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Characteristics of Chicken Feather Panel as an Alternative Insulation Material

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Abstract Chicken and poultry consumption is a major factor in the world's diet. But the growing popularity of eating chicken has significant negative implications for the environment, especially when it comes to waste management. And one of the most important chicken waste is its feathers. The purpose of this study is to determine the composition of chicken feathers, density, sound absorption, heat resistance, water absorption, ambient durability, and assessment as a fiber panel and classification before using it as a substitute for alternative panel materials in the community. As a result, the best composition for alternative panel materials made from chicken feathers is a 70:20:10 ratio of finely chopped chicken feathers, PVAc glue, white cement and water. With a density of 0.38-0.4, the material is categorized as a soft fiber board (RF) with low density and rigidity that is able to withstand loads up to 38.2 kg/cm², absorption value ᾱ 0.49-0.52, can withstand heat up to 10º C. The research also confirms the potential of chicken feathers with adequate adhesive composition as an alternative and advanced material in the field of architecture that has met the criteria as a green panel material, sustainable, and environmentally friendly.

Keywords Chicken Feathers, Characteristics, Insulation Panels, Alternative Materials

1. Introduction

There are billions of chicken feather waste produced by chicken businesses or the chicken slaughtering industry around the world due to the increasing consumption of chicken meat and the appetite for chicken meat in many communities. Chicken or poultry consumption is an important aspect of global food habits. Overtaking pigs and cows, chicken has surpassed pork as the most popular meat worldwide, about 74 billion chickens are raised and consumed by mankind every year; By 2032, that figure is expected to increase to nearly 85 billion [1,2], To illustrate, every year in the United States, people consume 8 billion chickens. In special events like the Super Bowl, nearly 100 million Americans watched and ate about 1.4 billion chicken wings and drumsticks taken from 700 million chickens, that's a mind-boggling number, a bigger picture of chicken consumption in America. Despite this, the U.S. is the world's largest poultry eater, consuming far more than any other country — about 15,000 metric tons per year. The second largest consumer of chicken is China, consuming about 12,000 metric tons per year; while in Europe chicken consumption is proportional to the combined consumption of China and the US [3,4]. About 11,000 metric tons of chicken are consumed annually in Europe. This shows that among the wide variety of foods consumed daily throughout Europe, chicken is the most popular food [1,5,6].

Over the past ten years, the demand for poultry has increased significantly worldwide, with developing and developing countries driving this expansion. It is estimated that poultry meat will continue to be the most popular livestock product consumed worldwide, especially in developing and developing countries where production opportunities are scarce. Statistics show that Brazil will continue to be the world's leading poultry exporter and could take over the percentage of chicken exports of the United States, the world's largest chicken consuming countries [2,7,8,9]. Moreover KFC – the most well-known brand for eating chicken – continues to expand its business and has more than 24,000 locations in more than 145 countries and territories around the world. These facts highlight the important role that chickens and poultry play an important role in global food consumption patterns [10]

However, there are substantial environmental effects of the increasing demand for chicken feed, especially when it comes to waste management. A common problem along with mismanagement of chicken waste is emissions from

intensive chicken farms that impact air, water, and soil and other environmental components. Human and animal health can be affected by waste products from chicken farms, such as manure, feathers, dead chickens, and manure [2,11-12]. Improper handling of waste by the chicken industry can lead to excessive concentrations of nutrients in water sources, which can result in the bloom of toxic algae that threatens human health and aquatic life. Rich in minerals such as phosphorus and nitrogen, chicken manure can pollute waterways and lakes, bringing potentially harmful elements into water bodies. Algae blooms caused by pollution can cause oxygen levels in water bodies to drop and result in fish deaths and other ecological imbalances [13-15].

The manufacture of chicken feed also adds to the environmental difficulties, as poultry businesses use a large number of the world's feed crops. Additionally, the disposal of chicken manure on farmland can result in soil contamination and further environmental damage [16-17]. In addition to affecting the world's water supply, this inefficiency of feed production diverts land that can be used more effectively to grow food directly for human consumption. These reports underscore the negative environmental impact of the increased demand for chicken products, highlighting the need for sustainable practices and waste management techniques in the poultry sector to minimize their impact [18-20].

Feathers as an important waste of the chicken industry are the most widely used waste in the form of household products, until now. The availability and sustainability of chicken feather raw materials for panel products is a promising action. The impact of increasing waste is very large and can cause environmental pollution if not immediately processed into products that can be used by the wider community [8,23]. Disposal management, processing technologies and methods are urged to reduce environmental threats [17,23-25]. In the view of researchers, the use of feathers as an alternative to panel materials is part of the action in protecting the environment. Chicken feather panel products are an innovation from chicken waste products that have been abandoned in many communities and discarded by the chicken farming and consumption industry.

