Article

Thermal conductivity and sound absorption performance of panels based on coir fiber and castor oil resin

Desempenho quanto à condutividade térmica e absorção sonora de painéis à base de fibra de coco e resina de óleo de mamona

Lucas Benício Rodrigues Araújo
Ingrid Lourrany Barreto Freitas
Madson Lucas de Souza
Antonio Eduardo Bezerra Cabral
Saulo Guths

Abstract

This study aimed to evaluate the thermal conductivity and sound absorption performance of panels based on coconut fiber and castor oil resin, with potential application in walls, roofs and floors, considering their alignment with current standards. Panels composed of a mass ratio of 85% fiber and 15% castor oil resin were produced by centrifugation mixing and pressing to achieve thickness of 5 cm. The produced panels were assessed at densities of 60 kg/m³, 80 kg/m³, and 100 kg/m³ and were evaluated by grammage, moisture absorption, longitudinal tensile strength, thermal conductivity, and sound absorption coefficient. The production process proved to be suitable. The thermal conductivity values ranged from 0.061 W/mK to 0.064 W/mK similar values to commercial products such as rock wool (0.046 W/mK) and glass wool (0.045 W/mK). Moreover, the sound absorption performance resembled that of insulating materials like melamine foam, demonstrating better performance at low emission frequencies.

Keywords: Coir fiber panels. Thermoacoustic insulators. Vegetable fibers. Vegetable resin.

[1]**Lucas Benício Rodrigues Araújo**
[1]Universidade Federal do Ceará
Fortaleza - CE - Brasil

[2]**Ingrid Lourrany Barreto Freitas**
[2]Universidade Federal do Ceará
Fortaleza - CE - Brasil

[3]**Madson Lucas de Souza**
[3]Universidade Federal do Ceará
Fortaleza - CE - Brasil

[4]**Antonio Eduardo Bezerra Cabral**
[4]Universidade Federal do Ceará
Fortaleza - CE - Brasil

[5]**Saulo Guths**
[5]Universidade Federal de Santa Catarina
Florianópolis - SC - Brasil

Resumo

O objetivo deste estudo foi avaliar o desempenho quanto à condutividade térmica e absorção sonora de painéis à base de fibra vegetal de coco e resina de óleo de mamona, com potencial aplicação em paredes, telhados e pisos, considerando sua conformidade com as normas vigentes. Os painéis, compostos por 85% de fibra e 15% de resina de óleo de mamona, em massa, foram produzidos por meio de mistura por centrifugação e prensagem para atingir espessura de 5 cm. Os painéis produzidos foram produzidos nas densidades de 60 kg/m³, 80 kg/m³ e 100 kg/m³ e foram avaliados quanto à gramatura, absorção de umidade, resistência à tração longitudinal, condutividade térmica e coeficiente de absorção sonora. O processo de produção proposto mostrou-se adequado. Como resultado, valores de condutividade térmica variando de 0,061 W/mK a 0,064 W/mK foram obtidos, alinhando-se com produtos comerciais como lã de rocha (0,046 W/mK) e lã de vidro (0,045 W/mK). Além disso, a absorção sonora apresentou desempenho semelhante ao de materiais isolantes como a espuma de melamina, demonstrando melhor desempenho em baixas frequências de emissão.

Recebido em 01/03/24
Aceito em 19/07/24

Palavras-chave: *Painéis de fibra de coco. Isolantes termoacústicos. Fibras vegetais. Resina vegetal.*

ISSN 1678-8621 Associação Nacional de Tecnologia do Ambiente Construído.
http://dx.doi.org/10.1590/s1678-86212025000100846

Introduction

Brazil is the 5th largest coconut producer in the world and the largest producer outside the Asian continent. In 2017, Brazil's annual coconut production reached 1.56 billion fruits, with the state of Ceará contributing with 186.7 million. This significant yield corresponds to an annual fiber production potential of 337.4 thousand tons (IBGE, 2018). Despite this, investments in studies exploring the use of coconut fruit fibers remain minimal, as does the amount recycled. Consequently, this material contributes to the matrix of urban solid waste in coastal municipalities, often accumulating on beaches and in landfills (Lacerda; Leitão, 2021). In this context, Brazil occupies the 9th global ranking in the number of patent applicants related to coconut fiber, with only 178 patent families (Santos; Martinez; Juiz, 2019). Therefore, the effective application of existing patents is necessary in addition to the importance of new studies that use coconut by-products.

The use of plant-based fibers has been increasing, in part, because of the environmental appeal. Besides that, these materials have a low amount of pollutant generation in their production process, unlike mineral fibers like glass, which depend on fossil fuels in their production chain (Bozsaky, 2019). It can be noted a great economic potential and opportunities for job creation by considering the substantial annual production of coconut and the simplified fiber extraction process compared to mineral-based counterparts. To illustrate such generation potential, if 12 operating companies had operated at full capacity, 7.7 million reais (R$) could have been generated in 2012 (EMBRAPA, 2016).

Given the significant volume of waste generated, the civil construction sector can play a crucial role in the use of this waste as an alternative to non-sustainable materials. Some research has explored the use of fibers to improve the thermal performance of mortars (Quiñones-Bolaños *et al.*, 2010); as a reinforcement element for concrete in aggressive environments (Ramli; Kwan; Abas, 2013); in the production of concrete pipes (Yan; Chouw, 2014), and in cementitious bricks (Silva *et al.*, 2018). However, these applications use a low amount of the coconut waste compared to the total produced.

