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Sound Absorption Properties of Natural Sago Leaf Fibers (Gaba-Gaba)

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ABSTRACT

This study aims to determine the characterization of the sound absorption coefficient of sago leaf stalk acoustic material (Gaba-Gaba) with thickness variations of 2 cm and 3 cm. Two-microphone impedance tube method (ISO 10534-2 and ASTM E1050-08). Materials made from natural Gaba-Gaba fibers are made with different thicknesses, namely 2 cm and 3 cm. The frequency range used in this test is 100-1000 Hz. The results of the sound absorption coefficient (α) for all samples meet the requirements, where the requirement as a sound/noise dampening material is a maximum α value above 0.15 (ISO 11654). The sound absorption coefficient of natural Gaba-Gaba fiber in a 3 cm thick sample is 0.34 at a frequency of 1000 Hz. Meanwhile, a sample with a thickness of 2 cm has the highest sound absorption coefficient at a frequency of 400 Hz with a value of 0.30. Gaba-Gaba natural fiber with a thickness of 3 cm is very suitable for use in audio rooms because it has a fairly high sound absorption coefficient at a frequency of 1000 Hz. This conclusion is interesting considering that Gaba-Gaba is a material made from natural fibers, which makes it organic, renewable, and environmentally friendly. This is certainly interesting amidst increasing attention to sustainability and reducing the environmental impact of construction materials.

1. INTRODUCTION

Sago is a source of carbohydrates in Indonesian society. Sago is known to be widely produced in eastern Indonesia. In Papua, the potential for sago fields reaches four million hectares. However, the development of sago production is currently not limited to the Land of Papua. Sago development continues to have potential throughout the entirety of Indonesia. Indonesia is undoubtedly one of the world's top exporters of sago given its enormous potential [1]. Sago (Metroxylon spp.) is a monocotyledonous plant belonging to the genus Metroxylon, the Palmae family, and the Spadiciflora order. It originates from Indonesia, and is generally consumed by people in the eastern part of the country [2]. Sago plants are also found across the wet tropical regions of Southeast Asia and Oceania, where they predominantly thrive in swampy, brackish, or waterlogged environments [3].

In addition to being a food, sago has the potential to be utilized in various industries such as food, paper, or textiles. Meanwhile, sago processing waste can be used as animal and fish feed, while the leaves and leaf stalks can be used as building materials [4]. In Indonesia, North Maluku is one of the fifteen provinces that produces the most sago [5].

With increasing global awareness of the importance of using environmentally friendly materials from renewable resources, sago offers the right solution. Gaba-Gaba, made from sago leaf stalks, is an example of an acoustic material that utilizes natural and renewable materials. This aligns with the global movement towards sustainability and minimizing the environmental impact of construction material.

In North Maluku, environmentally friendly materials such as Gaba-Gaba are still traditionally used as wall and ceiling materials. In addition, the Settlement Research and Development Center in Makassar City (South Sulawesi) has adopted natural Gaba-Gaba fiber material in the construction of RISHA (Simple Healthy Instant House) houses, as part of an effort to promote the use of sustainable and environmentally friendly materials in building construction [6]. Acoustic materials such as Gaba-Gaba plays an important role in managing sound quality in the environment because loud or soft sounds can vary depending on the sound source and how the material absorbs or reflects sound.

Loud or weak sounds vary depending on the source of the sound. The weak hard factor will cause noise. Noise can be mitigated by employing materials that effectively reduce and absorb sound. Most sound-absorbing materials available today are composed of synthetic substances. A key characteristic of these materials is their porosity, which acts as a cavity resonator. Sound waves enter these cavities and cause air molecules within the pores to vibrate [7]. The type of sound-absorbing material used in experiments or tests is porous natural fibers. Gaba-Gaba natural fiber is a fibrous and porous waste material that has undergone an extraction so that it can meet the requirements to be processed into panel boards.

The results showed that the natural fiber panel of Gaba-Gaba has a density value of 0.24-0.33 gram/cm^3 and a value of water tightness from 0.89 to 1.17 gram [8]. While similar materials derived from other natural fibers such as coconut belt fibers have a density value of 0.33 gram/cm^3 and a water-tightness value of 0.95 grams. The density value determined by SNI 03-2105-2006 (0.40-0.90 gram/cm^3), then the density of the natural fiber panel of the spider obtained in the research of Asriany et al. [8] is close to the quality standard set.