The use of advanced materials with innovations in buildings is in great demand because of the growth of the population with housing or residential needs while maintaining environmental, social, economic, and sustainability aspects. Therefore, this research is needed in terms of the development of alternative materials in supporting human life, such as research on the processing of chicken feather waste into panel materials - sustainable and advanced alternative materials, as the readiness and continuity of the supply of raw materials. Research on chicken feather panel product innovation has been carried out before [26-29], processing chicken feather waste into wall panel materials. There are still many people who are not aware of the economic value of this material, by utilizing local wisdom and the people's economy, then research will be carried out to identify the characteristics of chicken feather panels that have been formed to become alternative materials.

There are many studies related to the identification of the characteristics of chicken feather waste with its advantages, including the keratin levels contained and its effect on chicken feathers. Keratin is a fibrous protein consisting of long-chain peptides with fibers arranged lengthwise that can provide a structural role that can provide mechanical strength characteristics, as well as low solubility in water [12, 30-31]. The use of chicken feather waste in the context of the manufacturing process into panels or composite materials has also been carried out in several other studies, ranging from panels to composites [27, 32-33], its physical and chemical properties [30,34], modification of the mechanical characteristics of bul aym fiber material can reduce stiffness and improve the durability of the material[32], lightweight panel structural application made from waste chicken feathers and cartons[35], the use of aym wool material as a composite material [32, 36-37], and the advantages, privileges and other characteristics contained in chicken feathers that are of interest to many studies [22, 38-40].

Therefore, chicken feather waste that has been finely chopped and shaped into feather panels has wide possibilities as an alternative material in the field of architecture. Several identification of the characteristics of chicken feather panels as an alternative material is needed in supporting the empowerment of renewable, economical, and environmentally friendly materials. This study seeks methods and compositions to make better chicken feather panels through their density as well as knowing the ability of the material to withstand environmental loads, indoors and outdoors.

2. Significance/ Research Problem

In a previous study, the author investigated the use of chicken feather waste that is often left in our environment to become environmentally friendly panel products and used as an alternative building material in the field of architecture. In this study, chicken feather panels will be identified based on their characteristics as alternative panel materials, composition, sound absorption, durability and durability to the environment. What is more important is the application of alternative materials in the field of architecture to make the design of the space according to the needs.

3. Research Methods

This study will identify the characteristics of chicken feather panels as a continuation of preliminary research on the potential of chicken feather waste as a raw material for panels. This study continues the previous research on the processing of chicken feathers into panels, then identifies its characteristics by conducting experiments on various panel compositions and their durability, followed by testing the density and compressive strength of the material. Twenty-four circular panels with a diameter of 10 cm with a thickness of 0.9, 1.6 and 2.5 cm. One sample with a thickness of 2 cm is

prepared for the load test. Rectangular samples with a thickness of 0.9 cm vary in size, i.e. 20x20 cm; 22x22 cm; 22x30 cm and 26x29.5 cm, five pieces for each size, twenty panels in total, for space applications

The applicable chicken feather panels have undergone an experimental stage to accommodate the understanding of the basic characteristics of the resulting panels, namely soft, flexible, elastic, and lightweight so that they can be optimized into strong and sturdy panel products as well as lightweight and fibrous. This research also applies composite patterns to building structures to obtain feasible and accountable panel construction. Ultimately, the resulting panels should have strength and solidity and will be able to build a functional product with aesthetic value.

Experiments were carried out in the laboratory which was followed by analyzing and calculating the density of the panels, analysis of the resistance of the panels to ambient conditions (compressive strength, sound absorption, resistance of materials to ambient heat, etc.). The results of laboratory tests are then used as a reference before the development of alternative panel materials in the field of architecture.

The experimental process includes several stages: preparation, production plan, collection of raw materials, collection of supporting materials/equipment, specimen manufacturing process (washing, rinsing, soaking in formalin liquid, finely chopping and mixing other materials based on the mold).

The binding material is white cement and PVAc adhesive. Composite chicken feather particle board then bonds together, tested to resist forces in the compressive and transverse directions suggested in previous studies [32, 41-42].

