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MYCELIUM COMPOSITES COMBINING DIFFERENT WASTE SOURCES FOR SUSTAINABLE ACOUSTIC SOLUTIONS

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ABSTRACT

Mycelium is a biological material that consists of filamentous fungi, forming intricate networks of hyphal micro-filaments that naturally bind organic matter. This unique way of growing offers promising potential for developing innovative materials, including acoustic absorbers. A lot of variety is possible, since mycomaterial properties are highly dependent on the substrate used.

The presented research reports on the development and acoustic characterization of mycelium composites derived from diverse substrates. These include the fungal strain Pleurotus Pulmonarius, combined with leaves and grass clippings with textile waste. 3 distinct material combinations were made. For each material combination, the density and porosity were obtained by the gas pycnometer method. The sound absorption of the samples was determined using an impedance tube, in compliance with the ISO-10534-2 standard, spanning frequencies from 200 Hz to 5000 Hz. The microstructure of the samples was characterized by Scanning electron microscopy (SEM). The mycomaterials exhibited sound absorption values exceeding 50% across frequencies ranging from 1500 Hz to 4000 Hz.

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1. INTRODUCTION

Mycelium-based composites (MBC) have gained interest as viable alternatives to conventional synthetic materials in construction, packaging, and acoustic and thermal applications. These biocomposites are compostable and derived from renewable or waste resources. They also exhibit promising functional characteristics, including thermal insulation and sound absorption [1], [2]. Recent studies highlight the versatility of mycelium materials, demonstrating their potential to porous absorbers in acoustic solutions. For instance, mycelium-grown substrates such as agricultural waste, spent coffee grounds, and paper industry byproducts have achieved sound absorption coefficients comparable to traditional materials like polyurethane and extruded polystyrene [3], [4]. The acoustic performance of these composites is closely tied to their microstructure, which can be tailored through substrate selection, fungal species, and processing methods [5], [6], [7]. Despite these advances, gaps remain in understanding how specific waste streams, particularly urban biowaste (e.g., leaves, grass clippings) combined with textile waste, influence the acoustic and physical properties of mycelium composites. While prior research has explored lignocellulosic substrates like sawdust and straw [8], [9], [10], [11], the integration of textile waste into mycelium matrices requires further investigation. Textile processing methods (e.g., grinding, stripping) may significantly alter composite porosity, density, and hyphal adhesion, thereby impacting acoustic efficiency.

This study addresses these gaps by developing and characterizing mycelium composites derived from leaves, grass clippings, and recycled textiles (ground, stripped, and combined forms) using Pleurotus pulmonarius. Through impedance tube testing, helium pycnometry, and scanning electron microscopy (SEM), we evaluate how textile treatment methods affect the composites' sound absorption, density, and microstructure.

2. MATERIALS AND METHODS

2.1 Sample Preparation

The production of the composite samples was based on solid-state fermentation of Pleurotus pulmonarius cultivated on lignocellulosic and textile-based substrates. This was carried out in Medellín, Colombia, under controlled environmental conditions to eliminate the influence of external weather fluctuations.

Agro-industrial and textile residues were selected as the main substrate components, a mixture of grass cuttings and dry leaves sourced from the organic waste disposal system of Universidad Pontificia Bolivariana were used as the primary lignocellulosic materials. Additionally, recycled textile fibres were provided by a local textile recycling company and pre-processed into fine ground material and textile strips prior to use. By varying the textile processing method across samples, this study aims to evaluate its influence on the structural and acoustic properties of the resulting composites.

Preliminary treatment of the substrates included the removal of any non-organic contaminants from the grass and leaf mixture.

In order to reduce the microbial load, an autoclaving step was conducted, at 120 °C and 15 psi for 45 minutes. Excess moisture was subsequently removed from the substrates.

Each mixture was placed into sterile trays measuring and inoculated with Pleurotus pulmonarius grain spawn, with an amount corresponding to a 20 percent of the total substrate dry weight. The trays were covered with sterilized polyethylene bags to limit light exposure, then incubated at 21 °C with 50 percent relative humidity for 45 days to facilitate mycelial colonization.

