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The Mechanic and Acoustic Properties of Pineapple Leaf Fibers With Paper Waste As An Absorbing-Composite

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Keywords:

Composite;
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Sound absorption;
Impact strength.

ABSTRACT

Noise-absorbing composite is a material used to reduce noise. Natural product-based composite can be an alternative to replace synthetic fiber because of its advantages of high strength, toughness, low price, and abundance. The materials used were pineapple leaf fibers with paper waste. This research aims to study the advantage of natural products to reduce noise by analyzing the coefficient of sound absorption and impact strength to evaluate the absorbing composite. The characterization of sound absorption was carried out using an impedance tube at a frequency range of 250 – 3000 Hz and the impact strength was carried out using the Charpy method. The volume fraction of pineapple leaf fibers, paper waste, and resin epoxy concentrations were 20%:30%:50%, 25%:25%:50%, and 30%:20%:50%. The thickness for the sound absorption coefficient was 2 cm and 3 cm, while the thickness of the impact strength was 0.5 cm. The highest sound absorption coefficient of pineapple leaf fibers composite for 30%:20%:50% volume fraction was 0.788 for sample 2 cm. The highest impact strength for 20%:30%:50% volume fraction of the thickness of 0.5 cm was 3.527 J/mm2. The results of the sound absorption coefficient will increase if used more pineapple leaf fibers but it will decrease the impact strength.

INTRODUCTION

Noise pollution from traffic and industries may generate noise difficulties and disrupt or decrease human hearing capabilities. Noise pollution is one of the pollutants created by modern life and it may be particularly hazardous (Oguntunde, *et al.*, 2019). Noise pollution has the potential to harm fetuses, babies, children, and adults. Noise pollution has an impact on both physical and emotional health. The noise exposure causes psychomotor effects by increasing stress, disrupting sleep, causing difficulty in normal conversation, lack of concentration, irritability, violent behavior, increased heart rate commonly observed with loud drum beats, tachyarrhythmia, vasoconstriction, hypertension, and other diseases (Gupta, *et al.*, 2018). Installing sound-absorbing materials in buildings can help to minimize noise pollution.

Noise-absorbing materials are used to minimize noise because they comprise a filler that acts as an amplifier and a matrix that binds the fillers together. Alternatives to pineapple leaf fibers and paper waste that might be utilized as noise-absorbers in this study include pineapple leaf fibers and paper waste. The filler of the composite is usually a material that has the desired properties of the final composite product, this filler will be able to add to the properties possessed by the

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Commented [A9]: Apa alasan penggunaan serat daun nanas dan limbah kertas? Berikan penjelasan matrix such as mechanical, acoustic, electrical, and type strength. Fillers can be derived from natural or synthetic products, each of which has its advantages when used as a filler (Gibson, 2016). The usage of synthetic fiber is harmful to the environment and results in the accumulation of non-biodegradable trash. Natural fibers might be utilized as an alternative to synthetic fibers due to their benefits of high strength, toughness, low cost, and availability, as well as being clean and biodegradable. Pineapple leaf fibers and paper waste are still underused and end up in landfills (Juhana, 2020).

The study on the use of pineapple leaf fiber concrete composite as a noise-absorbing material generated a sound absorption coefficient value of 0.59 at a frequency of 2000 Hz (Arwanda, 2020). At a frequency of 800 Hz, the sound absorption coefficient of the paper waste, rice husk ash, and resin polyester-based composite was 0.48 (Isran & Kadir, 2018). Composites reinforced with natural fibers have a high impact strength value; for example, research using palm fiber with a 9% volume fraction gives a value of 32.7 kJ/m^2 (Surono & Sukoco, 2016). Another study using rami fiber as a composite obtained an impact strength of 0.0725 J/mm^2 (Purboputro & Hariyanto, 2018).

The excellent absorption ability was demonstrated by a composite with a low impact strength value. As noise absorbers, a few layered composites with pores were utilized. The composite may be used on walls, box speakers, and other surfaces. The sound wave that strikes the material's surface will be reflected, transmitted, and absorbed (Gonzalez, 2019). The sound wave absorbed by the material produces a drop in sound wave strength and absorbed energy, which is referred to as the sound absorption coefficient.

The fracture strength test is used to determine the toughness of a composite when it's forced to a rapid force as a result of a collision. The impact strength test is used to determine the material's physical characteristics as well as the ductility of the composite that has been created. The basic idea behind rupture testing is to compute the energy provided by the load and the energy absorbed by the sample. When the load possesses potential energy, which occurs when the weight is increased to a particular height, the maximum kinetic energy occurs. The Charpy and Izod techniques are used to determine impact strength. The distinction between the Charpy and Izod techniques lies in the location of the specimen to be evaluated. In the Charpy technique, the specimen is placed horizontally. Meanwhile, with the Izod technique, the specimen position is vertical (Callister, 2019). The high porosity of sawdust and pineapple leaf fiber, as well as its high cellulose content, are benefits of this material as a sound wave-absorbing composite.

METHODS

Pineapple leaf fibers, paper waste, and epoxy resin were used in this study. The pineapple leaf fibers and paper waste were chopped into little pieces. Water was used to soak and crush the paper waste. Epoxy resin is combined with hardener, then each reinforcement (pineapple leaf fibers and paper waste) is added to the resin and stirred until homogenous before pressing it with a hydraulic press. The composite thickness for the sound absorption test is 2 cm and 3 cm, while the composite thickness for the impact test is 0.5 cm.

Impact and sound absorption tests have been performed. The research's design is shown in Figure 1.

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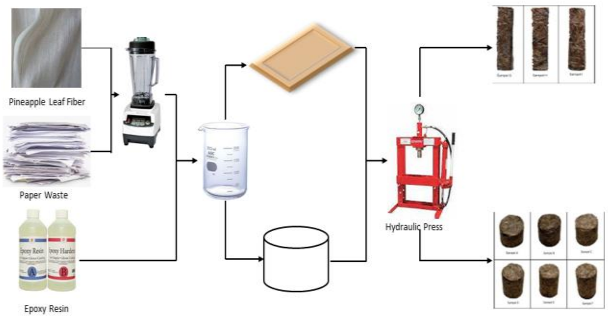
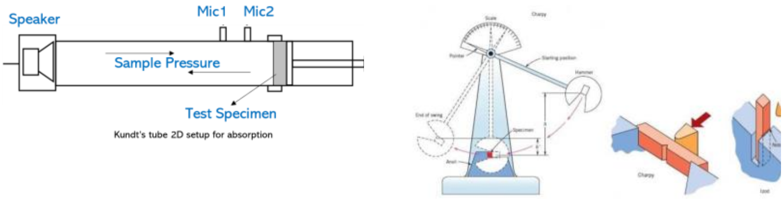


Figure 1. Research's design

Sound absorption coefficient measurements are performed by measuring the intensity level before (I_1) and after (I_2) passing through the absorbent material (I_2). The frequency ranges from 250 to 3000 Hz. The impact test is performed by swinging the weight on the test equipment until the composite breaks. The sound absorption coefficient and impact strength were determined with standard ISO 11654 and ASTM E23. The illustration of sound absorption coefficient and impact strength is shown in Figure 2.



(a) **(b)**

Figure 2. Illustration of the test used, (a) Sound absorption coefficient (b) Impact strength

RESULTS AND DISCUSSION

The impedance tube method was used for the sound absorption test, in which the sound source from the speaker was linked to a generator with a frequency range of 250 to 3000 Hz. Figure 3 depicts the relationships between the sound absorption coefficient and the frequency of the sample.

The sound absorption coefficient is the value possessed by the material in absorbing sound waves. According to ISO 11645 acoustic materials that are categorized as having sound absorption capacity are materials with a sound absorption coefficient greater than 0.15 (ISO, 1997). The relationship between the sound absorption coefficient and the thickness of the material is written in Equation 1

$$I = I_0 e^{-ax} \quad (1)$$

where I is the final intensity (dB), I_0 is the initial intensity (dB), α is the sound absorption coefficient, and x is the thickness of the sample (m). From Equation 1 it can be seen that the thickness of the material will affect the sound absorption coefficient, in addition to the thickness of the other factors that affect the porosity and density of the material (Li & Ren, 2011). Porosity will cause sound waves to be reflected in the cavities of the material so that its energy will

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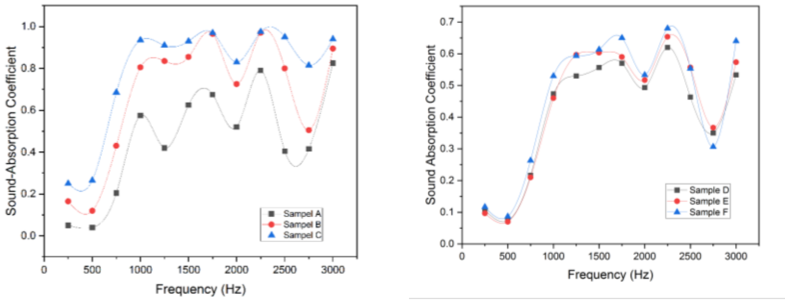
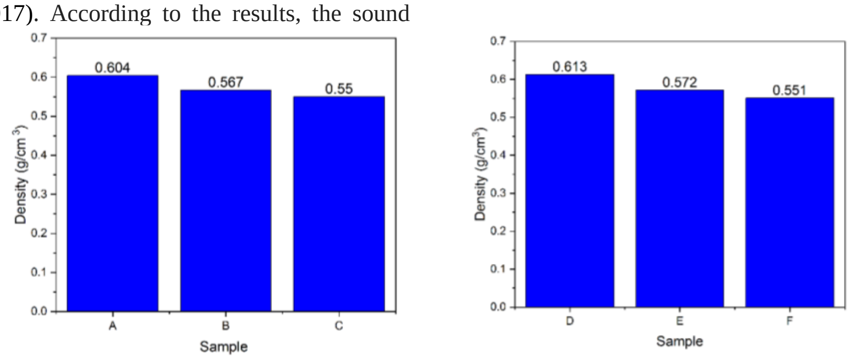


(a) **(b)**

Figure 3. The sound absorption coefficient at the frequency range of 250-2000 Hz, (a) The samples with 2 cm thickness (b) The samples with 3 cm thickness

The average sound absorption coefficients for A, B, and C with samples thickness of 2 cm were 0.462, 0.672, and 0.788, respectively. While the average sound absorption coefficients for D, E, and F with samples thickness of 3 cm were 0,415; 0,420; and 0,464, respectively. As shown in Figure 3. Figure 3 demonstrates that the sound absorption coefficient increases as the frequency ranges from 500 to 1750 Hz. At a frequency of 2000 Hz, the value of the sound absorption coefficient decreases. The sound absorption coefficient decreases because the particles are saturated, resulting in energy loss and destructive interference (Rus, *et al.*, 2017). According to the results, the sound absorption coefficient increased with the addition of fiber (Kirana, 2016). The value of the sound absorption coefficient can be impacted by the resonance that occurs in the composite cavity. Because of the resonance, some of the sound waves are unable to leave the sample cavity, reducing the reflected wave energy (Arwanda, 2020). The unevenness of the composite composition harms the sound absorption coefficient (Sandi, *et al.*, 2020). It generated a space between molecules on the sample, resulting in high porosity and low density. Figure 4 depicts a density sample (Arwanda, 2020). The density sample is shown in Figure 4.



(a) (b)

Figure 4. The density of Pineapple leaf fibers with paper waste, (a) Composite with a thickness of 2 cm (b) Composite with a thickness of 3 cm

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The densities of the samples from A, B, and C for the thickness of the samples 2 cm were 0.604 g/cm^3, 0.567 g/cm^3, and 0.550 g/cm^3, respectively. The densities of samples thickness of 3 cm from D, E, F samples were 0,613 g/cm^3; 0,572 g/cm^3; and 0,551 g/cm^3 as shown in Figure 4. Density causes sound waves to interact with the pores in the sample, causing the energy to drop (Elvaswer & Ridhola, 2015). The denser the sample, the more difficult it is for the sound wave to pass through the material, resulting in a lower sound absorption coefficient (Hardiana, *et al.,* 2021). Mechanical characteristics are essential for sound-absorbing composites. The impact strength test is used to determine a material's capacity to absorb energy during a collision, as shown in Figure 5.

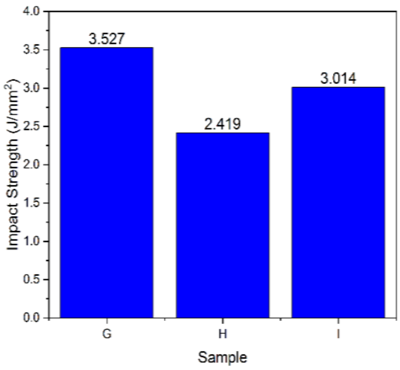

Figure 5. The impact strength value of pineapple leaf fibers with paper waste composite

The impact strengths of the G, H, and I samples were 3.527 J/mm^2, 2.419 J/mm^2, and 3.014 J/mm^2, respectively, as shown in Figure 5. The materials of pineapple leaf fibers with paper waste composite are brittle and have a high density, resulting in a high impact strength value, as shown in Figure 6.

Figure 1. The example of an image of the spectrum absorption coefficients of organic semiconductor materials

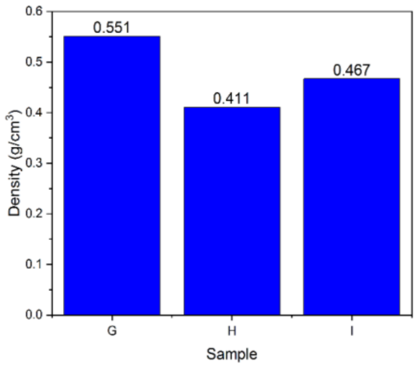

Figure 6. The impact strength density of pineapple leaf fibers with paper waste composite

Figure 6 indicated that the higher the density, the higher the impact strength. The density of the sample will increase as the concentration of paper increases. As a result, the sample would be difficult to break. The low density of composite has a low impact strength value, which causes voids or holes to form on each material bond and makes composites more brittle. In composites, the uneven component concentration resulted in the formation of voids and weakened the connection between filler and matrix (Hardiana, *et al.*, 2021).

