Utilization of *Luffa* for Acoustic Panel on Interior Wall, A Technical and Perceptual Approach

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Absract. *Luffa Cylindrica* is one of Indonesia's biodiversity, which provides several benefits, such as for making handycraft, cleaning tool and event for building materials. This study aims to investigate the ability of Luffa as a sound absorber and its visual impression when applied to interior walls. The first stage is testing the damping ability of panels made of *Luffa*. Several specimens of *Luffa* acoustic panels were made with PVAc adhesive and then tested to determine their damping ability. From the test results using the impedance tube method (ASTME1050-12), the samples met the soundproof requirements with an absorption coefficient of 0.15 - 0.206 at a frequency of 1600 Hz. The lost sound transmission values obtained are in the range of 40-60 dB. Thus, *Luffa* can be used as a good sound-absorbing material. The next stage is the development of the visual design of the panel so that it has a certain aesthetic or perceptual value. Three designs were made with variations in shape and color into nine samples applied to a wall of interior space. The semantic differential method assessment found that simple and decorative impressions dominated when the panel was applied to interior walls.

1. Introduction

Luffa Cylindrica, more commonly known as *Luffa*, is a vine plant from the *Cucurbitacae* family. According to Statistics Indonesia (BPS), the production of this plant increased to 17,85 million tonnes in the year 2019. During the time period of 2013-2019, it experienced an increase with a mean of 35,60% from 12,25 million tonnes in 2013 to 17,85 million tonnes in 2019. [1] However, this plant is still regarded as a minor vegetable commodity due to society not utilizing it optimally as of yet. Young *luffa* can be consumed, while the fruits of older ones have usually dried and have holes as well as fibers consisting of structures that resemble nets, creating a multimodal hierarchical pore system and making it useful as a structure/template shaper in the creation of porous materials, usually used as cleansing sponges as well as bath sponges.[1]

The results of a study by Koruk H and Genc G, 2015 [2] show that the sound absorption coefficients from a luffa fiber sample without a matrix could be quite high, even for samples with a small thickness (12 mm). This shows that *Luffa* is a good sound insulator. The demand for interior wall-coating panels for noise canceling and improving sound quality within a room is increasing [3], panel prices in the market are relatively more expensive, and synthetic

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materials are used, making them less environmentally friendly.

From this problem, the author found an idea to utilize the environmentally friendly luffa plant as a wall panel product. This was inspired by the product design project by Mauricio Alfonso, who founded the innovation of luffa-based wall panels in Luffa Lab. However, in this research, the author added design exploration for shape and visual design alternatives in the future, which were tested using visual impression and perception tests conducted on users. This study aims to utilize and understand the potential of luffa fibers as replacement materials for sound insulator wall panels, as well as explore wall panel designs to use as future design alternatives based on tests conducted on users' visual perception and impression.

2. Methods

The method used in this study consists of two stages; the first step is the material examination, which is the technical experimentation to examine material capability as a sound insulator, and the second step is the testing of visual perception responses by participants towards the *Luffa*-based insulator panel design that was prepared using certain concepts.

2.1 Material Examination

2.1.1 Specimen Preparation

A test is done to understand the potential of the main material (*Luffa*) as a sound insulator by analyzing the Transmission Loss and Absorption Coefficient characteristics. This test uses references the ASTM 1050-98, using the Brüel & Kjær impedance tube type 4206. [4] The tests specimens used are *Luffa* fibers purchased online through an e-commerce site. The obtained *Luffa* is dried under the sun until the water content reaches a maximum of 5%.

The test specimen creation stage is as shown in Figure 1, consisting of slicing, mixing with PVAc adhesive, molding, and drying.

Fig. 1 (A). Luffa is sliced and coated using an adhesive; (B). Luffa is packed into a baking dish; (C). Compressed; (D). Baking process; (E). Test Sample.

1. *Luffa* that has been boiled and dried, and then sliced and flattened, is packed into a 10x12x20cm baking dish whose insides have been coated with aluminum foil, and using a cross stacking method where the fiber grooves are crossing each other.
2. The baking dish containing *Luffa* with a thickness of 2,5 cm – 3 cm is pressed using another baking dish filled with weights (pebbles), and then tied tightly so that the mold is pressed evenly. It is then dried for half a day.
3. After it is dried, the restraint is removed, and then it is inserted into a stove oven with a temperature of 60°C - 80°C for an hour to accelerate the adhesive drying process.

