Electrospun Nanofibers and Mushroom Mycelium for Circular Textile Material Concepts: Opportunities and Research Gaps

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ABSTRACT

The transition toward circular textile systems requires the development of materials that combine functional performance with biodegradability and reduced environmental impact. Electrospun nanofibers and fungal mycelium-based materials have emerged as two promising approaches in this context. Electrospinning enables the fabrication of highly controlled fibrous architectures with tunable morphology, the ability to process a wide range of bio-based and synthetic polymers, high surface area, and application-specific functionality. In parallel, mycelium-based materials offer renewable, low-energy production and intrinsic biodegradability, and can be cultivated on lignocellulosic agricultural waste streams, making them attractive candidates for sustainable material design.

Initial studies indicate that mycelium can grow on fibrous substrates, including textile nonwovens, and that hybrid systems combining nanofibers and fungal components are technically feasible, although systematic investigations remain limited. However, this research direction is still in an early stage, with existing studies remaining fragmented and rarely developed with a specific focus on textile-engineered systems. Existing research predominantly treats fibrous materials as passive substrates or reinforcement phases, rather than as engineered textile systems with defined structural and functional properties.

This paper critically reviews recent advances in electrospun nanofibers, mycelium-based materials, and their emerging combinations. It identifies key challenges and open questions characteristic of an emerging research field, including the lack of systematic material design frameworks, limited understanding of nanofiber–mycelium interactions, insufficient evaluation of textile-relevant properties, and the lack of circularity and end-of-life assessments for hybrid materials.

The analysis highlights the potential of electrospun nanofibers have the potential to act as tunable textile architectures that influence the structural organisation of mycelial networks and composite formation. Bridging the gap between biofabrication and textile engineering could enable a new class of biohybrid materials, supporting the development of circular textile systems.

Keywords: Biofabrication; Biohybrid textile materials; Circular textile systems; Electrospun nanofibers; Mycelium-based composites; Structure–property relationships.

Introduction

The textile industry is facing increasing pressure to reduce its environmental impact and transition toward circular material systems (Niinimäki et al., 2020; Greeshma et al., 2026). In this context, the development of bio-based and biodegradable materials has gained significant attention. Two promising approaches are electrospun nanofibers and mycelium-based materials as emerging sustainable material systems (Czerwińska et al., 2025; Parhizi et al., 2025). Electrospinning enables the fabrication of fibrous structures with controlled morphology and high surface area (Xue et al., 2019), while mycelium-based materials offer renewable, low-energy production and intrinsic biodegradability (George et al., 2026; Sharma et al., 2026).

Although both material classes have been extensively studied, their integration into functional textile systems remains limited. Existing research has explored the use of fibrous substrates for mycelium growth (Fritz et al., 2025), but these approaches largely treat textiles as passive substrates rather than engineered material systems. While Romero-Cedillo et al. (2025) demonstrated that mycelium mats can exhibit textile-relevant properties such as sewability and tear strength, their performance remains constrained and lacks systematic structural design. Similarly, Kaniyamparambil et al. (2026) showed that mycelium can bind cotton and polyester textile residues into structurally stable biocomposites with flexural strengths of up to 82.5 kPa and enhanced flame-retardant properties; however, these approaches remain focused on material feasibility rather than textile-engineered functionality.

This paper therefore reviews recent developments in both fields and identifies key research gaps at their intersection, with a focus on biohybrid textile materials and circular design strategies.

Rather than reviewing an established research field, this paper aims to structure an emerging research direction at the intersection of electrospinning, biofabrication and textile engineering.

State of the Art

Electrospun Nanofibers in Textile and Functional Materials

Electrospinning has become a key technology for the fabrication of fibrous materials with highly controlled architectures, offering fiber diameters ranging from the nanometer to micrometer scale and enabling precise tuning of porosity, surface area, and functionality (Ilda et al., 2025). These characteristics make electrospun materials particularly attractive for applications in filtration, protective textiles and biomedical systems (Islam et al., 2026; Lu et al., 2026; Ramirez Candia et al., 2024).

A wide variety of polymers has been employed, including polyacrylonitrile (PAN), polyethylene oxide (PEO), poly(lactic acid) (PLA), polycaprolactone (PCL), cellulose acetate and biopolymers such as gelatin and chitosan (Dassmann et al., 2024; Mpofu et al.; 2024; Sabantina et al., 2018; Sam et al. 2025). Electrospinning is a relatively simple yet highly adaptable process that enables the use of diverse bio-based and synthetic polymers, their blends, and functional additives such as nanoparticles or bioactive agents.

Previous studies have demonstrated the versatility of electrospun nanofiber systems, including the incorporation of magnetic nanoparticles and the development of functional composite mats for sensing, filtration and biomedical applications (Mamun et al., 2023; Langwald et al., 2023; Mamun et al., 2022).

