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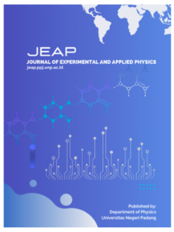

Analysis of the Influence Mass Variations of Banana STEM Fibres with Polypropylene (PP) Matrix on Accoustic and Porosity Properties

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Abstract: Noise pollution is sound that you do not want to hear or is known as noise. If people hears loud noises continuously, it can disrupt hearing function. Therefore, it is necessary to have noise control by making an acoustic material that will be coated on the room's walls. A cheap and environmentally friendly alternative material is using banana stem waste from the fibre taken and with polypropylene as a fibre binder. This research aims to determine the effect of variations in the mass composition of banana stem fibre with the matrix polypropylene on the value of the acoustic properties and porosity, and determine the relationship between porosity with acoustic properties. Characteristics of the acoustics that will be measured are sound absorption coefficient, sound reflection coefficient, and transmission loss. The method used is using a characterizaton tool with one microphone impedance tube and porosity test tool with a digital scale. Acoustic material is made by varying the mass percentage in the ratio of polypropylene and midrib fibre banana, namely 90%:10%; 85%:15%; 80%:20%; 75%:25%; and 70%:30%. Based on the research results, it is known that the more fibre composition in the composite, the sound absorption coefficient values, transmission loss values, and porosity values were higher produced, but the resulting sound reflection coefficient value was lower. Then, the relationship between porosity with acoustic properties was that the higher porosity value, the resulting sound absorption coefficient and transmission loss value are higher too. However, the resulting sound reflection coefficient value was getting lower.

Keywords: Acoustic Properties; Banana Stem Fibre; Composite Panel; Polypropylene; Porosity.

1. Introduction

As technology develops, it has had many positive and negative impacts on life man. Negative impacts include noise pollution. Noise pollution is sound that does not want to be heard or known as noise. Noise originates from a device industry where sound is undesirable at a certain level because it causes hearing loss [1]. For example, people who work in the manufacturing or factory industrial sector will hear loud noises produced by industrial equipment. The noise threshold values in the workplace have been regulated in the Minister of Manpower and Transmigration Number 13 of 2011 concerning threshold values for physical factor and chemical factors in the workplace is 85dB for 8 hours of work. If the sound intensity is 85dB or more, you can disturb the balance of the auditory system [2]. If people are continuously active in an area noise, it can disrupt people's productivity in their activities. Therefore, it is necessary to control noise by making an acoustic material that can reduce or even absorb sound intensity [3].

Acoustic materials are materials that absorb or dampen sound to reduce the noise industry [4]. Acoustic materials that can absorb noise well are porous materials [5]. This is because the incoming waves will be absorbed into the material through the pores. Porous materials are easily obtained from local plants. Porous plants that can be used are lignocellulosic raw materials such as coconut fibre, bagasse straw soap, and others with good quality [6]. Then, the porous material will be made into particle board or composite panels coated on the room's walls.

Composite panels are small pieces or particles made of lignocellulosic (fibre) materials mixed with other binders. Composite means a new single material made from two or more different materials [7]. This material is fibre as a filler or the main part in the case load-bearing [8]. Another material is the matrix as a fibre binder. These materials combine to form new materials through a steerable casting process to obtain the desired material properties [9]. The desired material properties can be reflected or absorb noise energy that occurs around the room with its ability as acoustic material.

So far, there has been much research on acoustic materials from synthetic materials such as foam, glasswool, or rockwool. However, the price of synthetic materials is relatively high, and they can cause health problems such as allergies and itching if they come into contact with the skin and disrupt breathing if the fibre powder is inhaled into the lungs [10]. Therefore, we need other alternative materials for noise absorption that are cheap and environmentally friendly. Another alternative for making sound-absorbing materials can be from natural porous materials sourced from nature directly, like plant fibre. Natural fibres have advantages over synthetic fibres, including they can be recycled and renewed, are not harmful to the environment and health because their properties and mechanics are better and do not cause abrasion on the tool, so the price is lower [11]. Natural fibre also has high strength and stiffness [12]. Many types of plants are found in the surrounding environment, such as on the side of the road, in rural rice fields, or the yard of the house that can be used, namely banana trees.