4. Results And Discussion

4.1. Panel formation and composition and density

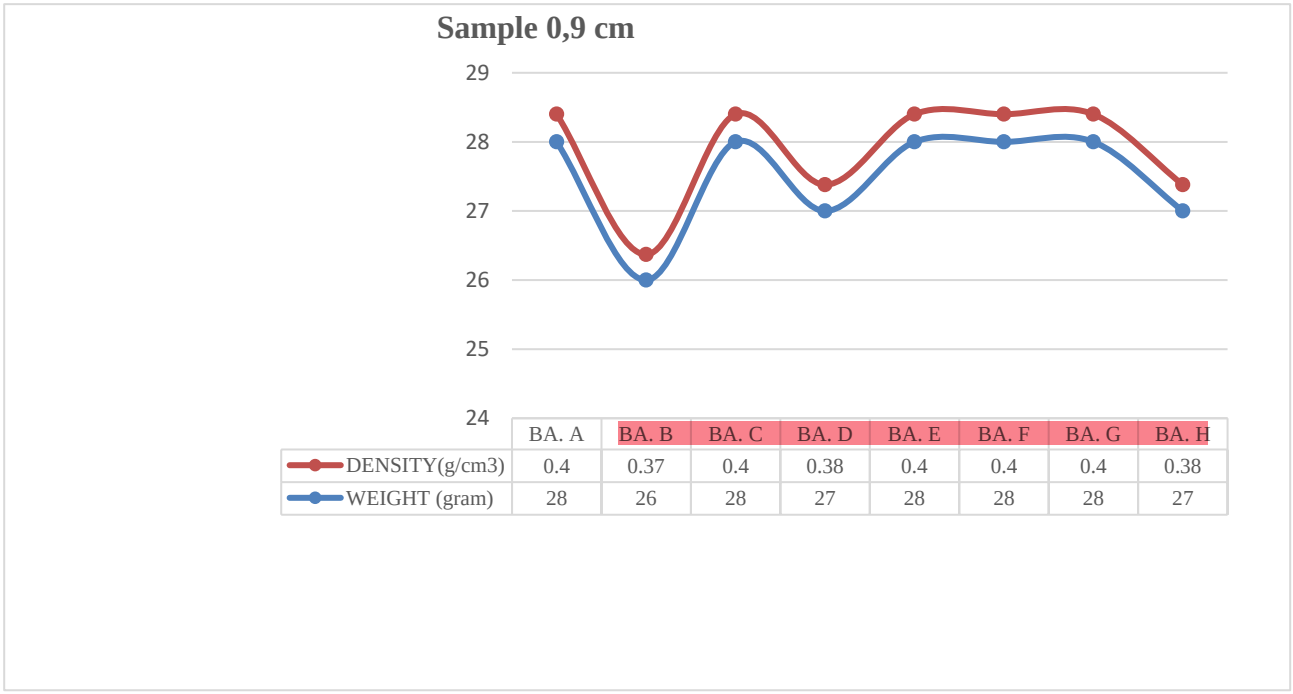
The nature of chicken feathers is light, smooth, and slippery due to the keratin in the feathers, therefore, care is required to make it easier for the feather parts to stick to each other in the layers as designed. This process requires adhesives and other substances in the panel forming process.

The panel consists of 4 elements with a composition of 70% finely chopped chicken feathers, 20% white cement and 10% PVAc plus water, stirred to taste. The substance is formed and left in the mold for 20 minutes, then pressed at a pressure of 2 tons/cm ^{2}for 45 minutes, before being heated in an electric oven for 30 minutes at 100 ^{o}C to optimize the mixture of ingredients. Then, the panels are removed from the mold and dried in the sun before the density analysis as produced in Figure 1 below.



Figure 1. 10 cm circular test sample with 3 thicknesses, 24 pieces

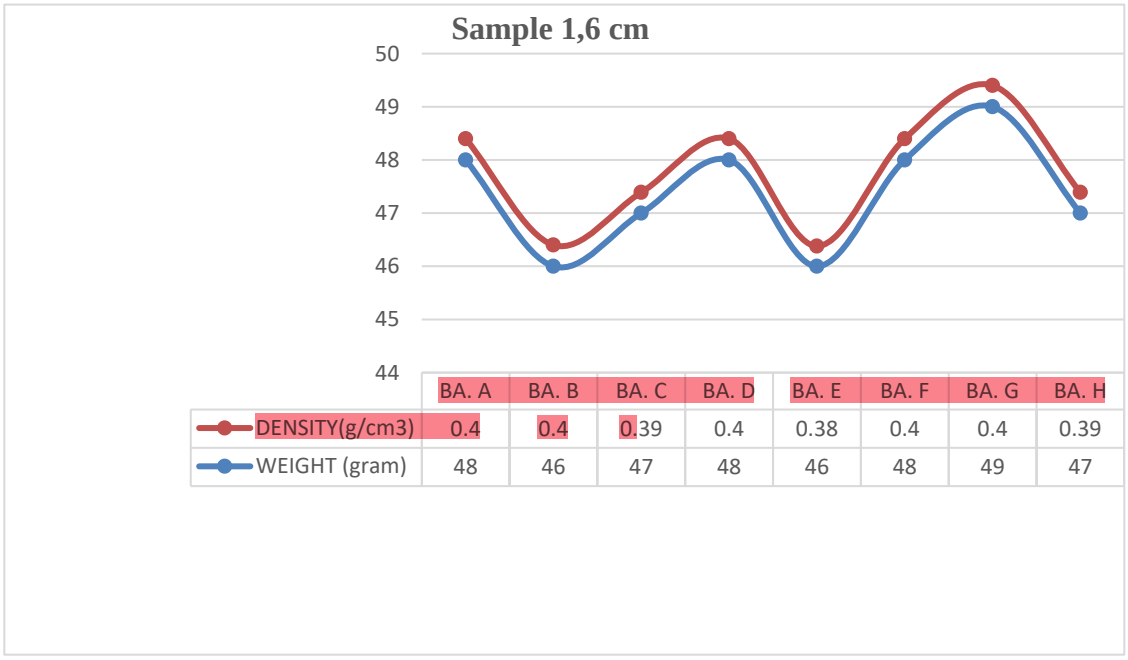
4.2. Identification of panel test for density