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CONCLUSION AND SUGGESTION

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Based on the results of this study, it is possible to conclude that:

a. More pineapple leaf fibers with a low amount of paper waste would enhance the sound absorption coefficient but reduce the impact strength.
b. The higher the density of the material, the lower the sound absorption coefficient and impact strength value.
c. The sound absorption coefficient of pineapple leaf fibers with paper waste is 0.462, 0.672, and 0.788 for the sample A, B, and C, respectively, while the average

sound absorption coefficients for D, E, and F with samples thickness of 3 cm were 0,415; 0,420; and 0,464, respectively. The impact strength of samples G, H, and I were 3.527 J/mm^2, 2.419 J/mm^2, and 3.014 J/mm^2.

ACKNOWLEDGMENTS

The author would like to thank the Ministry of Education, Culture, Research and Technology, Republic of Indonesia – BRIN Tahun 2021. This research was supported by a research grant of "Riset Peningkatan Kompetensi", Universitas Jenderal Soedirman.

AUTHOR CONTRIBUTIONS

The Author Contributions Statement can be up to several sentences long and should briefly describe the tasks of individual authors. Please list only 2 initials for each author, without full stops, but separated by commas (e.g. AS, AA). In the case of two authors with the same initials, please use their middle initial to differentiate between them (e.g. ATS, ASS). The Author Contributions Statement should be included at the end of the manuscript before the References.

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TABLE CONTENT OF REVISIONS

Comment [A]	REVISION
1	Corresponding Address : kartika.sari@unsoed.ac.id
2	The composites were tested with the Charpy method with ISO 11654 standard and ASTM E23 for sound absorption and impact strength. Sound absorption was carried out using an impedance tube at a frequency range of 250 – 3000 Hz.
3	It will improve the quality of the composite as an absorbing material as well.
4	Have done
5	Have done
6	Have done
7	Have done
8	Have done
9	Pineapple leaf fiber is one of the organic wastes, this fiber can be used as a sound absorber because of its high cellulose content. The cellulose content in pineapple leaf fiber is 55.1%. Then, the waste paper that is used as pulp has a porous morphology. The combination of cellulose and pore content of pineapple leaf fiber and paper waste makes these two wastes very potential to be developed as sound-absorbing composites (Fareez et al., 2018; Jain & Sinha, 2021; Nair & Dasari, 2022).
10	Have done
11	Have done
12	Have done
13	Have done
14	Have done
15	Have done
16	Have done
17	1. Correlation the other research : The composite of pineapple leaf fibers has a sound absorption coefficient of 0.9 in 1 kHz frequency (Putra et al., 2018). The other study using rami fiber as a composite obtained an impact strength of 0.0725 J/mm2 (Purboputro & Hariyanto, 2017). 2. Novelty : In this research, pineapple leaf fiber was combined with paper waste to create an absorbed composite. The addition of paper waste affected the structure and properties of the composite, paper waste is utilized to create a foam-like material with properties similar to conventional foam to make the composite structure more porous (Astrauskas et al., 2021). The impact test determined the mechanical properties of the composite.
18	Fig. 2 (a) demonstrates the test of sound absorption. The sound waves were generated from speakers with a specific frequency and sound waves will hit the sample. Some of the frequencies will be absorbed by the sample, but some will

<table>
<tr><td></td><td>be reflected because they cannot pass through the sample's pores. The sound waves that pass through the sample pores will be recorded by a detector (mic) due to sound absorption. The transfer function techniques, as well as the two-microphone technique, were applied. The frequency ranges from 250 to 3000 Hz.</td></tr>
<tr><td>19</td><td>Have done</td></tr>
<tr><td>20</td><td>Fig 2(a).
Fig. 2 (a) shows the test of sound absorption. The sound waves were generated from speakers with a specific frequency and sound waves will hit the sample. Some of the frequencies will be absorbed by the sample, but some will be reflected because they cannot pass through the sample's pores. The sound waves that pass through the sample pores will be recorded by a detector (mic) due to sound absorption. The transfer function techniques, as well as the two-microphone technique, were applied. The frequency ranges from 250 to 3000 Hz.
The ratio between pressures were create by wave sound on the microphone was calculated with transfer function (H_{12}):
$$H_{12} = \frac{p_1}{p_2} \quad (1)$$
$$H_I = \frac{p_{I1}}{p_{I2}} = e^{-jk_0(x_1-x_2)} \quad (2)$$
$$H_R = \frac{p_{2R}}{p_{1R}} = e^{-jk_0(x_1-x_2)} \quad (3)$$
H_I is the transfer function of the incident wave alone and H_R is the transfer function of the reflected wave. The coefficient of the reflected wave was calculated from equation (1) – (3):
$$R = \frac{H_{12} - H_1}{H_R - H_{12}} = e^{-jk_0(x_1-x_2)} \quad (4)$$
where R is the coefficient of the reflected wave, k is the wavenumber, and x is the distance between the microphone and the sample. The coefficient of reflected was used to calculate the sound absorption coefficient in the following expression:
$$\alpha = 1 - |R|^2 \quad (5)$$

Fig 2(b).
The impact strength test in Fig 2 (b) is used to determine the material's physical characteristics as well as the ductility of the composite that has been created. The basic idea behind rupture testing is to compute the energy provided by the load and the energy absorbed by the sample. When, the load possesses potential energy, the weight is increased to a particular height, the maximum kinetic energy. In the impact test, a notched test specimen is used which is struck with a pendulum. The specimen is clamped at one end until the notch is near the clamp in the Izod technique. A pendulum swinging from a certain height will strike the end of the specimen that is not clamped from the front of the notch.
In the Charpy test, the specimen is placed horizontally both ends are held, and the pendulum will hit the test rod from behind the notch. The impact energy can be seen on the scale of the testing machine. The magnitude of the impact energy theoretically can be calculated :</td></tr>
</table>

	$$E_0 = W \times h_0 \quad (6)$$ $$E_1 = W \times h_1 \quad (7)$$ $$\Delta E = E_0 - E_1 = W(h_0 - h_1) \quad (8)$$ from Fig. 3 obtained that: $$h_0 = l - l\cos\alpha \quad (9)$$ $$= l(1-\cos\alpha) \quad (10)$$ $$h_1 = l - l\cos\beta \quad (11)$$ $$= l(1-\cos\beta) \quad (12)$$ Finally, the impact energy was calculated with the following expression: $$\Delta E = W \times l(h_0 - h_1) \quad (13)$$ where E is energy (J), W is pendulum weight (N), h is pendulum height before-after released (m), l is pendulum length (m), α and β are angle before-after (°). The impact strength (I_s) was calculated by impact energy divided by cross-section area (A): $$I_s = \frac{\Delta E}{A} = \frac{W \times l(h_0 - h_1)}{A} \quad (14)$$
21	Have done
22	Have deleted
23	The volume fraction of pineapple leaf fibers, paper waste, and resin epoxy concentrations were 20%:30%:50%, 25%:25%:50%, and 30%:20%:50% for samples A, B, and C with the thickness of 2 cm, respectively. The thickness of samples D, E, and F is 3 cm with the same volume fraction.
24	Have explained in the method
25	This study shows that the combination of pineapple leaf fiber and paper waste can be used as a sound-absorbing material, and waste materials. It can reduce the environmental pollution, either organic pollution or noise pollution. The combination of pineapple leaf fiber and paper waste will improve the quality of the composite as an absorbing material as well. The next study to measure the optimum film's thickness and the thermal properties to get complete information was needed.
26	The pineapple leaf fiber and paper waste reinforcement composites can be used as sound-absorbing materials. The addition of fiber in the composite makes the absorption coefficient increase, but the mechanical properties decrease. The sound absorption coefficient increases due to the cellulose content and the structure of the fibers. Pineapple leaf fiber in the form of lamina affects on the mechanical properties. The paper waste in the form of particles will create a porous structure which has an impact on sound absorption. The arrangement of elongated-fibers makes the load-received by the composite spread evenly on other fibers. The porous structure causes sound waves-reflected in the pores thereby reducing energy. The pores capture the sound waves that pass through the composite. The pores and fibers interface can be seen through the density of the material. The high density indicates that the fiber's interface was closer and the pores formed are small so that the relationship between pores and fiber's arrangement using the analysis of the coefficient of

	sound fiber and the mechanical properties.
27	Contributions from : 1. Kartika Sari as the first author, co-author, review, editing and Conceptualization/ funding acquisition/formal analysis/ writing—original draft preparation 2. Yazid Zainur Isnen as the second autho, review and editing, formal analysis, and writing—original draft preparation 3. Agung Bambang Setio Utomo as the third author, methodology, data curation, and writing—original draft preparation 4. Sunardi as the fourth author, methodology, data curation, and writing—original draft preparation All authors have read and agreed to the published version of the manuscript.
28	Have done

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Impact strength.

ABSTRACT

Noise-absorbing composite is a material used to reduce noise. Natural product-based composite can be an alternative to replace synthetic fiber because of its advantages of high strength, toughness, low price, and abundance. The materials used were pineapple leaf fibers with paper waste. This research aims to study the advantage of natural products to reduce noise by analyzing the coefficient of sound absorption and impact strength to evaluate the absorbing composite. The composites were tested with the Charpy method with ISO 11654 standard and ASTM E23 for sound absorption and impact strength. Sound absorption was carried out using an impedance tube at a frequency range of 250 – 3000 Hz. The volume fraction of pineapple leaf fibers, paper waste, and resin epoxy concentrations were 20%:30%:50%, 25%:25%:50%, and 30%:20%:50%. The thickness for the sound absorption coefficient was 2 cm and 3 cm, while the thickness of the impact strength was 0.5 cm. The highest sound absorption coefficient of pineapple leaf fibers composite for 30%:20%:50% volume fraction was 0.788 for sample 2 cm. The highest impact strength for 20%:30%:50% volume fraction of the thickness of 0.5 cm was 3.527 J/mm^2. The results of the sound absorption coefficient will increase if used more pineapple leaf fibers but it will decrease the impact strength. Based on this research, it will improve the quality of composite that can be used as an absorbing material as well.

INTRODUCTION

Noise pollution from traffic and industries may generate noise difficulties and disrupt or decrease human hearing capabilities. Noise pollution has the potential to harm fetuses, babies, children, and adults. Noise pollution has an impact on both physical and emotional health. The noise exposure causes psychomotor effects by increasing stress, disrupting sleep, causing difficulty in normal conversation, lack of concentration, irritability, violent behavior, increased heart rate commonly observed with loud drum beats, tachyarrhythmia, vasoconstriction, hypertension, and other diseases (Gupta et al., 2018; Oguntunde et al., 2019). Installing sound-absorbing materials in buildings can help to minimize noise pollution.

Noise-absorbing materials are used to minimize noise because they comprise a filler that acts as an amplifier and a matrix that binds the fillers together. Alternatives to pineapple leaf fibers and paper waste that might be utilized as noise-absorbers in this study include pineapple leaf fibers and paper waste (Santulli et al., 2022). Pineapple leaf fiber is one of the organic wastes, this fiber can be used as a sound absorber because of its high cellulose content. The cellulose content in pineapple leaf fiber is 55.1%. Then, the waste paper that is used as pulp has a porous morphology. The combination of cellulose and pore content of pineapple leaf fiber and paper waste makes these two wastes very potential to be developed as sound-absorbing composites (Fareez et al., 2018; Jain & Sinha, 2021; Nair & Dasari, 2022). The filler of the composite is usually a material that has the desired properties of the final composite product, this filler will be able to add to the properties possessed by the matrix such as mechanical, acoustic, electrical, and type strength (Nhuapeng & Thamjaree, 2019). Fillers can be derived from natural or synthetic products, each of which has its advantages when used as a filler. The usage of synthetic fiber is harmful to the environment and results in the accumulation of non-biodegradable trash. Natural fibers might be utilized as an alternative to synthetic fibers due to their benefits of high strength, toughness, low cost, and availability, as well as being clean and biodegradable. Pineapple leaf fibers and paper waste are still underused and end up in landfills (Todkar & Patil, 2019; Zulaikha et al., 2022).

The study on the use of pineapple leaf fiber concrete composite as a noise-absorbing material generated a sound absorption coefficient value of 0.59 at a frequency of 2000 Hz (Arwanda & Sani, 2019). At a frequency of 800 Hz, the sound absorption coefficient of the paper waste, rice husk ash, and resin polyester-based composite were 0.48 (Isran et al., 2018). The composite of pineapple leaf fibers has a sound absorption coefficient of 0.9 in 1 kHz frequency (Putra et al., 2018). The other study using rami fiber as a composite obtained an impact strength of 0.0725 J/mm^2 (Purboputro & Hariyanto, 2017).

The excellent absorption ability was demonstrated by a composite with a low impact strength value. As noise absorbers, a few layered composites with pores were utilized. The composite may be used on walls, box speakers, and other surfaces. The sound wave that strikes the material's surface will be reflected, transmitted, and absorbed (González, 2019). The sound wave absorbed by the material produces a drop in sound wave strength and absorbed energy, which is referred to as the sound absorption coefficient.

In this research, pineapple leaf fiber was combined with paper waste to create an absorbed composite. The addition of paper waste affected the structure and properties of the composite, paper waste is utilized to create a foam-like material with properties similar to conventional foam to make the composite structure more porous (Astrauskas et al., 2021). The impact test determined the mechanical properties of the composite.

The impact strength test is used to determine the toughness of a composite when it’s forced to a rapid force as a result of a collision. The Charpy and Izod techniques are used to determine impact strength. The distinction between the Charpy and Izod techniques lies in the location of the specimen to be evaluated. In the Charpy technique, the specimen is placed horizontally. Meanwhile, with the Izod technique, the specimen position is vertical (Callister & Rethwisch, 2018). The high porosity of paper waste and pineapple leaf fiber, as well as its high cellulose content, are benefits of this material as a sound wave-absorbing composite.