Electrospinning also allows the fabrication of tailored fiber architectures and in situ functionalisation, making it a versatile technique for advanced material systems.

The ability to tailor fiber diameter, alignment and surface chemistry allows for the design of materials with specific mechanical and functional properties, representing a key advantage over conventional textile structures (Xue et al., 2019; Khalid et al., 2026).

Despite these advantages, electrospun nanofibers are still predominantly applied in non-textile or semi-textile contexts, such as membranes or coatings, rather than as fully integrated textile systems. For example, recent studies have focused on electrospun mixed-matrix nanofiber membranes for dye removal from textile wastewater, highlighting their high efficiency based on large surface area and tunable porosity, yet remaining within membrane-based applications (Fothedar et al., 2026).

At the same time, initial attempts toward textile integration have emerged, including embroidered platforms for motion sensing and energy harvesting (Zada et al., 2026) and wearable systems such as spacesuit gloves for improved moisture management (Rajagopal et al., 2025). However, these approaches remain primarily performance-driven and do not yet address textile-engineered or biohybrid material design.

Mycelium-Based Materials and Their Interaction with Fibrous Substrates

Mycelium-based materials are formed through the growth of fungal hyphae on lignocellulosic substrates, resulting in lightweight and biodegradable composites (Alemu et al., 2022; Akcay et al., 2023).

The mechanical and physical properties of these materials are strongly influenced by both the fungal species and the characteristics of the substrate, including its composition, structure and density. Angelova et al. (2025) demonstrated that mycelium-based composites grown on lignocellulosic by-products exhibit low densities (110–250 kg/m³), thermal conductivities of 0.043–0.054 W/mK, and compressive strengths up to 180 kPa, while also showing significant biodegradability under aerobic conditions.

Recent studies have demonstrated that fibrous substrates—including natural fibers, nonwoven textiles and textile waste—play a critical role in structuring mycelial networks and determining material performance. For instance, mycelium growth on fibrous nonwoven structures has been shown to depend on fiber orientation, density and porosity, which affect colonisation behaviour and resulting mechanical properties (Sharma et al., 2026). Xu et al. (2026) demonstrated that integrating mycelium with cellulose fibers forms robust bio-textiles with significantly enhanced performance, including up to sixfold increases in tensile strength and water contact angles of up to 139°, while maintaining breathability.

Similarly, textile waste has been successfully incorporated as a reinforcement phase in mycelium-based composites, highlighting its potential for circular material applications (Xu et al., 2026). Silm et al. (2026) demonstrated that unsorted textile waste can be directly upcycled into mycelium-based composites with tensile strengths of up to 14 MPa, while maintaining biodegradability and enabling reconfigurable material behavior. Romero-Cedillo et al. (2025) demonstrated that mycelium mats can exhibit textile-relevant properties such as sewability and tear strength (up to 12.7 N/mm), while showing high water absorption depending on processing conditions. In parallel, mycelium-based materials have been developed as leather-like sheets and flexible composites for potential textile applications.

However, their applicability remains limited by insufficient flexibility, durability and processability, as well as variability arising from biological growth conditions (Raman et al., 2022). These limitations continue to pose challenges for reproducibility, standardisation and integration into established textile systems.

Overall, these studies indicate that while substrate properties are a key factor in determining mycelium-based material performance, current approaches remain largely empirical and lack systematic design strategies for textile-engineered applications.

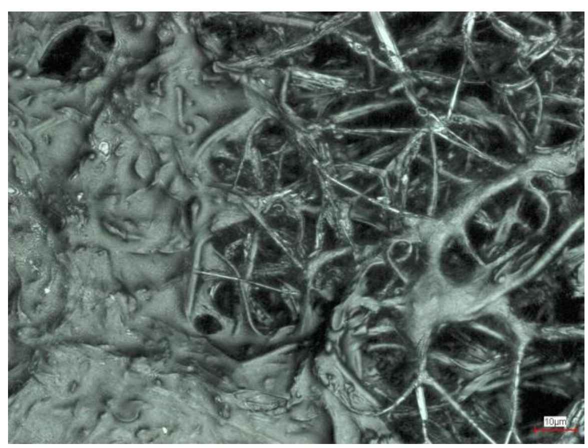
Hybridisation Approaches: From Textile Substrates to Engineered Fiber Systems

The integration of mycelium with fibrous materials has been explored primarily in the context of composite formation, where fibers act as passive substrates or reinforcement phases. In these approaches, textiles are typically used as structural templates or waste-derived fillers, without being designed as functional textile systems (Silm et al., 2026; Zheng et al., 2025).

