Comparative evaluation of Mycelium-based acoustics under different growth conditions and binding solutions

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Abstract- This study reviews and compares three significant research works on mycelium-based acoustic composites, highlighting their potential as sustainable alternatives to conventional sound-absorbing materials. Mycelium composites are produced by growing fungal mycelium on agricultural or paper waste, forming lightweight, porous structures that effectively absorb sound while supporting circular economy principles through biodegradability and waste valorization.

The first study demonstrated that shredded cardboard substrates combined with Pleurotus ostreatus fungi yield composites with strong structural integrity and sound absorption coefficients up to 0.9 across mid-to-high frequencies. The second research employed Ganoderma lucidum-grown composites molded via 3D-printed perforated molds incorporating Helmholtz resonator designs, achieving broadband absorption and peak coefficients near 1.0 at low-to-mid frequencies (~1200 Hz). The third explored scalable parametric design methods to fabricate panels from straw-based substrates, emphasizing aesthetic customization alongside acoustic performance.

Together, these findings show that substrate choice, fungal species, growth conditions, and fabrication techniques crucially affect acoustic efficiency, mechanical properties, and scalability. Optimized mycelium panels can match or approach the acoustic performance of synthetic panels in key frequency bands while offering environmental benefits such as lower embodied energy and compostability. Incorporating advanced digital fabrication enables tuning of material structure and form for interior applications like gaming office acoustics. This research supports the development of customizable, eco-friendly, and high-performance mycelium acoustic panels, promoting their adoption in sustainable commercial interior design.

Index-Terms: Mycelium composites; Acoustic absorption; Sustainable materials; Fungal substrates; Interior design; Sound absorption coefficient; Helmholtz resonators; Bio-fabrication

I.INTRODUCTION

Mycelium-based composites represent a paradigm shift in sustainable acoustic materials, offering biodegradable alternatives to petrochemical foams and mineral wools that dominate interior design applications. These living composites leverage fungal mycelium's natural binding capacity to consolidate agricultural and industrial waste into porous structures ideal for sound absorption. Recent research demonstrates their potential across diverse substrates and fabrication methods, achieving absorption coefficients comparable to commercial panels while maintaining circular economy principles through compostability and local production.

Three landmark studies provide comprehensive insights into mycelium acoustic performance. Walter & Gürsoy (2022) systematically evaluated waste paper substrates, establishing cardboard as optimal for both acoustic and structural properties. Sun et al. (2025) advanced the field through Helmholtz resonator integration via 3D-printed molds, achieving broadband absorption particularly at challenging low frequencies. Kourtidis-Vlachogiannis et al. (2024) emphasized parametric design and circular economy applications, demonstrating community-scale fabrication feasibility.

This comparative analysis synthesizes these findings to establish design parameters for mycelium acoustic panels in commercial interiors, particularly gaming offices requiring both acoustic control and aesthetic customization. Understanding substrate-fungus-fabrication interactions enables targeted optimization for specific frequency ranges and spatial requirements.

II.MATERIAL AND METHODS

1.1. Literature Selection and Analysis Framework

Three peer-reviewed studies were selected based on methodological rigor, acoustic testing standardization, and relevance to interior applications.

Table-1: Peak Sound Absorption Coefficients by Frequency Band

Aspect	Walter & Gürsoy (2022)	Kourtidis-Vlachogiannis (2024)	Sun et al. (2025)
Journal	Biomimetics	SSRN Preprint	Materials & Design
Objective	Study sound absorption properties of mycelium grown on waste paper substrates	Develop sustainable mycelium acoustic panels within circular economy context	Develop mycelium-bound composites with Helmholtz resonator design for broadband absorption

Fungi	Pleurotus ostreatus	Ganoderma lucidum, Pleurotus ostreatus	Ganoderma lucidum
Substrates	Cardboard, paper, newsprint	Wheat straw, flax straw	Rye straw, spent coffee grounds
Fabrication Method	Growth in autoclavable bags & formworks; oven-dried; samples cut for testing	Cultivation in molds created by laser-cut plywood, with parametric design	Growth in cardboard and 3D-printed molds with perforations for tuning resonance
Testing	Impedance tube with two-microphone transfer function; (ASTM E1050-12)	Not detailed, focus on making panels; pending large scale acoustic testing	Two-microphone transfer function in square impedance tube (ISO 10534-2:2023)