METHODS

Pineapple leaf fibers, paper waste, and epoxy resin were used in this study. The pineapple leaf fibers and paper waste were chopped into pieces. Water was used to soak and crush the paper waste. The pineapple leaf fibers and paper waste were used as reinforcement. Epoxy resin is combined with hardener and used as a matrix, then each reinforcement (pineapple leaf fibers and paper waste) is added to the resin and stirred until homogenous, then pressed with the hydraulic press. The composite thickness for the sound absorption test is 2 cm and 3 cm with diameter tube 2.5 cm, the dimension of composite for the impact test is 5.5 × 1 × 0.5 cm. The volume fraction of pineapple leaf fibers, paper waste, and resin epoxy concentrations were 20%:30%:50%, 25%:25%:50%, and 30%:20%:50% for samples A, B, and C with the thickness of 2 cm, respectively. The thickness of samples D, E, and F is 3 cm with the same volume fraction. The research's design is shown in Figure 1.

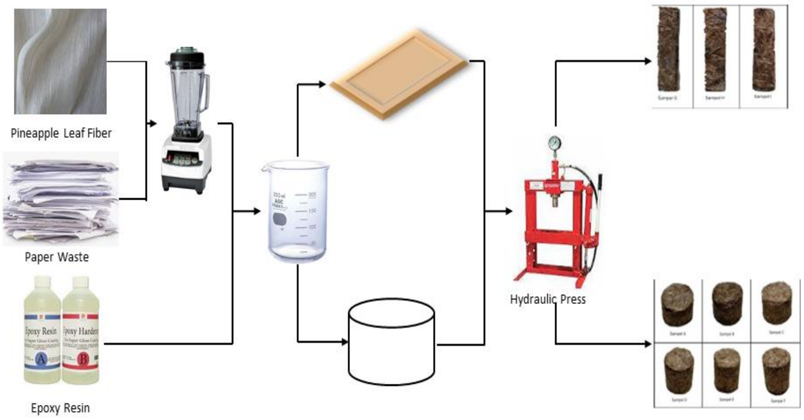
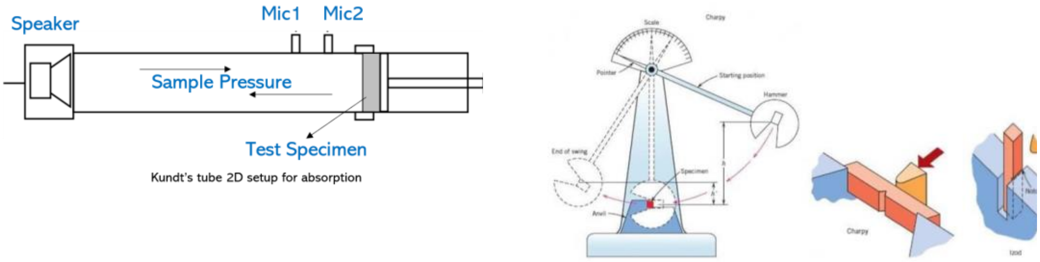


Figure 1. Research's design

Sound absorption coefficient measurements are performed by measuring the intensity level before (I_1) and after (I_2) passing through the absorbent material (I_2).

The impact test is performed by swinging the weight on the test equipment until the composite breaks. The sound absorption coefficient and impact strength were determined with standard ISO 11654 and ASTM E23. The illustration of sound absorption coefficient and impact strength is shown in Figure 2.



(a) **(b)**

Figure 2. Illustration of the test used, (a) Sound absorption coefficient (b) Impact strength

Fig. 2 (a) shows the test of sound absorption. The sound waves were generated from speakers with a specific frequency and sound waves will hit the sample. Some of the frequencies will be absorbed by the sample, but some will be reflected because they cannot pass through the sample's pores. The sound waves that pass through the sample pores will be recorded by a detector (mic) due to sound absorption. The transfer function techniques, as well as the two-microphone technique, were applied. The frequency ranges from 250 to 3000 Hz.

The ratio between pressures were create by wave sound on the microphone was calculated with transfer function (H_{12}):

$$H_{12} = \frac{p_1}{p_2} \qquad (1)$$

$$H_I = \frac{p_{I1}}{p_{I2}} = e^{-jk_0(x_1-x_2)} \quad (2)$$

$$H_R = \frac{p_{2R}}{p_{1R}} = e^{-jk_0(x_1-x_2)} \quad (3)$$

H_I is the transfer function of the incident wave alone and H_R is the transfer function of

where R is the coefficient of the reflected wave, k is the wavenumber, and x is the distance between the microphone and the sample. The coefficient of reflected was used to calculate the sound absorption coefficient in the following expression:

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

The impact strength test in Fig 2 (b) is used to determine the material's physical characteristics as well as the ductility of the composite that has been created. The basic idea behind rupture testing is to compute the energy provided by the load and the energy absorbed by the sample. When, the load possesses potential energy occurs the weight is increased to a particular height, the maximum kinetic energy.

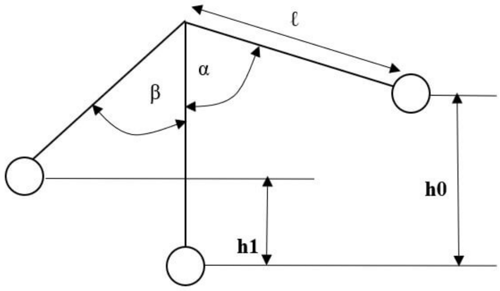


Figure 3. Illustration of impact energy calculated

In the impact test, a notched test specimen is used which is struck with a pendulum. The specimen is clamped at one end until the notch is near the clamp in the Izod technique. A pendulum swinging from a

the reflected wave. The coefficient of the reflected wave was calculated from equation (1) – (3):

$$R = \frac{H_{12} - H_1}{H_R - H_{12}} = e^{-jk_0(x_1-x_2)} \quad (4)$$

certain height will strike the end of the specimen that is not clamped from the front of the notch.

In the Charpy test, the specimen is placed horizontally both ends are held, and the pendulum will hit the test rod from behind the notch. The impact energy can be seen on the scale of the testing machine. The magnitude of the impact energy theoretically can be calculated:

$$E_0 = W \times h_0 \quad (6)$$

$$E_1 = W \times h_1 \quad (7)$$

$$\Delta E = E_0 - E_1 = W(h_0 - h_1) \quad (8)$$

from Fig. 3 obtained that:

$$h_0 = l - l\cos\alpha \quad (9)$$

$$= l(1 - \cos\alpha) \quad (10)$$

$$h_1 = l - l\cos\beta \quad (11)$$

$$= l(1 - \cos\beta) \quad (12)$$

Finally, the impact energy was calculated with the following expression:

$$\Delta E = W \times l(h_0 - h_1) \quad (13)$$

where E is energy (J), W is pendulum weight (N), h is pendulum height before-after released (m), l is pendulum length (m), α and β are angle before-after (°). The impact strength (I_s) was calculated by impact energy divided by cross-section area (A):

$$I_s = \frac{\Delta E}{A} = \frac{W \times l(h_0 - h_1)}{A} \quad (14)$$

RESULTS AND DISCUSSION

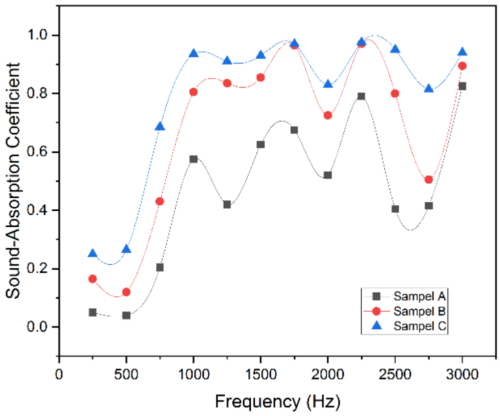
Pineapple leaf fiber has a laminated and elongated morphology, while paper waste is in the form of particles. The combination of the two in the composite makes the fiber interface classified as a hybrid composite (Abdul Ghofir & ., 2018; Andrew & Dhakal, 2022; Astrauskas et al., 2021; Tang & Yan, 2017).

The impedance tube method was used for the sound absorption test, in which the sound source from the speaker was linked to a generator with a frequency range of 250 to 3000 Hz. Figure 4 depicts the relationships between the sound absorption coefficient and the frequency of the sample.

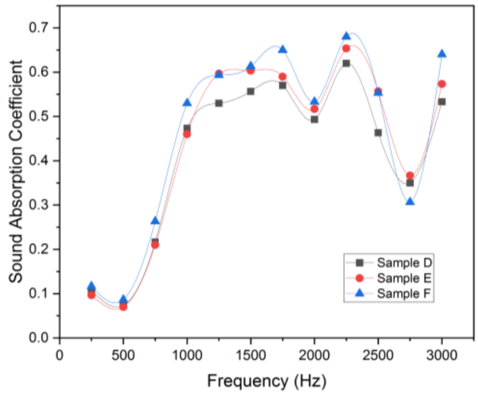
According to ISO 11645 acoustic materials that are categorized as having sound absorption capacity are materials with a sound absorption coefficient greater than 0.15. The relationship between the sound absorption coefficient and the thickness of the material is written in Equation 15

$$I = I_0 e^{-ax} \quad (15)$$

where I is the final intensity (dB), I_0 is the initial intensity (dB), α is the sound absorption coefficient, and x is the thickness of the sample (m). From Equation 15 it can be seen that the thickness of the material will affect the sound absorption coefficient, the thickness of the samples used are 2 cm and 3 cm, in addition to the thickness of the other factors that affect the porosity and density of the material (Sharma et al., 2020; Taban, Khavanin, Jafari, et al., 2019). Porosity will cause sound waves to be reflected in the cavities of the material so that the energy and intensity will decrease (Mwango & Kambole, 2019; Nhuapeng & Thamjaree, 2019)



(a)



(b)

Figure 4. The sound absorption coefficient at the frequency range of 250-2000 Hz, (a) The samples with 2 cm thickness (b) The samples with 3 cm thickness

Figure 4 demonstrates that the sound absorption coefficient increases as the frequency ranges from 500 to 1750 Hz. The average sound absorption coefficients for A, B, and C were 0.462, 0.672, and 0.788, respectively. While the average sound absorption coefficients for D, E, and F were 0,415; 0,420; and 0,464, respectively. At a frequency of 2000 Hz, the value of the sound absorption coefficient decreases. The sound absorption coefficient decreases because the particles are saturated, resulting in energy loss and destructive interference (Rus et al., 2017). According to the results, the sound absorption coefficient increased with the addition of fiber. The addition of fibers makes more pores formed in the composite structure, and density will increase. It makes sound waves harder to escape and increases the sound absorption coefficient (Pöhler et al., 2017; Xu et al., 2018). The value of the sound absorption coefficient can be impacted by the resonance that occurs in the composite cavity. Because of the resonance, some of the sound waves are unable to leave the sample cavity, reducing the reflected wave energy (Arwanda & Sani, 2019). The unevenness of the composite composition harms the sound absorption coefficient (Akbar & Sari, 2020). It generated a space between molecules on the sample, resulting in high porosity and low density. Figure 5 depicts a density sample

(Arwanda & Sani, 2019). The density sample is shown in Figure 5.

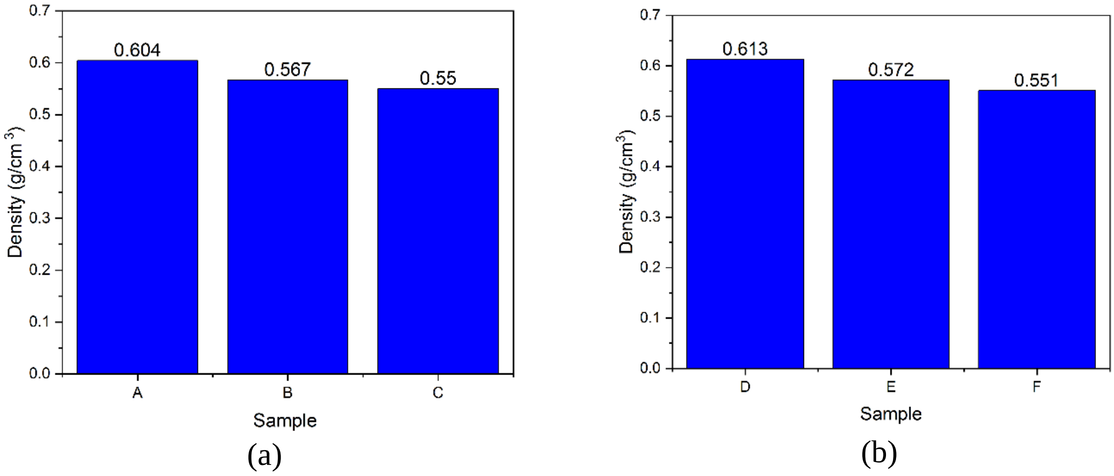


Figure 5. The density of Pineapple leaf fibers with paper waste, (a) Composite with a thickness of 2 cm (b) Composite with a thickness of 3 cm

The densities of the samples from A, B, and C for the thickness of the samples 2 cm were 0.604 g/cm^3, 0.567 g/cm^3, and 0.550 g/cm^3, respectively. The densities of samples thickness of 3 cm from D, E, F samples were 0,613 g/cm^3; 0,572 g/cm^3; and 0,551 g/cm^3 as shown in Figure 5. Density causes sound waves to interact with the pores in the sample, causing the energy to drop. The denser the sample, the more difficult it is for the sound wave to pass through the material, resulting in a lower sound absorption coefficient (Putra et al., 2018; Taban, Khavanin, Ohadi, et al., 2019). Mechanical characteristics are essential for sound-absorbing composites (Malalli & Ramji, 2022). The impact strength test is used to determine a material's capacity to absorb energy during a collision, as shown in Figure 6.