Buildings must not only serve as shelters but also provide users with adequate housing conditions. Criteria such as thermal and acoustic performance have become the subject of studies and innovations and can be assessed according to NBR 15575 (ABNT, 2024; Baird; Field, 2013). Moreover, the use of bio-based materials with high hygroscopic capacity, such as plant fibers, contributes to controlling moisture exchanges in the environment, enhancing air quality and indoor comfort (Bourdot *et al.*, 2019). Construction systems are always evolving. New technologies emerge resulting in higher quality and performance of the developed product. Innovations like drywall, wood frame, and steel frame systems are some examples. These systems have lower weight and serve both sealing and structural functions, while also enhancing thermal and acoustic comfort through the filling of empty spaces with thermal insulators and acoustic absorbent materials (Velosa; Fangueiro; Mendonça, 2013; Way, 2015). Thermal insulators and acoustic absorbents like glass wool and rock wool are also applied to other parts of buildings, such as ceilings and floors (Aditya *et al.*, 2017; Abu-Jdayil *et al.*, 2019). However, there is a need to develop products that, in addition to meeting the cited requirements, have a more sustainable approach, such as those based on alternative materials (Velosa; Fangueiro; Mendonça, 2013; Nguyen, 2018; Hassan *et al.*, 2020). Coir fiber, obtained from the coconut husk, appears as a potential alternative material for its favorable thermal and acoustic properties (Fiorelli; Bueno; Cabral, 2019).

Previous studies have shown promising results for the sound absorption coefficient of composites made with coir fiber. Hassan *et al.* (2020) manufactured rigid plates incorporating up to 20% of different fibrous materials, including coir fiber, combined with ecological epoxy resin. The authors demonstrated that increasing fiber content enhances the sound absorption coefficient. Notably, composites reinforced with coir fiber exhibit a higher sound absorption coefficient compared to those reinforced with other types of fibers. Bhingare and Prakash (2020) performed tests on samples composed only of coir fibers pressed at different densities. The Delany-Bazley model yielded promising results when compared to experimental data up to the frequency range of 2700–2900 Hz, beyond which deviations were observed. A sound absorption coefficient of 0.84 at 2900 Hz was recorded for a sample with a thickness of 35 mm and a density of 220 kg/m³. Beyond acoustic properties, plant fibers also exhibited favorable characteristics to their application for thermal insulation. Fiorelli, Bueno and Cabral (2019) produced high density panels, ranging from 500 kg/m³ to 700 kg/m³, composed of sugarcane bagasse and coir fiber, evaluating their thermoacoustic properties. Values of thermal conductivity between 0.14 W/mK and 0.17 W/mK were presented. However, there is currently no research that has developed thermal insulators and acoustic absorbers materials based on coir fiber with density, malleability, and cohesion comparable to conventional materials like glass wool and rock wool.

Given the versatility of coir fiber applications, its properties, and the potential to incorporate a larger amount of the material into a single product, this study aimed to evaluate the thermal conductivity and sound absorption performance of panels based on coconut fiber and castor oil resin, with potential applications in walls, roofs, and floors, considering their alignment with current standards.

Materials and methods

The panels were manufactured by using coir fiber donated by EMBRAPA (Brazilian Agricultural Research Corporation) and a natural bi-component resin based on vegetable polyurethane from castor oil, Imperveg® AGT 1315. This sustainable binder was used to facilitate the adequate connection between the fibers. To determine the optimal binder content, different fiber to binder mass ratio were tested. The proportions by mass (fiber - resin) of 75.0% - 25.0%, 77.5% - 22.5%, 80.0% - 20.0%, 82.5% - 17.5%, 85.0% - 15.0% and 87.5% - 12.5% were produced. Additionally, two different coir fibers were tested:

(a) long and with no residue from the production process; and

(b) different sizes and with residues.

The composition with 85% of long fibers and 15% of resin exhibited the minimum amount of binder with a proper composite cohesion.

The panels were produced with a thickness of 5 cm, a nominal thickness standardized for both glass wool and rock wool, which are conventional materials with thermal insulate and acoustic absorption properties (ABNT, 2019, 2014). The panels were produced in three different densities: 60 kg/m³, 80 kg/m³ and 100 kg/m³ (Korjenic; Zach; Hdroudová, 2016; Schiavoni; Bianchi; Asdrubali, 2016). The composition of the panels is presented in Table 1.

The production process is illustrated in Figure 1. The panel production process consisted of the following steps:

(a) weighing the fiber and binder;

(b) mixing the components using a glue blender machine through a centrifugation process for 3 minutes;

(c) weighing the mixture according to the desired density, considering a thickness of 5 cm;

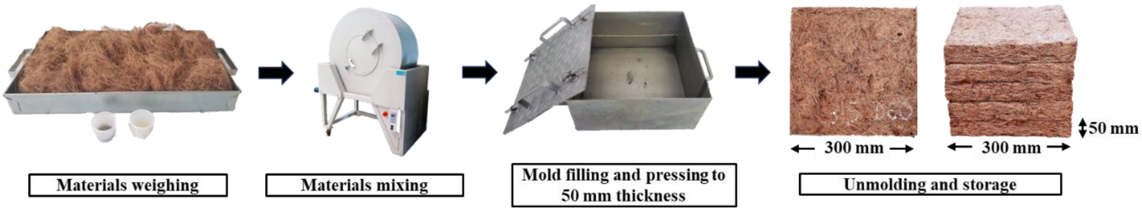
(d) pressing the mixture until it reaches a thickness of 5 cm; and

(e) locking the mold and allowing it to set for 24 hours before demolding and storage.

