The Use of Mushroom Mycelia in the Textile Industry: A Sustainable Approach to Fabric Innovation

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ABSTRACT
The textile industry is continuously exploring sustainable and innovative materials to reduce environmental impacts while meeting consumer demands. Mushroom mycelia, the vegetative part of fungi, have emerged as a promising alternative for textile production due to their renewable, biodegradable, and eco-friendly nature. This study examines the potential of mushroom mycelia as a sustainable material for textile applications, focusing on its properties, production methods, and industrial feasibility. Key characteristics such as tensile strength, flexibility, breathability, and water resistance of mycelium-based fabrics were evaluated and compared with traditional textiles. The study highlights the adaptability of mycelium to grow on agricultural waste substrates, offering dual benefits of waste valorization and cost-effective production. Furthermore, mycelium-based textiles were tested for their dye absorption, antimicrobial properties, and durability, demonstrating their viability in various fashion and functional applications. The findings underscore the role of mushroom mycelia in reducing the carbon footprint and water usage associated with conventional textile manufacturing processes. However, challenges such as scalability, production consistency, and consumer acceptance remain critical areas for further exploration. This research provides a foundation for integrating mushroom mycelia into the textile industry, promoting circular economy practices and advancing sustainable development goals.

Keywords: Mushroom mycelia, sustainable textiles, biodegradable materials, eco-friendly fabrics, mycelium-based textiles

1. INTRODUCTION

The textile industry is one of the largest contributors to environmental degradation, consuming vast amounts of water, energy, and chemicals while producing significant waste and pollution. As sustainability becomes a pressing global concern, researchers and industries are increasingly turning to bio-based materials as eco-friendly alternatives to conventional textiles. Among these materials, mushroom mycelia have gained attention due to their unique properties, renewable nature, and ability to grow on low-cost, waste-based substrates (Khairul Akter et al., 2022).

Accordingly, research on alternative materials and ecofriendly processes using renewable biomass is actively being conducted to reduce environmental pollution and pursue a healthy lifestyle (Lazăr et al., 2023). Fungi belong to a major group of eukaryotic organisms. They have a long evolutionary history since their emergence about 1.2–1.5 billion years ago. Many fungal members have been used in the traditional biotechnology sectors, such as food fermentation, antibiotics, and industrial enzyme production. Some saprotrophic fungi are cultivated as major food crops, such as fruiting bodies of various mushrooms. ’Mushroom’ refers to fungal species that can produce large sized fruiting bodies that are observable to the naked eye, including the mycelial network and fruiting body itself. Hereafter, vegetative mycelia and fruiting bodies of wood-decaying Agaricomycete fungi are the focus of interest for environmentally friendly and sustainable materials for the future. More recently, new trends have been shifting away from traditional biotechnology and applying fungal mycelia as eco-friendly resources in the formulation of alternative meats, fabrication of biocomposites, and production of mycelial leather, aiming to replace animal husbandry and recycle agricultural wastes (Aiduang et al., 2024; Antinori et al., 2020; Madusanka et al., 2024; Yang et al., 2021).

Mycelium is a fast-growing vegetative section of a fungus that is commonly found in biological and agricultural wastes. It is a harmless and sustainable material that bonds with the media to which it is attached. Mycelium-based vegan leather and packaging are created by growing mycelia into customized growth chambers and molds, so-called mycofabrication (Raman et al., 2022). The field of mycelium-based leather and packaging has been expanding (Ariyani et al., 2024) (Ariyani et al. 2024; Kniep et al. 2024; Madusanka et al. 2024; Amobonye et al. 2023; Raman et al. 2022). Patents in this area including various manufacturing methods are also abundant and publicly available (Elsacker et al. 2023). Beyond vegan leather/textile and packaging, mushroom mycelium-based materials expand into construction, electrical, and industrial materials (Ferrand 2024; Alaneme et al. 2023; Danninger et al. 2022). Although many review articles and research papers have been published on mycelium-based materials, there has been no review of the vertical approach from mushroom strains and mutation methods as biological resources to the mycelium production process. This paper explores the potential of mushroom mycelia to revolutionize the textile industry, addressing both opportunities and challenges associated with their application.

2. PROPERTIES OF MUSHROOM MYCELIA FOR TEXTILES

Mycelium-based materials exhibit remarkable tensile strength, making them resistant to tearing and stretching under tension. This property is critical for creating fabrics that are not only durable but also versatile in application. Additionally, mycelium's inherent flexibility allows it to be shaped and formed into various textures, mimicking the feel of conventional textiles like leather or cotton (Voutetaki & Mpalaskas, 2024).