Banana trees have many benefits for society, from roots to leaves. However, there is another part that, after being cut down, is left or thrown away. This part is like a banana stem. Banana stem is an agricultural waste that has yet to be widely utilized. Production of banana stem waste is estimated to reach 640,000 trees with the assumption of waste production of 80% from around 800,000 trees [13]. Midrib Bananas have cellular tissue with interconnected pores and have excellent absorption capacity quite good when dried ([14]. Banana stems have excellent fibre potential because they are resistant to wet, soft, fibrous, and porous, so they can be a basic ingredient for acoustic materials [6]. Therefore, this research uses banana stem waste as a fibre for composites. Then, tying the fibre matrix is required.

Matrix is a material that can bind fibres in composite materials to maintain overall stability, physics, and chemistry after the production process [15]. A matrix that has been widely used in previous research is the polymer matrix. This is because of its low price, high strength, and relatively simple manufacturing process [16]. Polymer matrices are divided into two parts, namely thermosetting and thermoplastic [17]. Thermosetting is plastic, which, if made in solid form, cannot be melted again by heating [17]. Meanwhile, thermoplastic is a plastic material that, if heated to a specific temperature, will melt and can be reshaped into the desired shape [17]. An example of a thermoplastic is polypropylene (PP). Polypropylene is the lightest type of polymer; its stiffness, hardness, and tensile resistance are especially high to high temperatures [17]. Previous research was conducted by [17] on the morphological characterization of traits acoustic and physical properties of Dendrocalamus asper fibre-reinforced polypropylene composites for automotive. Matrix Polypropylene is used. As a result of this research, the composition of the weight fraction of 20% fibre: 80% matrix is known To have excellent sound absorption capabilities. Therefore, this research utilizes matrices PP to bind fibre.

This research is important to know the quality of composite material with banana stem fibre as a filler and polypropylene as an matrik on sound absorption ability, sound reflection ability, and sound resisting ability which will be useful as a noise control material. Therefore, in this research will measure the values of sound reflection coefficient, sound absorption coefficient, transmission loss with using one microphone tube method impedance. The one microphone impedance tube method is an important simple method to determine the characteristics of the acoustic properties of a material [3].

The sound absorption coefficient is the arrival of a portion of sound energy that is not reflected by a sound surface but instead is absorbed [18]. The value of the sound absorption coefficient is expressed as α. The greater it means, the better the ability to absorb sound material as a sound absorber [19]. Coefficient sound reflection is the amount of reflection of sound waves when they hit a material surface [20]. Transmission loss is the ability of a material not to transmit sound from the sound source to the room receiver next to it [21]. Acoustic materials are expected to have absorption and retaining capabilities for sound rather than being reflected. So, the material is expected to have an absorption coefficient value of high sound and transmission loss and low reflection coefficient values. This research was carried out to find the most appropriate fiber and matrix composition to form an acoustic material that can absorb noise and isolate the sound effectively.

The ability of acoustic materials to absorb, transmit, and reflect sound is influenced by material porosity. Porosity is a comparison of the volume of space between the fibre in the form of pores to the overall fibre volume [22]. If the porosity value of a material is high, it will cause the material to absorb more sound than it reflects [23]. His height porosity is influenced by the number of fibres [24].

Based on the background above, this research will focus on the influence of variations in fibre mass banana steam with a polypropylene matrix on acoustic properties and porosity, as well as porosity relationships with acoustic properties. The acoustic properties tested are sound reflection coefficient, sound absorption coefficient, and transmission loss.

2. Materials and Method

This research made composite panel with a total mass of 70 grams. The comparison ratio of the mass composition between the PP matrix and fibre was 90%:10%; 85%:15%, 80%:20%, 75%:25%, and 70%:30%. The thickness of the composite panel was 0.8 cm, with a fibre length was 1 cm, and the frequencies used were 250 Hz, 500 Hz, 750 Hz, and 1000 Hz. The tools used to make samples were wire brushes, rulers, scissors, digital scales, sandpaper, stove, frying pan, mould, industrial gun thermometer, and beaker. Tools used for sample characterization, namely an one microphone impedance tube, an oscilloscope, a sound generator, a sound level meter, and a digital scale. Research materials used were banana stem fibre, PP, clean water, solid NaOH, and distilled water. Stages of this research there were seven stages, as in the flowchart in Figure 1 below.