Tabela 1 - **Composition of the panels produced**

Sample densities (kg/m^3)	Castor oil resin (kg/m^3)	Coconut fiber (kg/m^3)
60	9.0	51.0
80	12.0	68.0
100	15.0	85.0

Figure 1 - **Production process of coir fiber-based thermoacoustic panels**



Materials characterization

The resin presented density and curing time values of 1.08 g/cm³ and 24 hours, respectively, according to its manufacturer. The geometric characterization of the coir fibers was done by measuring the length and diameter of 100 samples using a ruler and a micrometer, respectively. Their density was determined using an adaptation of the Chapman flask method according to NBR 9776 (ABNT, 1987), with the sample immersed for 48 hours to ensure complete water filling of all pores. Moisture content was determined through an adjustment based on NBR 7190 (ABNT, 1997); and absorption was assessed through an adjustment based on NBR NM 53 (ABNT, 2009; Cáceres, 2016). For the thermal and sound absorption analyses, the specimens were produced in a panel format of 30 cm x 30 cm ensuring dimensional accuracy in length and width and complying with the maximum variation allowed by the standard.

Characterization of coir fiber-based panels

The panels characterization was based on the tests and standards shown in Table 2. All the equipment used was properly calibrated and certified. All tests were performed according to the standardized minimum number of samples. The obtained results will be presented with their average and standard deviation values.

Panels' physical characterization

The dimensional analysis, grammage, moisture absorption, and longitudinal tensile strength evaluated according to NBR 16726 (ABNT, 2019). The longitudinal tensile strength typically involves testing 5 specimens of 100 cm x 50 cm (length x width), extracted from the commercial product. However, in this study, the panels were produced in pre-fixed formats due to production conditions, with dimensions proportionally reduced for testing. However, the minimum stress level of the standardized model was maintained, to ensure the non-disaggregation of the panel during handling. All tests were conducted on 3 specimens for each density produced. The normality of the obtained results was assessed by the Shapiro-Wilk test.

Evaluation of thermal resistance and conductivity

To determine the thermal resistance and conductivity of the material, the fluximetric method was followed, with procedures outlined in C518 (ASTM, 2017). The panels thermal resistance was evaluated based on Fourier's Law (Kosky *et al*., 2021), shown in Equation 1.

$$R = \frac{T_1 - T_2}{\left(\frac{q_1 - q_2}{2}\right)} \qquad \text{Eq 1}$$

Where R is the thermal resistance (m^2K/W), T1 and T2 are the temperatures (K), and q1 and q2 are the heat flux densities (W/m²), both on the material faces.

Table 2 - **Characterization tests conducted on coir-based panels**

Standard	Title	Tests
NBR 16726, (ABNT, 2019*)	Glass wool for acoustic and thermal insulation for constructive systems for gypsum plaster plates for drywall – Requirements and test methods	Size analysis
		Grammage
		Moisture absorption
		Longitudinal tensile strength
C518, (ASTM, 2017)	Standard Test Method for Steady-State Thermal Transmission Properties by means of the Heat Flow Meter Apparatus	Thermal conductivity
ISO 10534-2, (ES, 2001)	Acoustics: Determination of sound absorption coefficient and impedance in impedance tubes, Part 2: Transfer Function Method	Sound absorption coefficient

Note: *the standard serves as a reference, as the developed product is an alternative to a commercial counterpart.

Considering the homogeneity of the material, the thermal conductivity was determined based on Equation 2. For this proposes, the material was considered as homogeneous. Thermal conductivity indicates the material capacity to transfer heat (Speight, 2018).

$$\lambda = \frac{L}{R} \quad \text{Eq. 2}$$

Where λ is the thermal conductivity (W/mK), L is the material thickness (m) and R is the previously calculated thermal resistance (m^2K/W).

For the test, an apparatus (Figure 2) including a thermal insulator, a heater, two heat flux transducers (one superior and one inferior), and a dissipater was used. The test was performed on 2 specimens with dimensions (length x width) of 30 cm x 30 cm and thickness of 5 cm for each density produced. The average test temperature was 25 ºC. The temperature difference between the faces of the sample was 15 ºC, with uncertainty around 3% and a duration of 72 hours (ES, 1991; ISO, 2008).

Evaluation of the sound absorption coefficient

To determine the sound absorption coefficient of the material, the acoustic impedance tube was employed, whose test is regulated by ISO 10534-2 (ES, 2001). The sound absorption coefficient was measured based on Equation 3. It indicates the material's ability to absorb sound, represented by the ratio between absorbed energy and incident energy (Peng, 2017). This coefficient varies with the incident frequency, and it is necessary to evaluate the material across different frequency ranges.

$$\alpha = \frac{E_a}{E_i} \quad \text{Eq. 3}$$

Where α is the sound absorption coefficient, E_a is the absorbed sound energy (W/m^2) and E_i is the incident sound energy (W/m^2).

For the test, an apparatus (Figure 3) including 1 capacitive microphone 1/2" BK4189 SN2953825 (53.1 mV/Pa), 1 capacitive microphone 1/2" BK4189 SN2953826 (48.0 mV/Pa), power amplifier BK 2708, signal analyzer BK 3039 (6 channels), and galvanized steel impedance tube was used. Frequencies ranging from 180 Hz to 1800 Hz were studied. The limitation of the analyzed frequency range is due to the size of the impedance tube. Some materials might have good absorption performance at higher cies (i.e., >2kHz) which cannot be seen using this method. Three specimens with a diameter of 10.7 cm (Figure 3) for each density produced were tested. Additionally, samples of rock wool with a density of 64 kg/m³ and a thickness of 50 mm and samples of melamine foam with a density of 10 kg/m³ and a thickness of 25 mm were considered for comparison.

Results and discussion

Coir fiber characterization

The fiber presented an average diameter and length of 0.22 ± 0.075 mm and 16.62 ± 4.10 cm, respectively. These values align with the literature reported, where the diameter is typically around 0.34 mm and the length surpasses 10 cm (Mishra; Basu, 2020). Fibers with greater length, such as the ones of this study, have greater cohesion due to the superior anchorage facilitated by these dimensions, allowing contact with a greater number of adjacent fibers.