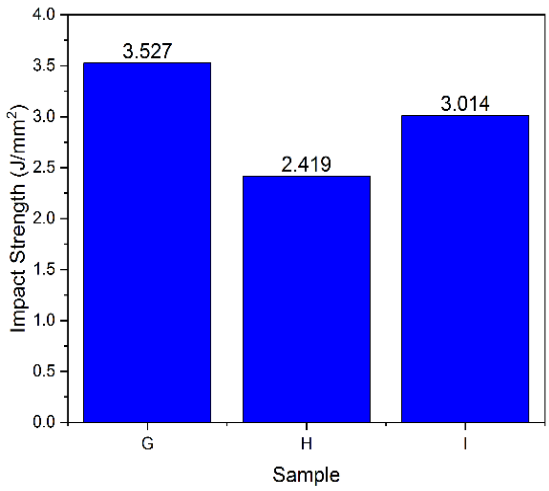


Figure 6. The impact strength value of pineapple leaf fibers with paper waste composite

The impact strengths of the G, H, and I samples were 3.527 J/mm^2, 2.419 J/mm^2, and 3.014 J/mm^2, respectively, as shown in Figure 6. The materials of pineapple leaf fibers with paper waste composite are brittle and have a high density, resulting in a high impact strength value, as shown in Figure 6.

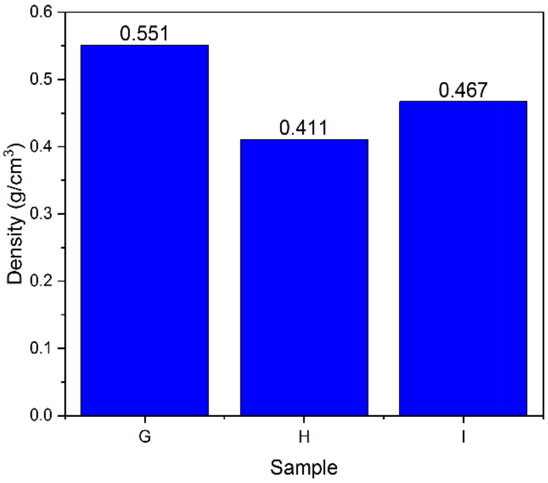


Figure 7. The impact strength density of pineapple leaf fibers with paper waste composite

Figure 7 indicated that the higher the density, the higher the impact strength. The density of the sample will increase as the concentration of paper increases. As a result, the sample would be difficult to break. The low density of composite has a low impact strength value, which causes voids or holes to form on each material bond and makes composites more brittle (Putra et al., 2020). In composites, the uneven component concentration resulted in the formation of voids and weakened the connection between filler and matrix (Hardiana, *et al.*, 2021). The sound absorption coefficient and mechanical properties are affected by the structure of the composite (porous and arrangement of fibers) and physical properties (density) (Hoque et al., 2022; Venkata Deepthi et al., 2019).

This study shows that the combination of pineapple leaf fiber and paper waste can be used as a sound-absorbing material, and waste materials, it can reduce the environmental pollution, either organic pollution or noise pollution. The combination of pineapple leaf fiber and paper waste will improve the quality of composite that can be used as an absorbing material as well. The next study to measure the optimum thickness and the thermal properties to get complete information was needed.

CONCLUSION

The pineapple leaf fiber and paper waste reinforcement composites can be used as sound-absorbing materials. The addition of fiber in the composite makes the absorption coefficient increase, but the mechanical properties decrease. The sound absorption coefficient increases due to the cellulose content and the structure of the fibers. Pineapple leaf fiber in the form of lamina affects on the mechanical properties. The paper waste in the form of particles will create a porous structure which has an impact on sound absorption.

The arrangement of elongated-fibers makes the load-received by the composite spread evenly on other fibers. The porous structure causes sound waves-reflected in the pores thereby reducing energy. The pores capture the sound waves that pass through the composite. The pores and fibers interface can be seen through the density of the material. The high density indicates that the fiber's interface was closer and the pores formed are small so that the relationship between pores and fiber's arrangement using the analysis of the coefficient of sound fiber and the mechanical properties.

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AUTHOR CONTRIBUTIONS

Contributions from :

1. Kartika Sari as the first author, co-author, review, editing and conceptualization/ funding acquisition/formal analysis/ writing—original draft preparation
2. Yazid Zainur Isnen as the second autho, review and editing, formal analysis, and writing—original draft preparation
3. Agung Bambang Setio Utomo as the third author, methodology, data curation, and writing—original draft preparation

4. Sunardi as the fourth author, methodology, data curation, and writing—original draft preparation

All authors have read and agreed to the published version of the manuscript.

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The Mechanic and Acoustic Properties of Pineapple Leaf Fibers with Paper Waste as An Absorbing-Composite

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Impact strength.

ABSTRACT

Noise-absorbing composite is a material used to reduce noise. Natural product-based composite can be an alternative to replace synthetic fiber because of its advantages of high strength, toughness, low price, and abundance. The materials used were pineapple leaf fibers with paper waste. This research aims to study the advantage of natural products to reduce noise by analyzing the coefficient of sound absorption and impact strength to evaluate the absorbing composite. The composites were tested with the Charpy method with ISO 11654 standard and ASTM E23 for sound absorption and impact strength. Sound absorption was carried out using an impedance tube at a frequency range of 250 – 3000 Hz. The volume fraction of pineapple leaf fibers, paper waste, and resin epoxy concentrations were 20%:30%:50%, 25%:25%:50%, and 30%:20%:50%. The thickness for the sound absorption coefficient was 2 cm and 3 cm, while the thickness of the impact strength was 0.5 cm. The highest sound absorption coefficient of pineapple leaf fibers composite for 30%:20%:50% volume fraction was 0.788 for sample 2 cm. The highest impact strength for 20%:30%:50% volume fraction of the thickness of 0.5 cm was 3.527 J/mm^2. The results of the sound absorption coefficient will increase if used more pineapple leaf fibers but it will decrease the impact strength. Based on this research, it will improve the quality of composite that can be used as an absorbing material as well.

INTRODUCTION

Noise pollution from traffic and industries may generate noise difficulties and disrupt or decrease human hearing capabilities. Noise pollution has the potential to harm fetuses, babies, children, and adults. Noise pollution has an impact on both physical and emotional health. The noise exposure causes psychomotor effects by increasing stress, disrupting sleep, causing difficulty in normal conversation, lack of concentration, irritability, violent behavior, increased heart rate commonly observed with loud drum beats, tachyarrhythmia, vasoconstriction, hypertension, and other diseases (Gupta et al., 2018; Oguntunde et al., 2019). Installing sound-absorbing materials in buildings can help to minimize noise pollution.

Noise-absorbing materials are used to minimize noise because they comprise a filler that acts as an amplifier and a matrix that binds the fillers together. Alternatives to pineapple leaf fibers and paper waste that might be utilized as noise-absorbers in this study include pineapple leaf fibers and paper waste (Santulli et al., 2022). Pineapple leaf fiber is one of the organic wastes, this fiber can be used as a sound absorber because of its high cellulose content. The cellulose content in pineapple leaf fiber is 55.1%. Then, the waste paper that is used as pulp

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has a porous morphology. The combination of cellulose and pore content of pineapple leaf fiber and paper waste makes these two wastes very potential to be developed as sound-absorbing composites (Fareez et al., 2018; Jain & Sinha, 2021; Nair & Dasari, 2022). The filler of the composite is usually a material that has the desired properties of the final composite product, this filler will be able to add to the properties possessed by the matrix such as mechanical, acoustic, electrical, and type strength (Nhuapeng & Thamjaree, 2019). Fillers can be derived from natural or synthetic products, each of which has its advantages when used as a filler. The usage of synthetic fiber is harmful to the environment and results in the accumulation of non-biodegradable trash. Natural fibers might be utilized as an alternative to synthetic fibers due to their benefits of high strength, toughness, low cost, and availability, as well as being clean and biodegradable. Pineapple leaf fibers and paper waste are still underused and end up in landfills (Todkar & Patil, 2019; Zulaikha et al., 2022).

The study on the use of pineapple leaf fiber concrete composite as a noise-absorbing material generated a sound absorption coefficient value of 0.59 at a frequency of 2000 Hz (Arwanda & Sani, 2019). At a frequency of 800 Hz, the sound absorption coefficient of the paper waste, rice husk ash, and resin polyester-based composite were 0.48 (Isran et al., 2018). The composite of pineapple leaf fibers has a sound absorption coefficient of 0.9 in 1 kHz frequency (Putra et al., 2018). The other study using rami fiber as a composite obtained an impact strength of 0.0725 J/mm^2 (Purboputro & Hariyanto, 2017). The excellent absorption ability was demonstrated by a composite with a low impact strength value. As noise absorbers, a few layered composites with pores were utilized. The composite may be used on walls, box speakers, and other surfaces. The sound wave that strikes the material's surface will be reflected, transmitted, and absorbed (González, 2019). The sound wave absorbed by the material produces a drop in sound wave strength and absorbed energy, which is referred to as the sound absorption coefficient.

In this research, pineapple leaf fiber was combined with paper waste to create an absorbed composite. The addition of paper waste affected the structure and properties of the composite, paper waste is utilized to create a foam-like material with properties similar to conventional foam to make the composite structure more porous (Astrauskas et al., 2021). The impact test determined the mechanical properties of the composite.

The impact strength test is used to determine the toughness of a composite when it's forced to a rapid force as a result of a collision. The Charpy and Izod techniques are used to determine impact strength. The distinction between the Charpy and Izod techniques lies in the location of the specimen to be evaluated. In the Charpy technique, the specimen is placed horizontally. Meanwhile, with the Izod technique, the specimen position is vertical (Callister & Rethwisch, 2018). The high porosity of paper waste and pineapple leaf fiber, as well as its high cellulose content, are benefits of this material as a sound wave-absorbing composite.

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METHODS

Pineapple leaf fibers, paper waste, and epoxy resin were used in this study. The pineapple leaf fibers and paper waste were chopped into pieces. Water was used to soak and crush the paper waste. The pineapple leaf fibers and paper waste were used as reinforcement. Epoxy resin is combined with hardener and used as a matrix, then each reinforcement (pineapple leaf fibers and paper waste) is added to the resin and stirred until homogenous, then pressed with the hydraulic press. The composite thickness for the sound absorption test is 2 cm and 3 cm with diameter tube 2.5 cm, the dimension of composite for the impact test is 5.5 × 1 × 0.5 cm. The volume fraction of pineapple leaf fibers, paper waste, and resin epoxy concentrations were 20%:30%:50%, 25%:25%:50%, and 30%:20%:50% for samples A, B, and C with the thickness of 2 cm, respectively. The thickness of samples D, E, and F is 3 cm with the same volume fraction. The research's design is shown in Figure 1.

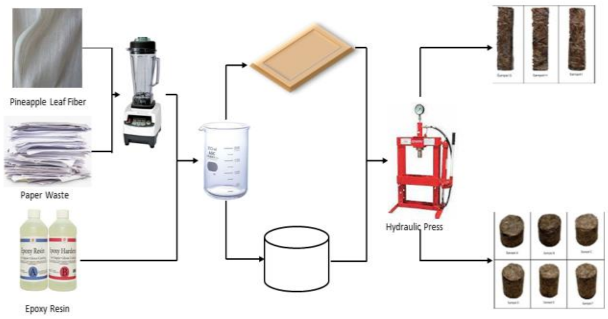
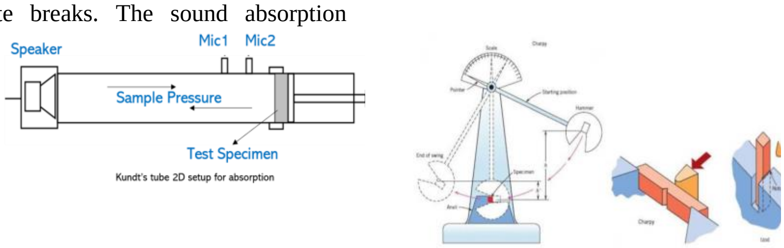


Figure 1. Research's design

Sound absorption coefficient measurements are performed by measuring the intensity level before (I_1) and after (I_2) passing through the absorbent material (I_2).

The impact test is performed by swinging the weight on the test equipment until the composite breaks. The sound absorption coefficient and impact strength were determined with standard ISO 11654 and ASTM E23. The illustration of sound absorption coefficient and impact strength is shown in Figure 2.



(a) **(b)**

Figure 2. Illustration of the test used, (a) Sound absorption coefficient (b) Impact strength

Fig. 2 (a) shows the test of sound absorption. The sound waves were generated from speakers with a specific frequency and sound waves will hit the sample. Some of the frequencies will be absorbed by the sample, but some will be reflected because they cannot pass through the sample's pores. The sound waves that pass through the sample pores will be recorded by a detector (mic) due to sound absorption. The transfer function techniques, as well as the two-microphone technique, were applied. The frequency ranges from 250 to 3000 Hz.

The ratio between pressures were create by wave sound on the microphone was calculated with transfer function (H_{12}):

$$H_{12} = \frac{p_1}{p_2} \quad (1)$$

$$H_I = \frac{p_{I1}}{p_{I2}} = e^{-jk_0(x_1 - x_2)} \quad (2)$$

$$H_R = \frac{p_{2R}}{p_{1R}} = e^{-jk_0(x_1 - x_2)} \quad (3)$$

where R is the coefficient of the reflected wave, k is the wavenumber, and x is the distance between the microphone and the sample. The coefficient of reflected was used to calculate the sound absorption coefficient in the following expression:

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

The impact strength test in Fig 2 (b) is used to determine the material's physical characteristics as well as the ductility of the composite that has been created. The basic idea behind rupture testing is to compute the energy provided by the load and the energy absorbed by the sample. When, the load possesses potential energy occurs the weight is increased to a particular height, the maximum kinetic energy.

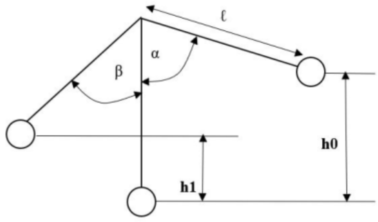


Figure 3. Illustration of impact energy calculated

In the impact test, a notched test specimen is used which is struck with a pendulum. The specimen is clamped at one end until the notch is near the clamp in the Izod technique. A pendulum swinging from a certain height will strike the end of the specimen that is not clamped from the front of the notch.