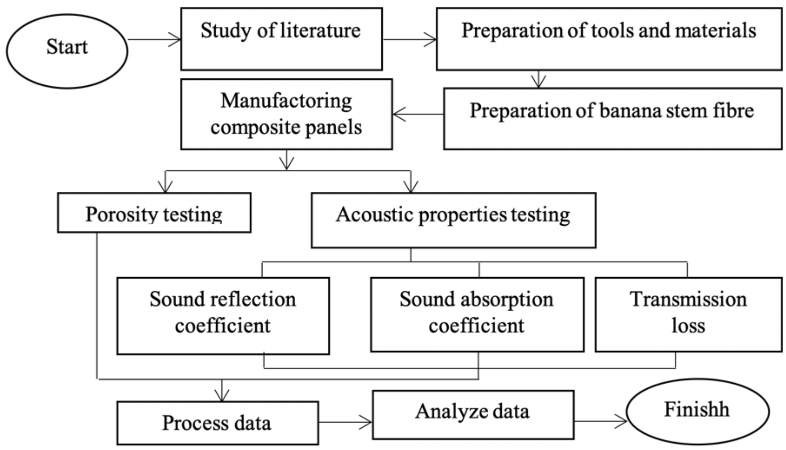

Figure 1. Research flow chart

Based on Figure 1 above, the second stage of this research is material preparation. The preparation of materials was take the banana stem. Then, the banana stem were cut into several parts to make the process easier to wash. After that, the banana stems was washed clean and soaked in plain clean water for 24 hours [25]. After soaked, dried it in the hot sun until dry. Once dried, the banana stem was brushed with a wire brush to get fibres like Figure 2.


Figure 2. Banana stem fibre

After got the fibre as in Figure 2, it alkalized with 5% NaOH solution for approximately 2 hours to remove cellulose and lignin [10]. After soaked with NaOH solution, rinsed with plain water until clean and dried in the sun again until the fibre dry. After dried, the banana stem fibres were cut into 1 cm long fibres. Then, the fibre and matrix were weighted according to the determined mass. In the making sample process, the PP was melted for 10 minutes. After that, mixed with fibre and stir evenly. Then, put into the mould and close. The samples in the mould were left for 20 minutes. After the mould cools, the sample was removed from the mould, and a composite panel sample was obtained, as shown in Figure 3 below.


Figure 3. Composite panels

Based on Figure 3 above, 3 test samples were made for each variation. So, a total of 15 test samples were made sample. The sample was made with a diameter of 9.5 cm and a thickness of 0.8 cm. Then, the test sample was carried out, testing acoustic properties used the one microphone impedance tube method as in Figure 4 below.


Figure 4. One microphone impedance tube

Based on Figure 4 above, the impedance tube of one microphone was connected to an oscilloscope, and a sound generator carries out calibration to test the sound reflection coefficient and sound absorption coefficient. After that, the sample was put into a tube. Then, slide the wire on the tube outward while observing wave changes on the oscilloscope monitor screen. Waves with large amplitudes were considered to have maximum amplitude. Meanwhile, a small amplitude was the minimum amplitude.

For testing transmission loss, one microphone the impedance tube was connected to another tube as a receiving chamber sound. Then, the sound level meter was inserted into the small hole at the top of the chamber tube sound source and sound receiving room alternately to obtain the sound pressure level value at the sound source room and sound receiver room.

