TECNIACÚSTICA
CUENCA 2023

SOUND ABSORPTION PROPERTIES OF MYCELIUM BASED MATERIALS WITH TEXTILE WASTE: AN EXPLORATORY STUDY.

Luis Miguel Garcia[1]
Tomas Simon Gomez[1,2,3]
Maria del Pilar Rivera[1]
Juan Camilo Oviedo[1]
Christ Glorieux[2]
Nelson Escobar[1]

[1]Universidad Pontificia Bolivariana, Escuela de ingeniería, Medellín, Colombia
[2]KU Leuven, Department of Physics and Astronomy, Laboratory for Acoustics - Soft Matter and Biophysics, Heverlee, Belgium;
[3]University of Brescia, Department of Mechanical and Industrial Engineering, Brescia, Italy

RESUMEN

Este artículo muestra un estudio exploratorio sobre la integración de residuos agroindustriales y textiles mediante un enfoque poco convencional. Mediante el cultivo de hongos dentro de una red fibrosa, actuando como aglutinante, se desarrolló un material absorbente acústico sostenible, partiendo del hongo Pleurotus pulmonarius, bagazo de caña de azúcar y tiras de residuos textiles sintéticos, utilizados como relleno. Los hongos se dejaron crecer en el sustrato durante 45 días y posteriormente se desactivaron y deshidrataron mediante tratamiento térmico. La absorción acústica, medida utilizando la norma ISO 10534-2, refleja la naturaleza típica de la absorción acústica porosa, caracterizada por una absorción deficiente a bajas frecuencias y un aumento gradual de la absorción con el incremento de la frecuencia. El promedio de absorción acústica (SAA) mostró una absorción energética de aproximadamente el 40% entre 200 y 2500 Hz.

ABSTRACT

This paper shows an exploratory study on the integration of agroindustrial and textile waste through an unconventional approach. By cultivating fungus within a fibrous network, acting as a binder, a sustainable sound absorptive material was developed, starting from Pleurotus pulmonarius fungus, sugarcane bagasse and strips of synthetic textile waste, used as fillers. Fungi were allowed to grow in the substrate for 45 days and were subsequently deactivated and dehydrated by heat treatment. The sound absorption, measured using ISO 10534-2, reflects a typical porous sound absorption nature, i.e small at low frequencies and gradually increasing absorption with increasing frequency. The sound absorption average (SAA) was about 40% between 200 and 2500 Hz.

Key Words— *mycelium, bio-composites, sound absorption, micelio, biocompuestos, absorción del sonido*

1. INTRODUCTION

Acoustic materials play a crucial role in many fields such as architecture and noise abatement. Their sound absorption and insulation can greatly impact the overall quality of sound within a space.

In recent years, the exploration of alternative sustainable materials has gained popularity in the field [1]–[4]. Among the wide range of sustainable materials, researchers have been investigating the use of agro-industry and textile waste in combination with different types of binders.

One particular alternative that has gained recent interest, owing to its low energy requirements and upcycling potential, makes use of mycelium-based foams and composites. Mycelium, which constitutes the vegetative growth of filamentous fungi, binds organic matter through a network of hyphal micro-filaments in a natural biological process that can be harnessed for the production of various products, including acoustic absorbers, thermal insulators, and packaging systems[1].

1 ***Autor de contacto***: *tomas.gomez@kuleuven.be*

Thanks to their high porosity and density [5], [6], mycelium-based materials prove suitable for both thermal and acoustic applications, as demonstrated by previous research [7]–[11].

Various mycelium-based materials with different types of filler have produced typical porous sound absorbers [7]–[10], which are driven by two phenomena, thermal conductivity and viscothermal losses, providing effective broadband absorption at mid-high frequencies, i.e over 500 Hz [12].

A recent examination of the state of research on acoustic applications for mycelium composites revealed a lack of comprehensive characterization despite the variety of substrates used, primarily consisting of agro-industry waste and, in one instance, paper-based waste [13]. Moreover, there is limited diversity in the fungal species employed by researchers, with the primary species being Pleurotus Ostreatus, Trametes Versicolor, and some undisclosed Basidiomycetes [13].

This paper presents an exploratory study in which a mycelium bio-composite was developed from sugarcane bagasse and textile waste, in combination with the fungi pleurotus pulmonarius sugarcane, followed by corresponding test to validate and compare its performance with previous research on mycelium based materials.

