an effective sound absorbing composite, a good adhesive is required to bind the pineapple leaf fibres in the composite structure, one of it is *Polyvinyl alcohol* (PVA). PVA is a non-toxic, water-soluble, biodegradable, and biocompatible synthetic polymer commonly used in medical research. PVA has unique characteristics, so it is widely used such as for membrane preparations, drug delivery control systems and recycled polymers [10].

Sound absorption is a process of absorption or reduction of sound energy using friction in the pores of porous materials, vibration of plates or membranes that form an air layer between the plates and steel walls, and resonator-based absorption devices [11]. The sound absorption process is related to the decrease in the amount of sound energy from the air that travels until it hits a porous or flexible medium. When an incoming sound wave meets a boundary surface that separates two regions, the sound wave will be reflected (R) and absorbed/transmitted (α), and the possibilities that occur are [12]:

1. Reflected all (R = 1), meaning that the wave is reflected back then the efficiency value R = 1 or the reflection coefficient (R) is 1.
2. Transmitted/absorbed all (α = 1), meaning that if the incident wave is absorbed all, then the value of the absorption coefficient (α) is 1.
3. If part of the wave is reflected and part is transmitted/absorbed, the value of the absorption coefficient is ($0 < \alpha < 1$).

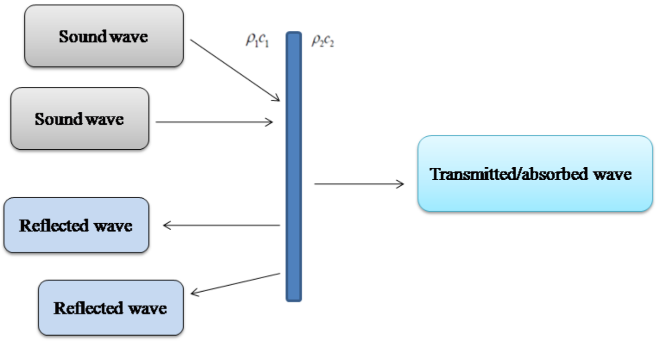

Figure 1. Reflection and absorption of acoustic materials [13]

In this study, acoustic materials were made from pineapple leaf fibre by adding PVA as an adhesive. The purpose of this study is to determine the ability of acoustic material from pineapple leaf fibre with PVA adhesive through measurement of sound absorption coefficient with composition variation and thickness variation using impedance tube method. The purpose of this research is to measure the value of the sound absorption coefficient using the impedance tube method with variations in composition and thickness.

2. RESEARCH METHOD

Immersion of Pineapple Leaf Fibre (Figure 2.):

(a) Prepare pineapple leaf fibers
(b) Put the pineapple leaf fibers into a container, then soak the pineapple leaf fibers in NaOH solution for 2 hours
(c) Then, wash the pineapple leaf fibers under running water
(d) Pineapple leaf fibers that have been rinsed are then dry under sunlight

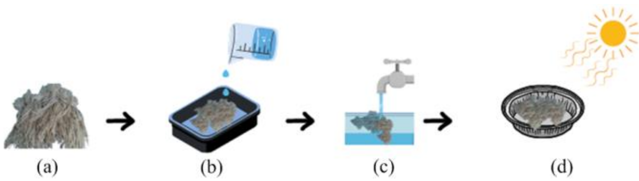

Figure 2. Soaking of Pineapple Leaf Fibre

Preparation of 5% PVA Solution (Figure 3)

(a) Prepare PVA powder
(b) Weigh 10 grams of PVA
(c) Dissolve it in 200 ml of distilled water
(d) Next, a magnetic stirrer was used to mix the PVA at 80°C with a speed of 200 rpm for 1 hour. After reaching room temperature, the PVA solution can be used in the composite manufacturing process.