In addition to its porous nature, sound absorption is influenced by the material's thickness. Generally, thicker materials exhibit a higher sound absorption coefficient (α) and provide better sound absorption [9, 10]. This is because the kinetic energy of incoming sound waves is transformed into low-level heat energy as they pass through thicker material. Thicker materials absorb more sound waves, leading to increased friction loss between the sound waves and the fibers, which diminishes the propagation of the sound waves. Similar studies that use natural fibers are sugar cane fiber as a sound absorber [11]. From the results of his research note the performance of sound absorption in sugarcane material with a thickness of 1.25 cm, and an average absorption coefficient value of 0.65 at a frequency of 1.2-4.5 kHz. Kartikaratri et al. [12] examined the manufacture of coconut fiber composites using phenol-formaldehyde resin as an acoustic dampening material. The results of the study of coconut fibers showed an absorption coefficient of 0.94 in the frequency range of 752-6400 H [12]. According to ISO 11654:1997, the requirement for a sound absorption coefficient value is greater than 0.05 [13]. Other studies on coconut fiber as an acoustic material have been carried out, including studies [14-16].

In addition to natural materials from sago leaf stalks (Gaba-Gaba), sugarcane fiber, and coconut fiber fibers, some are also derived from rice husk [17], and composite boards derived from straw, wood, and rice husk [18], kenaf fiber [19]. Several other studies that have been conducted on the ability of natural fibers that are used as a sound absorber include: Koizumi et al. [20] examined the acoustic properties of bamboo fibers and found that bamboo fibers have a sound absorption value equivalent to wool. The research by Abdullah et al. [21] on the acoustic properties of rice straw found that the sound absorption coefficient ranges from 0.6 to 0.9 within a frequency range of 2 to 3.5 kHz. Experimentally Fatima and Mohanty examined the sound absorption of jute fiber material, the results showed that in addition to having good acoustic properties, it also had fire suppression properties [22]. Some examine corncobs as sound insulation that is affordable and sustainable and suitable to be applied in the building materials industry and can be an alternative natural sound insulation product [23]. The fact that natural fibers may be more economical, lightweight, and environmentally friendly has been investigated by Joshi et al. [24].

From several studies that have been conducted, it is known that there has never been a study that utilizes sago leaf stalk waste (Gaba-Gaba) to be used as a soundproofing material. Sago leaf stalks (Gaba-Gaba) are one of the environmentally friendly organic materials that are very possible to be used as sound/noise absorbing materials. By making noise-reducing products, it can also increase economic potential and sustainability. For this reason, the main objective of this study is to determine the characterization of the sound absorption coefficient of sago leaf stalk acoustic material (Gaba-Gaba) with thickness variations of 2 cm and 3 cm. This is important to ensure that this material can be used effectively in acoustic applications, to evaluate its potential benefits as a natural and renewable material, and to provide useful data in the development of guidelines and standards for the use of acoustic materials. In addition, the use of natural Gaba-Gaba fibers in sustainable construction provides significant environmental benefits. This material supports carbon footprint reduction, waste utilization, resource sustainability, ecosystem preservation, pollution reduction, and improving the quality of the building environment. Utilizing natural fibers is expected to not only increase the sustainability of the construction industry but also support the principles of a circular economy and environmental preservation [25].

2. MATERIAL AND METHODS

This method determines the coefficient of the material's capacity to absorb sound waves in reaction to them. The sound absorption coefficient is the amount of incoming sound waves that the test sample absorbs, the portion of the waves that are not absorbed will be reflected by the sound source. Assessing the sound absorption coefficient (α) requires the use of an impedance tube and the standard test ASTM E 1050-10, two microphones, and a digital frequency analyzer [26]. The frequency range used in this experiment is 100-1000 Hz according to ISO 10534-2 standards [27]. The shape of the material can be seen in Figure 1, while the experimental method is explained in Figure 2.