In the Charpy test, the specimen is placed horizontally both ends are held, and

H_I is the transfer function of the incident wave alone and H_R is the transfer function of the reflected wave. The coefficient of the reflected wave was calculated from equation (1) – (3):

$$R = \frac{H_{12} - H_1}{H_R - H_{12}} = e^{-jk_0(x_1 - x_2)} \quad (4)$$

the pendulum will hit the test rod from behind the notch. The impact energy can be seen on the scale of the testing machine. The magnitude of the impact energy theoretically can be calculated:

$$E_0 = W \times h_0 \quad (6)$$

$$E_1 = W \times h_1 \quad (7)$$

$$\Delta E = E_0 - E_1 = W(h_0 - h_1) \quad (8)$$

from Fig. 3 obtained that:

$$h_0 = l - l\cos\alpha \quad (9)$$

$$= l(1 - \cos\alpha) \quad (10)$$

$$h_1 = l - l\cos\beta \quad (11)$$

$$= l(1 - \cos\beta) \quad (12)$$

Finally, the impact energy was calculated with the following expression:

$$\Delta E = W \times l(h_0 - h_1) \quad (13)$$

where E is energy (J), W is pendulum weight (N), h is pendulum height before-after released (m), l is pendulum length (m), α and β are angle before-after (°). The impact strength (I_s) was calculated by impact energy divided by cross-section area (A):

$$I_s = \frac{\Delta E}{A} = \frac{W \times l(h_0 - h_1)}{A} \quad (14)$$

RESULTS AND DISCUSSION

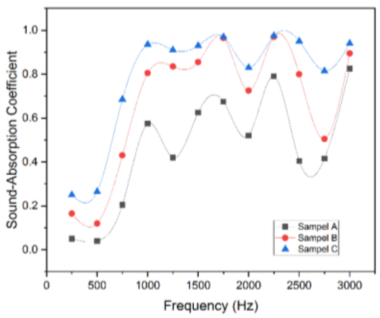
Pineapple leaf fiber has a laminated and elongated morphology, while paper waste is in the form of particles. The combination of the two in the composite makes the fiber interface classified as a hybrid composite (Abdul Ghofir & ., 2018; Andrew & Dhakal, 2022; Astrauskas et al., 2021; Tang & Yan, 2017).

The impedance tube method was used for the sound absorption test, in which the sound source from the speaker was linked to a generator with a frequency range of 250 to 3000 Hz. Figure 4 depicts the relationships between the sound absorption coefficient and the frequency of the sample.

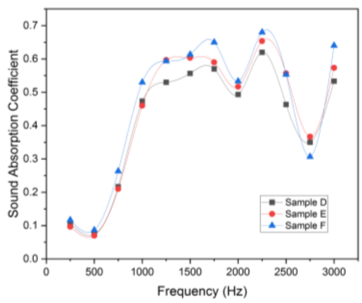
According to ISO 11645 acoustic materials that are categorized as having sound absorption capacity are materials with a sound absorption coefficient greater than 0.15. The relationship between the sound absorption coefficient and the thickness of the material is written in Equation 15

$$I = I_0 e^{-ax} \quad (15)$$

where I is the final intensity (dB), I_0 is the initial intensity (dB), α is the sound absorption coefficient, and x is the thickness of the sample (m). From Equation 15 it can be seen that the thickness of the material will affect the sound absorption coefficient, the thickness of the samples used are 2 cm and 3 cm, in addition to the thickness of the other factors that affect the porosity and density of the material (Sharma et al., 2020; Taban, Khavanin, Jafari, et al., 2019). Porosity will cause sound waves to be reflected in the cavities of the material so that the energy and intensity will decrease (Mwango & Kambole, 2019; Nhuapeng & Thamjaree, 2019)



(a)

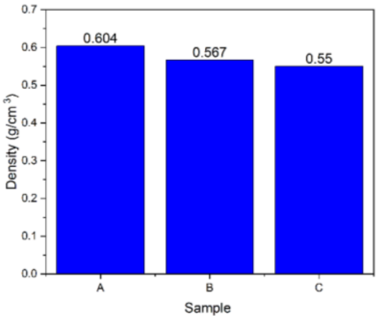


(b)

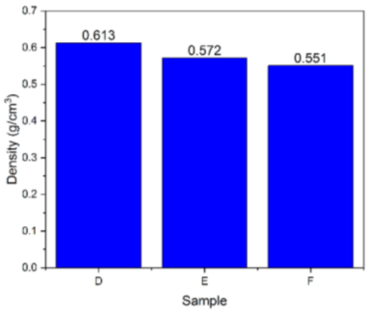
Figure 4. The sound absorption coefficient at the frequency range of 250-2000 Hz, (a) The samples with 2 cm thickness (b) The samples with 3 cm thickness

Figure 4 demonstrates that the sound absorption coefficient increases as the frequency ranges from 500 to 1750 Hz. The average sound absorption coefficients for A, B, and C were 0.462, 0.672, and 0.788, respectively. While the average sound absorption coefficients for D, E, and F were 0,415; 0,420; and 0,464, respectively. At a frequency of 2000 Hz, the value of the sound absorption coefficient decreases. The sound absorption coefficient decreases because the particles are saturated, resulting in energy loss and destructive interference (Rus et al., 2017). According to the results, the sound absorption coefficient increased with the addition of fiber. The addition of fibers makes more pores formed in the composite structure, and density will increase. It makes sound waves harder to escape and increases the sound absorption coefficient (Pöhler et al., 2017; Xu et al., 2018). The value of the sound absorption coefficient can be impacted by the resonance that occurs in the composite cavity. Because of the resonance, some of the sound waves are unable to leave the sample cavity, reducing the reflected wave energy (Arwanda & Sani, 2019). The unevenness of the composite composition harms the sound absorption coefficient

(Akbar & Sari, 2020). It generated a space between molecules on the sample, resulting in high porosity and low density. Figure 5 depicts a density sample (Arwanda & Sani, 2019). The density sample is shown in Figure 5.



(a)



(b)

Figure 5. The density of Pineapple leaf fibers with paper waste, (a) Composite with a thickness of 2 cm (b) Composite with a thickness of 3 cm

The densities of the samples from A, B, and C for the thickness of the samples 2 cm were 0.604 g/cm^3, 0.567 g/cm^3, and 0.550 g/cm^3, respectively. The densities of samples thickness of 3 cm from D, E, F samples were 0,613 g/cm^3; 0,572 g/cm^3; and 0,551 g/cm^3 as shown in Figure 5. Density causes sound waves to interact with the pores in the sample, causing the energy to drop. The denser the sample, the more difficult it is for the sound wave to pass through the material, resulting in a lower sound absorption coefficient (Putra et al., 2018; Taban, Khavanin, Ohadi, et al., 2019). Mechanical characteristics are essential for sound-absorbing composites (Malalli & Ramji, 2022). The impact strength test is used to determine a material's capacity to absorb energy during a collision, as shown in Figure 6.

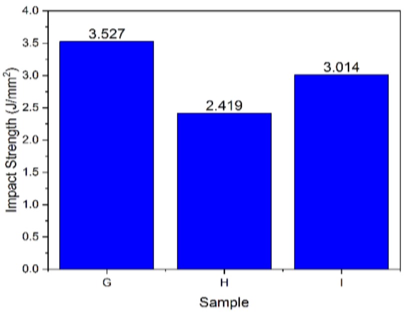


Figure 6. The impact strength value of pineapple leaf fibers with paper waste composite

The impact strengths of the G, H, and I samples were 3.527 J/mm^2, 2.419 J/mm^2, and 3.014 J/mm^2, respectively, as shown in Figure 6. The materials of pineapple leaf fibers with paper waste composite are brittle and have a high density, resulting in a high impact strength value, as shown in Figure 6.

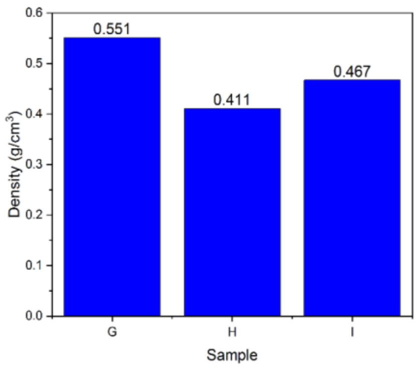


Figure 7. The impact strength density of pineapple leaf fibers with paper waste composite

Figure 7 indicated that the higher the density, the higher the impact strength. The density of the sample will increase as the concentration of paper increases. As a result, the sample would be difficult to break. The low density of composite has a low impact strength value, which causes voids or holes to form on each material bond and makes composites more brittle (Putra et al., 2020). In composites, the uneven component concentration resulted in the formation of voids and weakened the connection between filler and matrix (Hardiana, *et al.,* 2021). The sound absorption coefficient and mechanical properties are affected by the structure of the composite (porous and arrangement of fibers) and physical properties (density) (Hoque et al., 2022; Venkata Deepthi et al., 2019).

This study shows that the combination of pineapple leaf fiber and paper waste can be used as a sound-absorbing material, and waste materials, it can reduce the environmental pollution, either organic pollution or noise pollution. The combination of pineapple leaf fiber and paper waste will improve the quality of composite that can be used as an absorbing material as well. The next study to measure the optimum thickness and the thermal properties to get complete information was needed.

CONCLUSION

The pineapple leaf fiber and paper waste reinforcement composites can be used as sound-absorbing materials. The addition of fiber in the composite makes the absorption coefficient increase, but the mechanical properties decrease. The sound absorption coefficient increases due to the cellulose content and the structure of the fibers. Pineapple leaf fiber in the form of lamina affects on the mechanical properties. The paper waste in the form of particles will create a porous structure which has an impact on sound absorption.

The arrangement of elongated-fibers makes the load-received by the composite spread evenly on other fibers. The porous structure causes sound waves-reflected in the pores thereby reducing energy. The pores capture the sound waves that pass through the composite. The pores and fibers interface can be seen through the density of the material. The high density indicates that the fiber's interface was closer and the pores formed are small so that the relationship between pores and fiber’s arrangement using the analysis of the coefficient of sound fiber and the mechanical properties.

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AUTHOR CONTRIBUTIONS

Contributions from :

1. Kartika Sari as the first author, co-author, review, editing and conceptualization/ funding acquisition/formal analysis/ writing—original draft preparation
2. Yazid Zainur Isnen as the second autho, review and editing, formal analysis, and writing—original draft preparation
3. Agung Bambang Setio Utomo as the third author, methodology, data curation, and writing—original draft preparation

4. Sunardi as the fourth author, methodology, data curation, and writing—original draft preparation

All authors have read and agreed to the published version of the manuscript.

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Properties of Pineapple Leaf Fibers with Paper Waste as An Absorbing-Composite to Reduce noise

Author :
Add the implication for knowledge in this fields
Response :
Based on this research, the pineapple leaf fibers will improve the quality of the composite that can be used as a sound-absorbing material as well. These materials possess the promising potential to decrease waste and are used in industries for a low cost.

Introduction (Pendahuluan) *

Author :
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Response :
In this work, the preparation of the pineapple leaf fiber was combined with the paper waste aim to determine the mechanical properties using the Charpy method and sound absorption. The addition of paper waste to the pineapple leaf fiber composite makes another advantage, which has good absorption properties as an acoustic panel. This makes the application of composites wider and can be used in various industries.

Method (Metode) *

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Result (Hasil) *

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Discussion (Pembahasan/ Diskusi) *

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Conclusion (Kesimpulan) *

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Literature Cited (Kepustakaan) *

Author : **-** **Response :** **-**

Notes/ Reason (Catatan) For Author: *

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Properties of Pineapple Leaf Fibers with Paper Waste as An Absorbing-Composite to Reduce noise

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ABSTRACT

Natural product-based noise-absorbing composite can be an alternative to replace synthetic fiber because of its advantages of high strength, toughness, low price, and abundance to reduce noise. The materials used were pineapple leaf fibers with paper waste. This research aims to study the advantage of natural products to reduce noise by analyzing the coefficient of sound absorption and impact strength to evaluate the absorbing composite. The composites were tested with the Charpy method with ISO 11654 standard and ASTM E23 for sound absorption and impact strength. Sound absorption was carried out using an impedance tube at a frequency range of 250 – 3000 Hz. The volume fraction of pineapple leaf fibers, paper waste, and resin epoxy concentrations were 20%:30%:50%, 25%:25%:50%, and 30%:20%:50%. The thickness for the sound absorption coefficient was 2 cm and 3 cm, while the thickness of the impact strength was 0.5 cm. The highest sound absorption coefficient of pineapple leaf fibers composite for 30%:20%:50% volume fraction was 0.788 for sample 2 cm. The highest impact strength for 20%:30%:50% volume fraction of the thickness of 0.5 cm was 3.527 J/mm^2. The results of the sound absorption coefficient will increase if used more pineapple leaf fibers but it will decrease the impact strength. Based on this research, it will improve the quality of composite that can be used as a sound-absorbing materials as well.

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INTRODUCTION

Noise pollution from traffic and industries may generate noise difficulties and disrupt or decrease human hearing capabilities. Noise pollution has the potential to harm fetuses, babies, children, and adults. Noise pollution has an impact on both physical and emotional health. The noise exposure causes psychomotor effects by increasing stress, disrupting sleep, causing difficulty in normal conversation, lack of concentration, irritability, violent behavior, increased heart rate commonly observed with loud drum beats, tachyarrhythmia, vasoconstriction, hypertension, and other diseases (Gupta et al., 2018; Oguntunde et al., 2019). Installing sound-absorbing materials in buildings can help to minimize noise pollution.

Noise-absorbing materials are used to minimize noise because they comprise a filler that acts as an amplifier and a matrix that binds the fillers together. Alternatives to pineapple leaf fibers and paper waste that might be utilized as noise-absorbers in this study include pineapple leaf fibers and paper waste (Santulli et al., 2022). Pineapple leaf fiber is one of the organic wastes, this fiber can be used as a sound absorber because of its high cellulose content. The cellulose content in pineapple leaf fiber is 55.1%. Then, the waste paper that is used as pulp has a porous morphology. The combination of cellulose and pore content of pineapple leaf fiber and paper waste makes these two wastes very potential to be developed as sound-absorbing composites (Fareez et al., 2018; Jain & Sinha, 2021; Nair & Dasari, 2022).