2. MATERIALS AND METHODS

2.1. Sample preparation

Samples of the fungus species Pleurotus Pulmonarius were obtained from a local mycology laboratory. Additionally, sugar cane bagasse, a residue from the food industry, and textile scraps were sourced from local industries. The samples were fabricated in the city of Medellín, Colombia. It's worth noting that environmental conditions were controlled, rendering the influence of local weather variations negligible.

To prevent any potential contamination of the developed mycelium composites by microorganisms present in the substrates, a pasteurization process was employed for the sugarcane bagasse and textile scraps. Initially, an autoclave was preheated with water, brought nearly to the boiling point, and then the substrates were introduced into it. Subsequently, they were subjected to a pressure of 15 psi and 120 degrees Celcius for a duration of 45 minutes. Once the pasteurization process was completed, excess moisture in the substrates was manually removed in a sterile environment. The substrate was then placed inside trays measuring 21 x 13 x 1.2 cm, with a composition of 70% sugarcane bagasse and 30% textile scraps by weight. These trays were subsequently inoculated with the fungal spawn, constituting 20% of the weight of the substrate, which was evenly distributed among the trays to achieve the desired density. The inoculated trays were covered with sterilized black bags and kept at a temperature of 21 degrees Celsius and a relative humidity of 50% for a duration of 45 days.

Following the cultivation stage, the material was extracted from the bags and subjected to heat in a convection oven at 65 degrees Celsius for a period of 24 hours. This step aimed to deactivate the fungi and reduce moisture while preserving the mycelium structure. Subsequently, the density of the material was measured.

2.2. Sample characterization

The bulk density of the developed material was determined through precise measurements of volume and weight. This process involved using a metric tape and a precision scale with a resolution of 0.1 g.

The sound absorption coefficient was measured following the impedance tube method, specified in ISO standard 10534–2 [14] using an inhouse developed impedance tube, with two Behringer ECM8000 model microphones. A pseudo-random sequence of plane waves consisting of periodic pink noise was generated in the tube, and the complex acoustic transfer function of the two microphone signals was determined and used to compute the normal-incidence absorption coefficient of the samples. The Audio Measurement and Analysis Software (ARTA) by Artalabs [15] was used as a signal analyzer. The reflection coefficient, characteristic impedance, and absorption coefficient were calculated, following equations (1) and (2). Based on the dimension of the test rig and the spacing between microphones the test covered a frequency range from 200 to 5000 Hz.

$$R=\frac{H_{12}-e^{jks}}{e^{jks}-H_{21}}e^{2jk(L+s)} \tag{1}$$

$$\alpha=1-|R|^2 \tag{2}$$

Where α, and R, are the sound absorption and reflection coefficients, H_{xy} are the complex transfer function between microphones x and y, taking x as a reference; k, L, and s are the complex wavenumber, the thickness of the sample and the spacing between the two microphone respectively.

Three samples were measured and each of them was tested 3 times, for each test 100 ensemble averages were made with linear averaging. The tests were made preserving temperature and relative humidity constant, to ensure reproducibility and to dismiss possible environmental effects on the results.

3. RESULTS AND DISCUSSION

A cut sample of the resulting material for the impedance tube measurement is shown in figure 1, the resulting density of the material was 153 kg/m³ and the thickness 1.2 cm.

Figure 1. Mycelium composite from textile strips and sugarcane bagasse.

It was observed that the developed material had a brittle nature, also, the textile strips did not adhere to the mycelium, this mainly because of their synthetic nature, whereas the sugarcane bagasse components glued together with a whiteiss matrix which was the mycelium.

The resulting sound absorption coefficient is shown in figure 2, where the average sound absorption coefficient is shown the blue line with a range of minimum and maximum values for each third octave band. It can be seen that the sound absorption increases with frequency from 250 Hz to 2000 Hz.

To make a deeper analysis of the performance of the resulting material a comparison was made with previous results shown in the literature. The results compiled by [13] were compared with the present study and are shown in figure 3, in the same fashion as in figure 2, showing the range of values reported and measured.