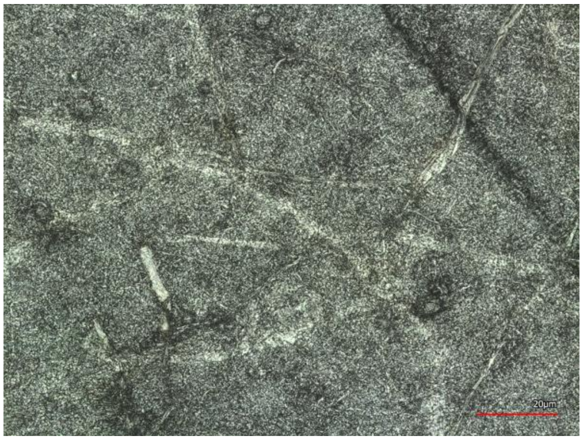
A shift toward more controlled hybridisation has been initiated by recent studies investigating the interaction between mycelium and engineered fiber architectures. Trabelsi et al. (2021) demonstrated that electrospun polyacrylonitrile (PAN) nanofiber mats can support mycelial growth, enabling the formation of biohybrid composites with improved structural integrity. This work highlights the potential of nanofiber-based scaffolds to influence biological growth at the microscale. Further advancing this concept, Mpofu et al. (2025) explored the incorporation of mycelium-derived particles into electrospun PAN nanofibers, demonstrating the feasibility of embedding bio-based components directly within the fiber matrix. This approach represents a shift from surface-based biological growth toward material-level integration, suggesting a pathway toward fully integrated biohybrid fiber systems.

In preliminary experiments, electrospun PAN nanofiber mats were modified by incorporating lignin particles into the fiber matrix, with the aim of exploring whether such components could act as an internal nutrient source for mycelial growth. This approach differs from conventional in vitro cultivation, where fungal growth typically relies on external nutrient-rich media such as malt extract agar (MEA). In this context, the nanofiber material itself could potentially serve not only as a structural scaffold but also as a localised nutrient carrier; however, this concept has not yet been systematically investigated.

Representative confocal laser scanning microscope (CLSM) images (Figure 1) provide qualitative insight into the interaction between Pleurotus ostreatus and electrospun PAN/lignin nanofiber mats. The images show hyphal growth on and along the fibrous network, indicating physical integration. While these observations confirm that mycelium can colonise lignin-containing nanofiber substrates, no conclusions can yet be drawn regarding the specific influence of lignin incorporation on growth behaviour.



(a)



(b)

Fig. 1. CLSM images of *Pleurotus ostreatus* mycelium (a) without a nanofiber substrate and (b) in the presence of electrospun PAN/lignin nanofiber mats, providing qualitative visual insight into the system (unpublished data).

Heide et al. (2023) demonstrated that mycelium-reinforced electrospun nanofiber mats can enhance both filtration efficiency and mechanical stability, with improved dye retention observed for compounds such as chlorophyll and safranin compared to pure nanofiber mats. Xu et al. (2026) further demonstrated that mycelium can be structurally integrated into cellulose-based fibrous systems, resulting in enhanced mechanical performance and water resistance.

These approaches differ fundamentally from earlier studies, as they move beyond the use of conventional textile substrates toward the design of engineered fiber systems that actively interact with biological processes.

Unlike conventional composites, these systems involve dynamic biological growth processes and complex interfacial interactions, including mechanical interlocking and biochemical adhesion between fungal hyphae and fibrous substrates (Sun et al., 2023).

Nevertheless, current research remains fragmented. While textile-based substrates have been widely investigated, the use of advanced fibrous architectures such as electrospun nanofibers is still in its early stages.

In particular, there is a lack of systematic studies addressing how nanofiber morphology, surface chemistry, and hierarchical structure influence mycelial growth, interfacial bonding, and resulting material properties.

Initial studies demonstrate the feasibility of combining electrospun nanofibers and mycelium, but systematic investigations are still limited due to the early stage of this research direction

From Existing Approaches to Emerging Research Needs

The current state of research demonstrates that the combination of mycelium and fibrous materials is not a novel concept per se. Numerous studies have successfully employed textile substrates, natural fibers, and fibrous waste streams to create mycelium-based composites (Rathinamoorthy et al., 2023; Rathinamoorthy et al.,2026).

However, these approaches share a common limitation: fibrous materials are predominantly treated as passive structural components rather than as actively designed material systems. At the same time, research on electrospun nanofibers has largely focused on functional performance in filtration or biomedical applications, with limited consideration of biological integration or circular material design (Liang et al., 2025). Chagas et al. (2024) review the use of recycled and bio-based polymers, including lignin, for the production of nanofibers, highlighting their potential for circular material design and sustainable high-performance applications.

This disconnect reveals a critical gap at the intersection of both fields. The integration of engineered nanofiber architectures with controlled mycelial growth has the potential to enable a new class of biohybrid textile materials, yet remains largely unexplored.

