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Mycelium Composites In Sustainable Building Applications: A Comprehensive Review Of Acoustic And Thermal Insulation Properties

Afrah Sheik Meeran[1] , Sajiyya Meera Ahmed Anies[2], Salma Al Zahabi[3], Dr. Soumaya Boudagga[4]

[1,2] Student, Department of Interior Design, Amity University Dubai, Dubai, UAE
[3] Lecturer, Department of Interior Design, Amity University Dubai, Dubai, UAE
[4] Assistant Professor, Department of Biotechnology, Amity University Dubai, Dubai, UAE
[1] afrahs1@amitydubai.ae ,[2] sajiyyam@amitydubai.ae ,[3]salzahabi@amityuniversity.ae
[4] sboudagga@amityuniversity.ae

Orchid ID [1] 0009-0008-8287-0259, [2] 0009-0000-6261-8883, [3] 0009-0003-1707-0435, [4] 0009-0000-2608-7114
Corresponding Author: Salma Al Zahabi

Abstract— The end goal of any interior space is to provide the ultimate human comfort. This is achieved through various factors such as thermal regulation, acoustics and general environmental well-being. Conventional insulation and acoustics materials are effective but not eco-friendly due to limited biodegradability. This review paper explores the potential of lightweight mycelium-based composites (MBC) as a promising alternative for conventional acoustic and insulation panels. Mycelium is the fungal network on agricultural waste of mushrooms. Many comparative studies suggest that the thermal and acoustic properties of MBCs are comparable to conventional materials, but its lower durability remains a challenge. This paper integrates the current research about performance, materials, processes, and limitations of mycelium as well as its potential to contribute to sustainable construction and circular economy.

Index Terms— Mycelium Based Composites, Acoustics, Insulation, Circular Economy, Sustainability.

I. INTRODUCTION

The architecture, engineering and construction field (AEC) accounts for approximately half of the consumption of mineral resources and generates the highest volume of landfill waste [1]. Waste generation, air and water pollution, large energy consumption & depletion of resources in the building sector is affecting the quality of urban life. The construction industry dependence on raw materials and energy-intensive techniques contributes considerably to environmental depletion of non-renewable resources and carbon [2]. As a result, it is essential to explore alternative construction materials and sustainable energy sources to mitigate industry's contribution to global greenhouse gas emissions and landfill waste

II. MYCELIUM AS A BUILDING MATERIAL

One of the best ways to stop this conventional approach is to use bio-based materials like Mycelium based composites (MBC). Mycelium based products have great potential in the AEC (Architecture, engineering and construction) field helping to reduce the waste produced during the construction process and its low energy inputs aiding to enhance sustainability and in finding eco-friendly building solutions [3].

A. Biological structure and growth mechanism

In the context of creating a more sustainable environment, adopting sustainable building practice and discovering more eco-friendly alternatives such as plant materials derived for both load bearing and non-load bearing aspects is the approach forward. Mycelium is an agricultural by-product of mushrooms. Multicellular fungi demonstrate a filamentous growth mechanism [4]. The basic filamentous structure is called hyphae. In other words, it is the vegetative structure of fungi; it basically consists of a fine thread-like network structure called hyphae. Mycelial growth occurs when hyphae penetrate a substrate, effectively uniting it into a single mass. When a spore is introduced to a nutrient source, it develops into a tube that undergoes rapid, non- photosynthetic growth [5][6]. It develops through elongation and branching at the tip, resulting in the mycelium, a multicellular complex network. The hyphae's cell walls are made up of complex protein, glucans, and Chitin (See Fig.1).

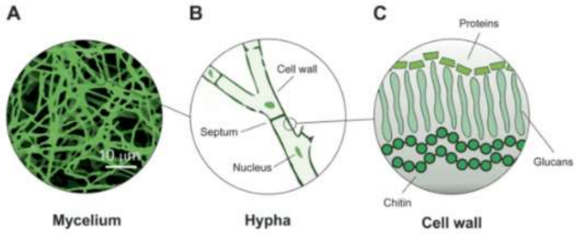


Fig. 1. Biological structure of mycelium[5]

B. Key mechanical and physical properties

To evaluate the insulation and acoustic mycelium-based composites, it is important to understand the core properties, as they determine performance and durability for any interior space. It is judged based on mechanical strength both compressive and tensile, structural strength, stability, and how it interacts with various factors such as moisture, fire and sound. The mechanical and physical properties are the core foundation for comparing conventional and mycelium-based composites.