Figure 1. Samples of Gaba-Gaba material with a thickness of 2 cm (bottom) and 3 cm (top)

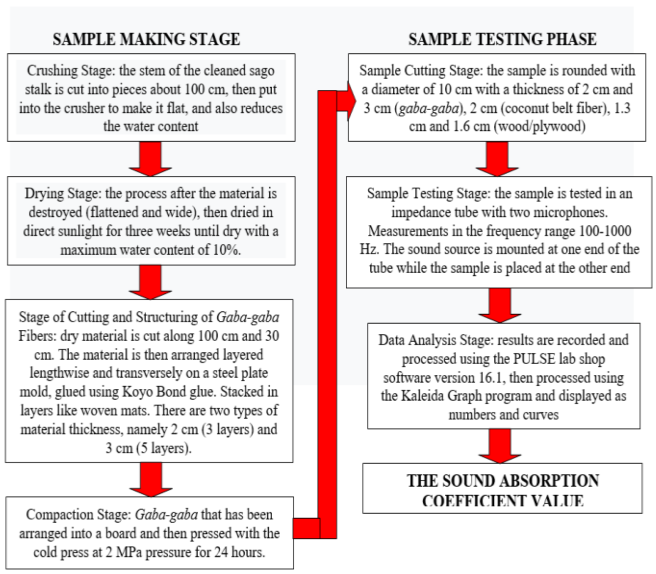

Figure 2. The research stages

The process of producing boards from Gaba-Gaba material to determine the sound absorption coefficient involves two stages, namely the stage of making samples and the testing stages of samples. Figure 2 shows the research stages:

1. Sample making stage

In the material collection and preparation stage, the sago leaf stalks (Gaba-Gaba) that will be used are collected first. After that, the stalks are cut into 100 cm long sections using a crosscut saw. This process ensures that the raw materials are ready for the next stage in panel making. Figure 3 shows the material collection and preparation process.

Figure 3. Material collection and preparation process

Once the stalks have expanded and flattened, the next step is to manually dry them for about one month. The subsequent process should not begin until the material has reached a water content of 10% or less. If the water content remains above 10%, additional drying is required until it reaches the maximum of 10%. Figure 4 shows the drying process of sago leaf stalk material.

Figure 4. Drying process of sago leaf material

The material is then cut into two lengths, 100 and 30 cm, depending on the size of the mold available. The bottom layer is made of 100 cm long Gaba-Gaba which is positioned lengthwise on the steel mold. For the first and second layers to unite and adhere well, glue is then applied. The second layer, 30 cm long and positioned transversely on top of the first layer, is made (like a woven mat that covers each other). Finally, the third layer is applied lengthwise, on top of the second layer, and is given a length of 100 cm after being applied with glue. The process of making the first, second, and third layers is shown in Figures 5-7.

Figure 5. The steps involved in forming first layer

Figure 6. The steps involved in forming second layer

Figure 7. The steps involved in forming third layer

Continue this process up to the fifth layer if desired. After that, the steel mold is placed on top of the layers and secured with bolts at several points to ensure that the material is pressed evenly and thoroughly. The next step involves using a cold press to apply a pressure of 2 MPa, while the material is clamped to maintain this pressure. Finally, the Gaba-Gaba is left to rest for 24 hours. The duration of the pressing process increases with the thickness of the material. The thicker the material being pressed, the longer the pressing process will take. Refer to Figure 8 for an illustration of the material pressing procedure.

Figure 8. Material pressing process

2. Acoustic testing of Gaba-Gaba material

In the second stage, which is the testing phase, the Gaba-Gaba panel sample is trimmed into a 10 cm round shape to fit the impedance tube for sound absorption testing, while maintaining the original sample's thickness. Measurements are conducted within the frequency range of 100-1000 Hz. The sample is positioned at one end of the tube, with a sound source at the other [26, 27]. The absorption coefficient of the sago composite board is determined using a two-microphone technique in the impedance tube. This approach is a standard practice among acoustic researchers for measuring the absorption coefficient and includes the calibration of the sensor tube [28, 29]. This tube is engineered to assess acoustic parameters by placing a small sample at one end. Sound generated by computer speakers is channeled into the impedance tube, where it is captured by two microphones. The data is then recorded and analyzed using PULSE lab shop software version 16.1. Sound wave recording data in the impedance tube will produce the value of the sound absorption coefficient. The notes are then processed using the Kaleida Graph program and displayed in numbers and curves for further measurement and testing. For further details, please refer to Figure 9 below.