The filler of the composite is usually a material that has the desired properties of the final composite product, this filler will be able to add to the properties possessed by the matrix such as mechanical, acoustic, electrical, and type strength (Nhuapeng & Thamjaree, 2019). Fillers can be derived

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from natural or synthetic products, each of which has its advantages when used as a filler. The usage of synthetic fiber is harmful to the environment and results in the accumulation of non-biodegradable trash. Natural fibers might be utilized as an alternative to synthetic fibers due to their benefits of high strength, toughness, low cost, and availability, as well as being clean and biodegradable. Pineapple leaf fibers and paper waste are still underused and end up in landfills (Todkar & Patil, 2019; Zulaikha et al., 2022).

The study on the use of pineapple leaf fiber concrete composite as a noise-absorbing material generated a sound absorption coefficient value of 0.59 at a frequency of 2000 Hz (Arwanda & Sani, 2019). At a frequency of 800 Hz, the sound absorption coefficient of the paper waste, rice husk ash, and resin polyester-based composite were 0.48 (Isran et al., 2018). The composite of pineapple leaf fibers has a sound absorption coefficient of 0.9 in 1 kHz frequency (Putra et al., 2018). The other study using rami fiber as a composite obtained an impact strength of 0.0725 J/mm^2 (Purboputro & Hariyanto, 2017). The excellent absorption ability was demonstrated by a composite with a low impact strength value. As noise absorbers, a few layered composites with pores were utilized.

The composite may be used on walls, box speakers, and other surfaces. The sound wave that strikes the material's surface will be reflected, transmitted, and absorbed (González, 2019). The sound wave absorbed by the material produces a drop in sound wave strength and absorbed energy, which is referred to as the sound absorption coefficient.

The addition of pineapple leaf fiber was combined with paper waste affected the structure and properties of the composite, paper waste is utilized to create a foam-like material with properties similar to conventional foam to make the composite structure more porous (Astrauskas et al., 2021). The high porosity of paper waste and pineapple leaf fiber, as well as its high cellulose content, are benefits of this material as a sound wave-absorbing composite (Haryadi et al., 2021).

The impact test determined the mechanical properties when it's forced to a rapid force as a result of a collision. The Charpy and Izod techniques are used to determine impact strength. The distinction between the Charpy and Izod techniques lies in the location of the specimen to be evaluated. In the Charpy technique, the specimen is placed horizontally. Meanwhile, with the Izod technique, the specimen position is vertical (Callister & Rethwisch, 2018).

In this work, the preparation of the pineapple leaf fiber was combined with paper waste aims to determine the mechanical properties using the Charpy method and sound absorption. The composites with low breaking strength indicate good sound absorption. Effect of pineapple leaf fiber was combined with paper waste can be got the environment-friendly, easy to obtain, and low in cost.

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METHODS

Pineapple leaf fibers, paper waste, and epoxy resin were used in this study. The pineapple leaf fibers and paper waste were chopped into pieces. Water was used to soak and crush the paper waste. The pineapple leaf fibers and paper waste were used as reinforcement. Epoxy resin is combined with hardener and used as a matrix, then each reinforcement (pineapple leaf fibers and paper waste) is added to the resin and stirred until homogenous, then pressed with the hydraulic press. The composite thickness for the sound absorption test is 2 cm and 3 cm with diameter tube 2.5 cm, the dimension of composite for the impact test is 5.5 × 1 × 0.5 cm. The volume fraction of pineapple leaf fibers, paper waste, and resin epoxy concentrations were 20%:30%:50%, 25%:25%:50%, and 30%:20%:50% for samples A, B, and C with the thickness of 2 cm, respectively. The thickness of samples D, E, and F is 3 cm with the same volume fraction. The research's design is shown in Figure 1.

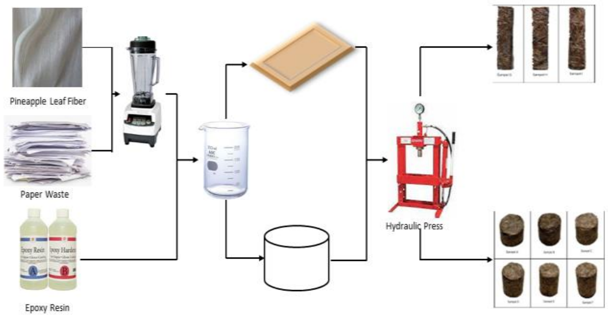
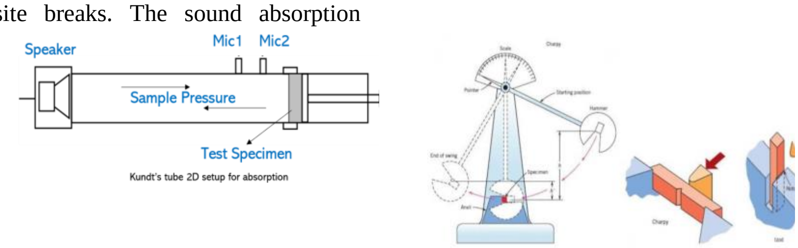


Figure 1. Research's design

Sound absorption coefficient measurements are performed by measuring the intensity level before (I_1) and after (I_2) passing through the absorbent material (I_2).

The impact test is performed by swinging the weight on the test equipment until the composite breaks. The sound absorption coefficient and impact strength were determined with standard ISO 11654 and ASTM E23. The illustration of sound absorption coefficient and impact strength is shown in Figure 2.



(a) **(b)**

Figure 2. Illustration of the test used, (a) Sound absorption coefficient (b) Impact strength

Fig. 2 (a) shows the test of sound absorption. The sound waves were generated from speakers with a specific frequency and sound waves will hit the sample. Some of the frequencies will be absorbed by the sample, but some will be reflected because they cannot pass through the sample's pores. The sound waves that pass through the sample pores will be recorded by a detector (mic) due to sound absorption. The transfer function techniques, as well as the two-microphone technique, were applied.

The frequency ranges from 250 to 3000 Hz. The ratio between pressures were create by wave sound on the microphone was calculated with transfer function (H_{12}):

$$H_{12} = \frac{p_1}{p_2} \quad (1)$$

$$H_I = \frac{p_{I1}}{p_{I2}} = e^{-jk_0(x_1-x_2)} \quad (2)$$

$$H_R = \frac{p_{2R}}{p_{1R}} = e^{-jk_0(x_1-x_2)} \quad (3)$$

H_I is the transfer function of the incident wave alone and H_R is the transfer function of the reflected wave. The coefficient of the reflected wave was calculated from equation (1) – (3):

$$R = \frac{H_{12} - H_1}{H_R - H_{12}} = e^{-jk_0(x_1 - x_2)} \tag{4}$$

where R is the coefficient of the reflected wave, k is the wavenumber, and x is the distance between the microphone and the sample. The coefficient of reflected was used to calculate the sound absorption coefficient in the following expression:

$$\alpha = 1 - |R|^2 \tag{5}$$

The impact strength test in Fig 2 (b) is used to determine the material's physical characteristics as well as the ductility of the composite that has been created. The basic idea behind rupture testing is to compute the energy provided by the load and the energy absorbed by the sample. When, the load possesses potential energy occurs the weight is increased to a particular height, the maximum kinetic energy.

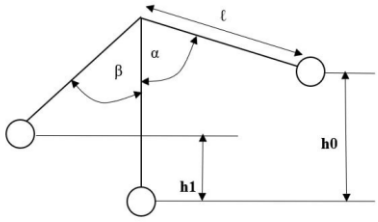


Figure 3. Illustration of impact energy calculated

In the impact test, a notched test specimen is used which is struck with a pendulum. The specimen is clamped at one end until the notch is near the clamp in the Izod technique. A pendulum swinging from a certain height will strike the end of the specimen that is not clamped from the front of the notch.

In the Charpy test, the specimen is placed horizontally both ends are held, and the pendulum will hit the test rod from behind the notch. The impact energy can be seen on the scale of the testing machine. The magnitude of the impact energy theoretically can be calculated:

$$E_0 = W \times h_0 \tag{6}$$
$$E_1 = W \times h_1 \tag{7}$$
$$\Delta E = E_0 - E_1 = W(h_0 - h_1) \tag{8}$$

from Fig. 3 obtained that:

$$h_0 = l - l\cos\alpha \tag{9}$$
$$= l(1 - \cos\alpha) \tag{10}$$
$$h_1 = l - l\cos\beta \tag{11}$$
$$= l(1 - \cos\beta) \tag{12}$$

Finally, the impact energy was calculated with the following expression:

$$\Delta E = W \times l(h_0 - h_1) \tag{13}$$

where E is energy (J), W is pendulum weight (N), h is pendulum height before-after released (m), l is pendulum length (m), α and β are angle before-after (°). The impact strength (I_s) was calculated by impact energy divided by cross-section area (A):

$$I_s = \frac{\Delta E}{A} = \frac{W \times l(h_0 - h_1)}{A} \tag{14}$$

RESULTS AND DISCUSSION

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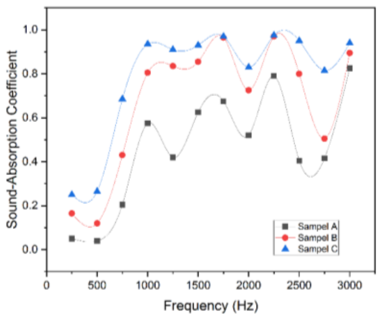
Pineapple leaf fiber has a laminated and elongated morphology, while paper waste is in the form of particles. The combination of the two in the composite makes the fiber interface classified as a hybrid composite (Abdul Ghofir & ., 2018; Andrew & Dhakal, 2022; Astrauskas et al., 2021; Tang & Yan, 2017).

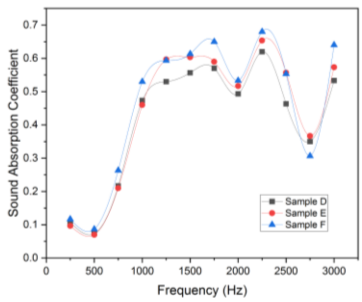
The impedance tube method was used for the sound absorption test, in which the sound source from the speaker was linked to a generator with a frequency range of 250 to 3000 Hz. Figure 4 depicts the relationships between the sound absorption coefficient and the frequency of the sample.

According to ISO 11645 acoustic materials that are categorized as having sound absorption capacity are materials with a sound absorption coefficient greater than 0.15. The relationship between the sound absorption coefficient and the thickness of the material is written in Equation 15

$$I = I_0 e^{-ax} \quad (15)$$

where I is the final intensity (dB), I_0 is the initial intensity (dB), α is the sound absorption coefficient, and x is the thickness of the sample (m). From Equation 15 it can be seen that the thickness of the material will affect the sound absorption coefficient, the thickness of the samples used are 2 cm and 3 cm, in addition to the thickness of the other factors that affect the porosity and density of the material (Sharma et al., 2020; Taban, Khavanin, Jafari, et al., 2019). Porosity cause sound waves to be reflected in the cavities so the energy and intensity will decrease (Mwango & Kambole, 2019; Nhuapeng & Thamjaree, 2019)

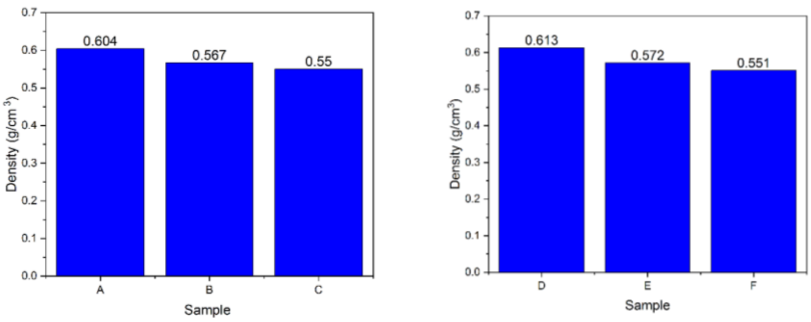




(a) **(b)**

Figure 4. The sound absorption coefficient at the frequency range of 250-2000 Hz, (a) The samples with 2 cm thickness (b) The samples with 3 cm thickness

Figure 4 demonstrates that the sound absorption coefficient increases as the frequency ranges from 500 to 1750 Hz. The average sound absorption coefficients for A, B, and C were 0.462, 0.672, and 0.788, respectively. While the average sound absorption coefficients for D, E, and F were 0,415; 0,420; and 0,464, respectively. At a frequency of 2000 Hz, the value of the sound absorption coefficient decreases. The sound absorption coefficient decreases because the particles are saturated, resulting in energy loss and destructive interference (Rus et al., 2017). According to the results, the sound absorption coefficient increased with the addition of fiber. The addition of fibers makes more pores formed in the composite structure, and density will increase. It makes sound waves harder to escape and increases the sound absorption coefficient (Pöhler et al., 2017; Xu et al., 2018). The value of the sound absorption coefficient can be impacted by the resonance that occurs in the composite cavity. Because of the resonance, some of the sound waves are unable to leave the sample cavity, reducing the reflected wave energy (Arwanda & Sani, 2019). The unevenness of the composite composition harms the sound absorption coefficient (Sandi; et al., 2020). It generated a space between molecules on the sample, resulting in high porosity and low density. Figure 5 depicts a density sample (Arwanda & Sani, 2019). The density sample is shown in Figure 5.



(a) (b)

Figure 5. The density of Pineapple leaf fibers with paper waste, (a) Composite with a thickness of 2 cm (b) Composite with a thickness of 3 cm

The densities of the samples from A, B, and C for the thickness of the samples 2 cm were 0.604 g/cm^3, 0.567 g/cm^3, and 0.550 g/cm^3, respectively. The densities of samples thickness of 3 cm from D, E, F samples were 0,613 g/cm^3; 0,572 g/cm^3; and 0,551 g/cm^3 as shown in Figure 5. Density causes sound waves to interact with the pores in the sample, causing the energy to drop. The denser the sample, the more difficult it is for the sound wave to pass through the material, resulting in a lower sound absorption coefficient (Putra et al., 2018; Taban, Khavanin, Ohadi, et al., 2019). Mechanical characteristics are essential for sound-absorbing composites (Malalli & Ramji, 2022). The impact strength test is used to determine a material's capacity to absorb energy during a collision, as shown in Figure 6.