- Thermal conductivity is a physical property that measures the heat transfer (λ-value). The lower the λ-value the better thermal insulation.
- Density is the mass per unit volume. Which means it affects weight and mechanical strength. Low density composites show better thermal insulation and high-density composites are more durable.
- The porosity is determined by the pores of the composites that trap heat and sound waves. improving both acoustic and thermal insulation.
- Moisture resistance is the ability of the composite to resist or regulate the water; this is extremely important as it helps to prevent moulds and maintains performance.
- Fire resistance is the ability of the composite to resist heat and fire. Some insulation and acoustics help to withstand fire without releasing some harmful gases.
- Mechanical strength is the extent of mechanical loads and pressure a composite can resist without collapsing.
- Acoustic performance is influenced by the fibrous and porous structure of the composite that helps to provide acoustic comfort.

C. Influence of substrate processing

There are various species of these fungi that are currently used to create mycelium-based composites because of their unique properties. The mushroom forming fungi depends on various agricultural factors and waste such as hemp seeds, rice, woodchips, fibers and sawdust etc. which is added as substrate. The base material or the feedstock that mushroom grows on is called a substrate. The choice of substrate is very important because it affects various physical and chemical properties such as density, strength, water absorption, thermal, and acoustic performance. For instance, fine or smaller substrates produce a denser mycelium with good insulation properties whereas a more rough, coarse substrate produces a composite with better acoustic property. According to various researchers and scientists the substrate used significantly influences various physical and chemical properties of the MBC [7].

Trametes versicolor mixed with hemp, flax, pine, softwood and wheat straw [9]. Oxyporus latermarginatu, Mgasporoporia minor, Ganoderma resinaceum mixed with wheat straw [10]. Pleurotus ostreatus mixed with rye berries [11]. Trametes versicolor and Ganoderma lucidium mixed beech sawdust and further nutrients [12]. Pleurotus ostreatus mixed with rice husks and sawdust [13]. Trametes pubescens and Trametes pubescens mixed beechwood sawdust [14]. Pleurotus ostreatus mixed with sawdust-coir pith [15]. White-rot saprotrophic fungus mixed with wood pulp, millet grain and wheat bran [16]. Pleurotus florida mixed with rice straw [17]. (See Table 1)

Pleurotus ostreatus stands out as a versatile and balanced stain when mixed with different substrates offering a reasonable compressive strength, thermal properties and moderate density. Its water absorption property may require treatment depending upon the substrate used. Ganoderma lucidum tends to offer moderate mechanical strength but offers good insulation like Trametes versicolor and another study suggests that it has water repellent properties like Pleurotus florida compared to Pleurotus ostreatus

TABLE I. **Influence of substrate**

Strain+ Substrate	Physical and chemical Properties				
	Density(kg/ m^3)	Thermal Cond. (W/m·K)	Young's Modules (MPa)	Compressive Strength (MPa)	Water Absorbtion %
T. versicolor – hemp, flax, pine, straw	94-135	0.040–0.058	1.14–1.32	0.35–0.45	24–30
Oxyporus spp., Ganoderma – Wheat straw	51,000–97,000	0.078–0.081	N/A	N/A	N/A
P. ostreatus – Rye berries	599	0.069–0.070	N/A	N/A	N/A
Ganoderma, T. versicolor – Beech sawdust, SMS	190–226	0.045–0.077	N/A	0.017–0.042	N/A
P. ostreatus – Rice husks + sawdust	153–239	0.069–0.081	0.015–0.165	0.011–0.265	85–246
T. versicolor, T. pubescens – Beech sawdust	480–515	0.054–0.057	N/A	0.011–0.013	N/A
P. ostreatus – sawdust + cotton	183–225	0.069	0.133–0.411	0.133–0.411	N/A
White-rot fungi – pulp, millet, bran	105–607	0.052–0.070	N/A	0.35–0.57	N/A
P. florida – rice straw	1420	0.029	N/A	8.7	17–38