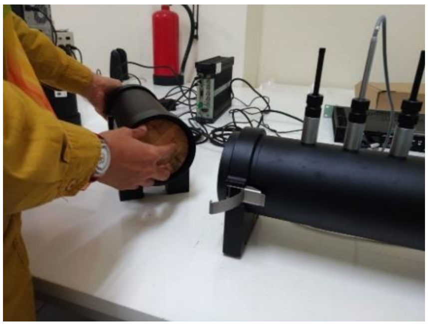

Figure 9. Test material installed on the sound level meter

3. RESULTS AND DISCUSSION

The experimental results for natural Gaba-Gaba fibers are detailed in Table 1 and Table 2, while the graphs illustrating the relationship between sound intensity and the sound absorption coefficient are presented in Figures 3 and 4. The tested material exhibits relatively low sound absorption coefficient values for Gaba-Gaba with a thickness of 2 cm. Specifically, the coefficient ranges from 0.06 to 0.30 across frequencies of 100 to 1000 Hz (see Table 1). The highest coefficient value of 0.30 occurs at 400 Hz, whereas the lowest is 0.06 at 100 Hz. Figure 10 shows the relationship between the sound absorption coefficient (α) and frequency. The test results indicate that natural Gaba-Gaba serves as a reflector, suggesting that additional materials are necessary to achieve sound absorption coefficients greater than 0.30 within the 100-1000 Hz frequency range.

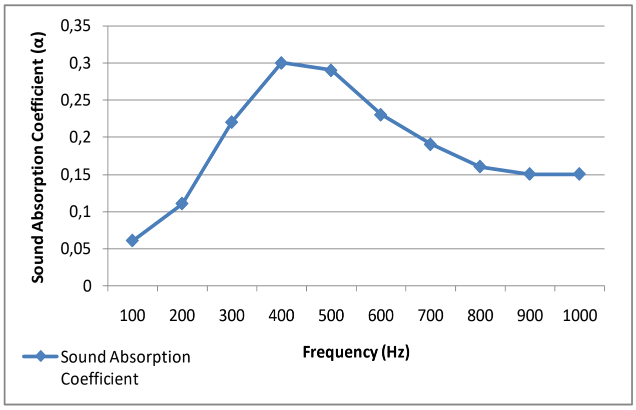

Figure 10. Graph of relationship between sound absorption coefficient against frequency in material gaba thickness Gaba-Gaba 2 cm

The material being tested exhibits a relatively high sound absorption coefficient for Gaba-Gaba with a thickness of 3 cm. For this thickness, the sound absorption coefficient ranges from 0.08 to 0.34 across frequencies between 100 and 1000 Hz (see Table 2). The coefficient peaks at 0.34 at 1000 Hz and reaches its lowest at 0.08 at 100 Hz. The relationship between the 3 cm thick Gaba-Gaba's sound absorption coefficient (α) and frequency is illustrated in Figure 11.

Table 1. Acoustic measurement results for Gaba-Gaba with a thickness of 2 cm

No.	Frequency (Hz)	Initial Sound Intensity (dB)	Sound Intensity Through Material (dB)	Decreased Sound Intensity (dB)	Sound Absorption Coefficient (α)
1.	100	71.40	55.89	15.51	0.08
2.	200	72.70	51.95	20.75	0.11
3.	300	79.20	45.20	34.00	0.19
4.	400	73.90	38.13	35.77	0.22
5.	500	82.90	45.05	37.85	0.20
6.	600	84.40	49.20	35.20	0.18
7.	700	81.40	48.38	33.02	0.17
8.	800	89.40	49.41	39.99	0.20
9.	900	88.90	36.33	52.57	0.30
10.	1000	87.50	31.90	55.60	0.34