The sixth stage was processing sample data that has been characterized. The formula used in acoustic data processing using a one microphone impedance tube method and a porosity test tool as. To get the sound reflection and sound absorption coefficient values, we need to know the SWR value obtained from the following Equation (1):

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

Where, SWR is Standing Wave Ratio [26], (A+B) is maximum amplitude, and (A-B) is minimum amplitude. Then, from equation (1), the reflection coefficient can be determined from the following Equation (2):

$$r_{\Pi} = (\frac{SWR-1}{SWR+1})^2 \tag{2}$$

Where, r_{Π} is sound reflection coefficient [27]. From equation (2), the sound absorption coefficient (sound absorption) at a spesific frequency can be seen from the following Equation (3):

$$\alpha = 1 - (\frac{\mathrm{SWR}-1}{\mathrm{SWR}+1})^2 \tag{3}$$

Where, α is sound absorption coefficient [26]. Meanwhile, the relationship between the transmission loss and noise reduction is expressed in the following Equation (4):

$$NR = L_1 \ L_2 \tag{4}$$

Where, NR is noise reduction [21], L_1 is sound pressure level in the sound source room, and L_2 is sound pressure level in the sound receiving room. The relationship between transmission loss and noise reduction is expressed in the following Equation (5):

$$TL = NR + 10log\,(\frac{S}{A2}) \tag{5}$$

Where, TL is transmission loss (dB) [21], NR is noise reduction (dB), S is sample surface area (m2), and A_2 is total absorption of the receiving space (sabin.m^2). For get the porosity value, we use the following Equation (6):

$$P = \left(\frac{Wb - Wk}{Wk}\right) x100\% \tag{6}$$

Where, P is Porosity (%) [24], Wb is weight of test sample in wet condition after being soaked in water (grams), and Wk is dry condition test sample weight (grams).

3. Results and Discussion

Based on the data that has been characterized, the results of testing the sound reflection coefficient and sound absorption coefficient are two indirect data obtained when taking measurements using an impedance tube, namely the maximum amplitude (A+B) and minimum amplitude (A-B). After that, the data obtained from the measurement results was entered into equation 1 to get the SWR value. Then, the SWR value was entered into Equation 2 to get the values of the sound reflection coefficient and Equation 3 to obtain the sound absorption coefficient value. The following were data from test results with predetermined variations in matrix and fibre composition. Following were the test results of the sound reflection coeffiecient analysis for each sample with variations in composition and frequency used can be seen in Table 1.

Table 1. Results for sound reflection coefficient values

Variation	Frequency			
	250 Hz	500 Hz	750 Hz	1000 Hz
90% : 10%	0.36	0.33	0.31	0.28
85% : 15%	0.34	0.30	0.27	0.25
80% : 20%	0.30	0.27	0.24	0.22
75% : 25%	0.27	0.23	0.22	0.21
70% : 30%	0.24	0.21	0.18	0.16

Based on Table 1, it can be seen that the highest sound reflection coefficient value on the composite panel was 0.36 at a frequency of 250 Hz with a matrix and fibre composition of 90%:10%. In comparison, the lowest sound reflection coefficient value on composite panels is 0.16 at a frequency of 1000 Hz with matrix and fibre composition 70%:30%. Below, it can be seen a graph of the influence of composition on the sound reflection coefficient in Figure 5.

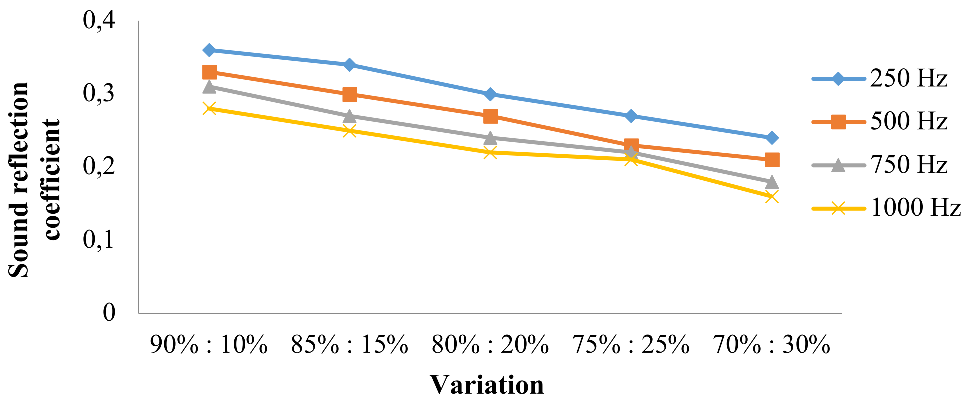

Figure 5. Graph of the influence of composition with the sound reflection coefficient