Also, the porous structure of mycelia enables excellent breathability, which is vital for comfort in clothing applications. This property allows for effective air circulation, reducing moisture buildup and enhancing wearability. Moreover, with appropriate post-processing treatments, such as coating with natural waxes or resins, mycelium-based textiles can achieve significant water resistance without compromising their biodegradability (Nam & Lee, 2019).

Mycelia are composed of natural polymers such as chitin and glucans, which decompose readily under environmental conditions. This characteristic ensures that mycelium-based textiles break down into non-toxic byproducts at the end of their lifecycle, significantly reducing environmental waste and pollution compared to synthetic textiles like polyester (Camilleri et al., 2025).

Many fungal species produce bioactive compounds that exhibit antimicrobial activity. These properties are retained in mycelium-based materials, providing a natural resistance to bacterial and fungal growth. This feature is particularly advantageous for hygiene-focused textiles, such as those used in medical applications, activewear, or undergarments, where odor and microbial buildup are common concerns (Sułkowska-Ziaja et al., 2023).

3. PRODUCTION OF MYCELIUM-BASED TEXTILES

The production of mycelium-based textiles involves several key steps, each contributing to the creation of a sustainable and functional material. These steps can be summarized substrate preparation, inoculation, growth and formation and processing.

Substrate Preparation

Agricultural by-products such as straw, sawdust, corn husks, or other lignocellulosic materials serve as the primary substrate for mycelium growth. These materials are selected for their abundance and low cost. The substrate is sterilized or pasteurized to eliminate contaminants and ensure optimal conditions for fungal growth. This step not only provides a nutrient-rich base for the mycelium but also valorizes agricultural waste, reducing its environmental impact (Mohd Rashid et al., 2020).

Inoculation

The prepared substrate is inoculated with fungal spores or mycelium starter cultures. This process takes place under controlled environmental conditions, such as regulated temperature, humidity, and light exposure, to facilitate rapid and uniform colonization of the substrate. The choice of fungal species is critical, as it influences the final material properties, including texture, strength, and durability (Sharma et al., 2014).

Growth and Formation

Over a period of days to weeks, the mycelium spreads throughout the substrate, forming a dense, interconnected network. During this phase, the material can be shaped by growing the mycelium in molds or flat trays, depending on the desired end-use application. This stage determines the structural integrity and dimensions of the final product, and adjustments can be made to tailor the material's properties, such as thickness or flexibility (Chan et al., 2021).

Processing

Once the mycelium has fully colonized the substrate, it is harvested and subjected to a series of post-growth treatments. Drying is a crucial step to halt fungal activity and ensure the material's stability. Additional treatments may include compression to enhance strength, coating with natural substances to improve water resistance, and heat treatments to sterilize and solidify the material. These processes are designed to optimize the mechanical and aesthetic properties of the mycelium-based textile, making it suitable for industrial and consumer applications (Camilleri et al., 2025).

This production process is inherently energy-efficient, requiring minimal inputs compared to traditional textile manufacturing. The use of agricultural waste as a substrate aligns with principles of waste valorization, offering an eco-friendly alternative that addresses both material sustainability and resource efficiency.

4. APPLICATIONS OF MYCELIUM-BASED TEXTILES

Mycelium-based textiles can be applied across various sectors. Mycelium-based textiles offer a unique opportunity for creating clothing, footwear, and accessories that are both stylish and sustainable. The distinctive textures and natural aesthetic of mycelium-based fabrics appeal to eco-conscious consumers and designers seeking innovative materials. Footwear made from mycelium, for instance, combines durability with breathability, making it a popular choice for environmentally friendly shoe designs. Accessories such as handbags and wallets also benefit from the leather-like feel of mycelium while maintaining a lower environmental impact (Silverman et al., 2020).

In the realm of interior design, mycelium-based textiles are gaining traction for use in furniture upholstery, curtains, and decorative items. Upholstered furniture using mycelium-based materials provides a sustainable alternative to synthetic options, combining comfort with biodegradability. Curtains and wall panels made from mycelium-based textiles add a natural and sophisticated touch to interiors, aligning with modern trends of minimalistic and eco-friendly design. Additionally, decorative items such as lampshades or acoustic panels made from mycelium enhance the ambiance while contributing to a sustainable living environment (Rashdan, 2023).