4. After an hour, it is removed from the oven and cooled, and then the sample is taken out from the dish.

2.1.2 Sound Proofing Test

After specimens are prepared, the next stage is to obtain the data from a soundproofing capability test to understand the sound absorption coefficient and transmission loss using an Impedance Tube (Fig. 2). This test is done within a certain frequency range and said frequency will then be converted into a sound intensity unit, decibel (dB) [5]. The obtained measurement of sound intensity will be processed to find the sound absorption coefficient and transmission loss values. The test is conducted once for each sample. This test is assisted by a lab assistant or physics expert who better understands the procedures of acoustic testing in an Acoustic Laboratory.

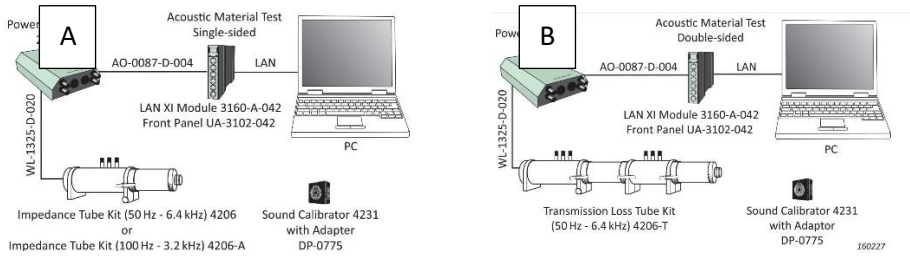

Fig. 2. (A). PULSE Acoustic Material Testing settings; (B). Transmission Loss settings [6]

2.2 Visual Perception on Applied Wall Tile

2.2.1 Designing and Prototyping

The prototype creation process begins with design exploration by considering current design developments (design trends). New designs are obtained through discussions and brainstorming sessions with five experienced designers and five potential users based on the concept of shapes that are suitable for modern-day building interiors. Semantic words are then determined to represent the concept of shapes: simple, natural, futuristic, and decorative. From these four concepts of shapes, digital 3D models are made using the 3Ds Max application for visual displays and AutoCAD 2021 version to create work drawings in the mold manufacturing process. Afterwards, color exploration is done using natural dyes used in batik, such as sappanwood (red), tingi (brown), and indigo (blue) [7]. After mold manufacturing and color exploration are finished, prototype creation uses the same method and composition as the test sample creation. The cold felting method, which is done by arranging *Luffa* material sheets at a certain thickness on a mold and gluing it using PVAc adhesive, is used.

To understand the visual responses of users (respondents) towards *Luffa*-based wall tiles applied on interior walls, a Semantic Differential scale based on Osgood theory [8] measurement is done online using Google Forms. Target respondents are those between the ages of 30 to 50, male and female. Laptop or PC devices ranging from 14 to 20 inches are required for respondents to participate in this stage, where 3D interior pictures are displayed on the Google Form. As many as 100 respondents participated in this stage to deliver their visual impressions towards three variants of wall tile designs applied on interior walls in Figures 3, 4, and 5. This study uses a scale of 5 to make it easier for respondents. The Semantic Differential scale appointed is as shown in the table below:

Table 1. Semantic Differential Scale

	Semantic Scale					
Opposite Words	**1**	**2**	**3**	**4**	**5**	**Opposite Words**
Complex						Simple
Artificial						Natural
Old-fashioned						Futuristic
Non-Decorative						Decorative

Fig. 3. Design 1 Blue

Fig. 4. Design 2 Red

Fig. 5. Design 3 Brown

3. Results and Discussion

3.1 Acoustic Testing

Table 2. Absorption Coefficient Result Values

Frequency (Hz)	Absorption Coefficient
200	0.024
400	0.072
600	0.075
800	0.075
1000	0.089
1200	0.126
1400	0.171
1600	0.206

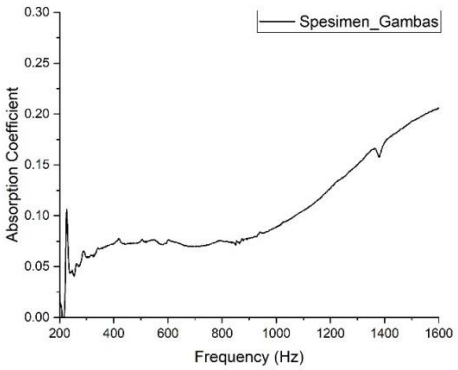

Fig. 6. Line Diagram of Absorption Coefficient Result Values

In the results of the conducted test, the highest coefficient value is 1600 HZ with an absorption coefficient value of 0,206. The minimum absorption coefficient of a sound insulator is 0,15 [8]. This means that the test conducted on *luffa* resulted in absorption coefficient values higher than the minimum threshold. Therefore, *luffa* can be used as a sound insulator with good sound insulation that can be used indoors.