Based on Figure 5 above, the composite sample test results showed that the sound reflection coefficient value was lower as the fibre composition increases in the composite panel. So the highest sound reflection coefficient value was in composite panels with the least fibre composition. It is due to incoming sound waves will be absorbed by materials that contain many pores, so that more sound waves were absorbed than reflected [28]. This was also because waves sound that travel in a dense medium due to the increasing density of the material by the fibres have a speed slower propagation than sound waves traveling in a thin medium [14].

Based on Figure 5 above, it can also be seen that the higher frequency gets the lower sound reflection coefficient value. This was because low frequencies have long wavelengths long when passing through a porous absorption material the incoming sound was more reflected or passed on rather than absorbed [28]. So that the value of the sound reflection coefficient is higher when the high sound frequency than the low sound frequency. Following are were test results of the sound absorption coefficient analysis for each sample with variations in composition and frequency used can be seen in Table 2.

Table 2. Results For Sound Absorption Coefficient Values

Variation	Frequency			
	250 Hz	500 Hz	750 Hz	1000 Hz
90% : 10%	0.64	0.67	0.69	0.72
85% : 15%	0.66	0.70	0.73	0.75
80% : 20%	0.70	0.73	0.76	0.78
75% : 25%	0.73	0.77	0.78	0.79
70% : 30%	0.76	0.79	0.82	0.84

Based on Table 2 above, it can be seen that the highest sound absorption coefficient value in the composite panel value was 0.84 at a frequency of 1000 Hz with a matrix and fibre composition of 70%:30%. In comparison, the lowest sound absorption coefficient value for composite panels was 0.64 at a frequency of 250 Hz with matrix and fibre composition 90%:10%. Below it can be seen a graph of the influence of composition on the sound reflection coefficient in Figure 6.

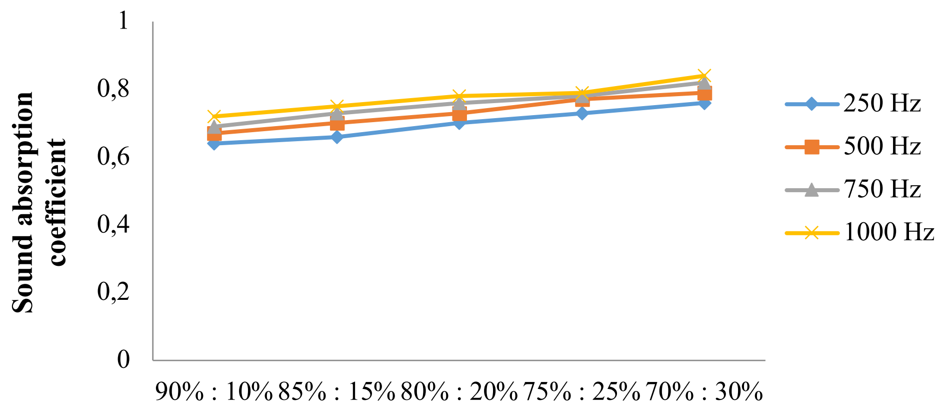

Figure 6. Graph of the effect of composition with the sound absorption coefficient

Based on Figure 6, the composite sample test results showed that the sound absorption coefficient increases with increasing fibre composition in the composite. So, the highest sound absorption coefficient value was in the most fibre composition. This was due to the increasing size of the cavity, so the sound wave energy was mostly consumed by resonance events in the cavity [29]. The denser the material, the greater sound absorption at medium and high frequencies [8].

Apart from that, based on Figure 6 above, it can also be seen that the more frequency increases, the more increase sound absorption coefficient. This was due to the large frequency and wavelength short when passing through a porous absorption material more of the incoming sound was absorbed than reflected or forwarded [28]. The following is the standard classification of sound absorption coefficients based on ISO 11654:1997, as seen in Table 3.