Acoustic Material Manufacture (Figure 4)

Preparation of Pineapple Leaf Fibre *(Ananas comosus)* Acoustic Material with PVA Adhesive The composite material was made from pineapple leaf fibre (*Ananas comosus)* with

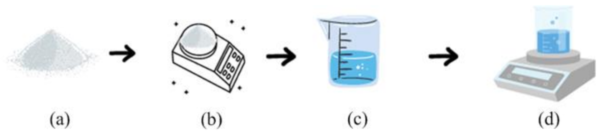

Figure 3. Preparation of 5% PVA Solution

s(PVA). Pineapple leaf fibre was first oaked with 5% NaOH for 2 hours, then wash under running water, and dry under sunlight. Pineapple leaf fibre that has gone through the soaking and drying process is then cut into small pieces. Next, mix the pineapple leaf fibre with (PVA) in a container according to the composition variation according to the table 1, and the thickness variation according to table 2. In the thickness variation, use a composition variation by adding 2 times the sample composition C.

(a) Dried pineapple leaf fibers
(b) Then, cut the pineapple leaf fibers ±1 cm
(c) Mix the pineapple leaf fibers with PVA
(d) The composite that has been mixed evenly is inserted into a 10 cm diameter mould. Then, it is pressed evenly on its surface.
(e) The composite that has been pressed evenly is dried in a microwave at 65°C for 4 hours.
(f) The ready composite will then be tested for its sound absorption ability.

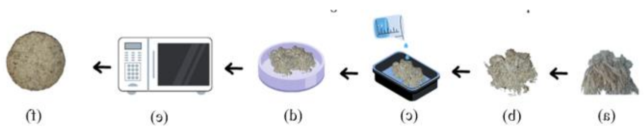

Figure 4. Acoustic material manufacturing

Table 1. Variation of Pineapple Leaf Fibre Composition with PVA

Sample	PVA (%)	Pineapple Leaf Fibre (%)	PVA (ml)	Pineapple Leaf Fibre (g)
A	70	30	35	15
B	75	25	37,5	12,5
C	80	20	40	10
D	65	35	32,5	17,5

Table 2. Thickness Variation of Pineapple Leaf Fibre with PVA

Sample	PVA (ml)	Pineapple Leaf Fibre (g)	Thickness (cm)
E	80	20	1
F	120	30	1,5
G	160	40	2

Testing the Coefficient of Sound Absorption (Figure 5)
The sound absorption coefficient test was conducted using an impedance tube. The sample was placed in a holder on a 10 cm diameter impedance tube. The impedance tube is switched on by giving a sound source connected to an amplifier. The impedance tube used is an impedance tube with a maximum frequency of 125 Hz - 1600 Hz. The sound from the amplifier will enter the impedance tube through the cable connected to the speaker on the impedance tube. The sound from the speaker moves towards the material in the holder and the complex transfer of sound pressure on the two microphones. The sound that is not absorbed by the material will be captured by the microphone on the impedance tube and the result of the sound absorption coefficient will immediately appear on the computer through the pulse. The results are in the form of numbers and can be converted into graphical form using the excel application on the computer.

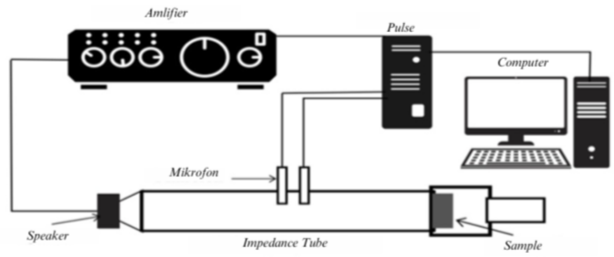

Figure 5. Illustration of measurement using an impedance tube

3. RESULTS AND DISCUSSION

Sound absorption coefficient (α) is the ratio of absorbed sound energy to incoming sound energy. The greater the α value, the better the sound absorption and attenuation. The value of α ranges from 0 to 1. If α is 0, the sound is not absorbed. If α is more than 0 but less than 1, the sound is partially absorbed and partially reflected or transmitted. If α is 1, the sound is completely absorbed [14].

