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The Feasibility of Future Applications for Mycelial Materials

I、Introduction

In today's world, sustainable development has become the focal point across various fields. In this context, mycelial materials have garnered widespread attention due to their outstanding sustainability and diverse potential applications. Mycelium is a fibrous structure formed through the growth of fungi, and its interwoven network provide high strength and elasticity to the material. This structural attribute endows mycelial materials with significant potential in sustainable design and manufacturing (Knowles, 2015).

In the realm of leather alternatives, mycelial materials exhibit superior flexibility and texture, while imposing a lower environmental impact. In comparison to the traditional leather production process, the manufacturing of mycelial materials is more environmentally friendly, reducing dependence on animals and plants and concurrently lowering energy consumption. This presents innovative possibilities for sustainable fashion and products. In the field of packaging materials, the biodegradability and recyclability of mycelial materials make them an ideal choice for reducing plastic waste. This bio-based material can effectively replace single-use plastic packaging while maintaining superior protective performance, thus reducing the environmental impact on the Earth and steering the packaging industry toward a more sustainable direction. As for building materials, the lightweight nature, structural stability, and thermal insulation properties of mycelial materials make them a promising new type of construction material. Architectural materials manufactured using mycelial materials not only demonstrate outstanding sustainability but also offer improved temperature control and energy efficiency, presenting viable innovative solutions for the construction industry (Knowles, 2015).

This article will delve into the characteristics of this bio-based material, with a particular focus on its applications in leather, packaging materials, and building materials, considered as potential alternatives to

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traditional materials. Through a comprehensive exploration of its properties and prospects in various application areas, we can better understand how this bio-based material has the potential to bring substantial changes to society and the environment.

II、Literature Review

(i) Leather Alternative

In recent years, fungal-based materials have become a focal point of patent research in the realms of leather alternatives, textiles, and fabrics. Since late 2019, there has been a sharp increase in the number of patents describing fungi-based materials resembling leather, primarily originating from the United States. This research conducted a detailed analysis of the fungal species mentioned in the selected patents, identifying a total of 69 fungal species. Among them, *Ganoderma* and *Trametes* were the most mentioned genera in the patent descriptions, followed by *Fomes, Fusarium, Pleurotus,* and *Schizophyllum*. Considering the evolutionary diversity of filamentous fungi, there may be numerous untapped species with potential advantages in producing mycelial materials with different properties. Additionally, besides exploring the diversity of natural strains, genetic engineering serves as another approach to improving material characteristics. Overall, these patent studies demonstrate the potential commercial value of these fungal materials while highlighting the need for a deeper understanding and application of their properties. Currently, there is a lack of standardized characteristics studies for mycelial leather alternatives. Although some independent characteristic test results exist, variations in testing standards persist between different countries and product compositions (Elsacker et al., 2023).

The relevant characteristics of leather alternatives include thickness, apparent density, tensile strength, elongation at break, tear strength, abrasion resistance, and colorfastness, among others. Due to the often complex combination of mycelium with other components, the manufacturing process becomes more intricate. The