Figure 2 - **Thermal conductivity test based on ad ISO 8301 (ES, 1991) and C518 (ASTM, 2017)**

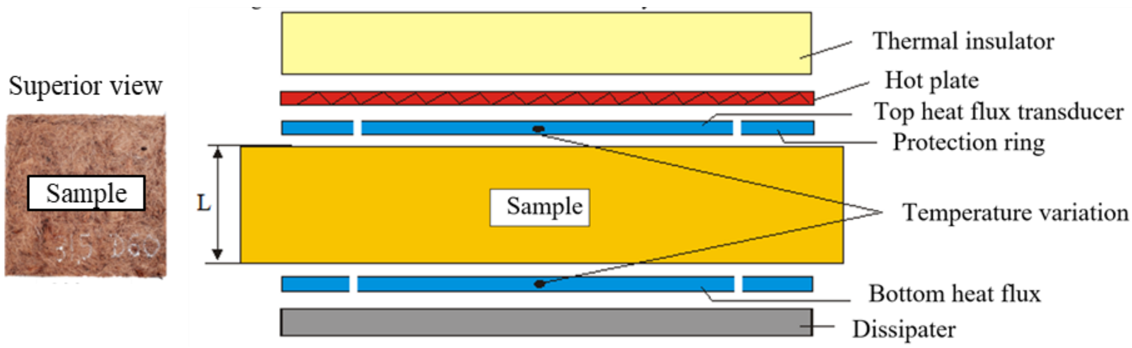
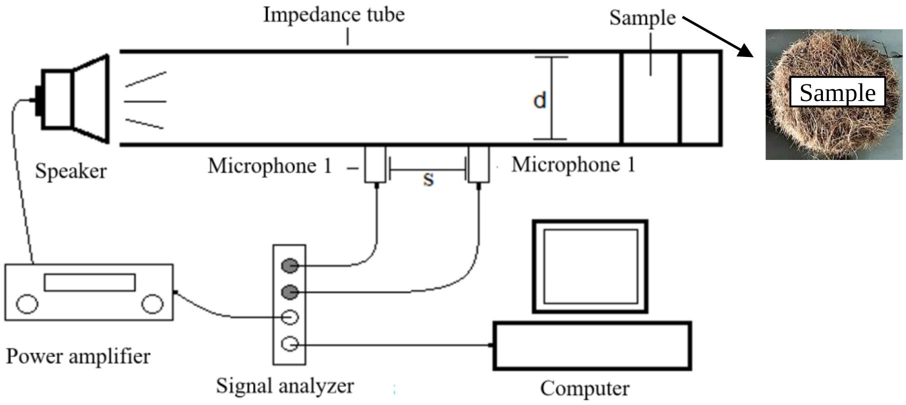


Figure 3 - **Acoustic impedance tube test based on ISO 10534-2 (ES, 2001)**



The fibers specific gravity was 0.578 ± 0.126, a lower value than those reported in the literature (ranging between 0.9 and 1.3) (Tran *et al.,* 2015; Lomelí-Ramírez *et al.*, 2018). This difference may be attributed to factors such as the absence of particles adhered along the fiber, limitations in the test method (Mishra; Basu, 2020), or the use of long fibers, which have lower density (Tran *et al*., 2015). Regarding humidity, a value of 11.2 ± 0.4 % was found, aligning closely with literature values (approximately 12%) (Ferreira *et al*., 2016). Additionally, the fiber presented an absorption of 213.8 ± 3.9%. Despite exhibiting high absorption when submerged in water, this behavior can be minimized during the production of the composite, as the material will be partially or totally covered by resin. Moreover, the material is proposed for use in dry areas. The obtained results showed normal distribution, validated by Shapiro-Wilk test, with p-values higher than 0.05.

Physical, thermal, and acoustic characterization of coir fiber and castor oil resin panels

Dimensional analysis, grammage, moisture absorption and longitudinal tensile strength

The panels physical characterization is presented in Table 3. The obtained results showed normal distribution, validated by Shapiro-Wilk test, with p-values higher than 0.05. The results of the nominal thicknesses indicate that all panels adhered to the prescribed tolerances (10% of the desired thickness – 5 cm). The variation remained within a maximum of 1%, according to NBR 16726 (ABNT, 2019), confirming the quality control in the production process with respect to dimensional accuracy. All specimens exhibited a grammage of 0.45 kg/m² or greater, as specified in NBR 16726 (ABNT, 2019), which is comparable to commercial products such as glass wool and rock wool (Schiavoni; Bianchi; Asdrubali, 2016).

All specimens surpassed the moisture absorption limit of 5% (ABNT, 2019). However, it should be noted that this standard was designed for materials of mineral origin. Coconut fibers are vegetable fibers which, due to their structure, can regulate not only temperature but also humidity changes, which is essential for comfort and air quality. Previous studies performed with plant-based insulators reported residual moisture of 25% after production (Correia, 2011) and international applications concluded that high moisture levels do not invalidate the material's functionality (Korjenic; Zach; Hdroudová, 2016). Higher natural moisture content is already expected in fibers of plant origin, consequently for the panels. Moreover, if necessary, water-repellent additives could be incorporated to reduce moisture levels. Furthermore, the longitudinal tensile strength values surpassed the values of 6 kPa, 8 kPa and 10 kPa for the densities of 60 kg/m³, 80 kg/m³ and 100 kg/m³, respectively (ABNT, 2019). This demonstrates the material's applicability without undergoing disintegration during handling.