	BA. A	BA. B	BA. C	BA. D	BA. E	BA. F	BA. G	BA. H
DENSITY(g/cm3)	0.4	0.37	0.4	0.38	0.4	0.4	0.4	0.38
WEIGHT (gram)	28	26	28	27	28	28	28	27

Figure 2. Specimen density 0.9 cm thick

Figure 2 shows the wavy shape following the density and thickness of eight different panels. The sample panels are made in the same dimensions and to ascertain the physical characteristics then each sample is measured for density and weight. The density of the samples of 0.9 cm is close to each other, in the range of 0.37-0.40 gr/cm3 because the weight is almost similar in the range of 26 – 28 grams each



	BA. A	BA. B	BA. C	BA. D	BA. E	BA. F	BA. G	BA. H
DENSITY(g/cm3)	0.4	0.4	0.39	0.4	0.38	0.4	0.4	0.39
WEIGHT (gram)	48	46	47	48	46	48	49	47

Figure 3. Specimen density 1.6 cm thick

Figure 3 shows the wavy shape following the density and thickness of eight different panels. The sample panels are made in the same dimensions and to ascertain the physical characteristics then each sample is measured for density and weight. The density of the 0.9 cm samples is close to each other, in the range of 0.38-0.40 gr/cm3 because the weight is almost the same in the range of 46 – 49 grams each