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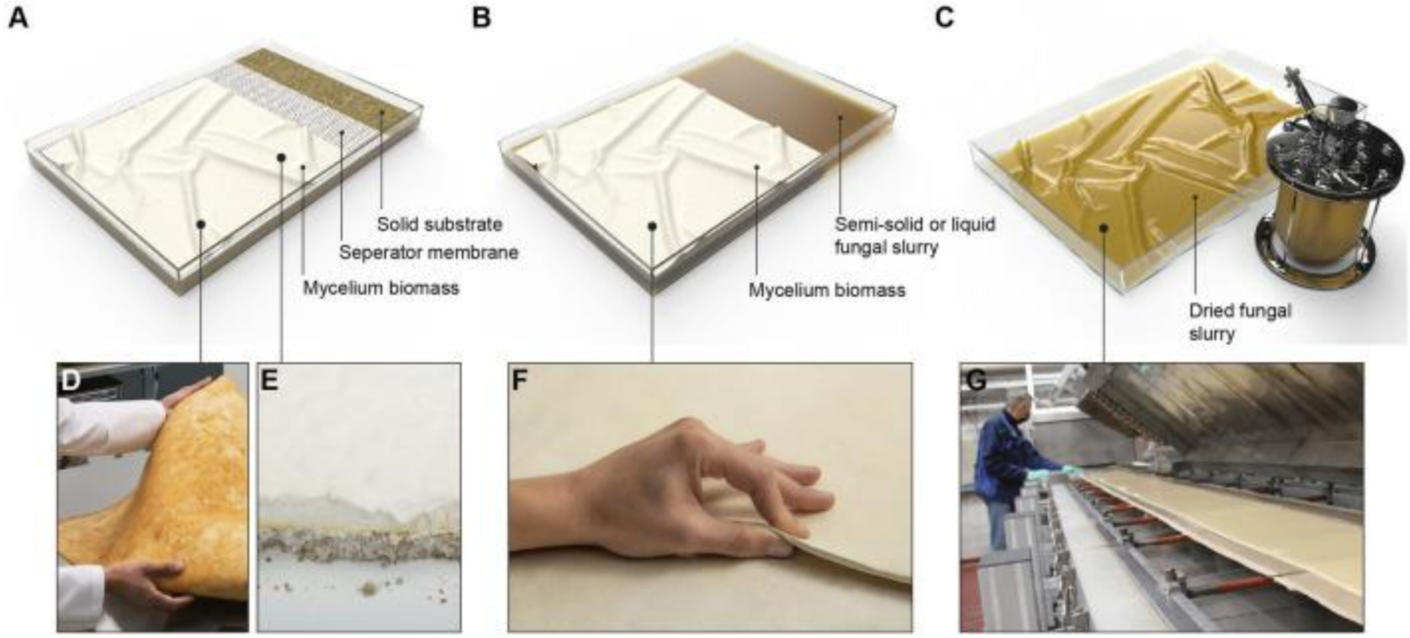
advantage of this material lies in its ability to tailor properties according to specific requirements and achieve a zero-waste process. However, due to variations in components and processing methods, standardized testing becomes complicated (Figure 1). Hence, there is a need for more scientific research to comprehensively understand the properties and potential applications of these materials (Elsacker et al., 2023).



Reference: Front Bioeng Biotechnol, 2023

Figure 1. Mycelium leather alternative manufacturing processes.

(A) Schematic representation of solid-state surface fermentation. (B) Schematic representation of liquid-state surface fermentation. (C) Schematic representation of stirred liquid deep fermentation. (D) Myco-leather, known as Reishi™, manufactured by Mycoworks (USA). (E) Foam named Forager manufactured by Ecovative (USA). (F) 100% mycelium material named ephea™ developed by SQIM/MOGU (Italy). (G) Continuous mycelium leather production by VTT Technical Research Centre of Finland.

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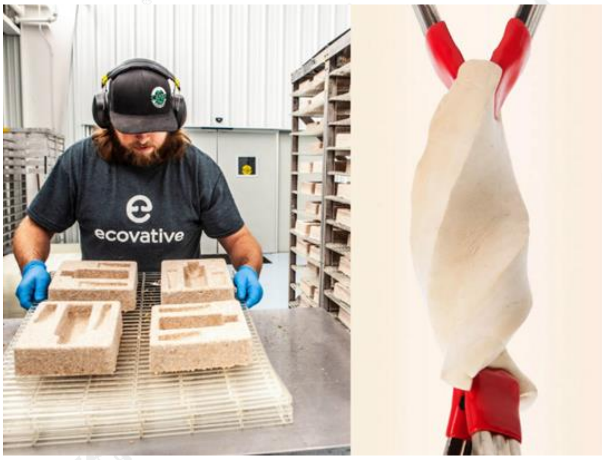
(ii) Packaging Materials

Mycelium has found widespread applications in the packaging industry, where it is used as a binding agent combined with agricultural by-products to form sturdy materials intended to replace expanded polystyrene (EPS) in packaging, achieving commercial success. MycoFlex (Figure 2) is a pure mycelium flexible foam, serves as a sustainable alternative to polyurethane. These solutions have been successful in practical applications, with some products collaborating with well-known brands (Team Source Green, 2022).

In addition to the packaging industry, mycelium has also gained prominence in other sectors such as skincare, animal leather, and alternative proteins. Despite concerns about carbon footprint, the natural sourcing, renewability, and compostable nature of mycelium make it an environmentally appealing material. Its versatility and market acceptance indicate that mycelium could emerge as an eco-friendly solution spanning multiple industries (Team Source Green, 2022).