III. APPLICATIONS & SUSTAINABILITY

A. Applications

The diverse properties of mycelium as a material enables its application across a wide range of industries such as Fashion, packaging, Electronics, Furniture and Building components. One notable example is the mycelium-based leather – Myco leather produced from leather substitute species such as Ganoderma spp., Trametes versicolor, Fomes spp., Pycnoporus spp. and Perenniporia spp. [18][19]

In the AEC Industry Mycelium has found its way into small scale applications including furniture, Acoustic and thermal insulation panels. Its most notable success has been acoustic and thermal uses as these are non-load bearing applications that align with the materials limited structural performances. Moreover, the naturally porous and fibrous structure of mycelium makes it well suited for the same. [20]

Biohms is an example of bio-based insulation Panels. Their mycelium insulation panel has achieved a thermal conductivity of 0.024 W/m·K, outperforming conventional but less sustainable materials such as glass fibre, mineral wool, and polystyrene. Additionally, their low manufacturing cost makes them a competitive and sustainable alternative in building applications. [20] [21]

Another material in its research phase is a Heat-pressed and compressed MBC panel exhibiting properties and compressive strength comparable to timber products such as OSB and MDF is being developed. This is achieved due to the lignin softening and the formation of reinforcing cross-links. [20].

Apart from the small-scale applications mycelium has also been featured in larger scale architectural projects (See Fig.2) such as Voxel Bio-Welding and Jammed Bio-Welding (2019), Tallinn Architecture Biennale Installation (2022), The Growing Pavilion (2019) and many more.

Fig. 2. Top Left : Tallinn Architecture Biennale Installation (2022),Top Right: Bio-Welding and Jammed Bio-Welding – Domus, Bottom : The Growing Pavilion (2019). [22][23][24]

B. Sustainability

As Kirchherr et al. defined: "A circular economy is an economic system that is aimed at using as few materials and resources as possible by maximizing reuse and minimizing value loss. A circular economy is more than 'closing the circle' by means of recycling, because it focuses on using minimal resources in the designing phase and modular design aimed at easy disassembling in the end-of-life phase. A circular economy is an economy which is regenerative by design, with the aim to retain as much value as possible of products, parts, and materials." [25]

MBCs are great material in the context of sustainability and Circular economy. As mentioned in one research, it's so due to the main 2 factors "(a) That the material can be produced locally by using agricultural waste as raw material. Secondly, they are biodegradable and can be naturally cold composted at the end of their life, thereby preventing landfill buildup and reducing carbon emissions from waste management. [26]

Advances in MBC highlight their capacity to Transform Low value industrial and agricultural waste into sustainable, high – value material suitable for various applications. In all Phases of its manufacturing and processing, MBCs have shown immense sustainable values and opportunity.

1) Waste Upcycling through Substrate

Since the texture and fibrous quality of the substrate plays a crucial role in mycelium growth, this opens the first opportunity of circular economy: use of waste material in the substrate mixture. For instance, spent coffee grounds were one such example being used in the substrate mixture along with Rye straw.[27] Walter & Gürsoy used wastepaper substrates (cardboard, newsprint, office paper) to grow MBCs with Pleurotus ostreatus, and showed that cardboard-based composites performed well acoustically and structurally.[28]

2) Low energy manufacturing

MBCs stands advantage in terms of embodied energy (EE) compared to conventional construction materials. Unlike concrete, steel or mineral wool, which require energy intensive processes such as high- temperature kilns and furnaces, MBCs grow at room temperature without any chemical additives. Elsacker et al. emphasize that this low-energy growth process drastically reduces the EE of MBCs, making them highly competitive with conventional insulation materials in terms of sustainability.[29]

They also note that the greenhouse gas (GHG) emissions during production are 0.3668 kg CO_2e per kg of material, which is a ~45% reduction in GHG emissions compared to traditional fossil-based insulations. [29]