Table-1

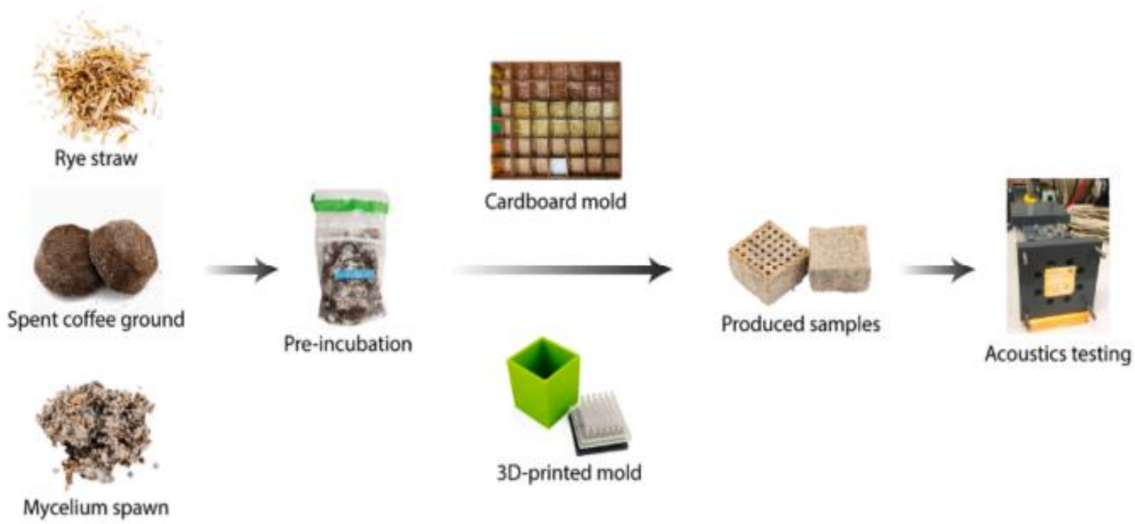


Fig-1

1.2. Comparative Metrics

- Acoustic Performance: Normal-incidence sound absorption coefficients (α) across 100-6400 Hz
- Physical Properties: Density, porosity, structural integrity, shrinkage
- Fabrication: Scalability, precision, material efficiency
- Sustainability: Waste utilization, energy consumption, end-of-life

1.3. Data extraction protocol

Absorption curves, statistical analyses (p-values, standard deviations), material compositions, growth protocols, and fabrication details were systematically extracted. Performance was normalized to 38mm thickness for cross-study comparison, with frequency bands categorized as low (≤500Hz), mid (500-2000Hz), and high (≥2000Hz).

III.RESULTS AND DISCUSSION

Table-2 Peak Sound Absorption Coefficients by Frequency Band

Study	Walter & Gürsoy (2022)	Kourtidis-Vlachogiannis (2024)	Sun et al. (2025)
Low Freq (≤500Hz)	α=0.51 (SCL, 500Hz)	Strong <1500Hz	α=1.0 (1200Hz)
Mid Freq (500-2000Hz)	α=0.90+ (multiple peaks)	70-75% @1000Hz	α=0.77 (SAA)
High Freq (≥2000Hz)	α=0.85+ (SCH)	Not tested	Excellent consistency
SAA (200-2500Hz)	Not reported	Not tested	0.77±0.02

Table-2

- SCL – Shredded cardboard low frequency
- SCH – Shredded cardboard high frequency
- SAA – Sound absorption average

1.4. Key Findings

Shredded cardboard (Walter) and 3D-perforated composites (Sun) achieve α≥0.9 peaks, competitive with commercial panels (α=0.80-0.95). Straw composites show promise but require empirical validation.

1.5. Substrate performance

- Cardboard (α=0.9+, minimal warpage, high repeatability)
- Straw/Coffee blends (SAA=0.77, broadband via perforations)
- Newsprint/Paper (α=0.6-0.8, structural failure risk)

1.6. Fabrication innovation impact

- 3D-Printed Molds (Sun et al.): Enabled precise Helmholtz resonator geometry, shifting resonance peaks and achieving α=1.0@1200Hz. Single-step perforated/foam integration eliminates assembly.
- Parametric Design (Kourtidis): Grasshopper-generated surface articulation enhances diffusion while maintaining modular scalability.
- Traditional Formworks (Walter): Cost-effective but limited geometric control.

1.7. Substrate growth interactions

- Growth Uniformity: Pleurotus ostreatus showed superior colonization across paper substrates vs. Ganoderma's preference for nutrient-rich agro-waste.
- Structural Challenges: Fine substrates (newsprint) exhibited 100% structural failure post-shaping; cardboard maintained integrity.
- Dimensional Stability: 3D molds compensated 3-4.5cm shrinkage; traditional methods required oversized formworks.