Overall, mycelium, as a natural and sustainable material, presents viable alternatives for the packaging industry and beyond. While carbon footprint remains a concern, its natural sourcing and compostable nature make it attractive in terms of sustainability. In the future, with increasing demand for eco-friendly materials, mycelium may become a more widely adopted green solution (Team Source Green, 2022).



Reference: Team Source Green

Figure 2. Composite material replacing EPS (left) and 100% pure mycelium foam (right).

(iii) Building Materials

In the past decade, fungal biomaterials have shown significant developments in the field of architecture and design. These materials, based on mycelium and combined with fibers from agricultural waste, manufacture new building

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elements through a circular economy model, promoting a more environmentally friendly and economically sustainable transformation in the construction industry. Simultaneously, research on these materials not only brings technical knowledge to building materials but also inspires and transforms the process of architectural design. This interdisciplinary research not only incorporates fungal biomaterials into the construction elements of architecture but also influences architectural design by discovering and altering the characteristics of the materials.

Numerous interdisciplinary teams are actively working towards integrating fungal bio-composite materials into the construction industry. Among them, MY-CO SPACE (Figure 3) is a collaborative project led by biotechnology expert Vera Meyer and architect Sven Pfeiffer. The prototype combines functions of temporary shelter, sleeping and learning stations, and exhibition space, inspired by the design and functionality of spacecraft, referencing the 'tinyBE' exhibition in Frankfurt, Germany. The project consists of 300 coated mycelium

Reference: Eric Melander

Figure 3. MY-CO SPACE (a) Exterior view of the 'Growth Pavilion' located in Eindhoven during the 2019 Dutch Design Week. (b) Interior view and exhibition of the displays.

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components attached to a mycelium-infused wood substructure, using a biodegradable assembly method. The strain used is *Fomes fomentarius*, grown on hemp core, forming the mycelium-wood composite material. This represents an innovative application of fungal biomaterials in architecture, combining fungal growth technology with sustainable architectural design (Almpani-Lekka et al., 2021).

Overall, these fungal biomaterial projects have not only enriched the technical knowledge in the fields of architecture and fungal biotechnology but have also had profound cultural impacts. By combining science, art, and architecture, this innovative material application has not only altered the appearance of architecture but has also propelled the entire industry towards a more sustainable future (Almpani-Lekka et al., 2021).

(iv) Choice of Fungal Species

Mycelial materials are considered to have the potential to replace unsustainable products in the market, and they may even offer properties not provided by other materials. This material could find widespread applications in the future, not only in home environments and workplaces but potentially also as wearable materials. However, when applying this novel material, risk assessments must be conducted. This includes selecting fungal species for material production, ensuring the appropriateness of manufacturing conditions, and implementing corresponding measures to prevent adverse environmental effects after the product leaves the production facility (van den Brandhof JG and Wösten HAB, 2022).

According to assessments of pathogenicity and mycotoxin data, materials manufactured using fungal species described in the scientific literature pose low, if not negligible, risks to workers, consumers, and the environment. Wösten HAB mentions the application of genetic modification in the article, which can be used to improve the properties of mycelial materials, including reducing pathogenicity, invasiveness, mycotoxin production, environmental spread, and attractiveness to insects (van den Brandhof JG and Wösten HAB, 2022).

Even with such innovative

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products entering the market, there may still be associated risks, especially when the product contains viable fungi. Therefore, while promoting the application of mycelial materials, a cautious risk assessment should still be undertaken (van den Brandhof JG, Wösten HAB, 2022)."

III、Conclusion

Summing up the entire text, mycelial materials, with their unique structure and outstanding performance, showcase extensive potential applications in fields such as leather, packaging, and construction, providing sustainable solutions for various industries. In leather alternatives, the distinctive structural characteristics give mycelial materials exceptional strength and flexibility, coupled with lower environmental impact. In the realm of construction, applications demonstrate lightweight, stability, and thermal insulation, offering a feasible green solution for the building industry. These applications not only bring about technical innovations but also have profound cultural impacts. However, careful risk assessments are still necessary in their application to ensure environmental and safety considerations throughout the production and usage processes.

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IV、Reference

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