Thermal conductivity

The thermal conductivity results are presented in Figure 4. The panels exhibited low values of thermal conductivity, and there was no significant difference between the 3 densities produced. The variations ranged from 0.061 W/mK to 0.064 W/mK. These values are aligned with the thermal conductivity values of established commercial products like rock wool (0.046 W/mK) and glass wool (0.045 W/mK), which were tested for comparative analysis. The observed low thermal conductivity for the panels may be attributed to the voluminous structure of the fiber lumen (Liu *et al*., 2012; Hassan *et al.*, 2020). And consequently, fiber high porosity (Danfeu; Meukam; Jannot, 2016), high volume of interfiber voids and random fibers distribution

(Ismail *et al.*, 2021). The panels exhibited thermal resistivity values of 0.772 m²k/W, 0.835 m²k/W and 0.869 m²k/W for densities of 60 kg/m³, 80 kg/m³ and 100 kg/m³, respectively.

These results align with research that used natural fibers for thermal insulation. In a comprehensive review by Schiavoni, Bianchi and Asdrubali (2016), investigations into hemp-based insulators demonstrated that, within the density ranging between 20 kg/m³ and 90 kg/m³, thermal conductivity ranged from 0.038 W/mK to 0.060 W/mK. For kenaf fiber, the density range of 30 kg/m³ to 180 kg/m³ represented a variation in thermal conductivity between 0.034 W/mK and 0.043 W/mK. Danfeu, Meukam and Jannot (2016) tested different fibrous materials for their thermal properties, and the coir fiber showed a thermal conductivity of 0.058 W/mK, values slightly lower than the ones found on this research. This small increase may be attributed to the partial filling of the lumen by the resin used to maintain material cohesion (Liu *et al.*, 2012).

Hence, the potential application of coir fiber panels as effective thermal insulators is validated by their thermal insulating properties. In addition, the incorporation of fiber-based materials can improve the energy efficiency of buildings due to their hygrothermal properties which can contribute to the regulation of room temperature and humidity (Palumbo *et al.*, 2018; Rosa Latapie *et al*., 2023).

Sound absorption coefficient

The average results for the sound absorption coefficients (α) are shown in Figure 5. At a frequency of 500 Hz, the panels exhibited coefficients of 0.15, 0.19, and 0.22 for densities of 60 kg/m³, 80 kg/m³, and 100 kg/m³, respectively. These values were lower than those reported by Berardi and Iannace (2015) for coir fiber without binder, in the thickness of 50 mm and density of 60 kg/m³, reaching α equal to 0.34 and 0.67 at 500 Hz and 1000 Hz, respectively. This reduction in sound absorption efficiency can be attributed to the use of vegetable resin to agglomerate the fibers, since its use increases stiffness, which adversely affects acoustic properties (Fouladi *et al.*, 2012). When compared to commercial products, coir fiber panels performed like to melamine foam and are inferior to rock wool.

Table 3 - **Physical characterization of the panels**

Sample/Density	60 kg/m³	80 kg/m³	100 kg/m³
Thickness (mm)	50.45 ± 0.51	50.25 ± 0.25	50.50 ± 0.43
Grammage (kg/m²)	3.07 ± 0.03	4.09 ± 0.10	4,99 ± 0.02
Moisture absorption (%)	10.82 ± 1.13	18.70 ± 1.06	25.30 ± 1.57
Tensile strength (kPa)	30.14 ± 1.31	72.54 ± 3.99	112.00 ± 5.32

Figure 4 - **Thermal resistance and conductivity results**

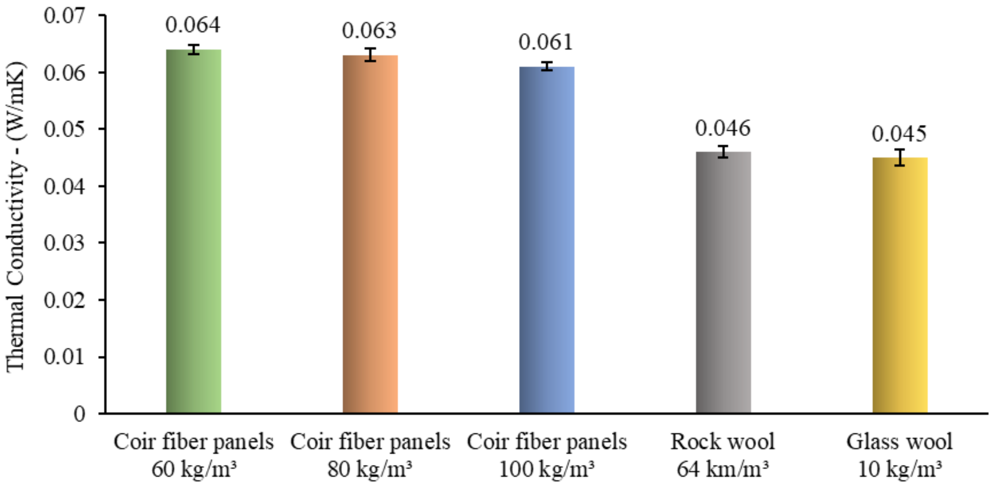
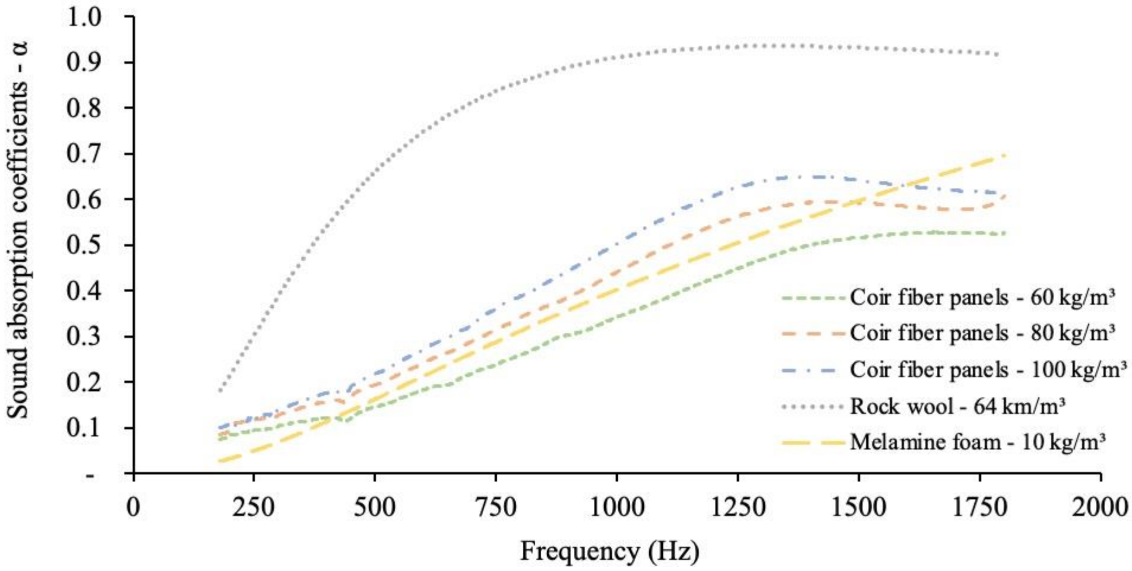