1.8. Observations

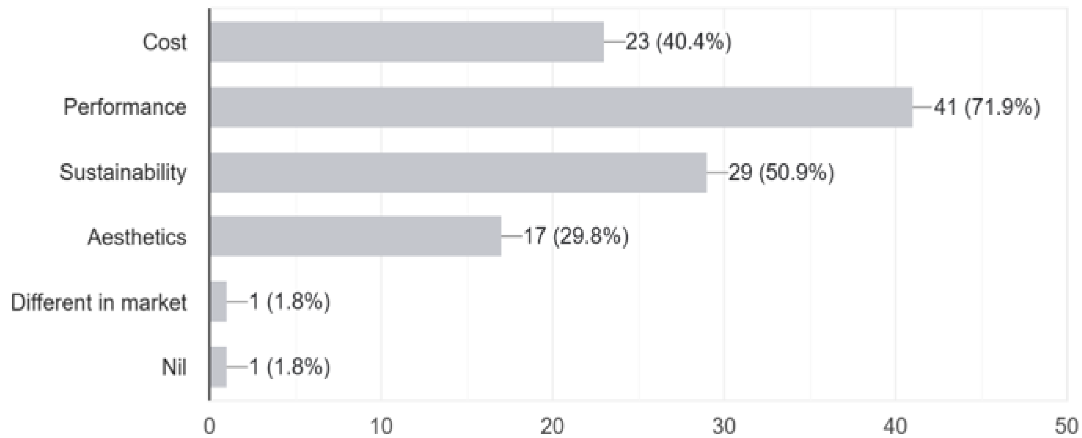
- All papers emphasize sustainability, biodegradability, and the use of agricultural/agro-industrial waste as feedstock for mycelium growth.
- Acoustic absorption across mid to high frequencies is a common outcome, with Paper 3 (Sun et al. (2025)) particularly improving low-frequency absorption by combining microperforated Helmholtz resonator principles with mycelium composites.
- Paper 1 (Walter & Gürsoy (2022)) provides detailed material characterization with various paper-based substrates, noting structural integrity challenges in finer paper types.
- Paper 2 (Kourtidis-Vlachogiannis et al. (2024)) focuses strongly on the design and fabrication process, emphasizing parametric aesthetics customization and a circular economy approach, with acoustic testing as a future priority.
- Material variability is an inherent challenge for all studies due to biological growth patterns, affecting reproducibility and consistency.
- Advanced fabrication techniques like 3D printing (Paper 2) allow precise control of perforations and promising acoustic tuning.

1.9. Recommendations & Future Work

- Further research needed on thickness, density, porosity effects; testing larger scale prototypes and durability. (Paper 1: Walter & Gürsoy (2022)).
- Scaling production; improving contamination control; lab testing of acoustic performance; improving mold fabrication. (Paper 2: Kourtidis-Vlachogiannis et al. (2024))
- Optimization of cavity geometry and composite density; scale-up and real-life testing suggested. (Paper 3: Sun et al. (2025))

1.10. Survey analysis

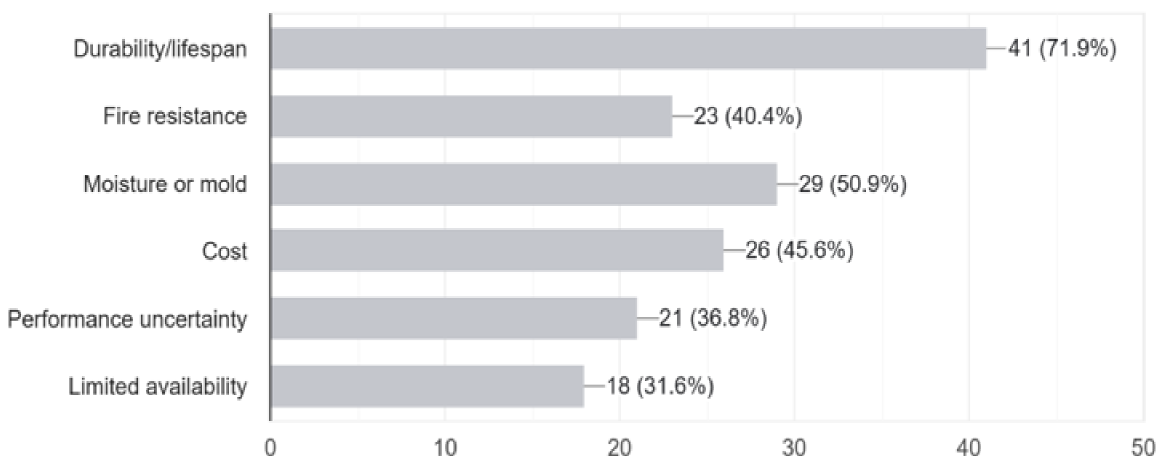
- Total responses: 56, with a mix of students, software/engineering professionals, architects, interior designers, AV consultants, teachers, and government employees, indicating a diverse but educated, urban-leaning sample.
- Motivators to adopt mycelium over traditional materials cluster around:
- Performance and measurable acoustic benefit.
- Sustainability and eco-friendliness.
- Aesthetics and uniqueness of design.
- Competitive or acceptable cost.