3) Biodegradability and Composability

The acoustic and thermal properties of MBCs are increasingly recognized for its sustainability, from clean production to its biodegradability. Some current research share ideas of end-of-life scenarios for these MBCs.

option (a) being incinerating the material and energy being recovered. Option (b) to have the composites recycled to form a new substrate. This option could be used for recycling waste mycelium block. For the analysis they assumed that 70% of the MBC could be recycled as a substrate for a new one.[30]

4)Local Production

"In a circular economy, products and materials are kept in circulation through processes like maintenance, reuse, refurbishment, remanufacture, recycling, and composting. The circular economy tackles climate change and other global challenges by decoupling economic activity from the consumption of finite resources" [31]

Mycelium-based composites (MBCs) can be cultivated using locally available agricultural or industrial waste, such as sawdust, bagasse, or coffee husks which is usually sourced locally. This establishes circular system enabling agro-industries to manage their waste while providing the MBCs production facility an important component to creating a high value material. This also helps minimize the carbon footprint associated with material transport.

5)Carbon sequestration

MBCs effectively sequester carbon during their growth phase converting agricultural waste substrates into stable biomass. Studies have found that MBCs can lock away approximately 244 kg CO_2 equivalent per cubic meter during their growth process, rendering them carbon-negative materials [8]. Additionally, research indicates that MBCs can reduce greenhouse gas emissions by up to 45% compared to conventional fossil-based insulation materials (De et al., 2025). This capacity for carbon sequestration makes MBCs a sustainable alternative in construction, aligning with circular economy principles by preventing the release of carbon from waste streams and reducing reliance on fossil-based materials.[32][33]

Fig. 3. : Mogu Acoustic Panels [36]

As discussed in section 4.1 this material is versatile. By consolidating multiple functions into a single bio-based material, MBCs enhance resource efficiency and promote sustainability by supporting circular economy principles, making them a potential alternative.

IV. ACOUSTICS

The growing density of urban environments, where residential, commercial, and retail functions coexist in proximity, has intensified the demand for effective acoustics, While external noise is a concern, interior acoustics play a greater role in ensuring speech intelligibility, comfort and overall well-being.

Studies Show that prolonged exposure to high noise levels have direct impact on the health and wellbeing of humans such as hearing impairments and loss, increased blood pressure and cardiovascular issues.

A good sound quality is a result of the ability of materials and forms within the space to Absorb, Reflect, Diffuse and isolate sound. In a space a good sound quality is often achieved through thoughtful acoustic design, strategic spatial planning and well considered furnishing placements. And out of all the main element is the acoustic design / treatment of the space. The most widely used acoustic treatment is through sound absorption. Sound-absorbing materials are among the most effective and widely applied passive methods for noise reduction.[34].

A. Acoustic Panels

Conventional acoustic panel though effective, rely on synthetic materials. These materials, such as mineral wool, polyurethane, and melamine foams, are derived from non-renewable sources and present significant environmental concerns, including microplastic emissions and toxic chemical release throughout their lifecycle. [35]

A Bio Based alternative, The porous and Dense nature of mycelium composite panels make it a Potential Acoustic panel alternative to the commercially available acoustic panels made with synthetic materials.

Similar to other lightweight bio-based foams, MBCs are more effective at absorbing high frequency sounds (1000–4000 Hz) as the shorter wavelengths correspond closely to the scale of the material's small pores. The combination of both the small pore size and high surface area allows for greater scattering and dissipation of sound energy as the waves travel through the material [27]

Several research papers have been exploring the acoustic properties in mycelium composite boards. In addition, the company Mogu [36] (Fig.3) has developed commercially available Mycelium based Acoustic wall panels. Currently, Mogu offers five acoustic panel types: Wave Hex, Plain, Kite, Fields, and Aspen/Foresta. Each panel is coated with water-based, heavy metal free paint. The technical data sheets include the acoustic performance and characteristics of each panel; however, Mogu does not disclose its growth methodologies, nor the substrate type and fungal species used to cultivate their panels. [34]

B. Mycelium Based Composite as Sound Absorber

Researchers from around the world have tested different strains, substrates mixtures and combinations to ascertain the best working result. While there is no standard protocol overlooking the process, each research has their own growth and fabrication methods according to the type of materials used.