Throughout the incubation period, mycelial growth was monitored. Any fruiting bodies that emerged were removed to maintain focus on vegetative mycelium development. Upon completion of the cultivation phase, the samples were removed from the bags and dehydrated in a convection oven at 65 °C for 24 hours. This post-processing step deactivated the fungal metabolism. After deactivation the samples had a thickness of 2 cm.

Table 1 shows the different sample compositions. The substrate composition consisted of 70 percent lignocellulosic material and 30 percent recycled textile by weight; with these different sample configurations the effect of the textile processing method on the structure and acoustic capabilities of the developed materials is being evaluated.

Fig. 1 to 3 show developed samples, Fig 1. Ground Textile (GT), Fig 2. Striped Textile (ST), Fig 3. Combined Textile (CT), Respectively.

Table 1. Sample composition

Sample	Composition
GT	70% lignocellulosic composite - 30% ground textile
ST	70% lignocellulosic composite - 30% striped textile
CT	70% lignocellulosic composite - 15% ground textile - 15% stripped textile

Figure 1. Ground Textile mycelium sample (GT)

Figure 2. Striped Textile mycelium sample (ST)

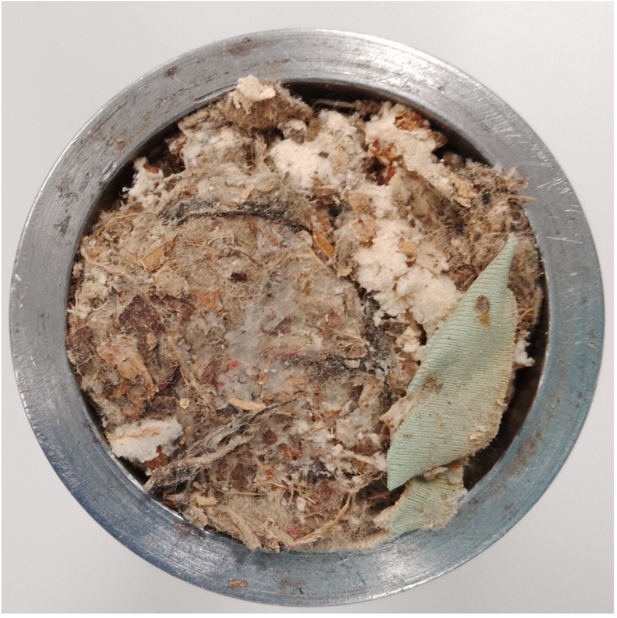

Figure 3. Combined Textile sample (CT)

2.2 Sample characterization

Following the cultivation of the mycelium-based composites, a series of physical and acoustic characterization procedures were conducted to evaluate their suitability as sound-absorbing materials.

2.2.1 Density and Porosity Analysis

The physical characterization of the mycelium composites included the determination of their bulk density and open porosity. The bulk density was calculated as the ratio between the oven-dried mass and the geometric volume of the samples. To obtain the true (skeletal) density of the solid phase, a helium gas pycnometry was performed using an AcuPyc II 1345 pycnometer, in accordance with ASTM D923. Each measurement included 50 purges and measurement cycles to ensure accuracy and stability of the results. Open porosity (ϕ) was then calculated using:

$$\phi = 1 - \frac{\rho_{Bulk}}{\rho_{Real}} \qquad (1)$$

2.2.2 Sound absorption coefficient

The sound absorption spectra of the mycelium composites were determined using the impedance tube method, following the guidelines established in ISO

10534-2. Measurements were conducted using a custom-built impedance tube setup equipped with two Behringer ECM8000 condenser microphones. Pink noise was generated within the tube to simulate plane wave propagation under normal incidence conditions, the frequency range of the analysis went from 200 Hz to 5000 Hz. Cylindrical samples with a 38 mm diameter were cut to fit the inner diameter of the impedance tube, ensuring airtight contact with the tube walls. Each test was repeated three times per sample type to assess experimental variability. The resulting absorption coefficient curves were analyzed to compare the acoustic behavior of the different substrate combinations and to identify trends associated with material composition and structure.