Figure 5 - **Values of sound absorption coefficients under different frequencies**



The incorporation of the panel in building envelopes, such as dry-wall systems, can produce a system with high acoustic performance. This system operates on the "mass-spring-mass" principle:

(a) the first solid acts as a mass, reflecting some noise while allowing the remainder to pass through;

(b) the residual noise enters the acoustic material, where it is absorbed, reducing wave amplitude;

(c) the second solid reflects additional noise into the acoustic material, enhancing absorption; and

(d) transmits attenuated noise into the adjacent room (El Hajj *et al*., 2011).

Lightweight porous materials, like coconut fiber panels, operate through absorption rather than mass. Reinforcing sound performance can be achieved by applying either the mass law principle – where increased wall mass improves insulation – or the mass-spring-mass principle – where two heavy walls separated by a flexible insulator absorb and disperse sound energy within the cavity (El Hajj *et al.*, 2011).

To improve the sound absorption performance of the panels, some strategies can be adopted, such as:

(a) increasing the material's density and, in turn, its resistance to flow and tortuosity, which hinders the propagation of sound waves through the fibers (Putra *et al*., 2018);

(b) chemical pretreatment of plant fibers to increase their flexibility, resulting in a more compact composite with a better void distribution (Cherradi *et al*., 2021); and

(c) study of the introduction of a free space with the sample in the system, which leads to an increase in the sound absorption coefficient at low frequencies, a problem presented in this study (Lim *et al*., 2018).

Conclusions

This work aimed to evaluate the thermal conductivity and sound absorption performance of panels based on coconut fiber and castor oil resin, with potential applications in walls, roofs, and floors, considering their alignment with current standards.

Based on commercial products and standards NBR 16726 (ABNT, 2019), C518 (ASTM, 2017), ISO 10534-2 (ES, 2001) and ISO 8301 (ES, 1991), coir fiber panels fulfill the specified criteria for dimensional analysis, grammage, tensile strength, and thermal conductivity and sound absorption performance. The only criterion not met was the moisture absorption, which is a characteristic of plant fibers that can be improved through optimization.

The panels exhibited low thermal conductivity values, reaching a maximum of 0.064 W/mK, which is comparable to those presented by commercial insulators like glass wool and rock wool. Additionally, varying the densities of coir fiber panels from 60 kg/m³ to 100 kg/m³ did not lead to significant differences in the material's thermal performance, which indicates the potential for producing lighter panels without sacrificing performance.

Regarding sound absorption performance, the panels demonstrated comparable effectiveness to commercial materials like melamine foam, especially at low sound frequencies. The sound absorption coefficient ranged up to 0.22 at 250 Hz and 0.63 at 1600 Hz. Furthermore, variation in the densities of the coir fiber panels, from 60 kg/m³ to 100 kg/m³ did not lead to significant differences in the material's acoustic absorption performance, indicating only minor increases with higher density.

In conclusion, the panels developed in this study not only represent a more sustainable alternative to existing market products but also demonstrate economic competitiveness (Korjenic; Zach; Hroudová, 2016). Therefore, considering the factors mentioned above, panels composed of coir fiber and castor oil resin showed significant potential for application as thermal insulators and acoustic absorbent.

For future works, it is recommended to characterize the panels regarding their performance in case of fire and its sound insulation potential, which are important information for the material's use in civil construction. Also, due to the limitation of the impedance tube it would be important to extend the frequency range for a better understanding of the product, especially at higher frequencies. Besides that, an analysis of the industrial scale production of the material is proposed.

References

ABU-JDAYIL, B. *et al.* Traditional, state-of-the-art and renewable thermal building insulation materials: an overview. **Construction and Building Materials**, v. 214, p. 709-735, 2019.

ADITYA, L. *et al*. A review on insulation materials for energy conservation in buildings. **Renewable and Sustainable Energy Reviews**, v. 73, p. 1352-1365, 2017.