One prominent research done by Walter and Gürsoy (2022) studied the sound absorption properties of MBC cultivated of Waste - Paper Based substrates. They used Pleurotus ostreatus fungi species on 4 different waste materials: waste cardboard, paper, and newsprint substrates of varying processing techniques. 7 different samples were experimented in "three stages: (1) the cultivation of mycelium-based composites, (2) the assessment of the cultivated samples' acoustic performance, and (3) the cultivation of mycelium-based acoustic panel prototypes." The samples were left to grow in controlled environment in autoclavable bags for 12 days then for an additional 16 days in a sterile framework after which the samples were dried and heated in oven. Once the samples were created, they were shaped to be fit for various tests. "The results of this study indicate that mycelium-based composites grown on waste shredded and fine cardboard show potential as sound-absorbing materials, specifically in the mid- to high-frequency ranges (1000–4000 Hz). The shredded cardboard samples (SCH) achieved the highest average normal-incidence absorption coefficient of 0.42, slightly outperforming the fine cardboard samples (FCH), which recorded an average of 0.36, with both materials demonstrating stronger absorption at higher frequencies." [28]

Another Study was conducted by Pennsylvania State University, Department of Architecture included an Acoustic simulation and analysis of sound absorption panels made from MBC using data from impedance tube test run as an input for simulations, using raytracing and image-source methods. Through performance Based Design Approach, the acoustic performance of the MBC was quantified. Aspects Such as Three-Dimensional Qualities of Panels, Number of Panels, Location of Panels in the room were considered. The simulation results showed that when compared to commercially available acoustic panel (Acoustics America Panels) resulted in a longer reverberation time than the extruded panels at 500 Hz, but shorter reverberation times at high frequencies. This made the extruded panel comparable in performance to the commercially available acoustic panel. [34]

Experimental Findings by Kim et al. (2026) found that "the average coefficients are around the 0.5 range for all samples tests. Additionally, that all samples resulted in absorption coefficients above 0.5 for frequencies of 600 Hz and above." These absorption coefficients from MBCs are desirable as they achieve absorption better than certain acoustic materials. concluded that "MBCs show substantial promise as effective acoustic absorption materials. They achieve near-total sound absorption at specific frequencies with a thickness of 40 mm, offering acoustic performance comparable to conventional materials. [37]

V. INSULATION

A. Insulation Panels

Insulation is crucial in interior spaces as it affects factors such as (i) comfort, (ii) efficiency, and (iii) sustainability. Thermal insulation is key in making interior spaces comfortable for human beings. The reason behind this is that it has the ability to block heat transfer, keeping the indoor temperature warmer in cold climates and cooler in hotter climates. This significantly reduces the utility bills and results in energy savings because of thermal regulation and reduction in our reliance on artificial heating and cooling systems.

A well-designed interior space with an insulation system doesn't just increase energy efficiency but also enhances indoor comfort for human beings by maintaining highly stable temperatures. Additionally, it enhances acoustic performance by reducing noise transmission from exterior to interior, this is very important in residential and commercial design.

A good thermal insulation quality of any interior space depends on good heat resistance, controllable heat transfer, ventilation, and effective thermal isolation. This is frequently achieved by appropriate material selection, spatial planning and strategic placements of insulation panels. These panels, which reduce heat transfer, are the most commonly used insulation treatment.