Table 3. Sound Absorption Class

Weighted coefficient of acoustic absorption	Class of acoustic absorption	Weighting
>0.90	A	Maximum absorption
0.80-0.85	B	very high absorption
0.60-0.75	C	High absorption
0.30-0.55	D	Normal absorption
0.15-0.25	E	Low absorption
<0.15	F (not classified)	Reflection

Based on Table 3, the banana stem fibre composite panel with PP matrix produces a value the sound absorption coefficient was above 0.6 and meets the ISO 11654 standard in the class B and C categories. Following were the test results of the transmission loss analysis for each sample with variations in composition and frequency used can be seen in Table 4.

Table 4. Results For Transmission Loss Values

Variation	Frequency			
	250 Hz	500 Hz	750 Hz	1000 Hz
90% : 10%	34.26 dB	34.94 dB	35.18 dB	35.50 dB
85% : 15%	34.82 dB	35.12 dB	35.38 dB	35.73 dB
80% : 20%	34.97 dB	35.36 dB	35.44 dB	35.84 dB
75% : 25%	35.16 dB	35.43 dB	36.06 dB	36.22 dB
70% : 30%	35.77 dB	36.06 dB	36.30 dB	36.40 dB

Based on Table 4, it can be seen that the highest transmission loss value for composite panels was 36.40 dB at a frequency of 1000 Hz with a matrix and fibre composition of 70%:30%. Meanwhile, the lowest transmission loss on the composite panel was 34.26 dB at a frequency of 250 Hz with matrix and fibre composition 90%:10%. Below it can be seen a graph of the influence of composition on the sound reflection coefficient in Figure 7.

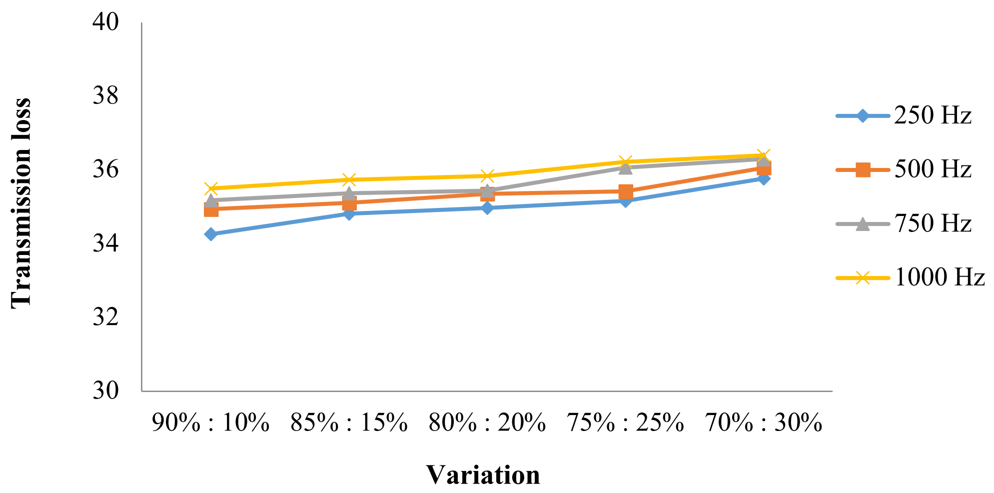

Figure 7. Graph of the influence of composition with transmission loss

Based on Figure 7 above, the composite sample test results showed that transmission loss increases as the fibre composition of the composite increases. So, the highest transmission loss is at more fibre composition. This was caused when the greater mass of a material exposed to sound waves, the smaller the vibrations caused by the sound waves so that the possibility of sound waves being transmitted becomes smaller [21].

Apart from that, in Figure 7, it can also be seen that the more the frequency increases, the more increasing value of transmission loss. Low frequencies will pass through acoustic materials more easily than high frequencies [30]. This is due to low frequencies with long wavelengths when passing through a porous absorption material, more of the incoming sound is reflected or passed on rather than absorbed [28]. Following were test results of the porosity analysis for each sample with variations in composition can be seen in Table 5.

