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THE RISE OF MYCELIUM-BASED MATERIALS ACROSS INDUSTRIES: A REVIEW

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Abstract:
Mycelium-based materials are an interesting area of research, several industries are involved in exploring the possibilities. This review aims to identify the main industries and product group. Not only the most popular areas are mentioned, such as architecture, fashion and packaging. We also collected some special applications where these materials could be used in the future. This material family have several advantageous properties, but their application also faces many challenges. Our collection of precedents includes good and questionable examples, to draw attention to the need of further research.

Keywords: *biodesign, mycelium, biocomposites, sustainable materials, bio-manufactured products*

1. INTRODUCTION

Is it possible to think of our everyday objects in a way that serves not only us, humans, but also the environment? We sought to address the question of sustainable industry through biodesign. Biodesign explores both new and traditional technologies that enable nature to be involved in design and production [1-2]. This process can be done by plants, algae, and microorganisms, such as bacteria and fungi [3].

Mycelium, the network of fungal filaments (hyphae), has attracted significant interest in the fields of biodesign and sustainable materials research [2-6]. Scientists, designers, and engineers are exploring the potential of cultivating materials, structures, and everyday products through collaboration with this living organism.

It is a biodegradable, renewable, and highly adaptable material family. These characteristics position them as promising, environmentally responsible alternatives to conventional materials [7]. The global market for mycelium-based products is experiencing rapid expansion, with an estimated value of USD 2.9 billion in 2024 and projections reaching up to USD 5.2 billion by 2034 [4]. This growth is driven by environmental regulations, increasing demand for circular-economy models, and rising investments in research and development for sustainable innovation [4-6].

Despite these advances, several challenges have to be addressed. On one hand, the need for standardised production methods, scalability of manufacturing, technical benchmarking against established industrial materials, and market regulations [4-6]. On the other hand, consumer acceptance, aesthetic values, and unfamiliarity with the new materials [2, 8]. Addressing these issues calls for continuous research, cross-sector collaboration, and effective communication of the material’s benefits to both producers and consumers.

2. REVIEW METHOD

The following sections of this review will examine mycelium’s diverse applications, current technical challenges, and its broader implications for industry and society. By integrating insights from market data, design and research, this paper provides a comprehensive overview of the ongoing rise of mycelium-based materials across industries. This review is based on an analysis of peer-reviewed

articles, design case studies, books and industry reports focusing on the use of mycelium-based materials in market-ready products and experimental use cases.
We explore the whole landscape of mycelium-based materials, both composites and pure mycelium materials. Mycelium-based composites are composed of a substrate material (mostly lignocellulosic waste) and the mycelium as the binder of the substrate's particles [2; 7-8]. Pure mycelium materials are separated from their substrate, they can be grown on solid substrates as composites, and in the end, peeling off the fungal part [7], or on liquid cultures [8].

3. PRECEDENTS

More and more individual artists and designers have been involved [9] in exploring mycelium and mushrooms as sources of materials. Their artworks and experiments contributed to a better understanding of the material and to raising awareness and increasing its popularity.
Based on patents, available products, and collaborations [10], the most active and successful company in the field of mycelium-based solutions is Ecovative LLC. They are very clear about their activities and operations, making all information available on their website [11]. Ecovative researches new mycelium capabilities, then develops applications with sector specialists, and ultimately spins these into focused businesses that work directly with brands and designers. Their patents and public materials govern the entire chain, from substrate and growth-environment engineering through harvesting, post-processing, and applications. Their Open Patent Program and collaborations with both large and small companies, as well as individual designers, promote open innovation. [11]

3.1 Architectural aspects

Mycelium-based composite materials exhibit several properties that make them well-suited for architectural applications (see Fig. 1). They can have low thermal conductivity [12], making them good thermal insulators. Excellent sound absorption and acoustic insulation properties [12-13] enable their use in interior applications. Fire performance is still under investigation, but research suggests promising potential compared to petroleum-based materials [12, 14]. Some fungi species can develop hydrophobic surfaces with high water contact angles, and their surface wettability can be tuned chemically [12].

Figure 1: From left to right: 1) Ecovative's Grown.bio building bricks [16]; 2) The Living Studio: Hy-Fi Tower, led by David Benjamin, built from Grown.bio building bricks building bricks [12]; 3) Op't Oog columns, 3D printed [19]

Mycelium composites can be used in architecture as building bricks [11-12; 15-16], insulation panels and sheets [12-13; 15; 17], panelling and flooring [12; 17], furnishing [15], injection moulded parts [12], 3D printed parts [18-19], mycelium-based elements merged into a framework [20], sandwich panels [21], and self-healing materials, such as self-healing concrete [22].