B. Conventional Insulation Panels

Thermal insulation of a building's external walls has become essential in recent decades to lower the energy demand of the building due to temperature changes between the interior and exterior. Thermal and acoustic insulation for buildings is being provided by a growing number of traditional insulation types. Based on their composition, these materials can be divided into two groups: (i) inorganic and (ii)organic [8].(Fig.4)

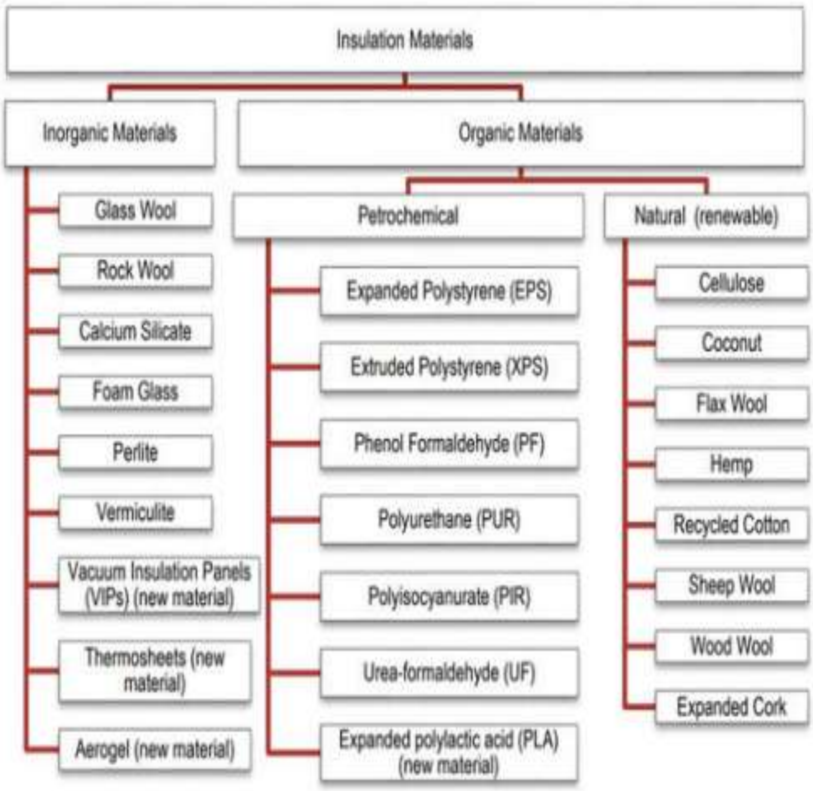


Fig. 4. Conventional Insulation materials classification [38]

There are various types of insulation materials like inorganic cellular insulation materials, thermo-plastics, aerogel, vacuum insulated panels (VIP'S), and petrochemical insulation materials. Traditional insulation materials are very effective. Although traditional insulation panels perform exceptionally well, they are not eco-friendly. This is why there is an urgent need for a more sustainable option for insulation [8].

C. Mycelium based composites as Insulation panels

In recent times there has been several research done exploring mycelium-based composites as insulation materials. There is one such company that is a US based biotechnology startup. "They have developed a system for using agricultural byproducts with fungal mycelium (a natural, self-assembling binder) to grow high performance insulation. Ecovative Mushroom® Insulation is seen as a viable competitor to plastic foams that can be found both in packaging and building insulation [39]."

A study investigated the potential of mycelium and miscanthus based composites as an insulation material, with different ratios of Ganoderma resinaceum strain of mycelium, miscanthus fibres, and potato starch were tested. The optimal ratio was 0.3:1:0.1. The composite exhibited a low thermal conductivity averaging between 0.8882 and 0.104 W/m-k with density of 122kg per meter cube, along with good compressive strength and fire resistance. A microstructural analysis confirmed that the mycelium-based composite formed a porous structure which will help to trap heat. Overall, the results suggest that the performance of the composite is comparable to the conventional insulation materials hence making it suitable for interior application [40].

Another study investigated the fabrication of lightweight mycelium-based composites by adjusting components like substrate type, size and fugal strain to enhance the mechanical and thermal insulation performance. The results showed that the Trametes versicolor colonization on polar substrates that are small sized achieved growth and good structural integrity, and the substrate strongly influenced the physical properties of the composites. Then a multiscale porous that was hierarchical was created by using large sized polar substrate which exhibited excellent thermal insulation, and the layers of mycelium were hydrophobic which helped to maintain mechanical strength even after water immersion. One sample composite showed good thermal insulation better than expanded polystyrene showing its potential as a sustainable alternative for building insulation. However, there are challenges such as water resistance in the long term, long production time, and durability [41].