The unique properties of mycelium-based materials make them suitable for specialized applications in technical textiles. In the medical field, the antimicrobial properties of mycelium-based textiles can be harnessed to create hygienic solutions such as wound dressings, surgical gowns, or bedding. Industrial applications also benefit from the biodegradable nature of mycelium, enabling the production of disposable yet environmentally friendly materials. Furthermore, the lightweight yet durable nature of mycelium-based fabrics positions them as viable candidates for packaging materials and protective gear (Manan et al., 2021).

5. CHALLENGES AND LIMITATIONS

While promising, the adoption of mushroom mycelia in the textile industry faces challenges. Producing mycelium-based textiles at an industrial scale is complex, as it requires maintaining consistent growth conditions for fungal cultures while ensuring high yield and quality. Setting up large-scale facilities that balance efficiency with sustainability remains a significant challenge (Yaacob et al., 2024).

Uniformity in the texture, thickness, and strength of mycelium-based textiles is essential for their acceptance in the market. Variations during growth, substrate composition, or environmental conditions can affect the final product's quality, making it critical to standardize production protocols. Although mycelium-based textiles are gaining attention, many consumers remain unfamiliar with the concept. Addressing potential concerns about the durability, aesthetics, and usability of such fabrics will require educational campaigns and marketing strategies to build trust and awareness (Shin et al., 2025).

Initial production costs of mycelium-based textiles are higher than those of conventional fabrics due to the specialized substrates, controlled environments, and post-processing treatments involved. However, technological advancements and economies of scale are expected to reduce costs over time, making them more competitive (Camilleri et al., 2025).

6. ENVIRONMENTAL AND ECONOMIC BENEFITS

The integration of mushroom mycelia in textiles offers significant environmental and economic advantages. Mycelium-based textiles have considerably lower greenhouse gas emissions compared to synthetic fabrics. Unlike petroleum-based materials, the production of mycelium relies on biological processes that emit minimal carbon dioxide. Additionally, the use of renewable agricultural waste as a substrate offsets emissions associated with raw material extraction and processing, making it a greener alternative (Jin et al., 2025).

The production of mycelium-based textiles requires substantially less water than traditional fabric manufacturing. For instance, growing mycelium on agricultural waste involves minimal hydration, whereas cotton cultivation demands large-scale irrigation and substantial water inputs. This efficiency not only conserves water resources but also reduces wastewater generation and associated environmental harm. Mycelium-based textile production capitalizes on agricultural and organic waste as its primary feedstock. Materials such as straw, sawdust, or corn husks, which would otherwise be discarded or left to decompose in landfills, are repurposed into valuable textiles. This practice supports the principles of a circular economy by transforming waste into a resource, reducing landfill burden, and contributing to sustainable waste management (Rathinamoorthy et al., 2023).

7. FUTURE PROSPECTS

Advancing the use of mushroom mycelia in textiles requires interdisciplinary collaboration among researchers, manufacturers, and policymakers. Key areas for future research include:

- **Enhancing the Mechanical Properties:** Developing innovative treatments to enhance the mechanical properties of mycelium-based fabrics is crucial. Techniques such as cross-linking, blending with natural fibers, or incorporating bio-based resins can improve tensile strength, elasticity, and resistance to wear, enabling broader applications in fashion and technical textiles.

- **Developing Cost-Effective and Scalable Production Methods:** Streamlining the production process to reduce costs while maintaining quality is essential for industrial adoption. Research into automation, optimization of growth conditions, and the use of locally available substrates can make the production of mycelium-based textiles more economical and sustainable.
- **Exploring Hybrid Materials:** Combining mycelium with other natural fibers, such as hemp, jute, or bamboo, offers an opportunity to create hybrid materials with enhanced functionality. These materials can leverage the strengths of both components, resulting in textiles that are stronger, more breathable, or have improved aesthetics.
- **Conducting Life Cycle Assessments:** Comprehensive life cycle assessments (LCAs) are necessary to quantify the environmental benefits of mycelium-based textiles compared to conventional materials. LCAs can provide data on carbon emissions, water usage, energy consumption, and waste reduction, enabling informed decisions for sustainable manufacturing practices.

8. CONCLUSION

Mushroom mycelia present a sustainable and innovative solution for the textile industry, addressing critical environmental challenges while offering versatile applications. Although hurdles remain in scaling and consumer adoption, continued research and technological advancements are likely to unlock the full potential of mycelium-based textiles. By integrating this bio-based material, the textile industry can contribute to a circular economy and promote a more sustainable future.

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