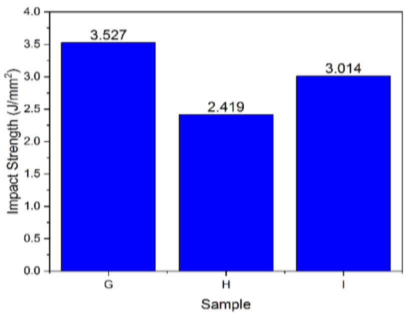


Figure 6. The impact strength value of pineapple leaf fibers with paper waste composite

The impact strengths of the G, H, and I samples were 3.527 J/mm^2, 2.419 J/mm^2, and 3.014 J/mm^2, respectively, as shown in Figure 6. The materials of pineapple leaf fibers with paper waste composite are brittle and have a high density, resulting in a high impact strength value, as shown in Figure 6.

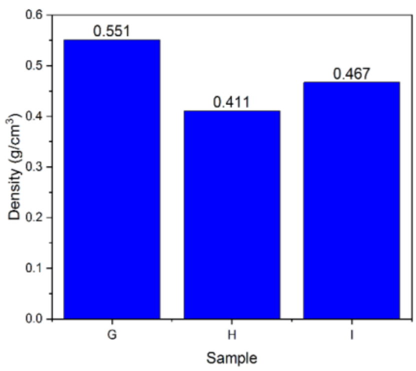


Figure 7. The impact strength density of pineapple leaf fibers with paper waste composite

Figure 7 indicated that the higher the density, the higher the impact strength. The density of the sample will increase as the concentration of paper increases. As a result, the sample would be difficult to break. The low density of composite has a low impact strength value, which causes voids or holes to form on each material bond and makes composites more brittle (Putra et al., 2020). In composites, the uneven component concentration resulted in the formation of voids and weakened the connection between filler and matrix (Hardiana, *et al.*, 2021). The sound absorption coefficient and mechanical properties are affected by the structure of the composite (porous and arrangement of fibers) and physical properties (density) (Hoque et al., 2022; Venkata Deepthi et al., 2019).

This study shows that the combination of pineapple leaf fiber and paper waste can be used as a sound-absorbing material, and waste materials, it can reduce the environmental pollution, either organic pollution or noise pollution. The combination of pineapple leaf fiber and paper waste will improve the quality of composite that can be used as an absorbing material as well. The next study to measure the optimum thickness and the thermal properties to get complete information was needed.

CONCLUSION

The pineapple leaf fiber and paper waste reinforcement composites can be used as sound-absorbing materials. The addition of fiber in the composite makes the absorption coefficient increase, but the mechanical properties decrease. The sound absorption coefficient increases due to the cellulose content and the structure of the fibers. Pineapple leaf fiber in the form of lamina affects on the mechanical properties. The paper waste in the form of particles will create a porous structure which has an impact on sound absorption.

The arrangement of elongated-fibers makes the load-received by the composite spread evenly on other fibers. The porous structure causes sound waves-reflected in the pores thereby reducing energy. The pores capture the sound waves that pass through the composite. The pores and fibers interface can be seen through the density of the material. The high density indicates that the fiber's interface was closer and the pores formed are small so that the relationship between pores and fiber's arrangement using the analysis of the coefficient of sound fiber and the mechanical properties.

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AUTHOR CONTRIBUTIONS

Contributions from :

1. Kartika Sari as the first author, co-author, review, editing and conceptualization/ funding acquisition/formal analysis/ writing—original draft preparation
2. Yazid Zainur Isnen as the second autho, review and editing, formal analysis, and writing—original draft preparation
3. Agung Bambang Setio Utomo as the third author, methodology, data curation, and writing—original draft preparation
4. Sunardi as the fourth author, methodology, data curation, and writing—original draft preparation

All authors have read and agreed to the published version of the manuscript.

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Properties of Pineapple Leaf Fibers with Paper Waste as An Absorbing-Composite to Reduce Noise

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ABSTRACT

Natural product-based noise-absorbing composite can be an alternative to replace synthetic fiber because of its advantages of high strength, toughness, low price, and abundance to reduce noise. The materials used were pineapple leaf fibers with paper waste. This research aims to study the advantage of natural products to reduce noise by analyzing the coefficient of sound absorption and impact strength to evaluate the absorbing composite. The composites were tested with the Charpy method with ISO 11654 standard and ASTM E23 for sound absorption and impact strength. Sound absorption was carried out using an impedance tube at a frequency range of 250 – 3000 Hz. The volume fraction of pineapple leaf fibers, paper waste, and resin epoxy concentrations were 20% : 30% : 50%, 25% : 25% : 50%, and 30% : 20% : 50%. The thickness for the sound absorption coefficient was 2 cm and 3 cm, while the thickness of the impact strength was 0.5 cm. The highest sound absorption coefficient of pineapple leaf fibers composite for 30% : 20% : 50% volume fraction was 0.788 for sample 2 cm. The highest impact strength for 20% : 30% : 50% volume fraction of the thickness of 0.5 cm was 3.527 J/mm^2. The results of the sound absorption coefficient will increase if used more pineapple leaf fibers but it will decrease the impact strength. Based on this research, the pineapple leaf fibers will improve the quality of the composite that can be used as a sound-absorbing material as well. These materials possess the promising potential to decrease waste and are used in industries for a low cost.

INTRODUCTION

Noise pollution from traffic and industries may generate noise difficulties and disrupt or decrease human hearing capabilities. Noise pollution has the potential to harm fetuses, babies, children, and adults. Noise pollution has an impact on both physical and emotional health. The noise exposure causes psychomotor effects by increasing stress, disrupting sleep, causing difficulty in normal conversation, lack of concentration, irritability, violent behavior, increased heart rate commonly observed with loud drum beats, tachyarrhythmia, vasoconstriction, hypertension, and other diseases (Gupta et al., 2018; Oguntunde et al., 2019). Installing sound-absorbing materials in buildings can help to minimize noise pollution.

Noise-absorbing materials are used to minimize noise because they comprise a filler that acts as an amplifier and a matrix that binds the fillers together. Alternatives to pineapple leaf fibers and paper waste that might be utilized as noise-absorbers in this study include pineapple leaf fibers and paper waste (Santulli et al., 2022). Pineapple leaf fiber is one of the organic wastes, this fiber can be used as a sound absorber because of its high cellulose content. The cellulose content in pineapple leaf fiber is 70 – 82%.

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Then, the waste paper that is used as pulp has a porous morphology. The combination of cellulose and pore content of pineapple leaf fiber and paper waste makes these two wastes very potential to be developed as sound-absorbing composites (Fareez et al., 2018; Jain & Sinha, 2021; Nair & Dasari, 2022).

The filler of the composite is usually a material that has the desired properties of the final composite product, this filler will be able to add to the properties possessed by the matrix such as mechanical, acoustic, electrical, and type strength (Nhuapeng & Thamjaree, 2019). Fillers can be derived from natural or synthetic products, each of which has its advantages when used as a filler. The usage of synthetic fiber is harmful to the environment and results in the accumulation of non-biodegradable trash. Natural fibers might be utilized as an alternative to synthetic fibers due to their benefits of high strength, toughness, low cost, and availability, as well as being clean and biodegradable. Pineapple leaf fibers and paper waste are still underused and end up in landfills (Todkar & Patil, 2019; Zulaikha et al., 2022).

The study on the use of pineapple leaf fiber concrete composite as a noise-absorbing material generated a sound absorption coefficient value of 0.59 at a frequency of 2000 Hz (Arwanda & Sani, 2019). At a frequency of 800 Hz, the sound absorption coefficient of the paper waste, rice husk ash, and resin polyester-based composite were 0.48 (Isran et al., 2018). The composite of pineapple leaf fibers has a sound absorption coefficient of 0.9 at 1 kHz frequency (Putra et al., 2018). The other study using rami fiber as a composite obtained an impact strength of 0.0725 J/mm^2 (Purboputro & Hariyanto, 2017). The excellent absorption ability was demonstrated by a composite with a low impact strength value. As noise absorbers, a few layered composites with pores were utilized.

The composite may be used on walls, box speakers, and other surfaces. The sound wave that strikes the material's surface will be reflected, transmitted, and absorbed (González, 2019). The sound wave absorbed by the material produces a drop in sound wave strength and absorbed energy, which is referred to as the sound absorption coefficient.

The addition of pineapple leaf fiber combined with paper waste affected the structure and properties of the composite, paper waste is utilized to create a foam-like material with properties similar to conventional foam to make the composite structure more porous (Astrauskas et al., 2021). The high porosity of paper waste and pineapple leaf fiber, as well as its high cellulose content, are benefits of this material as a sound wave-absorbing composite (Haryadi et al., 2021).

The impact test determined the mechanical properties when it’s forced to a rapid force as a result of a collision. The Charpy and Izod techniques are used to determine impact strength. The distinction between the Charpy and Izod techniques lies in the location of the specimen to be evaluated. In the Charpy technique, the specimen is placed horizontally. Meanwhile, with the Izod technique, the specimen position is vertical (Callister & Rethwisch, 2018).

In this work, the preparation of the pineapple leaf fiber was combined with the paper waste aim to determine the mechanical properties using the Charpy method and sound absorption. The addition of paper waste to the pineapple leaf fiber composite makes another advantage, which has good absorption properties as an acoustic panel. This makes the application of composites wider and can be used in various industries. The composites with low breaking strength indicate good sound absorption. The effect of pineapple leaf fiber combined with paper waste can be got environment-friendly, easy to obtain, and low in cost.

METHODS

Pineapple leaf fibers, paper waste, and epoxy resin were used in this study. The pineapple leaf fibers and paper waste were chopped into pieces. Water was used to soak and crush the paper waste. The pineapple leaf fibers and paper waste were used as reinforcement. Epoxy resin is combined with hardener and used as a matrix, then each reinforcement (pineapple leaf fibers and paper waste) is added to the resin and stirred until homogenous, then pressed with the hydraulic press. The composite thickness for the sound absorption test is 2 cm and 3 cm with a diameter tube of 2.5 cm, and the dimension of the composite for the impact test is 5.5 × 1 × 0.5 cm. The volume fraction of pineapple leaf fibers, paper waste, and resin epoxy concentrations were 20%:30%:50%, 25%:25%:50%, and 30%:20%:50% for samples A, B, and C with the thickness of 2 cm, respectively. The thickness of samples D, E, and F is 3 cm with the same volume fraction. The research's design is shown in Figure 1.

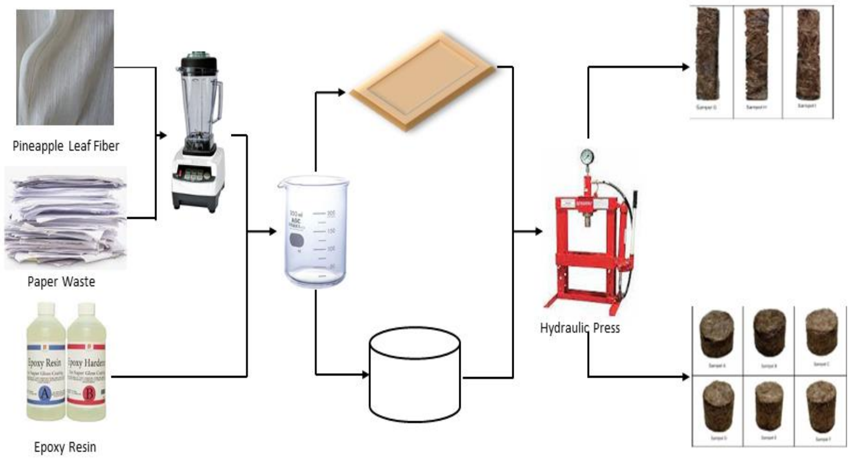
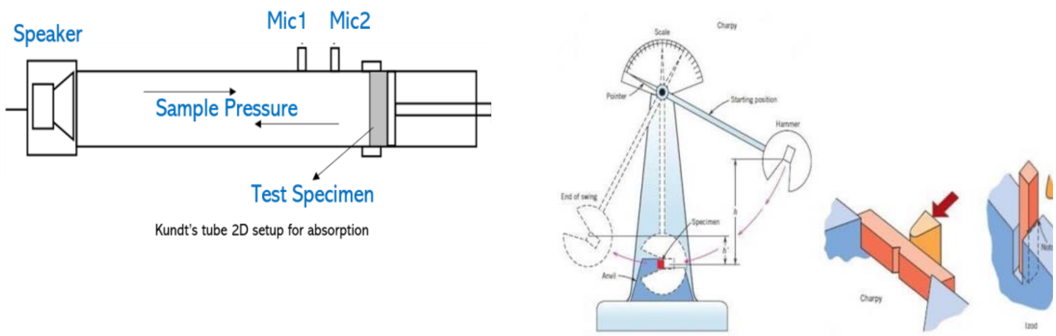


Figure 1. Research's design

Sound absorption coefficient measurements are performed by measuring the intensity level before (I_1) and after (I_2) passing through the absorbent material (I_2).

The impact test is performed by swinging the weight on the test equipment until the composite breaks. The sound absorption coefficient and impact strength were determined with standard ISO 11654 and ASTM E23. The illustration of the sound absorption coefficient and impact strength is shown in Figure 2.



(a) (b)

Figure 2. Illustration of the test used, (a) Sound absorption coefficient (b) Impact strength

Fig. 2 (a) shows the test of sound absorption. The sound waves were generated from speakers with a specific frequency and sound waves will hit the sample. Some of the frequencies will be absorbed by the sample, but some will be reflected because they cannot pass through the sample's pores. The sound waves that pass through the sample pores will be recorded by a detector (mic) due to sound absorption. The transfer function techniques, as well as the two-microphone technique, were applied.