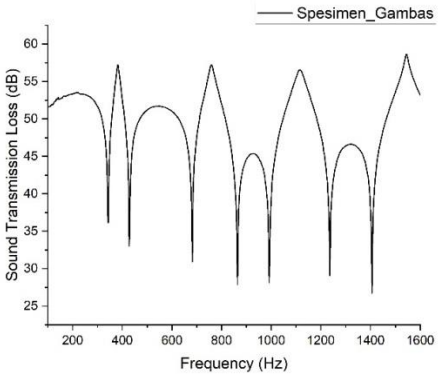

Fig. 7. Line Diagram of Transmission Loss Result Values

From the results of the test conducted, sound transmission loss values ranging from 40 dB to 60 dB were obtained. The higher the sound transmission loss value, the better a material is at insulating sound [9]. However, the minimum sound transmission loss value in a sound insulator cannot be strictly determined. This is because the sound transmission loss value depends on the desired needs. Therefore, Sound Transmission Class (STC) is used as a parameter to understand insulation threshold values. Based on STC, if the STC is higher than 40 dB, then sound can be insulated [10].

3.2. Equations

The mean is calculated to determine which concept and design was the most chosen. This mean is obtained by finding the sum of all existing data and dividing it by the number of respondents. The results of this are shown in the following table to ease the creation of visual impression and preference diagrams.

Table 3. Visual Impression Diagram

Impresi Visual	DESAIN								
	D1 M	D1 B	D1 C	D2 M	D2 B	D2 C	D3 M	D3 B	D3 C
Simple	0,69	0,73	0,8	-1,15	-1,15	-1,03	-0,78	-0,66	-0,65
Natural	-0,38	-0,09	0,14	-0,98	-0,79	-0,35	-0,83	-0,71	-0,39
Futuristik	-0,51	-0,06	-0,65	0,22	0,5	-0,23	0,78	0,75	0,22
Dekoratif	0,5	0,47	0,52	0,85	0,92	0,92	0,77	0,85	0,77

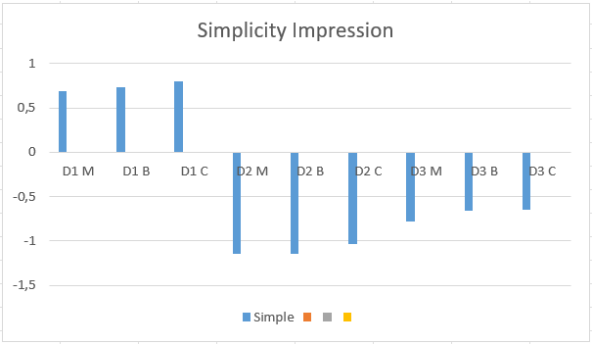

Fig. 8. Bar Diagram of Simple Visual Impression

The above simple visual impression diagram shows the design trend results for the concepts. Based on this diagram, it is known that the simplest design is Design 1 Brown (D1 C). Then, the most complex design is Design 2 Red and Blue (D2 M and D2 B).

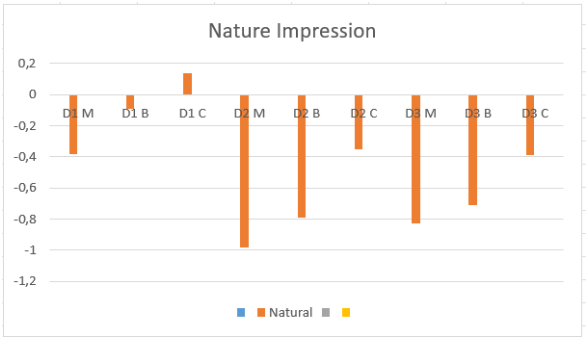

Fig. 9. Bar Diagram of Natural Visual Impression

The above natural visual impression diagram shows the design trend results for the concepts. Based on this diagram, it is known that the most natural design is Design 1 Brown (D1 C). Then, the most unnatural design is Design 2 Red (D2 M).