Emerging Research Challenges and Open Questions

Existing studies demonstrate the feasibility of combining mycelium with fibrous materials (Sayfutdinova et al., 2023).; however, the field is still in an early stage, and systematic understanding has not yet been established. The key challenge is therefore not the absence of mycelium–textile composites, but the lack of a structured, textile-engineering-oriented framework for understanding and designing these emerging biohybrid systems (Le Ferrand, 2024). Current research gaps centre on the lack of systematic design, evaluation and circular-material integration of mycelium–fiber hybrids for functional textile applications (Rashdan and Ashour, 2024). Recent studies on mycelium composites have shown strong potential for sustainable materials, but they also highlight persistent challenges in reproducibility, material performance, standardisation and scalability (Attias et al., 2021; Wattanavichean et al., 2025).

Lack of systematic design and structure–property understanding

Several studies have demonstrated that mycelium can grow on fibrous substrates, including lignocellulosic fibres, textile nonwovens and electrospun nanofiber mats (Elsacker et al., 2019; Trabelsi et al., 2021; Mpofu et al., 2025). These works confirm the feasibility of mycelium–fiber composites and highlight the influence of substrate characteristics on growth behaviour and resulting material properties. In particular, parameters such as fibre density, porosity and orientation have been shown to affect mycelial colonisation and composite formation (Biront et al., 2025). Nejati et al. (2025) demonstrate that substrate selection directly influences mycelial network formation and resulting material properties, with multiscale analyses revealing strong structure–property relationships.

However, existing approaches largely treat fibrous materials as passive substrates or reinforcement phases rather than as engineered textile systems with defined and tunable properties. As a result, there is currently no systematic understanding of how fibre architecture influences mycelial growth, interfacial bonding and final material performance. This limitation is particularly relevant for electrospun nanofibers, where parameters such as fibre diameter, surface chemistry, alignment and hierarchical structure can be precisely controlled. Mamun et al. (2024) showed that variations in electrospinning parameters significantly affect nanofiber morphology, underlining the high degree of structural tunability that remains largely unexplored in nanofiber–mycelium systems.

Current research therefore remains at the stage of feasibility studies, focusing on whether mycelium can grow on fibrous materials, rather than how fibrous architectures can be deliberately designed to control biological processes and material functionality. A key open question is how nanofiber parameters—such as diameter, porosity, wettability and polymer type—interact with biological variables including fungal species, growth conditions and nutrient availability to determine structure–property relationships.

Addressing this gap is essential for transitioning from empirical composite formation toward controlled, textile-engineered biohybrid material design.

Insufficient textile-performance evaluation

Many mycelium composites are evaluated for construction, packaging, acoustic insulation or leather-like applications, rather than for textile use. Reviews and recent studies repeatedly identify limitations related to flexibility, durability, reproducibility and product requirements (Rathinamoorthy et al., 2023; Le Ferrand, 2024; Attias et al., 2021).

Some new studies move closer to textile testing. Romero-Cedillo et al. (2025), for example, produced mycelium mats for textile applications and assessed thickness, water absorption, surface coverage and tear strength for sewing. This is highly relevant, but it also shows how young the field still is: essential textile parameters such as drape, bending stiffness, abrasion resistance, air permeability, moisture management, washability, dimensional stability and long-term wear behaviour remain insufficiently investigated.

Limited circularity and end-of-life evidence

Mycelium-based materials are often described as sustainable because they can use renewable substrates and biological growth processes. However, recent studies indicate that environmental performance depends strongly on production conditions, energy input and system boundaries (Le Ferrand, 2024). Volk et al. (2024) reported climate-change and fossil-energy benefits for laboratory-scale mycelium-based composite production, but also identified relevant environmental burdens such as electricity demand and hemp cultivation.

For hybrid textile systems, the circularity question is even more complex. A mycelium component may be biodegradable, but this does not automatically make the whole composite circular, especially when combined with persistent synthetic polymers. Existing nanofiber–mycelium studies are therefore important, but they do not yet provide full answers regarding compostability, biodegradation kinetics, material separation, recycling, microplastic release or safe biological end-of-life pathways. This is a critical gap for any paper claiming relevance to circular textiles.

At present, circularity claims are largely conceptual, and experimental validation remains limited.

Missing design framework for biohybrid circular textiles

The reviewed literature suggests that mycelium–textile research is moving in three partly separate directions: mycelium grown on fibrous substrates, mycelium mats as textile-like sheets, and electrospun nanofiber–mycelium hybrids. What remains absent is an integrated design framework that connects these approaches into a coherent textile-engineering strategy. Such a framework would need to link biological growth parameters, fibre architecture, textile performance, functional properties and end-of-life behaviour.

Addressing this gap represents a key priority for advancing the field. Electrospun nanofibers, in particular, should be reconsidered not merely as passive reinforcement of carrier materials, but as tunable textile architectures capable of directing mycelial growth and enabling functional, circular material systems. Research should therefore focus on establishing design principles that enable controlled structure development, measurable textile performance, and verifiable circular end-of-life pathways in nanofiber-mycelium hybrid materials.