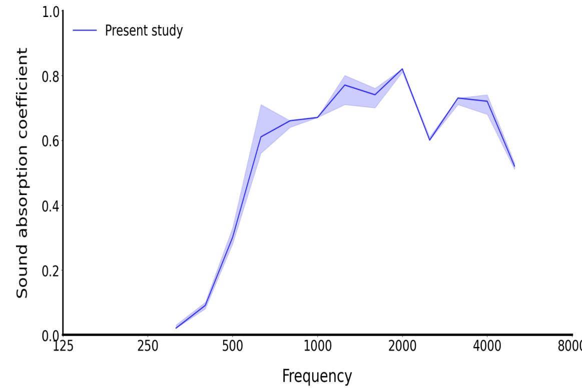

Figure 1. Sound absorption coefficient of mycelium composite from sugarcane bagasse with textile strips.

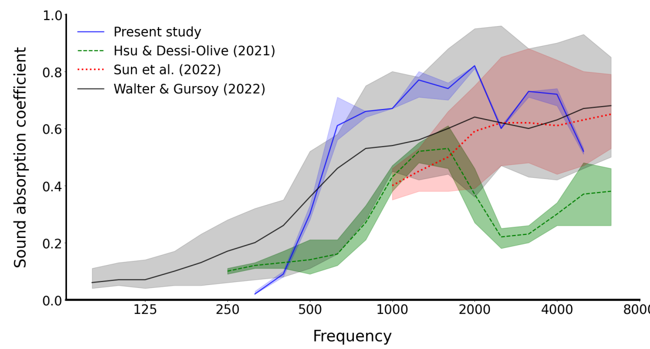

Figure 3. Sound absorption coefficient of mycelium composite from sugarcane bagasse with textile strips.

It is possible to identify that although the sample has low absorption below 500 Hz, it increases sharply, surpassing the average sound absorption reported by all previous studies. It should be noted that the thickness of the sample developed is comparable to the one reported by Sun et al. [9], but below what Hsu & Dessi-Olive [16] and Walter & Gursoy [7] reported. Sun et al [9]. reports a density of 200 kg/m³, higher that the one showed in the developed material, Walter & Gursoy [7] and Hsu & Dessi-Olive [16] do not report density therefore is not possible to make a comparison on such dimension.

Sugarcane bagasse usually has a high diameter 0.79±0.03 mm [17] compared to other reported types of waste such as shredded paper, cardboard and hemp fibers [13], thus asuming that the densities are comparable, it could be inferred that the addition of textile waste in mycelium composites could potentially increase average sound absorption.

Finally the sound absorption average between 200 and 4000 was caculated and compiled in table 1, for the measured samples and reported results in literature which have a broadband characterization.

Table 1. Sound absorption average values for the reported values in literature and measured samples.

Material	Frequency range (Hz)	SAA	Source
Sugarcane bagasse – textile strip mycelium	200 - 2500	0.42	Present study
Hemp-based mycelium	250 - 2500	0.27	[16]
Paper-based mycelium	200 - 2500	0.42	[7]

From table 1, it is observed that both paper-based mycelium and the developed samples have a similar performance, however, the paper-based material has greater sound absorption coefficient at lower frequencies, whereas the one presented in this research shows better performance at higher frequencies.

4. CONCLUSIONS

A mycelium composite made of sugarcane bagasse and synthetic textile waste with a different fungal species was developed, and its sound absorption coefficient was tested and compared with previous studies.

The sound absorption behavior of this material shows a typical absorption curve for porous absorbers, nevertheless, it shows a superior average absorption than other mycelium composites present in literature, which might be caused by the inclusion of the textile waste.

This study demonstrates the potential of mycelium-based composites as effective sound absorbers, with the unique advantage of incorporating sustainable waste materials. This opens new possibilities for eco-friendly acoustic solutions, paving the way for innovative approaches in construction and environmental design.

Further investigations into the optimization of mycelium composites and their broader applications should be made in order to have a competitive sound absorber also at low frequencies.

5. REFERENCES

[1] M. Jones, A. Mautner, S. Luenco, A. Bismarck, and S. John, “Engineered mycelium composite construction materials from fungal biorefineries: A critical review,” Materials & Design, vol. 187, p. 108397, Feb. 2020, doi: 10.1016/j.matdes.2019.108397.

[2] R. Cottone, L. Shtrepi, V. Serra, and S. L. Pagliolico, “The Recycling and Reuse of Natural Materials: Sound Absorbing Box Patterns That Use Waste from Olive Tree Pruning,” Acoustics, vol. 5, no. 1, pp. 177–192, Feb. 2023, doi: 10.3390/acoustics5010011.