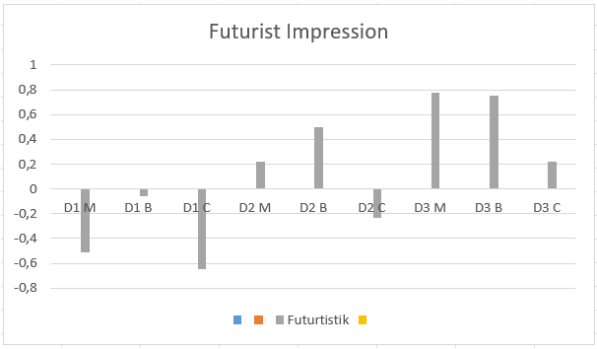

Fig. 10. Bar Diagram of Futuristic Visual Impression

The above futuristic visual impression diagram shows the design trend results for the concepts. Based on this diagram, it is known that the most futuristic design is Design 3 Red (D3 M). Then, the most old-fashioned design is Design 1 Brown (D1 C).

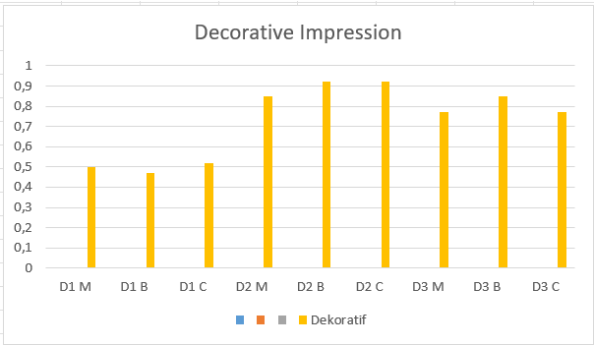

Fig. 11. Bar Diagram of Decorative Visual Impression

The above decorative visual impression diagram shows the design trend results for the concepts. Based on this diagram, it is known that the most decorative design is Design 2 Blue and Brown (D2 M and D2 C). Then, the least decorative design is Design 1 Blue (D1 B).

Table 4. Preference Diagram

Gender	Preferensi berbasis gender								
	D1 M	D1 B	D1 C	D2 M	D2 B	D2 C	D3 M	D3 B	D3 C
Laki-laki	1	4	5	1	6	2	0	5	1
Perempuan	4	2	3	2	9	4	1	4	6
Jumlah	5	6	8	3	15	6	1	9	7

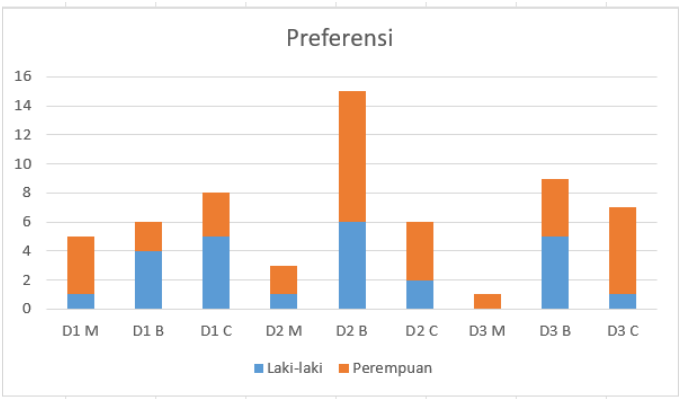

Fig. 12. Bar Diagram of Preferences

The above preference diagram shows the users' favorite designs. First, both male and female groups like Design 2 Blue (D2 B). Then, the second designs liked by the male group were Design 1 Brown (D1 C) and Design 3 Blue (D3 Blue). Finally, the second design liked by the female group is Design 3 Brown (D3 C).

4. Conclusion

Based on the study analysis results, the following can be concluded:

1. According to the absorption coefficient and transmission lost test results, the *Luffa* panel sample obtained very high results on both, meaning that the panel can absorb sounds well and keep sounds within a room. The absorption coefficient increased and decreased according to the characteristics of the material, as well as the pore structure that could affect how sound is absorbed at different frequencies, which was in the medium and high range.
2. From the prototype sample creation stage, the panel designs based on the determined concepts were realized well. However, the details were not visible enough. The shapes and colors of the panels were almost perfect, and the thickness density was in accordance with the desired standards.
3. The questionnaire results showed that respondents had a simple, natural, and old impression of D1 C. Design D2 B gave a complex and decorative impression. Similarly, design D2 M gave a complex and artificial impression. Lastly, design D2 C gave a decorative impression, and D1 B gave a non-decorative impression.
4. Based on the questionnaire, the favorite design overall was D2 B; the male group liked D1 C and D3 C most, while the female group liked D3 C most.

5. Acknowledgement

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