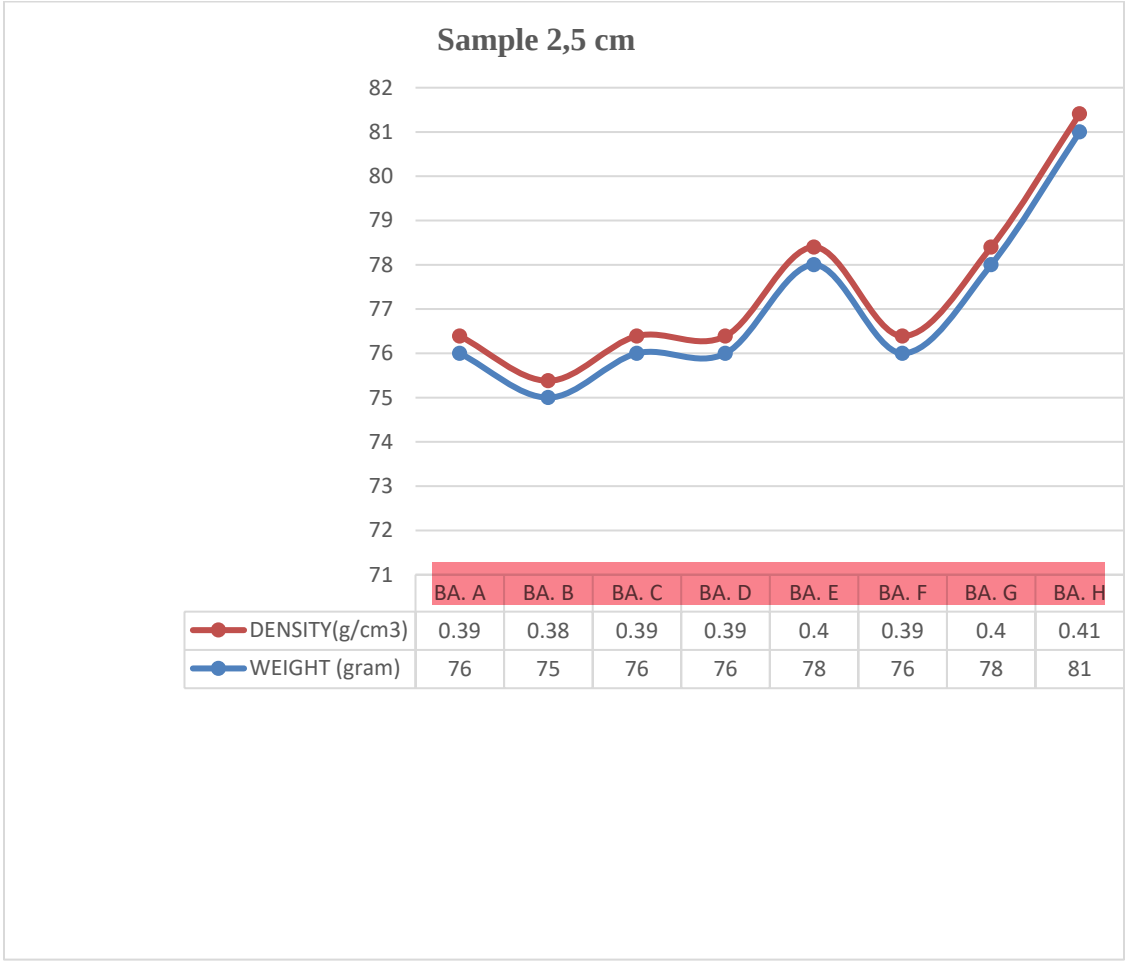


Figure 4. Density of 2.5 cm thick specimen

Figure 4 shows the wavy shape following the density and thickness of eight different panels. The sample panels are made in the same dimensions and to ascertain the physical characteristics then each sample is measured for density and weight. The density of the samples of 2.5 cm is close to each other, in the range of 0.38-0.41 gr/cm3 because the weight is almost the same in the range of 75-81 grams each.

Table 1. Average density values for each panel thickness

Thickness, *t* (cm)	**0.9**	**1.6**	**2.5**
Average mass, *m* (gr)	27.2	47.4	77
Volume, *v* (cm^3)	70.65	125.6	196.25
Density, ρ (gr/cm^3)	0.38	0.38	0.39

The average table image of the three thicknesses of the 10 cm circle test sample shows that the panel density values for each thickness (0.9, 1.6, and 2.5 cm) are close together, the values are between 0.38-04, it can be seen that the sample weight is consistent, and these include rigid type, RF (rigid), 0.15-0.40 g/cm3 soft fiber board, and according to ASTM 1974 is categorized as Low Density Particle Board in the standard designation 1554 -67, classify. Low-density particle board is a particle board that has a density of less than 37 lb/ft ³or a specific gravity of less than 0.59 g/cm ³

4.3 Identification Testing the Compressive Strength of Chicken Feather Panels

In the compressive strength test of chicken feather panel materials, it was found that chicken feathers have high durability and resistance to degradation because they have significant cross-linking and strong bonding in their structure[18], to determine the ability of the chicken feather panel material to withstand the compressive weight of the material. Conducted at the Structural Laboratory of the Muslim University of Indonesia, the experiment was carried out by measuring the compressive strength of the material after the panel was formed.



Figure 5. Panel compressive strength testing process.

The process of observing the resistance of materials to loads was carried out in the Laboratory of the Structure of the Muslim University of Indonesia.

The flow of the procedure is as follows: Preparation of chicken feather panel test sample materials; Placing the test sample on the base of the prepared panel; Adjust the position of the test material on the CSCM machine.D. Observe the pressure generated by the CSCM tool. Results of the tested material.

In the compressive strength test, the panels are molded in the form of cylinders (referring to the SK SNI M-62-1990-03 Concrete Compressive/Pressurizing Strength Testing Standard). In this case, a diameter of 10 cm with a mold thickness of 2 cm is used



A B

Figure 6. A. Panel before material compression test, B. Panel after compression test.

Testing materials:

Weight: 112 g, width 10 cm, thickness 2.5 cm
Compressive strength: 30 kN (direct compressive strength): 30 kN x 100 kg = 3000 kg
L = R ²(cross-sectional area) = 3.14 x 25 = 78.5 cm ²

$$\text{Crushed Load} = \frac{\text{Press firmly}}{\text{Cross-sectional area}} = \frac{3000}{78.5} = 38.2 \text{ kg/cm}^2$$

The value for analysing the compressive strength of the chicken feather panel material was 38.2 Kg/cm ²and the result was that it broke. The material could not withstand large loads because the material was categorized as low-density particleboard and was an RF rigid soft fiberboard (right) with a specific gravity of 0.15-0.40 gm/cm ³, or in other words, chicken feather panels are a material with a low-density value and can later be used as a sound-absorbing material.

4.4 Identify the panel's ability to diffuse sound



Figure 7. B&K Impedance Tube type 4206.