2.2.3 Scanning Electron Microcopy

Scanning Electron Microscopy (SEM) was employed to investigate the internal microstructure and hyphal network formation within the mycelium composites. Prior to imaging, small cross-sectional fragments of each sample were cut and coated with a thin layer of gold. SEM imaging was carried out at an accelerating voltage of 15 kV.

3. RESULTS AND DISCUSSION

The physical properties of the mycelium composites are presented in Table 2. Density values ranged from 1.05 to 1.08 g/cm³,. Bulk density values, as measured via helium gas pycnometry, varied between 0.13 and 0.15 g/cm³ depending on the textile waste used.

Calculated porosity values ranged from 86% to 88%. The GT sample showed the highest porosity, while ST and CT had slightly lower porosities. These small differences suggest that the processing method of the textile component may have a subtle effect on the internal structure of the resulting composites.

Table 1. Density and porosity of leaves and grass cuttings based mycelium composites with different textiles.

Sample	Real Density (g/cm³)	Bulk Density (g/cm³)	Porosity (%)
GT	1.08	0.13	88
CT	1.06	0.15	86
ST	1.05	0.15	86

Examination of the acoustic performance (Figure 4) of the composites showed a typical trend for porous materials: the sound absorption increased with frequency. However, notable distinctions were observed among the different textile treatments. The GT sample demonstrated the highest absorption coefficients, particularly in the mid to high frequency range (1000–4000 Hz). In comparison, both ST and CT exhibited similar absorption, with slightly lower performance, especially at higher frequencies, whilst having greater absorption at low frequencies.

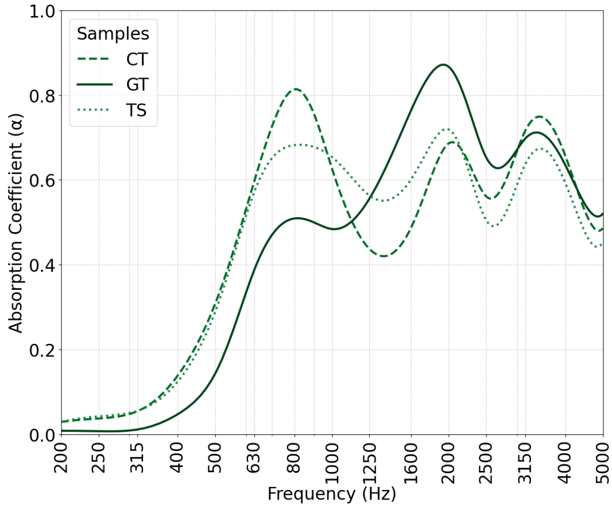

Figure 4. Sound absorption coefficient of mycelium based composites.

These differences in acoustic performance are further supported by the density and porosity results and SEM imaging, which revealed variations in the internal structures of the composites. The GT sample displayed a porous network, while ST showed a more compact and layered micro-structure with lower porosity.

The SEM images revealed key differences in the internal structure of the based mycelium composites, which help contextualize the observed acoustic and physical properties.

The GT (Ground Textile) sample (Fig 5) presents a highly irregular and open structure. The fibres are fragmented and loosely packed, creating an interconnected network with visible voids. This morphology is consistent with its higher porosity and lower bulk density. The open and tortuous structure increases the surface area available for interaction with sound waves, supporting the superior acoustic performance observed. Fig. 6 and Fig. 7 show how mycelium does not grow over the textile fibers.