The frequency ranges from 250 to 3000 Hz. The ratio between pressures were create by wave sound on the microphone was calculated with the transfer function (H_{12}):

$$H_{12} = \frac{p_1}{p_2} \quad (1)$$

$$H_I = \frac{p_{I1}}{p_{I2}} = e^{-jk_0(x_1 - x_2)} \quad (2)$$

$$H_R = \frac{p_{2R}}{p_{1R}} = e^{-jk_0(x_1 - x_2)} \quad (3)$$

H_I is the transfer function of the incident wave alone and H_R is the transfer function of the reflected wave. The coefficient of the reflected wave was calculated from equation (1) – (3):

$$R = \frac{H_{12} - H_1}{H_R - H_{12}} = e^{-jk_0(x_1 - x_2)} \quad (4)$$

where R is the coefficient of the reflected wave, k is the wavenumber, and x is the distance between the microphone and the sample. The coefficient of reflected was used to calculate the sound absorption coefficient in the following expression:

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

The impact strength test in Fig 2 (b) is used to determine the material's physical characteristics as well as the ductility of the composite that has been created. The basic idea behind rupture testing is to compute the energy provided by the load and the energy absorbed by the sample. When, the load possesses potential energy occurs the weight is increased to a particular height, the maximum kinetic energy.

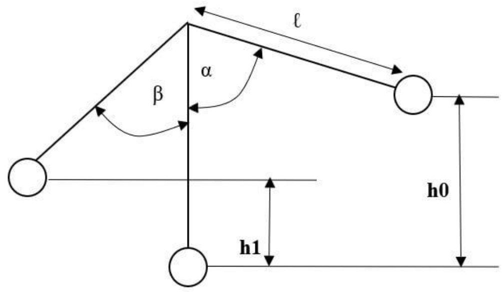


Figure 3. Illustration of impact energy calculated

In the impact test, a notched test specimen is used which is struck with a pendulum. The specimen is clamped at one end until the notch is near the clamp in the Izod technique. A pendulum swinging from a certain height will strike the end of the specimen that is not clamped from the front of the notch.

In the Charpy test, the specimen is placed horizontally both ends are held, and the pendulum will hit the test rod from behind the notch. The impact energy can be seen on the scale of the testing machine. The magnitude of the impact energy theoretically can be calculated:

$$E_0 = W \times h_0 \quad (6)$$

$$E_1 = W \times h_1 \quad (7)$$

$$\Delta E = E_0 - E_1 = W(h_0 - h_1) \quad (8)$$

from Fig. 3 obtained that:

$$h_0 = l - l\cos\alpha \quad (9)$$

$$= l(1 - \cos\alpha) \quad (10)$$

$$h_1 = l - l\cos\beta \quad (11)$$

$$= l(1 - \cos\beta) \quad (12)$$

Finally, the impact energy was calculated with the following expression:

$$\Delta E = W \times l(h_0 - h_1) \quad (13)$$

where E is energy (J), W is pendulum weight (N), h is pendulum height before-after released (m), l is pendulum length (m), and α

and β are angled before-after (°). The impact strength (I_s) was calculated by impact energy divided by cross-section area (A):

$$I_s = \frac{\Delta E}{A} = \frac{W \times l(h_0 - h_1)}{A} \qquad (14)$$

RESULTS AND DISCUSSION

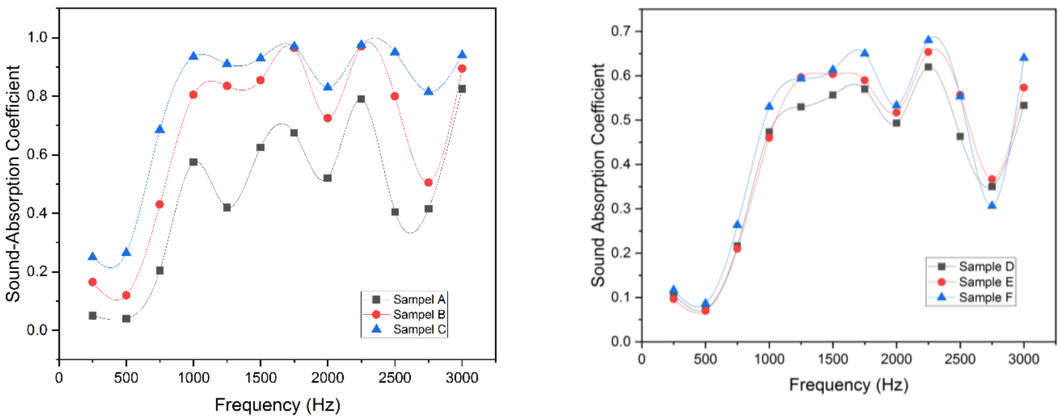
Pineapple leaf fiber has a laminated and elongated morphology, while paper waste is in the form of particles. The combination of the two in the composite makes the fiber interface classified as a hybrid composite (Andrew & Dhakal, 2022; Astrauskas et al., 2021; Ghofir & Sutanto, 2018; Tang & Yan, 2017). According to (Jain & Sinha, 2021), pineapple leaf fiber (PALF) contains high cellulose and cellulosic molecules model is a three-dimensional structure that runs parallel to the fiber's crystalline area. Within amorphous regions, the remaining molecular structural components are meant to associate.

The impedance tube method was used for the sound absorption test, in which the sound source from the speaker was linked to a generator with a frequency range of 250 to 3000 Hz. Figure 4 depicts the relationships between the sound absorption coefficient and the frequency of the sample.

According to ISO 11645 acoustic materials that are categorized as having sound absorption capacity are materials with a sound absorption coefficient greater than 0.15. The relationship between the sound absorption coefficient and the thickness of the material is written in Equation 15

$$I = I_0 e^{-ax} \qquad (15)$$

where I is the final intensity (dB), I_0 is the initial intensity (dB), α is the sound absorption coefficient, and x is the thickness of the sample (m). From Equation 15 it can be seen that the thickness of the material will affect the sound absorption coefficient, the thickness of the samples used are 2 cm and 3 cm, in addition to the thickness of the other factors that affect the porosity and density of the material (Sharma et al., 2020; Taban et al., 2019). Porosity causes sound waves to be reflected in the cavities so the energy and intensity will decrease (Mwango & Kambole, 2019; Nhuapeng & Thamjaree, 2019)



(a) (b)

Figure 4. The sound absorption coefficient at the frequency range of 250-2000 Hz, (a) The samples with 2 cm thickness (b) The samples with 3 cm thickness

Figure 4 demonstrates that the sound absorption coefficient increases as the frequency ranges from 500 to 1750 Hz. The average sound absorption coefficients for A, B, and C were 0.462, 0.672, and 0.788, respectively. While the average sound absorption coefficients for D, E, and F were 0,415; 0,420; and 0,464, respectively. At a frequency of 2000 Hz, the value of the sound absorption coefficient decreases. The sound absorption coefficient decreases because the particles are saturated, resulting in energy loss and destructive interference (Rus et al., 2017). According to the results, the sound absorption coefficient increased with the addition of fiber. The addition of fibers makes more pores formed in the composite structure, and density will increase. It makes sound waves harder to escape and increases the sound absorption coefficient (Pöhler et al., 2017; Xu et al., 2018). The value of the sound absorption coefficient can be impacted by the resonance that occurs in the composite cavity. Because of the resonance, some of the sound waves are unable to leave the sample cavity, reducing the reflected wave energy (Arwanda & Sani, 2019). The unevenness of the composite composition harms the sound absorption coefficient (Sandi; et al., 2020). It generated a space between molecules on the sample, resulting in high porosity and low density. Figure 5 depicts a density sample (Arwanda & Sani, 2019). The density sample is shown in Figure 5.

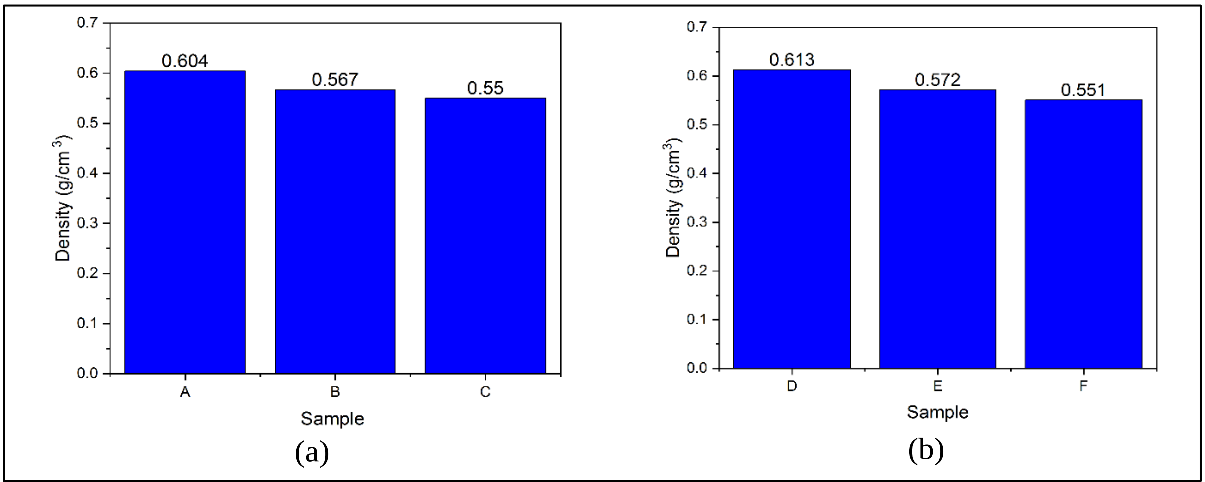


Figure 5. The density of Pineapple leaf fibers with paper waste, (a) Composite with a thickness of 2 cm (b) Composite with a thickness of 3 cm

The densities of the samples from A, B, and C for the thickness of the samples 2 cm were 0.604 g/cm^3, 0.567 g/cm^3, and 0.550 g/cm^3, respectively. The densities of samples thickness of 3 cm from D, E, and F samples were 0,613 g/cm^3; 0,572 g/cm^3; and 0,551 g/cm^3 as shown in Figure 5. Density causes sound waves to interact with the pores in the sample, causing the energy to drop. The denser the sample, the more difficult it is for the sound wave to pass through the material, resulting in a lower sound absorption coefficient (Putra et al., 2018; Taban et al., 2019). Mechanical characteristics are essential for sound-absorbing composites (Malalli & Ramji, 2022). The impact strength test is used to determine a material's capacity to absorb energy during a collision, as shown in Figure 6.

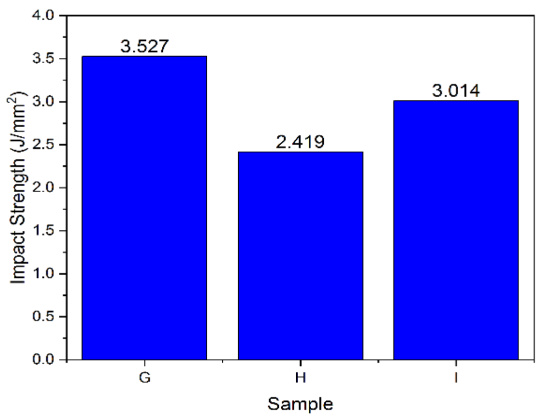


Figure 6. The impact strength value of pineapple leaf fibers with paper waste composite

The impact strengths of the G, H, and I samples were 3.527 J/mm^2, 2.419 J/mm^2, and 3.014 J/mm^2, respectively, as shown in Figure 6. The materials of pineapple leaf fibers with paper waste composite are brittle and have a high density, resulting in a high impact strength value, as shown in Figure 6.

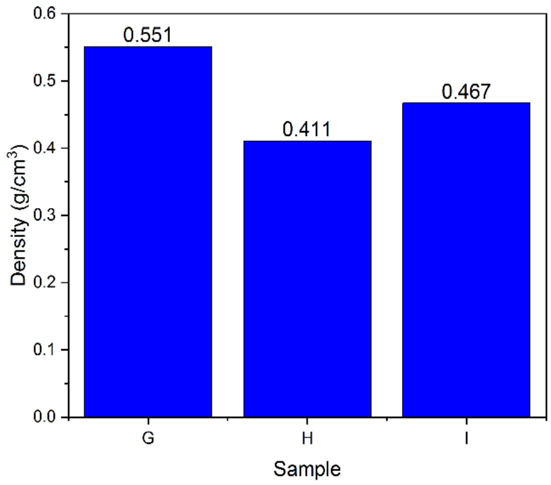


Figure 7. The impact strength density of pineapple leaf fibers with paper waste composite

Figure 7 indicated that the higher the density, the higher the impact strength. The density of the sample will increase as the concentration of paper increases. As a result, the sample would be difficult to break. The low density of the composite has a low impact strength value, which causes voids or holes to form on each material bond and makes composites more brittle (Putra et al., 2020). In composites, the uneven component concentration resulted in the formation of voids and weakened the connection between filler and matrix. The sound absorption coefficient and mechanical properties are affected by the structure of the composite (porous and arrangement of fibers) and physical properties (density).

This study shows that the combination of pineapple leaf fiber and paper waste can be used as a sound-absorbing material, and waste material. It can reduce environmental pollution, either organic pollution or noise pollution. The combination of pineapple leaf fiber and paper waste will improve the quality of the composite which can be used as an absorbing material as well. The next study to measure the optimum thickness and the thermal properties to get complete information was needed.

CONCLUSION

The pineapple leaf fiber and paper waste reinforcement composites can be used as sound-absorbing materials. The addition of fiber in the composite makes the absorption coefficient increase, but the mechanical properties decrease. The sound absorption coefficient increases due to the cellulose content and the structure of the fibers. Pineapple leaf fiber in the form of lamina affects the mechanical properties. The paper waste in the form of particles will create a porous structure that has an impact on sound absorption.

The arrangement of elongated fibers makes the load received by the composite spread evenly on other fibers. The porous structure causes sound waves-reflected in the pores thereby reducing energy. The pores capture the sound waves that pass through the composite. The pores and fibers interface can be seen through the density of the material. The high density indicates that the fiber's interface was closer and the pores formed are small so that the relationship between pores and fiber's arrangement using the analysis of the coefficient of sound fiber and the mechanical properties.

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AUTHOR CONTRIBUTIONS

KS as the first author, co-author, review, editing, and conceptualization/funding acquisition/formal analysis/writing original draft preparation. YZ as the second author, reviews and edits, does formal analysis, and writes original draft preparation. AB and SD as the third author and fourth author, methodology, data curation, and writing original draft preparation. All authors have read and agreed to the published version of the manuscript.

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