[3] T. S. Gomez et al., “Evaluation of Colombian Crops Fibrous Byproducts for Potential Applications in Sustainable Building Acoustics,” Polymers, vol. 13, no. 1, p. 101, Dec. 2020, doi: 10.3390/polym13010101.

[4] T. S. Gomez et al., “Sound absorption behavior of repurposed waste fibers: Effects of fiber size, density, and binder concentration,” Applied Acoustics, vol. 202, p. 109174, Jan. 2023, doi: 10.1016/j.apacoust.2022.109174.

[5] G. A. Holt, G. Mcintyre, D. Flagg, E. Bayer, J. D. Wanjura, and M. G. Pelletier, “Fungal Mycelium and Cotton Plant Materials in the Manufacture of Biodegradable Molded Packaging Material: Evaluation Study of Select Blends of Cotton Byproducts,” J Biobased Mat Bioenergy, vol. 6, no. 4, pp. 431–439, Aug. 2012, doi: 10.1166/jbmb.2012.1241.

[6] F. V. W. Appels et al., “Fabrication factors influencing mechanical, moisture- and water-related properties of mycelium-based composites,” Materials & Design, vol. 161, pp. 64–71, Jan. 2019, doi: 10.1016/j.matdes.2018.11.027.

[7] N. Walter and B. Gürsoy, “A Study on the Sound Absorption Properties of Mycelium-Based Composites Cultivated on Waste Paper-Based Substrates,” Biomimetics, vol. 7, no. 3, p. 100, Jul. 2022, doi: 10.3390/biomimetics7030100.

[8] C. Dognini, S. Basu, P. Piana, and E. Gobbi, “Variation Of The Acoustic Characteristics Of Mycelium-Based Biomaterials With Time,” in Proceedings of the 29th International Congress on Sound and Vibration, Prague, Czechia: IIAV, 2023.

[9] W. Sun, M. Tajvidi, C. Howell, and C. G. Hunt, “Insight into mycelium-lignocellulosic bio-composites: Essential factors and properties,” Composites Part A: Applied Science and Manufacturing, vol. 161, p. 107125, Oct. 2022, doi: 10.1016/j.compositesa.2022.107125.

[10] S. Sivaprasad, S. K. Byju, C. Prajith, J. Shaju, and C. R. Rejeesh, “Development of a novel mycelium bio-composite material to substitute for polystyrene in packaging applications,” Materials Today: Proceedings, vol. 47, pp. 5038–5044, 2021, doi: 10.1016/j.matpr.2021.04.622.

[11] H. Schritt, S. Vidi, and D. Pleissner, “Spent mushroom substrate and sawdust to produce mycelium-based thermal insulation composites,” Journal of Cleaner Production, vol. 313, p. 127910, Sep. 2021, doi: 10.1016/j.jclepro.2021.127910.

[12] J. P. Arenas and M. J. Crocker, “Recent Trends in Porous Sound-Absorbing Materials,” Sound & Vibration, vol. 44, no. 7, pp. 12–17, 2010.

[13] T. S. Gomez, M. Rychtarikova, R. Armstrong, and E. Piana, “Acoustic Applications Of Bio-Mycelium Composites, Current Trends And Opportunities: A Systematic Literature Review,” in Proceedings of the 29th International Congress on Sound and Vibration, Prague, Czechia: IIAV, 2023.

[14] ISO, “10534-2: Acoustics — Determination of sound absorption coefficient and impedance in impedance tubes — Part 2: Transfer-function method.”.

[15] J. Rodina, “ARTA Software.”

[16] T. Hsu and J. Dessi-Olive, “A design framework for absorption and diffusion panels with sustainable materials,” in Proceedings of the 50th International Congress and Exposition of Noise Control Engineering, Washington D.C., USA, 2021. doi: 10.3397/IN-2021-2074.

[17] N. P. Pérez, D. T. Pedroso, E. B. Machin, J. S. Antunes, C. E. Tuna, and J. L. Silveira, “Geometrical characteristics of sugarcane bagasse for being used as fuel in fluidized bed technologies,” Renewable Energy, vol. 143, pp. 1210–1224, Dec. 2019, doi: 10.1016/j.renene.2019.05.082.