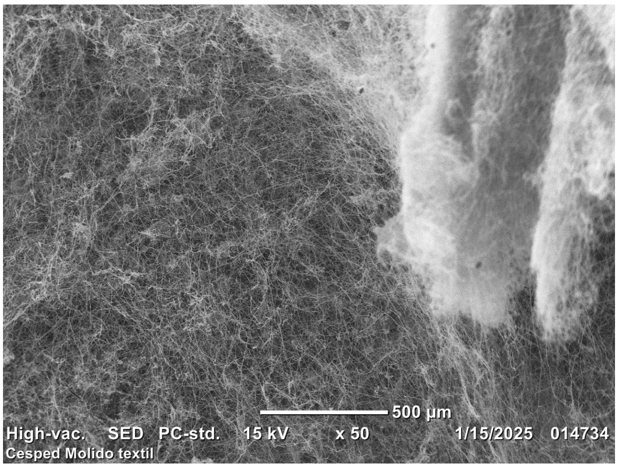

Figure 5. SEM image of the GT (Ground Textile) sample at 50× magnification, showing a fragmented and loosely packed fiber network with high porosity and open structure.

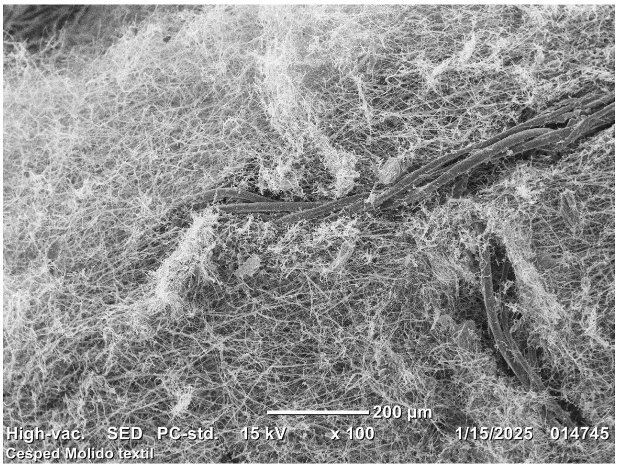

Figure 6. SEM image of the GT sample at 100× magnification. Exposed textile fibers remain largely uncovered by mycelium, suggesting limited adhesion or colonization.

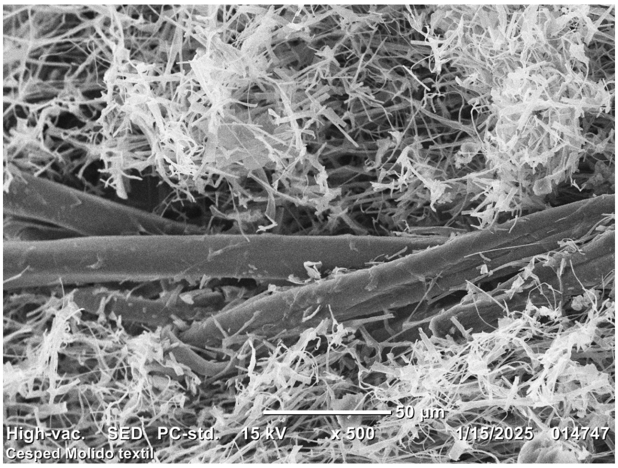

Figure 7. SEM image of the GT sample at 500× magnification. The mycelium grows around but not across the textile fibers, maintaining distinct fiber contours.

Composites with textile strips (Figs 8–10) show a more compact microstructure. Large woven threads and continuous regions of dense material are visible. At higher magnification (Fig 9), the textile structure exhibits a low porosity, compared to the GT sample.
The mycelial coverage is extensive in both samples, but the distributions of pores differ. In the GT composite, the broken-down textile allows the mycelium to colonize a fragmented, aerated matrix. In CT and ST, the woven structure may limit the internal pathway for sound wave dissipation.
These findings align with the fact that finer textile processing in GT likely facilitates better air-flow and energy dissipation, whereas the denser structure in CT and ST may restrict sound penetration to some extent, resulting in a somewhat lower absorption performance at higher frequencies.