3.2 Product Design and Consumer Applications

Furniture is a popular area for mycelium-based design, with several examples, many of them unappealing in appearance (see Fig. 2). Grown furniture found in the literature mostly includes chairs, stools, tables and lamps [8-9; 15; 23].

Figure 2: 1) Ivanova & Cox:Projet MYCELIUM + TIMBER [9]; 2) 'Yamanaka Furniture' by Phil Ross [9]; 3) Olle Sahlqvist: Zwampen mycelium stool&chair [23]; 4-5) Eric Klarenbeek: Mycelium Chair [9]; 6) Ecovative x Atelier la Gadoue: Lucid chair [16]

One of the most successful areas of application is the **fashion industry**, which started numerous experiments and product development processes to replace leather with mycelium-based alternatives [9]. Mycelium "leather" is made by engineering fungal mycelium into dense, sheet-like structures. Companies such as MycoWorks (Reishi) [24], Ecovative (Forager) [11; 25], and Bolt Threads (Mylo) [26] have developed controlled growth and finishing processes to achieve the strength, durability, and surface quality expected in fashion [9]. Mycotech, an Indonesian company, published a detailed paper on the development of their mycelium leather, called Mylea [27-28]. Chosun University and Korean research institutes also wrote a paper about mycofabricating leather-like materials [29]. An increasing number of publications detailing the fabrication processes of mycelium-based materials highlights the importance of open knowledge exchange.

Packaging applications are also a developed and commercialised area of myco-matrials [9]. Most of the examples concern protective packaging that can replace styrofoam [8; 30], but there are also experiments with mycelium composite food containers to replace single-use plastics [31].

In the **automotive industry**, mycelium-based composites currently appear most promising for interior, non-load-bearing automotive applications, such as the replacement of conventional textiles, panels, and polymer foams. Their good fire resistance, sound-absorbing and impact-energy-absorbing capabilities suggest potential use as bio-based foam materials in bumper inserts, door and engine-bay liners, as well as seat and trunk inserts [32-33].

However, their durability still raises concerns, particularly for long lifespan products such as cars. These materials are sensitive to moisture and weather [7; 33], which can be partly mitigated through surface treatments and coatings, but this area requires further development. Despite numerous patents and studies [10; 34], practical automotive implementation remains largely at the concept stage.

Ford is among the frontrunners [10; 33] to develop mycelium-based biocomposites that can replace conventional synthetic foams in automotive components [32]. Kia has also embarked on experiments with mushroom-derived materials in collaboration with the Bulgarian company Biomyc [35], focusing on durable, visually exposed interior elements grown from mycelium.

3.3 Specialised Applications

Paul Stamets describes mycelium, drawing on the ideas of Gaia theory, as a **manifestation of nature's living intelligence**. According to this view, mycelium weaves through the soil, forming a sentient membrane that can sense the footsteps of other living beings, as well as changes caused by weather or pollution, and is able to respond to them. He is also the originator of the concept of "mycorestoration," which he divides into four main areas: mycopesticides, mycoremediation, mycoforestry, and mycofiltration. Mycofiltration refers to a method in which fungal mycelium functions as a biological filter, removing various pollutants from water, soil, or air. [36]

The application of fungi in **biofiltration** is an increasingly researched field, as both filamentous and non-filamentous fungi have shown the ability to degrade pollutants present in the air. Further research is needed to establish the safe and effective use of them [37]. The Biopod project (see Fig. 3) is a good example of how mycelium-based composites can be used in biofiltration. It was developed by students and researchers at the Rhode Island School of Design (RISD) along the Providence River in the United States. The aim of the project was to create a biodegradable, floating filtration system based on a mycelium composite, which naturally purifies polluted water through the combined action of plants and microorganisms, helping the restoration of wetland habitats. [38]

Figure 3: Rhode Island School of Design (RISD): Biopod project [38]

By leveraging the biodegradability of mycelium-based materials, the company Loop Biotech has developed fully biodegradable, toxin-free funeral solutions. The company has established a product portfolio that includes both **coffins** (see Fig. 4) **and urns**. According to the manufacturer, these products are designed to accelerate natural decomposition processes and to nourish the soil, thereby contributing back to the ecological cycle. [39].