Future research directions

Given the early stage of research, future work should prioritise fundamental understanding and move beyond proof-of-concept studies toward systematic, application-oriented material development. In particular, a stronger focus on controlled material design, textile performance, circularity and scalable processing is required.

A key priority is the establishment of structure–property–function relationships in nanofiber–mycelium systems. Electrospinning allows precise control over fiber diameter, porosity, alignment and surface chemistry (Xue et al., 2019), all of which are known to influence biological adhesion and growth processes. At the same time, fungal morphology and mechanical performance are strongly dependent on substrate structure and environmental conditions, as different lignocellulosic substrates have been shown to influence hyphal network formation, growth rate and resulting mechanical properties (Majib et al., 2026; Bayomei et al., 2026). Future studies should therefore systematically vary nanofiber parameters—such as fiber diameter, mat density, wettability and polymer type (e.g. PAN, PLA, cellulose-based fibers)—to investigate their effect on mycelial colonisation, interfacial bonding and composite performance.

In parallel, textile-specific performance evaluation must be significantly expanded. While mycelium-based materials have been explored for structural and leather-like applications (Nguena-Dongue et al., 2026; Aditiawati et al., 2026), their suitability for textile use remains insufficiently characterised. Key properties such as tensile strength, flexibility, bending stiffness, abrasion resistance, air permeability and sewability should be assessed using standardized textile testing methods. Recent work on mycelium sheets highlights the importance of parameters such as thickness, water absorption and tear strength, but also demonstrates the lack of comprehensive testing frameworks (e.g. Romero-Cedillo et al., 2025). Without such data, the translation of biohybrid materials into textile applications remains limited.

Another critical research direction is the integration of circularity and end-of-life design into material development. Although mycelium-based materials are often considered biodegradable, their environmental performance depends strongly on processing conditions and system boundaries (Niinimäki et al., 2020; Volk et al., 2024; Jin et al., 2025). For hybrid systems, the combination of biodegradable fungal components with synthetic polymers introduces additional challenges. Future research should therefore address biodegradation behaviour, compostability, potential microplastic formation and material separation strategies, supported by life cycle assessment approaches.

Finally, the development of scalable biohybrid manufacturing processes remains a major challenge. Electrospinning is increasingly being adapted for scalable production, for example through needleless and roll-to-roll processes; however, challenges related to process stability, production rate and material uniformity continue to limit large-scale implementation (Persano et al., 2013; Atay and Altan, 2023), whereas mycelium cultivation is inherently biological and sensitive to environmental conditions (Schoder et al., 2024). Integrating these processes requires new production concepts that ensure reproducibility, process control and economic feasibility. Previous work has highlighted the need for improved standardisation in mycelium-based materials (Attias et al., 2021; Bitting et al., 2022), which becomes even more critical in hybrid systems.

Overall, future research should treat nanofiber–mycelium systems as engineered biohybrid textile architectures, in which fiber design and biological growth are co-optimized. This approach has the potential to enable functional, scalable and circular textile materials, bridging the gap between biofabrication and textile engineering.

The field is currently transitioning from exploratory feasibility studies to hypothesis-driven material design.

Conclusion

This paper has examined an emerging research direction at the intersection of electrospun nanofibers and mycelium-based materials. Electrospun nanofibers and mycelium-based materials have been widely studied as sustainable material solutions, yet their integration into functional textile systems remains limited. Existing approaches demonstrate compatibility between mycelium and fibrous substrates but largely treat fibers as passive components.

The key gap lies in the lack of a textile-engineering-oriented framework for designing nanofiber–mycelium hybrids. In particular, the potential of electrospun nanofiber architectures to actively control mycelial growth and material properties remains insufficiently explored.

Nanofiber–mycelium systems should therefore be understood as programmable biohybrid textile materials, in which fiber design and biological processes are co-optimized. Advancing this concept requires systematic research on structure–property relationships, textile performance, circularity and scalable manufacturing.

If addressed, these challenges could enable a new class of functional and circular textile materials at the intersection of biofabrication and textile engineering.

As such, this work contributes to structuring a novel research field rather than summarizing a mature body of literature.

References

Aditiawati, P., Dungani, R., Prakoso, T., Priharto, N., Suwardi, M.I.A.-R., Ramdhani, M.R., Fitriyanti, M., Mutsla, D. and Fatriasari, W. (2026) 'Development of mycelium leather (Mylea) from oil palm empty fruit bunch (OPEFB) waste using white rot fungi as a renewable leather material', Journal of Renewable Materials, 14(1). doi:10.32604/jrm.2025.02025-0113.

Akcay, C., Ceylan, F. and Arslan, R. (2023) 'Production of oyster mushroom (Pleurotus ostreatus) from some waste lignocellulosic materials and FTIR characterization of structural changes', Scientific Reports, 13, 12897. doi:10.1038/s41598-023-40200-x.