Sound Absorption Coefficient with Variation in Composition

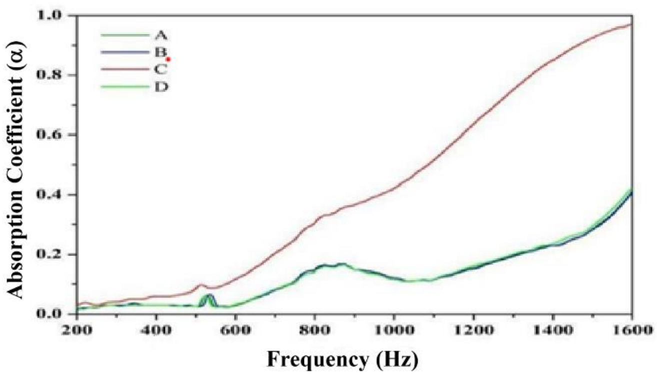

Figure 6. Graph of the relationship between composition and sound absorption coefficient value

Figure 6 shows that samples A and B with variations in composition only work well at a frequency of 800Hz, namely sample A has an absorption coefficient (α) of 0.18, while for sample B it is 0.17. Shows that sample C has an absorption coefficient of 0.37 at a frequency of 800 Hz, and sample D has an absorption coefficient of 0.18. The factor that affects the value of the absorption coefficient in sample C is due to thickening in several places on the surface of the sample, which covers the pores and reduces the ability of the sample to absorb sound. As a result, the louder the sound, the more the material tends to reflect it.

Sound Absorption Coefficient with Thickness Variation

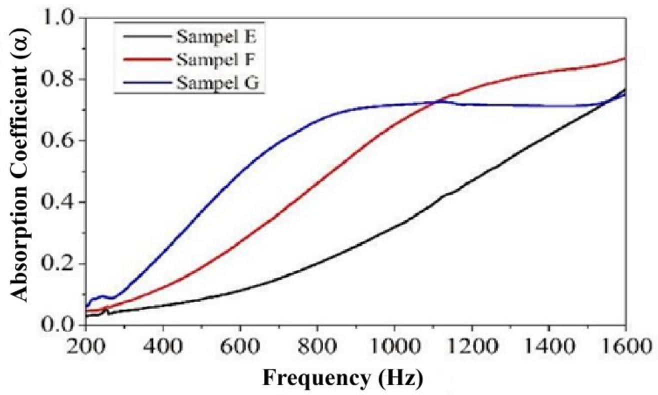

Figure 7 Graph of the relationship between thickness and sound absorption coefficient values

Graph 7 shows that the sound absorption coefficient value in sample E with a thickness of 1 cm obtained a coefficient value of 0.47, sample F with a thickness of 1.5 cm obtained 0.73 while in sample G with a thickness of 2 cm obtained a coefficient value of 0.65. Acoustic materials in samples E, F and G on average can absorb the maximum in the frequency range 800-1600 Hz. Based on the value of the sound absorption *coefficient of the* three thickness variation samples obtained in the frequency range of 800-1600Hz has met the standards of the *International standardization organization* (ISO) 11654 states that a silencer material can be said to absorb sound well if the *Noise absorption coefficient* (NAC) value is more than 0.15.

Factors affecting the value of the sound absorption coefficient in composition variations and thickness variations are when making acoustic materials; the sample is pressed manually, so the sample surface is uneven and when mixing *Polyvinyl Alcohol* (PVA) is not mixed on the fibre properly, so there is thickening at a certain point on the sample surface. As a result, at that point the pores of the sample are closed and cause a reduction in the sound intensity value. The louder the sound, the more a material tends to reflect.

Based on the value of the sound absorption coefficient of acoustic material composition variations and thickness variations obtained in the frequency range 800-1600 Hz has met the *standards of the International standardization organization* (ISO) 11654 states that a silencer material can be said to absorb sound well if the *Noise absorption coefficient* (NAC) value is more than 0.15 [15].

4. CONCLUSIONS

Based on the results of the research conducted, it can be concluded that the highest acoustic material sound absorption coefficient value in the composition variation is in sample C with a frequency of 800 Hz. While in the thickness variation, the highest sound absorption coefficient value is in sample F with a frequency of 800-1600 Hz. The more pineapple leaf fibre and PVA used, the absorption coefficient value also increases.

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