AMERICAN SOCIETY FOR TESTING AND MATERIALS. **C518-17:** standard test method for steady-state thermal transmission properties by means of the heat flow meter apparatus. West Conshohocken, 2017.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 11722:** feltros termoisolantes à base de lã de rocha. Rio de Janeiro, 2014.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 15575-1**: edificações habitacionais: desempenho: parte 1: requisitos gerais. Rio de Janeiro, 2024.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 15575-4:** edificações habitacionais: desempenho: parte 4: requisitos para os sistemas de vedações verticais internas e externas – SVVIE. Rio de Janeiro, 2024.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 16726:** feltro de lã de vidro para isolamento acústico e térmico em sistemas construtivos em chapas de gesso para drywall: requisitos e métodos de ensaio. Rio de Janeiro, 2019.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 7190:** projeto de estruturas de madeira. Rio de Janeiro, 1997.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 9776:** agregados: determinação da massa específica de agregados miúdos por meio do frasco de Chapman. Rio de Janeiro, 1987.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR NM 53:** agregado graúdo: determinação de massa específica, massa específica aparente e absorção de água. Rio de Janeiro, 2009.

BAIRD, G.; FIELD, C. Thermal comfort conditions in sustainable buildings–Results of a worldwide survey of users' perceptions. **Renewable Energy**, v. 49, p. 44-47, 2013.

BERARDI, U.; IANNACE, G. Acoustic characterization of natural fibers for sound absorption applications. **Building and Environment**, v. 94, p. 840-852, 2015.

BHINGARE, N. H.; PRAKASH, S. An experimental and theoretical investigation of coconut coir material for sound absorption characteristics. **Materials Today: Proceedings**, v. 43, p. 1545-1551, 2020.

BOURDOT, A. *et al.* Impact of bio-aggregates properties on the chemical interactions with mineral binder, application to vegetal concrete. **Journal of Advanced Concrete Technology**, v. 17, n. 9, p. 542-558, 2019.

BOZSAKY, D. Nature-based thermal insulation materials from renewable resources: a state-of-the-art review. **Slovak Journal of Civil Engineering,** v. 27, p. 52 – 59, 2019.

CÁCERES, A. R. E. **Caracterização geométrica e mecânica de macrofibras poliméricas.** São Paulo, 2016. 93 f. Dissertation (Master degree) **-** Universidade de São Paulo, São Paulo, 2016.

CHERRADI, Y. *et al.* Acoustic properties for composite materials based on alfa and wood fibers. **Applied Acoustics,** v. 174, p. 107759, 2021.

CORREIA, F. M. **Balanço energético da utilização de kenaf na produção de energia e painéis isoladores, em Portugal.** Lisboa, 2011. Dissertation (Master degree) - Faculdade de Ciências e Tecnologia, Lisboa, 2011.

DAMFEU, J. C.; MEUKAM, P.; JANNOT, Y. Modeling and measuring of the thermal properties of insulating vegetable fibers by the asymmetrical hot plate method and the radial flux method: kapok, coconut, groundnut shell fiber and rattan. **Thermochimica Acta**, v. 630, p. 64-77, 2016.

EL HAJJ, N. *et al*. Development of thermal insulating and sound absorbing agro-sourced materials from auto linked flax-tows. **Industrial Crops and Products**, v. 34, n. 1, p. 921-928, 2011.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. **Beneficiamento da casca de coco verde para a produção de fibra e pó.** 2016. Available: https://embrapa.br/busca-de-solucoes-tecnologicas/-/produto-servico/33/beneficiamento-da-casca-de-coco-verde-para-a-producao-de-fibra-e-po. Access: 12 may 2020.

EUROPEAN STANDARDS. **EN ISO 10534-2:** acoustics: determination of sound absorption coefficient and impedance in impedance tubes transfer-function method. Geneva, 2001.

EUROPEAN STANDARDS. **EN ISO 8301:** thermal insulation: determination of steady-state thermal resistance and related properties: heat flow meter apparatus. Geneva, 1991.

FERREIRA, A. F. B. *et al.* Caracterização energética da fibra da casca do coco com posterior produção de briquete. In: CONGRESSO BRASILEIRO DE ENGENHARIA QUÍMICA, 21., Fortaleza, 2016. **Anais […]** Fortaleza, 2016.

FIORELLI, J.; BUENO, S. B.; CABRAL, M. R. Assessment of multilayer particleboards produced with green coconut and sugarcane bagasse fibers. **Construction and Building Materials**, v. 205, p. 1-9, 2019.

FOULADI, M. H. *et al.* Enhancement of coir fiber normal incidence sound absorption coefficient. **Journal of Computational Acoustics**, v. 20, n. 1, p. 1250003, 2012.

HASSAN, T. *et al.* Acoustic, mechanical and thermal properties of green composites reinforced with natural fibers waste. **Polymers**, v. 12, n. 3, p. 654, 2020.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. **ISO/IEC GUIDE 98**, Guide to the expression of uncertainty in measurement. Geneva, 2008.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Produção Agrícola Municipal**. 2018. Available: http://www2.sidra.ibge.gov.br/bda/tabela/listabl.asp?c=16. Access: 11 may 2020.

ISMAIL, B. *et al.* Modelling of thermal conductivity and nonlinear mechanical behavior of straw insulation composite by a numerical homogenization approach. **Journal of Building Engineering**, v. 43, p. 103144, 2021.

KORJENIC, A.; ZACH, J.; HROUDOVÁ, J. The use of insulating materials based on natural fibers in combination with plant facades in building constructions. **Energy and Buildings**, v. 116, p. 45-58, 2016.

KOSKY, P. *et al.* Mechanical Engineering. **Exploring Engineering**, p. 317–340, 2021.

LACERDA, M. S.; LEITÃO, F. O. Challenges and opportunities of the circular economy: the case of green coconut residues. **Informe Gepec**, v. 25, n. 2, p. 164-181, 2021.

LIM, Z. Y. *et al*. Sound absorption performance of natural kenaf fibres. **Applied Acoustics**, v. 130, p. 107-114, 2018.