Building on Stamets's earlier assertion that mycelial networks are capable of sensing and responding to their environment [36], a further potential field of application has emerged: the concept of the **fungal computer** [40]. Mycelium and living mycelium-based composites can behave as logical circuits and unconventional computers by transforming electrical inputs into complex, non-linear electrical outputs that implement Boolean functions [41]. These studies indicate that mycelium may one day serve as a living material for embedding computation, opening the possibility of bio-based, low-energy computing systems. One of the greatest difficulties in this area is that the constantly growing mycelium reconfigures itself as it is growing [41].

Figure 4: Loop Biotech: Loop Living Cocoon™ [39]

Researchers at NASA also have high expectations about mycelium-based materials. The Mycotecture Off Planet project aims to develop **buildings for Lunar and Martian missions** using fungal mycelium-based materials, instead of transporting heavy, pre-built habitats. They investigated various material mixtures, including mycelium with bacterial and algal partners, and they also tested sand and regolith simulants to see if future habitats can be built using local materials found on the Moon or Mars. The technology is still at proof-of-concept stage and needs much more development before use. The main advantages would be mass savings, in-situ fabrication, and potential for self-healing and bioengineered functions. The key challenges include sterilisation, structural optimisation, and long-term reliability. [42]

In the field of **biomedicine**, mycelium-based materials also have good potential. Researchers found that Ganoderma l. and Pleurotus o. are biocompatible and support skin tissue repair in preclinical wound models [43]. Additional studies are required before such materials can be translated into clinical practice.

4. CATEGORIES

In order to systematize the potential application domains of mycelium-based materials, we categorized their functional roles across major industry sectors as on *Table 1*.

The use of mycelium-based materials is expanding across industries, especially in packaging, textiles, automotive, construction, and environmental protection. The most successful areas, that have marketed, industrialised products are packaging, textiles and insulation.

Typically, the primary objective is to replace petroleum-based materials. This is a challenging objective, as petroleum-based synthetic polymers are highly diverse. One of the most significant advantages of mycelium-based materials is their modifiability, but this is also one of their challenges. Material properties depend on substrate composition, fungal species, growth conditions, surface treatment, porosity, thickness, and other factors. Designers also have to consider locally available waste materials and which fungal species can most effectively colonise them to achieve the desired properties.

Table 1: Application areas of mycelium-based materials

1. Architecture and Interior Design	**2. Product Design**
1.1. Structural and semi-structural elements	2.1. Furniture
1.2. Insulation materials	2.2. Decorative objects
1.3. Decorative elements and claddings	2.3. Functional everyday products
1.4. Self-healing concrete	2.4. Funerary applications
3. Packaging Industry	**4. Fashion and Textile Industry**
3.1. Void-filling and cushioning elements	4.1. Footwear
3.2. Molded protective packaging	4.2. Garments
3.3. Food packaging	4.3. Accessories
3.4. Plantable (biodegradable and soil-integrable) packaging	4.4. Upholstery, covers, and surface textiles for furniture
5. Environmental Protection, Biofiltration	**6. Bioelectronics**
5.1. Air filtration	6.1. Circuits and logic gates
5.2. Remediation of aquatic habitats	6.2. Unconventional computing systems
5.3. Degradation of plastic polymers	6.3. Biosensors
7. Automotive Industry	**8. Biomedicine**
7.1. Interior design components	8.1. Wound care and dressing materials
7.2. Technical parts and components	

5. CONCLUSIONS

An analysis of the examined precedents indicates that the advantageous properties of mycelium-based materials would, in principle, enable a wide range of applications. At the same time, it must be acknowledged that not all application domains are equally successful. In the case of furniture, for example, it is not necessarily evident that well-established materials such as wood, metal, and textiles should be replaced. Beyond aesthetic considerations, questions also arise regarding their resistance to long-term mechanical use and wear. Even in sectors where mycelium-based products have already reached the market and demonstrated commercial success, important issues remain open, particularly with respect to durability and behaviour under exposure to moisture. Consequently, research and development in mycelium-based materials requires an explicitly interdisciplinary approach, involving coordinated collaboration across multiple scientific and professional fields. The participation of biologists, engineers, materials scientists, and designers is essential to address both the technical and functional challenges of these emerging materials.

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