Table 5. Composite Porosity PP Matrix With Banana Stem Fibre

Variaton	Sample	Wet Weight (gr)	Dry Weight (gr)	Porosity (%)	Average of porosity (%)
90% : 10%	1	54.3	56.7	4.4	3.51
	2	59	60.7	2.9	
	3	55.5	57.3	3.2	
85% : 15%	4	57.4	60.8	5.9	5.68
	4	57.4	60.5	5.4	
	6	57.6	60.9	5.7	
80% : 20%	7	54.8	58	5.8	7.35
	8	55.4	59.7	7.8	
	9	50.9	55.2	8.4	
75% : 25%	10	54.5	59.5	9.2	8.28
	11	55	59.3	7.8	
	12	52.2	56.3	7.9	
70% : 30%	13	50	57.6	15.2	12.88
	14	50.1	56.3	12.4	
	15	52.4	58.2	11.1	

Based on Table 5 above, it can also be seen that the highest porosity value was 12.88% at variation 5 with a PP: fibre matrix composition of 70%:30%. Meanwhile, the lowest porosity value was 3.51% in variation 1 with a PP matrix composition: fibre 90%: 10%.

However, as seen in Table 5, although several samples have the same fibre composition, they produce different porosity values. This was caused by stirring and mixing the matrix, and the fibres are uneven and inhomogeneous so that the cavity density in each part of the material was not the same [24]. Below it can be seen a graph of the influence of composition on porosity in Figure 8.

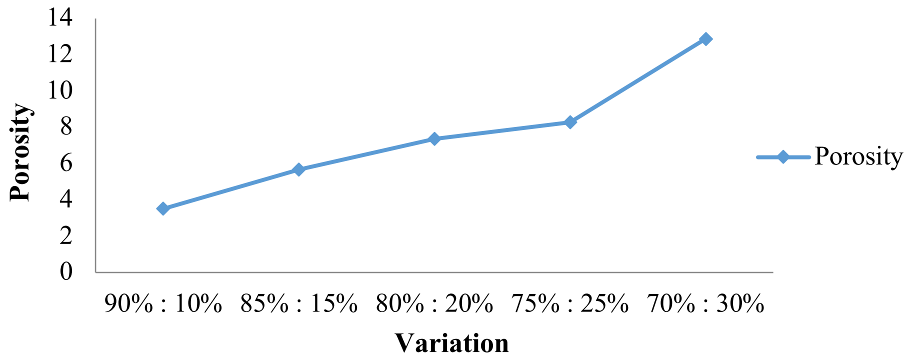

Figure 8. Graph of the effect of composition with porosity

Based on Figure 8 above, the composite sample test results show that as it increases the composition of the banana stem fibre in the composite panel, the resulting porosity value increases. So, the highest porosity was in the sample with the highest fibre composition. This matter was because composites have more fibre composition, so there was not a small amount of resin able to wet all the fibres because the interface between the fibres and the matrix was not dense enough, so there will be many cavities or gaps in the composition which results in the composite porosity value being high [31].

The high or low porosity value of a material will affect the sound absorption coefficient value, sound reflection coefficient, and transmission loss. The composite sample test results show that as the fibre mass composition increases, the porosity value also increases. If the porosity value is higher, the greater the value of the sound absorption coefficient and transmission loss produced. However, the resulting sound reflection coefficient value is getting lower. This is due to the material has many cavities or gaps in the material, so it absorbs more sound rather than being reflected [23].

The effect of mixing between the resin and the coir fibre forms gaps or pores. So that the incoming sound easily enters the pores if the surface porosity is high, then in the pores a resonance occurs which causes the sound to be converted into heat energy, and the remaining energy that has been reduces is reflected by the surface of the material [32].

4. Conclusion

Based on the research results obtained, it can be concluded that the influence of variations in fibre mass of banana fronds with a polypropylene matrix in the composite on acoustic properties and porosity, namely the more fibre composition in the composite, the sound absorption coefficient values, transmission loss values, and porosity values were higher produced, but the resulting sound reflection coefficient value was lower. Then, the relationship between porosity with acoustic properties was that the higher porosity value, the resulting sound absorption coefficient and transmission loss value are higher too. However, the resulting sound reflection coefficient value was getting lower.

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