The results of measuring the absorption coefficient of chicken feather panel material using the impedance tube method

with two microphones with the selection of tubes with a diameter of 10 cm, presented in the form of curves, data at frequencies of 100 Hz - 1,600 Hz, in accordance with the limitations of this study.

a. Sample Panel Thickness 0.9 cm

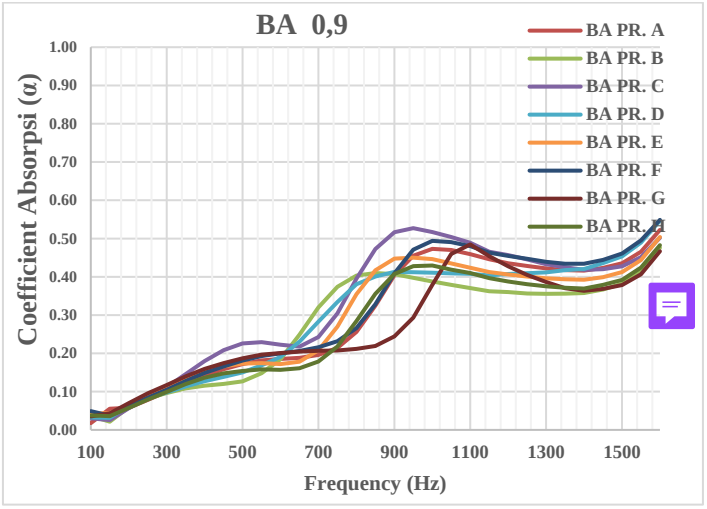


Figure 8. Absorption Coefficient Curve BA 0.9 (A,B,C,D,E,F,G,H).

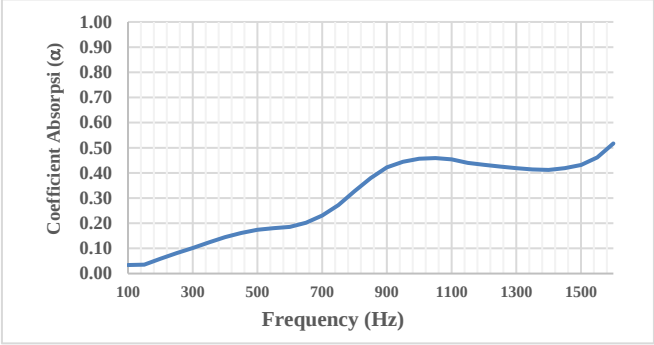


Figure 9. The average curve of the Absorption Coefficient BA is 0.9

Table 2. BA sample average absorption coefficient 0.9 cm

Frek (Hz)	Absorption coefficient
100	0,03
150	0,04
200	0,06
250	0,08
300	0,10
350	0,12
400	0,14
450	0,16
500	0,17
550	0,18
600	0,19
650	0,20
700	0,23
750	0,27
800	0,33
850	0,38

Freak (Hz)	Absorption coefficient
900	0,42
950	0,44
1000	0,46
1050	0,46
1100	0,45
1150	0,44
1200	0,43
1250	0,43
1300	0,42
1350	0,41
1400	0,41
1450	0,42
1500	0,43
1550	0,46
1600	0,52

In the measurement of the BA sample of 0.9 cm as seen in Figure 9, it shows the average value of the absorption coefficient of 8 samples. At the frequency of 100 Hz to 700 Hz, the absorption value increases gradually with a α value of 0.03 to α 0.23 and experiences an acceleration of sound waves at a frequency of 700 Hz to 1050 Hz with a α of 0.23 to α 0.44 and again decreases α 0.43-α 0.41 at the frequency of 1250-1400 Hz, then continues to increase until the maximum frequency of 1600 Hz from a α value of 0.41 to α 0.52

b. Sample Panel Thickness 1.6 cm

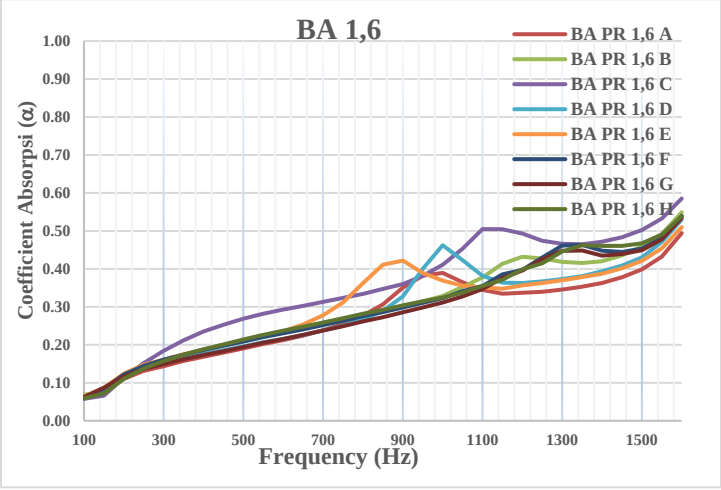


Figure 10. Absorption Coefficient Curve BA 1,6 (A,B,C,D,E,F,G,H).