TABLE II. **Comparison between mycelium and other conventional materials [8]**

Property	Mycelium	Other Conventional Materials	Comments
Specific Heat	x		Mycelium has higher specific heat than all other conventional materials
Density	x		Mycelium has a wide range of densities that suit different applications
Thermal conductivities	x	x	Both mycelium and other materials have comparative thermal conductivities
Cost	x		Mycelium has a much lower cost than most other conventional materials
Durability		x	Mycelium is, on average, less durable than most conventional materials
Water absorption rate	x	x	Both mycelium and other materials have acceptable water absorption properties

Both the studies show the promising thermal performance of MBCs, but with some limitations. The first study [41] reports low thermal conductivity and its good fire resistance but the conductivity range (0.088–0.104 W/m·K) indicate that there might be potential inconsistencies in measurement. The second study [42] shows how we can control porosity and hydrophobicity by altering the substrate, yet they emphasize on the limitations such as water resistance, durability, and scalability. Together these findings suggest that there is a strong potential for replacing the conventional insulation but also suggest the need for more standardized testing, long-term durability assessment and scalability. (See Table II)

VI. MATERIALS AND PROCESSES

The process of creating mycelium-based composites involves several crucial stages. From choosing the appropriate strain and substrate to processing steps like sterilization, inoculation, and packing how every stage contributes to the final outcome. Growth conditions, drying and post processing contribute to density and durability. The following table shows the key stages in producing mycelium-based products along with how each stage affects the outcome and applications. (See Table III)

TABLE III. **Key stages in producing mbc [42]**

Factors in Mycelium based composites		
Stages	**Production Method**	**Impact on Characteristics**
Components		
Fungal Species	Choice of strain	Bonding, biomass density, growth rate, filament thickness, regrowth and lignin degradation
Feedstock	Type and composition	Reinforcement, cracking, compressive strength, and flammability
Sterilization	Autoclaving, pasteurization, chemical treatment	Thermal stability, fiber structure growth rate
Processing Variables		
Inoculation	Grain spawn, liquid medium, pre-grown substrate	Compressive strength, dimensional stability
Packing	Pre-compression, void spaces, surface direction	Dimensional stability, tensile strength, water absorption, density, stiffness
Growth Condition	Temperature, CO2, light, humidity	Density, tensile strength

Time	Duration of growth	porosity, water absorption, thermal decomposition, elastic modulus
Drying	Temperature and Moisture control	Thermal conductivity
Post- Processing	Coatings, hot/cold pressing	Weather proofing, stiffness, strength
Application	Final products	Packaging, acoustic and insulation panels and blocks

VII. FABRICATION AND MANUFACTURING OF ACOUSTIC PANELS

A. Panel Fabrication Methods

The most common approach to creating panels is by creating mold from materials such as silicone, Plywood, Cardboard and 3D printed materials. The subsequent steps in the fabrication process have been discussed in the study by Kim et al. [38] which explores both additive and subtractive manufacturing (SM) methods. The Additive method (AM) refers to the fabrication approach where there are interventions being introduced during the growth phase of the mycelium, such as shaping, layering or integrating structures within the substrate. In contrast, Subtractive manufacturing refers to modifying the panels grown in a mold using techniques such as cutting milling or other subtractive techniques. [20]

1) **SM methods:**

- Milling can damage surface finish, geometry and structural integrity can only be used for MBC boards that are dense and structurally sound.
- Wire cutting is faster and preserves the fungal skin proving it being more efficient while needing the cut bigger slabs into smaller panels.