Alemu, D., Tafesse, M. and Mondal, A.K. (2022) 'Mycelium-based composite: the future sustainable biomaterial', International Journal of Biomaterials, 2022, 8401528. doi:10.1155/2022/8401528.

Angelova, G., Yemendzhiev, H., Zaharieva, R., Brazkova, M., Koleva, R., Stefanova, P., Baldzhieva, R., Vladev, V. and Krastanov, A. (2025) 'Mycelium-based composites derived from lignocellulosic residual by-products: an insight into their physico-mechanical properties and biodegradation profile', Applied Sciences, 15, 6333. doi:10.3390/app15116333.

Atay, E. and Altan, A. (2023) 'Scale up and industrialization of electrospinning/electrospraying encapsulation approaches: Current state, challenges, limitations, and future trends', in Encapsulation of Food Bioactives. doi:10.1016/B978-0-443-22228-3.00004-5.

Attias, N., Livne, A. and Abitbol, T. (2021) 'State of the art, recent advances, and challenges in the field of fungal mycelium materials: A snapshot of the 2021 Mini Meeting', Fungal Biology and Biotechnology, 8, 12. doi:10.1186/s40694-021-00118-3.

Bayomei, A., Bassuoni, M.T. and Shalaby, A. (2026) 'Evaluation of mycelium-based composites grown on sunflower seed shell and oat husk substrates inoculated with Trametes versicolor and Pleurotus ostreatus', Materials Today Sustainability, 33, 101319. doi:10.1016/j.mtsust.2026.101319.

Biront A, Sillen M, Van Dijck P, Wurm J. 'Growth propagation of liquid spawn on non-woven hemp mats to inform digital biofabrication of mycelium-based composites'. Biomimetics. 2025;10(1):33. doi:10.3390/biomimetics1001003.

Bitting, S., Derme, T., Lee, J., Van Mele, T., Dillenburger, B. and Block, P. (2022) 'Challenges and opportunities in scaling up architectural applications of mycelium-based materials with digital fabrication', Biomimetics, 7(2), 44. doi:10.3390/biomimetics7020044.

Chagas, P.A.M., Lima, F.A., Medeiros, G.B., Mata, G.C., Tanabe, E.H., Bertuol, D.A., Oliveira, W.P., Guerra, V.G. and Aguiar, M.L. (2025) 'From waste to innovation: Advancing the circular economy with nanofibers using recycled polymers and natural polymers from renewable or waste residues', Journal of Industrial and Engineering Chemistry, 147, pp. 56–84. doi:10.1016/j.jiec.2024.12.053.

Czerwińska, N., Giosuè, C., Generosi, N., Pierpaoli, M., Jbr, R., Luzi, F., Corinaldesi, V. and Ruello, M.L. (2025) 'Electrospun fibers from biobased and recycled materials for indoor air quality enhancement', Molecules, 30, pp. 1214. doi:10.3390/molecules30061214.

Dassmann, N., Brockhagen, B. and Ehrmann, A. (2024) 'Investigation of the optical contrast between nanofiber mats and mammalian cells dyed with fluorescent and other dyes', Physical Sciences Forum, 10, 5. doi:10.3390/psf2024010005.

Elsacker, E., Vandelook, S., Brancart, J., Peeters, E. and De Laet, L. (2019) 'Mechanical, physical and chemical characterisation of mycelium-based composites with different types of lignocellulosic substrates', PLoS ONE, 14(7), e0213954. doi:10.1371/journal.pone.0213954.

Fothedar, D.K., Hou, J., Balu, R., Vongsvivut, J., Arundhathi, B., Sahu, N., Dutta, N.K., Sridhar, S. and Roy Choudhury, N. (2026) 'Electrospun mixed matrix nanofiber membranes for sustainable dye removal from textile wastewater', Chemical Engineering Journal, 532, 174239. doi:10.1016/j.cej.2026.174239.

Fritz, C., Olivera, J.F., Garrido-Manque, V. and Garay, R. (2025) 'Development and evaluation of mycelium-based composites from agroforestry residues: a sustainable approach to the design of innovative building materials', Buildings, 15, 1764. doi:10.3390/buildings15111764.

George, K., Rodríguez-Grau, G., Manikandan, V.S., Molina, P., Sancy, M. and Thirumurugan, A. (2026) 'Engineering functional mycelium-based composites: innovations in thermal and acoustic insulation', Composites Part B: Engineering, 315, pp. 113470. doi:10.1016/j.compositesb.2026.113470.

Greeshma, B.S., Khanna, R. and Sankar, B. (2026) 'Bridging the gap: India's circularity and sustainability landscape in apparel and textiles compared to global trends', Social Sciences & Humanities Open, 13, pp. 102734. doi:10.1016/j.ssaho.2026.102734.

Heide, A., Wiebe, P., Sabantina, L. and Ehrmann, A. (2023) 'Suitability of mycelium-reinforced nanofiber mats for filtration of different dyes', Polymers, 15, 3951. doi:10.3390/polym15193951.