- Several respondents explicitly mention that they would switch if performance is similar and price difference is minimal, highlighting the importance of value-for-money positioning.

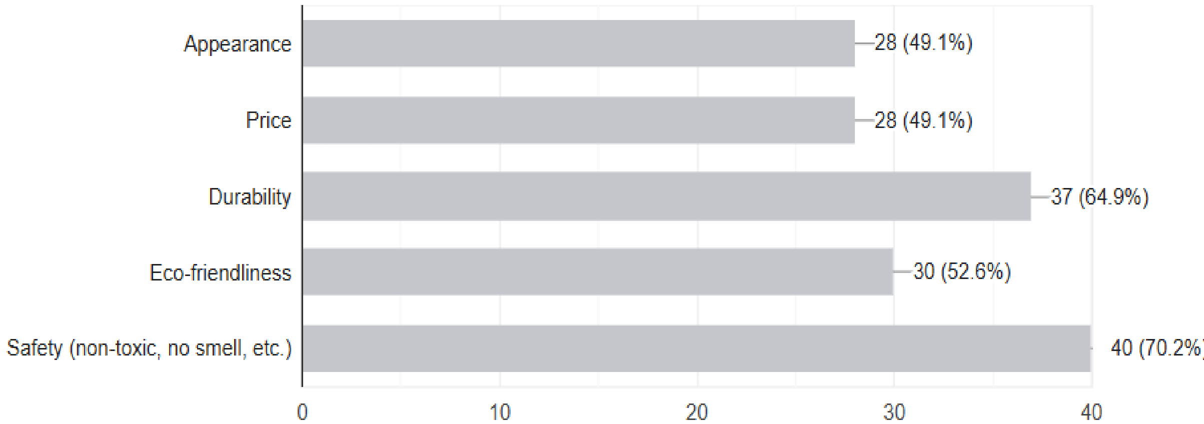
Repeated concerns include:

- Durability and lifespan (very frequent).
- Fire resistance and safety.
- Moisture/mold, smell, and hygiene.
- Cost, performance uncertainty, and limited availability.

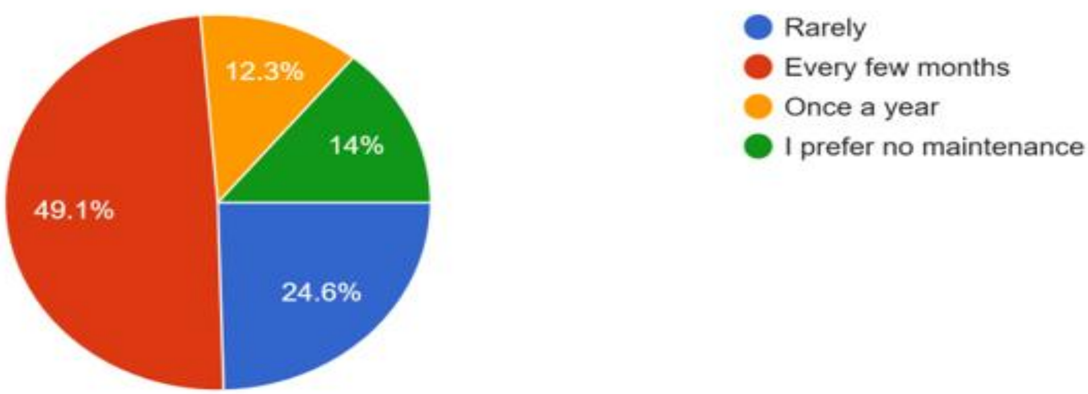


Preferred features when choosing sound-absorbing materials are:

- Durability and safety (non-toxic, no smell).
- Price and eco-friendliness.
- Appearance/aesthetics



- Maintenance: most respondents are comfortable with cleaning "every few months" or "rarely", and a few prefer "no maintenance", so panels should be **low-maintenance and easy to clean** (e.g., dusting/wiping).



IV.CONCLUSION

This comparative analysis establishes shredded cardboard mycelium composites grown with Pleurotus ostreatus as optimal for interior acoustic applications, achieving $\alpha \geq 0.9$ with excellent structural repeatability. Helmholtz resonator integration via 3D-printed molds represents breakthrough innovation for broadband performance, while parametric design enables aesthetic customization critical for commercial interiors. Collectively, these studies validate mycelium composites as viable sustainable alternatives, reducing embodied carbon by 80-90% versus synthetic panels while meeting Class C acoustic standards.

Future research should standardize impedance tube protocols across studies and validate large-scale reverberation room performance. For interior designers, these findings enable specification of locally-grown, waste-based acoustic solutions that enhance both environmental performance and spatial quality.

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