2) **AM methods:**

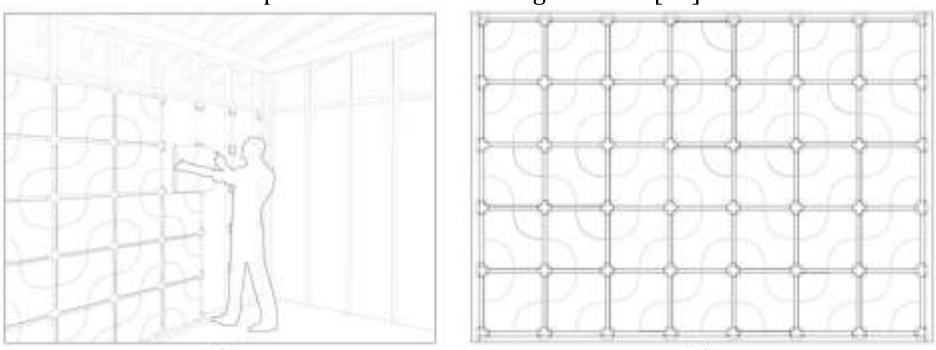
- Substrate Core deposition creates simple scaffold formations and is limited to small structures and requires inoculation
- Filament-Based Scaffolds: Supports modular scaffold design and fungal growth; dependent on filament composition and mostly experimental.
- Bio-Inks: Integrates fabrication and inoculation for large, load-bearing structures; requires precise control and complex material preparation.

The kind of technique used depends on various factors such as the design , mechanical structure of the board, thickness etc.AM technique integrates shaping during the growth phase , allowing greater control over porosity, density and over all geometry.AM techniques fall more favourable with acoustic and insulation panels which are lightweight, porous structures that might easily get damaged if SM techniques were used on it. [20]

B. Panel Assembly and Installation

Once the test results are analyzed, the best performing sample is then manufactured in bigger batches to produce panels in commercial acoustic panel sizes. The panels are designed to be assembled in different ways.

The mechanism adopted by Walter and Gürsoy (2022) (Fig.5) included the panels being fabricated using CNC-milling machine. The positive wooden form of 380 mm _ 380 mm _ 50 mm was created and then thermoformed with PVC sheets to create a reusable framework. This formwork was then filled with a fine cardboard substrate mixture, and panels were made. Once the panels were all created, they used a parametric system for panel placements to the wall to fix the Truchet tile which can be placed in different configurations. [28]



(a) (b)

Fig. 5. Parametric acoustic panel wall prototype design: (a) Acoustic panel installation illustrated (b) Example wall configuration.[28]

VIII. Challenges & Future Directions

A. Challenges

The following challenges were found from various research discussed above:

- Durability in Large-Scale The durability of the material when produced on a larger scale seems to be a problem. "In order to ensure durability with the fine cardboard material, additional support may be necessary. This could potentially be remedied with additional substrate materials, internal support, or external backing. [28]

- Accuracy in acoustic performance: Many Studies have overlooked the aspect of additional acoustic performance contributed by the air gap between the panel and wall as well as a rigid backing surface which slightly reduces the accuracy of the acoustic performance in a pace.

- Lack of standardization: Achieving consistent results in large scale production of mycelium panels remain challenging, necessitating testing of each individual panel due to the absence of standardized methodologies. Variations such as warpage and defects arising at any phase of the growth and formation process can result in panels with diminished acoustic performance.

- Mechanical Strength: Mycelium based composites often have low mechanical strength and durability compared to the traditional acoustic and insulation materials. This limits their application in non-load bearing and load bearing structures and tests their ability in demanding conditions.
- Moisture and Porosity: The porous nature of mycelium-based composites traps a lot of moisture which leads to swelling, reduced stability, and degradation. This is a challenge for using mycelium-based composites in a hot and humid environment.

B. Future Direction

At this stage MBCs have shown immense potential and has been successful in entering the commercial market with few bio-based companies providing MBC based acoustic and insulation panels. As discussed, there are many challenges still present to convert this idea to full force implementation.

As the first line to the paper read "The end goal of any interior space is to provide the ultimate human comfort". The next step towards this research is tailoring the microstructure for specific acoustic or thermal targets. To optimize properties for large-scale applications. and on enhancing mechanical strength, improving moisture resistance. Additionally, standardization of production methods will be crucial to ensure consistency and reliability.

Another important point is to take region-based approach optimizing the use of locally available resources available in the highest potential. This strategy can identify the best performing materials and foster the development of localized circular economies promoting sustainable production and resource efficiency within regional context.

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