Ilda, K., Joshi, J.S., Mpofu, N.S. and Ehrmann, A. (2025) '3D biomaterials produced by near-field electrospinning and melt electrowriting', Hemijska Industrija, 79(4), pp. 209–217. doi:10.2298/HEMIND250111013K.

Islam, S., Lahiri, S.K., Akhter, M.A., Imran, M., Mengmeng, D. and Liu, Y. (2026) 'Green engineering of water-insoluble PVA/PAA nanofiber respiratory membranes for efficient particulate matter filtration with low pressure drop', Polymer, 347, 129634. doi:10.1016/j.polymer.2026.129634.

Jin, Y., De, G., Wilson, N., Qin, Z. and Dong, B. (2025) 'Towards carbon-neutral built environment: A critical review of mycelium-based composites', Energy and Built Environment. doi:10.1016/j.enbenv.2025.01.004.

Khalid, W., Golshany, H., Seddiek, A.S., Fan, M., Li, Y., Qian, H. and Wang, L. (2026) 'Tailoring electrospun fava bean protein–PVA nanofibers: unlocking enhanced thermal, antibacterial, and antioxidant functions', Food Bioscience, 76, 108268. doi:10.1016/j.fbio.2026.108268.

Langwald, S.V., Ehrmann, A. and Sabantina, L. (2023) 'Measuring physical properties of electrospun nanofiber mats for different biomedical applications', Membranes, 13, 488. doi:10.3390/membranes13050488.

Le Ferrand, H. (2024) 'Critical review of mycelium-bound product development to identify barriers to entry and paths to overcome them', Journal of Cleaner Production, 450, 141859. doi:10.1016/j.jclepro.2024.141859.

Liang, Y., Liu, Y., Yu, Q., Yu, D. and Liu, H. (2025) 'Advances in antibacterial air filters based on electrospun nanofibers', Journal of Environmental Chemical Engineering, 13(6), 119695. doi:10.1016/j.jece.2025.119695.

Lu, P., Zhang, H., Zhao, K., Guan, X., Zhen, Q., Zhai, Q. and Zhang, Z. (2026) 'Scalable-hydroentangled HDPE microfibrous textiles with high strength, breathability, and daytime radiative cooling for durable personal protective equipment', Polymer, 343, 129446. doi:10.1016/j.polymer.2025.129446.

Majib, N.M., Yaacob, N.D., Ting, S.S. and Rohaizad, N.M. (2026) 'Fungal foam: Effect of different substrates on the growth performance, mechanical, physical and biodegradability properties', Sustainable Chemistry for the Environment, 13, 100314. doi:10.1016/j.scenv.2026.100314.

Mamun, A., García-Mateos, F.J., Sabantina, L., Klöcker, M., Diestelhorst, E., Ruiz-Rosas, R., Rosas, J.M., Rodríguez-Mirasol, J., Blachowicz, T. and Cordero, T. (2023) 'Electrospinning of magnetite–polyacrylonitrile composites for the production of oxygen reduction reaction catalysts', Polymers, 15, 4064. doi:10.3390/polym15204064.

Mamun, A., Klöcker, M., Blachowicz, T. and Sabantina, L. (2022) 'Investigation of the morphological structure of needle-free electrospun magnetic nanofiber mats', Magnetochemistry, 8, 25. doi:10.3390/magnetochemistry8020025.

Mamun, A., Klöcker, M., Blachowicz, T. and Sabantina, L. (2024) 'Electrospinning poly(acrylonitrile) containing magnetite nanoparticles: Influence of magnetite contents', Fibers, 12(3), 19. doi:10.3390/fib12030019.

Mpofu, N.S., Stepula, E., Güth, U., Ehrmann, A. and Sabantina, L. (2025) 'Electrospinning poly(acrylonitrile) (PAN) nanofiber mats with mushroom mycelium powder', Engineering Proceedings, 87, 45. doi:10.3390/engproc2025087045.

Mpofu, N.S., Topuz, Y., Stepula, E., Güth, U., Grothe, T., Storck, J.L., Wortmann, M., Mahltig, B. and Ehrmann, A. (2024) 'Influence of the PAN:PEO ratio on the morphology of needleless electrospun nanofiber mats before and after carbonization', Fibers, 12, 97. doi:10.3390/fib12110097.

Nejati, M., Zha, L., Mensah, R.A., Das, O., Capezza, A.J. and Jiménez-Quero, A. (2026)

‘Agro-food waste upcycling into mycelium insulation: Linking structure with mechanical and fire performance’, Materials Today Sustainability, 33, 101295. doi:10.1016/j.mtsust.2025.101295.

Nguena-Dongue, B.-N., Amobonye, A., Muniyasamy, S. and Pillai, S. (2026) 'Mycelium-based leather-like material from Absidia koreana grown on agro-residues: Process optimisation, functionalisation, and material performance', Sustainable Materials and Technologies, 48, e01970. doi:10.1016/j.susmat.2026.e01970.