Table 2. Acoustic measurement results for Gaba-Gaba with a thickness of 3 cm

No.	Frequency (Hz)	Initial Sound Intensity (dB)	Sound Intensity Through Material (dB)	Decreased Sound Intensity (dB)	Sound Absorption Coefficient (α)
1.	100	74.60	65.64	8.96	0.06
2.	200	75.70	60.62	15.08	0.11
3.	300	80.10	51.74	28.36	0.22
4.	400	77.30	42.05	35.25	0.30
5.	500	79.60	44.98	34.62	0.29
6.	600	80.30	50.75	29.55	0.23
7.	700	75.90	52.06	23.84	0.19
8.	800	83.90	60.48	23.42	0.16
9.	900	74.20	54.54	19.66	0.15
10.	1000	80.70	60.26	20.44	0.15

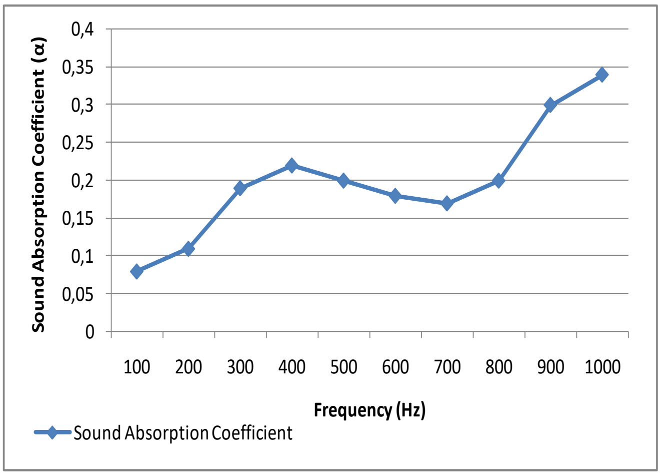

Figure 11. Graph of relationship between sound absorption coefficient against frequency in material gaba thickness Gaba-Gaba 3 cm

The test results show that the thicker the thickness the greater the sound absorption coefficient. It was found that the sound absorption performance of the *Gaba-Gaba* material reached a peak value in the range of 0.30-0.34, depending on its thickness. In this experiment/testing also carried out a test of coconut belt fiber with a thickness of 2 cm as a comparison to the natural material of *Gaba-Gaba*. Where for the coconut fiber natural fiber material, the sound absorption coefficient value is 0.38 at a frequency of 1000 Hz. This test strengthens the research studies [9, 10] that material thickness is the dominant determinant of sound absorption.

Overall, increasing material thickness generally leads to an increase in the sound absorption coefficient, which can have a significant impact on design and practical applications. By selecting materials with appropriate thickness, better acoustic control, increased comfort, and cost efficiency can be achieved, while utilizing sustainable and environmentally friendly materials.

4. CONCLUSIONS

The sound absorption coefficient values (α) for all samples have satisfied the specified requirements, where the conditions as sound dampening material/sound is a maximum α value above 0.15 (ISO 11654). The best performance is obtained from the sago leaf stalk material (Gaba-Gaba) with a thickness of 3 cm. The natural fiber Gaba-Gaba with a thickness of 3 cm is very suitable when used in the audio room because it has a sound absorption coefficient that is quite high at a frequency of 1000 Hz. This conclusion is interesting when considering that sago leaf stalks (Gaba-Gaba) are building materials, especially sound absorbers/natural, organic, renewable and local sound materials. Future research directions include:

- Exploration of Thickness and Composition Variations: Further Testing: Further research could be conducted to explore how different thickness variations and processing methods affect the sound absorption coefficient of Gaba-Gaba. This could include testing combinations of layers or the addition of other materials to improve acoustic performance.
- Performance Assessment in Different Conditions: Testing in Different Environmental Conditions: Additional research could assess how Gaba-Gaba performs in different environmental conditions, such as high humidity or extreme temperatures, to ensure its long-term durability and effectiveness.
- Development of More Efficient Production Methods: Process Optimization: Research could focus on developing more efficient and environmentally friendly production methods to produce Gaba-Gaba on a larger scale, including improvements in the drying and compaction processes.
- Integration with Modern Building Technologies: Innovation and Integration: Applying modern technologies in the design and production of Gaba-Gaba, and integrating them with the latest building techniques, to create more innovative and effective solutions for the construction industry.

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NOMENCLATURE

Mpa	Megapascal
Hz	Hertz
kHz	Kilohertz
cm	Centimeter

Greek symbols

α	Coefficient
%	Percent