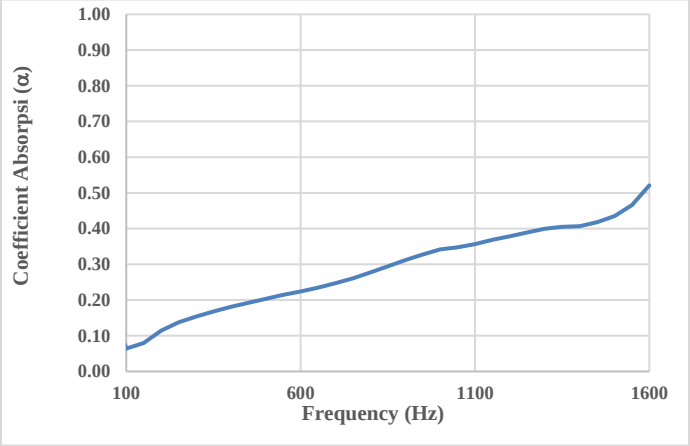


Figure 11. Average curve of Absorption Coefficient BA 1.6

Table 3. BA Absorption Coefficient 1.6 cm

Freak (Hz)	Absorption coefficient
100	0,06
150	0,08
200	0,11
250	0,14
300	0,15
350	0,17
400	0,18
450	0,19
500	0,20
550	0,21
600	0,22
650	0,23
700	0,25
750	0,26
800	0,28
850	0,29

Freak (Hz)	Absorption coefficient
900	0,31
950	0,33
1000	0,34
1050	0,35
1100	0,36
1150	0,37
1200	0,38
1250	0,39
1300	0,40
1350	0,40
1400	0,41
1450	0,42
1500	0,44
1550	0,47
1600	0,52

In the measurement of the BA.1.6 cm sample as seen in Figure 11, it shows the average absorption coefficient value of 8 samples. From Table 3, it can be seen that starting from the frequency of 100 Hz to the maximum frequency of 1600 Hz, there is a balanced rhythm of the movement of sound waves for the BA 1.6 sample test, from α 00.6 to a maximum frequency of α 0.52.

c. Sample Panel Thickness 2.5 cm

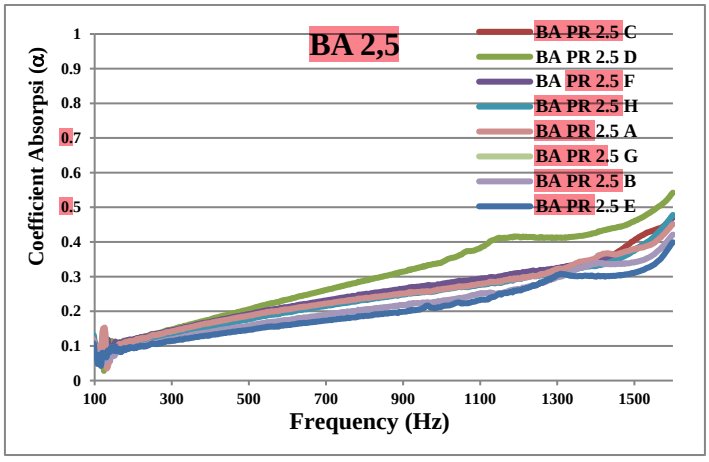


Figure 12. Absorption Coefficient Curve BA 12.5 (A,B,C,D,E,F,G,H).

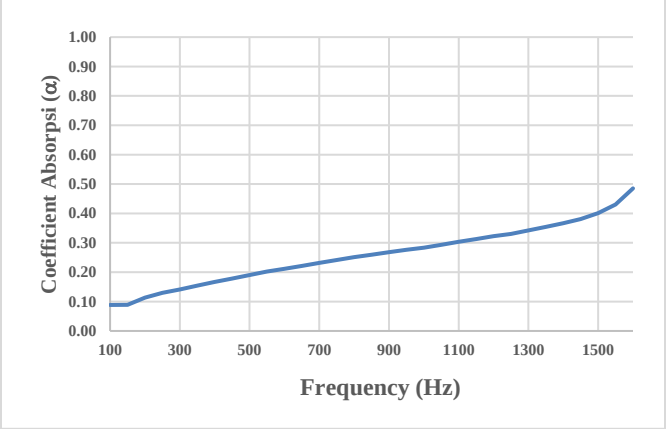


Figure 13. Average curve of Absorption Coefficient BA 2.5

Table 4. BA Absorption Coefficient 2.5 cm

Freak (Hz)	Absorption coefficient
100	0,09
150	0,09
200	0,11
250	0,13
300	0,14
350	0,15
400	0,17
450	0,18
500	0,19
550	0,20
600	0,21
650	0,22
700	0,23
750	0,24
800	0,25
850	0,26
900	0,27