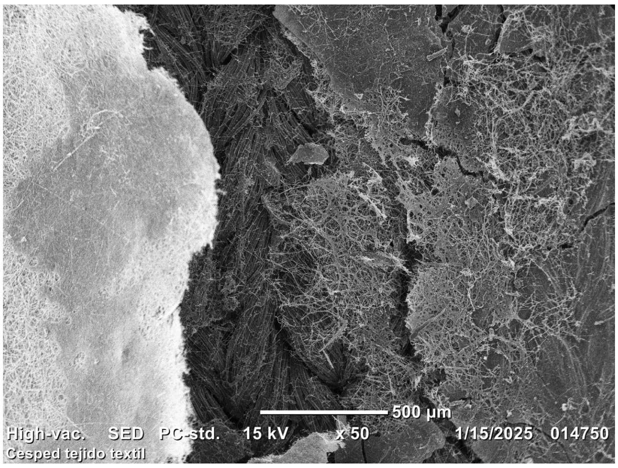

Figure 8. SEM image of the ST sample at lower magnification (50×), highlighting a more continuous and layered surface with reduced structural openness compared to GT.

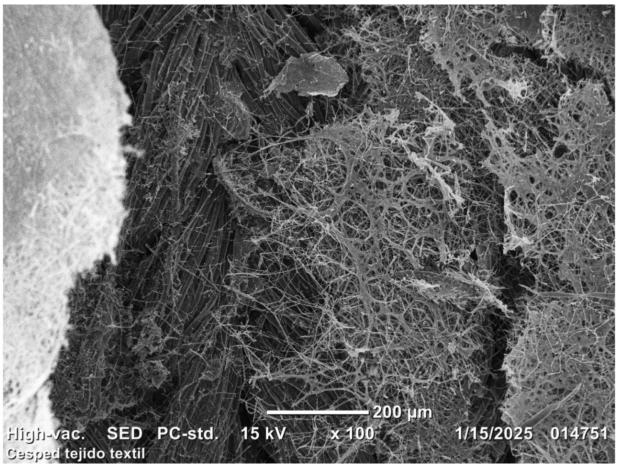

Figure 9. SEM image of the ST (Textile Strip) sample at 100× magnification. Large textile bundles and a more compact structure are clearly visible.

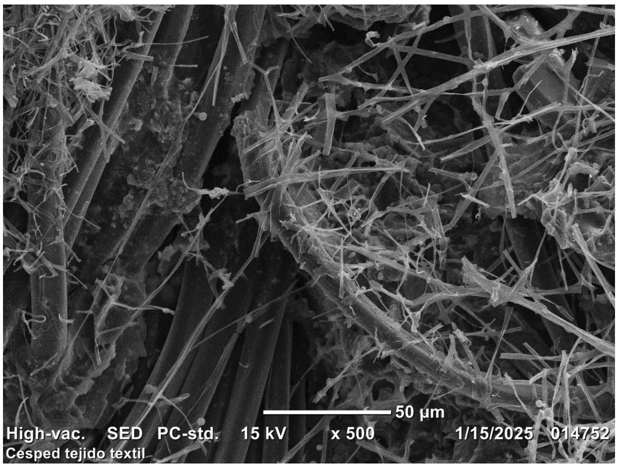

Figure 10. Higher magnification SEM image (500×) of the ST sample, revealing limited porosity and dense fiber regions surrounded by mycelial growth.

4. CONCLUSIONS

This study explored the development and characterization of mycelium-based composites using leaves and grass clippings combined with different forms of textile waste. The influence of textile processing was examined through physical measurements, acoustic absorption testing, and scanning electron microscopy (SEM).

All based composites exhibited high porosity and relatively low bulk density, confirming their potential as lightweight, bio-based acoustic materials. Among the samples, the GT (Ground Textile) formulation showed the most favorable acoustic performance, particularly in the mid-to-high frequency range. This correlated with its lower bulk density and microstructural features observed under SEM, which revealed a more open, irregular internal network with greater void content. In contrast, CS and CT samples presented slightly denser structures, with larger, more continuous fibre zones and moderately reduced sound absorption.

These results suggest that substrate processing plays a critical role in defining the physical and functional behavior of mycelium composites. Loose fibres appear to enhance porosity and acoustic absorption by promoting a more penetrable internal structure for sound wave dissipation. Overall, the findings provide preliminary support for the viability of mycomaterials as sustainable alternatives for acoustic applications, with potentially adjustable properties through substrate formulation.

5. ACKNOWLEDGMENT

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