LIU, K. *et al.* Effect of physicochemical structure of natural fiber on transverse thermal conductivity of unidirectional abaca/bamboo fiber composites. **Composites Part A: Applied Science and Manufacturing**, v. 43, n. 8, p. 1234-1241, 2012.

LOMELÍ-RAMÍREZ, M. G. *et al.* Comparative study of the characteristics of green and brown coconut fibers for the development of green composites. **BioResources**, v. 13, n. 1, p. 1637-1660, 2018.

MISHRA, L.; BASU, G. Coconut fibre its structure, properties and applications. In: HANDBOOK of NATURAL FIBRES. Cambridge: Woodhead, 2020.

NGUYEN, D. M. *et al*. Building bio-insulation materials based on bamboo powder and bio-binders. **Construction and building materials**, v. 186, p. 686-698, 2018.

PALUMBO, M. *et al*. Bio-based insulation materials and their hygrothermal performance in a building envelope system (ETICS). **Energy and Buildings**, v. 174, p. 147-155, 2018.

PENG, L. Sound absorption and insulation functional composites. In: ADVANCED high strength natural fibre composites in construction. Amsterda: Elsevier, 2017.

PUTRA, A. *et al*. Sound absorption of extracted pineapple-leaf fibres. **Applied Acoustics**, v. 136, p. 9-15, 2018.

QUIÑONES-BOLAÑOS, E. *et al*. Potential use of coconut fibre modified mortars to enhance thermal comfort in low-income housing", **Journal of Environmental Management**, v. 277, p. 111503, 2020.

RAMLI, M.; KWAN, W. H.; ABAS, N. F. Strength and durability of coconut-fiber-reinforced concrete in aggressive environments. **Construction and Building Materials**, v. 38, p. 554-566, jan. 2013.

ROSA LATAPIE, S. *et al.* Multiscale modelling of bio-composites: towards prediction of their thermal conductivity based on adequate knowledge of their constituents. In: INTERNATIONAL Conference on Bio-Based Building Materials. Cham: Springer Nature Switzerland, 2023.

SANTOS, D. E.; MARTINEZ, F. C. C.; JUIZ, P. J. L. A fibra de coco como matéria-prima para o desenvolvimento de produtos: uma prospecção tecnológica em bancos de patentes. **Cadernos de Prospecção**, Salvador, v. 12, n. 1, p. 153-164, 2019.

SCHIAVONI, S.; BIANCHI, F.; ASDRUBALI, F. Insulation materials for the building sector: a review and comparative analysis. **Renewable and Sustainable Energy Reviews**, v. 62, p. 988-1011, 2016.

SILVA, E. J. D. *et al.* Compósito cimentício com elevado teor de fibra de coco tratada: propriedades físicas e durabilidade. **Matéria,** Rio de Janeiro, v. 23, n. 3, 2018.

SPEIGHT, J. G. **Unconventional gas**. Boston: Elsevier Books, 2018.

TRAN, L. Q. N. *et al.* Investigation of microstructure and tensile properties of porous natural coir fibre for use in composite materials. **Industrial Crops and Products**, v. 65, p. 437-445, 2015.

VELOSA, J. C.; FANGUEIRO, R.; MENDONÇA, P. Estudo das propriedades térmicas de materiais fibrosos aplicados em paredes divisórias leves. **Ciência & Tecnologia dos Materiais**, v. 25, n. 1, p. 50-56, 2013.

WAY, D. J. **Proof of concept for a three-dimensional molded core wood-strand sandwich panel.** Oregon, 2015. Dissertation (Master degree) - Wood Science - Oregon State University, Oregon, 2015.

YAN, L.; CHOUW, N. Natural FRP tube confined fibre reinforced concrete under pure axial compression: a comparison with glass/carbon FRP. T**hin-Walled Structures**, v. 82, p. 159-169, 2014.

Lucas Benício Rodrigues Araújo
Conceptualization, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft.

Programa de Pós-Graduação em Engenharia Civil: Estruturas e Construção Civil | Universidade Federal do Ceará | Campus do Pici, Bloco 733 | Fortaleza – CE – Brasil |CEP 60955-900 | Tel.: (85) 3366-9607 | E-mail: lucas.araujo@entpe.fr

Ingrid Lourrany Barreto Freitas
Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft.

Programa de Pós-Graduação em Engenharia Civil: Estruturas e Construção Civil | Universidade Federal do Ceará | E-mail: ingridlourrany@alu.ufc.br

Madson Lucas de Souza
Data curation, Formal analysis, Investigation, Writing – review and editing.

Programa de Pós-Graduação em Engenharia Civil: Estruturas e Construção Civil | Universidade Federal do Ceará | E-mail: madsonlucas@alu.ufc.br

Antonio Eduardo Bezerra Cabral
Conceptualization, Supervision, Visualization, Writing – review and editing.

Programa de Pós-Graduação em Engenharia Civil: Estruturas e Construção Civil | Universidade Federal do Ceará | E-mail: eduardo.cabral@ufc.br

Saulo Guths
Conceptualization, Formal analysis, Visualization, Writing – review and editing.

Departamento de Engenharia Mecânica | Universidade Federal de Santa Catarina | Centro Tecnológico, Trindade | Florianópolis – SC – Brasil | CEP 88040-900 | Tel.: (48) 3721-7709 | E-mail: saulo@lmpt.ufsc.br

Editor: **Enedir Ghisi**

Ambiente Construído
Revista da Associação Nacional de Tecnologia do Ambiente Construído
Av. Osvaldo Aranha, 99 - 3º andar, Centro
Porto Alegre – RS - Brasil
CEP 90035-190
Telefone: +55 (51) 3308-4084
www.seer.ufrgs.br/ambienteconstruido
www.scielo.br/ac
E-mail: ambienteconstruido@ufrgs.br