Freak (Hz)	Absorption coefficient
950	0,28
1000	0,28
1050	0,29
1100	0,30
1150	0,31
1200	0,32
1250	0,33
1300	0,34
1350	0,35
1400	0,37
1450	0,38
1500	0,40
1550	0,43
1600	0,49

In the measurement of the BA.2.5 cm sample as seen in Figure 13, at a frequency of 100 Hz to a maximum frequency of 1600 Hz, the coefficient value obtained is α 0.09- α 0.49, which indicates the value of the sample coefficient that experiences an increase in frequency that increases according to the increase in frequency.

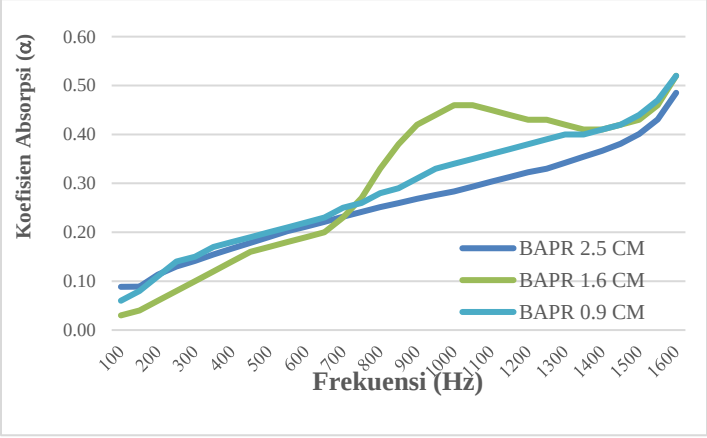


Figure 14. BA Composite Curve (0.9. 1,6. 2,5)

In Figure 14 of the combined curve of the panel (BA), it can be seen that the absorption value of α for each thickness at the peak frequency of 1600 Hz reaches 0.49 - 0.52, and for the thickness of BAPR 1.6 cm at the frequency of 650 Hz to 1000 Hz, there is a slightly different sound pressure from the BAPR samples of 0.5 cm and 2.5 cm, namely the absorption value of α 0.25 to α 0.46.

The stages of the thermal testing process of chicken feather panel material can be seen in Table 5, that the panel material can lower the temperature by 10 ℃, with a conductivity value of 0.7317 (watt/m °C) so that the chicken feather panel material can be classified as a good material and can be used in tropical areas such as Indonesia, referring to the Indonesian Lifecycle Assessment (LCA) standard, so that the chicken feather panel material meets the criteria as a green and sustainable material [48].

Table 5. Thermal measurement of chicken feather panels

Material	Initial Size (m)			Air Temperature (℃)					Temperature Drop
	Long	Wide	Thick	T1	T2	T3	T4	(watts/m ℃)	Rooms (℃)
1	2	3	4	5	6	7	8	9	10
Panel	0,190	0,180	0,090	52,000	42,000	32,000	30,000	0,732	10,000

4.5 Identify the thermal resistance of the Panel to room conditions

According to Kock [43], chicken feathers have unique characteristics including relatively low density and good thermal and acoustic insulation properties.

The proof of this statement is by processing chicken feather waste into panel materials. Chicken feathers contain fibers that have good physical and mechanical properties, are quite durable, and can be used for material engineering purposes. Soft feathers and acoustic feathers are made of keratin with a protein content of 85-90%, so it is difficult to dissolve in

water, making chicken feathers quite durable [44-47], feathers are very good for use in panel components, flooring or building materials as an alternative to composites thereby contributing to an increase in the waste value of chicken feathers as a renewable material.

Identification of the ability of chicken feather panel materials to withstand heat was carried out in a science and technology laboratory using a thermal test box and the results are shown in table 5.

5. Conclusions

Based on the results of the research on Waste Management and Product Recycling: Chicken Feather Panels as an Alternative Green Material, it was concluded that the composition of making chicken feather panels is to use 70% chicken feather waste materials, 20% for white cement, and 10% PVA and sufficient water (100-120%), the density of chicken feather panels was found to be0.38-0.4, which means that the panels meet the standards of SNI 03-2105-1996 and JIS A 5908-2003 as particle boards, with the classification of rigid type soft fibreboard, RF (rigid), with the ability to withstand a load of 38.2 kg/cm², because it is a material with low density so that it can absorb sound ᾱ 0.49-0.52 and the ability to withstand heat in ambient conditions is 10 ℃ which can be used as a tropical material according to conditions in Indonesia, so it can be recommended as a renewable, sophisticated and environmentally friendly alternative material

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