Niinimäki, K., Peters, G., Dahlbo, H., Perry, P., Rissanen, T. and Gwilt, A. (2020) 'The environmental price of fast fashion', Nature Reviews Earth & Environment, 1(4), pp. 189–200. doi:10.1038/s43017-020-0039-9.

Parhizi, Z., Dearnaley, J., Kauter, K., Mikkelsen, D., Pal, P., Shelley, T. and Burey, P. (2025) 'The fungus among us: innovations and applications of mycelium-based composites', Journal of Fungi, 11, pp. 549. doi:10.3390/jof11080549.

Persano, L., Camposeo, A., Tekmen, C. and Pisignano, D. (2013) 'Industrial upscaling of electrospinning and applications of polymer nanofibers: A review', Macromolecular Materials and Engineering, 298(5), pp. 504–520. doi:10.1002/mame.201200290.

Rajagopal, S.J., Kaybal, H.B., Ijaola, A.O., Amick, R.Z. and Asmatulu, R. (2025) 'Integrating superhydrophobic and superhydrophilic nanofiber layers into astronaut spacesuit gloves for better sweat mitigation', Acta Astronautica, 236, pp. 1287–1295. doi:10.1016/j.actaastro.2025.08.003.

Raman, J., Kim, D.-S., Kim, H.-S., Oh, D.-S. and Shin, H.-J. (2022) 'Mycofabrication of mycelium-based leather from brown-rot fungi', Journal of Fungi, 8, 317. doi:10.3390/jof8030317.

Ramirez Candia, H.G., Güth, U., Grothe, T. and Ehrmann, A. (2024) 'Optimization of the spinning parameters for wire-based electrospinning of casein–PEO nanofiber mats', Engineering Proceedings, 81, 7. doi:10.3390/engproc2024081007.

Rashdan, W. and Ashour, A.F. (2024) 'Growing design”: The role of mycelium-based materials in interior and furniture design', The International Journal of Designed Objects, 18(2), pp. 37–62. doi:10.18848/2325-1379/cgp/v18i02/37-62.

Rathinamoorthy, R., Logitha, N. (2026). Mycelium: The Sustainable Revolution in Eco-friendly Materials. In: Martínez, L.M.T., Kharissova, O.V., Kharisov, B.I. (eds) Handbook of Ecomaterials. Springer, Cham. https://doi.org/10.1007/978-3-319-48281-1_207-1

Rathinamoorthy, R., Sharmila Bharathi, T., Snehaa, M. and Swetha, C. (2023) 'Mycelium as sustainable textile material – review on recent research and future prospective', International Journal of Clothing Science and Technology, 35(3), pp. 454–476. doi:10.1108/IJCST-01-2022-0003.

Romero-Cedillo, R.K., Robledo-Leal, E.R., Aguilar-Marcelino, L., Acosta-Urdapilleta, M.d.L. and Téllez-Téllez, M. (2025) 'Production of mycelium mats for textile applications', Journal of Fungi, 11, 700. doi:10.3390/jof11100700.

Sabantina, L., Kinzel, F., Hauser, T., Többer, A., Klöcker, M., Döpke, C., Böttjer, R., Wehlage, D., Rattenholl, A. and Ehrmann, A. (2019) 'Comparative study of Pleurotus ostreatus mushroom grown on modified PAN nanofiber mats', Nanomaterials, 9, 475. doi:10.3390/nano9030475.

Sabantina, L., Wehlage, D., Klöcker, M., Mamun, A., Grothe, T., García-Mateos, F.J., Rodríguez-Mirasol, J., Cordero, T., Finsterbusch, K. and Ehrmann, A. (2018) 'Stabilization of electrospun PAN/gelatin nanofiber mats for carbonization', Journal of

Nanomaterials, 2018, 6131085. doi:10.1155/2018/6131085.

Sam, V., Beg, M. and Alcock, K.M. (2025) 'Comparative analysis of sustainable nanocomposite cellulose nanofiber membranes with polycaprolactone and polylactic acid', Next Materials, 9, 101173. doi:10.1016/j.nxmate.2025.101173.

Sayfutdinova, A.R., Cherednichenko, K.A., Rakitina, M.A., Dubinich, V.N., Bardina, K.A., Rubtsova, M.I., Petrova, D.A., Vinokurov, V.A. and Voronin, D.V. (2023) 'Natural fibrous materials based on fungal mycelium hyphae as porous supports for shape-stable phase-change composites', Polymers, 15, 4504. doi:10.3390/polym15234504.

Schoder, K.A., Krümpel, J., Müller, J. and Lemmer, A. (2024) 'Effects of environmental and nutritional conditions on mycelium growth of three Basidiomycota', Mycobiology, 52(2), pp. 124–134. doi:10.1080/12298093.2024.2341492.

Sharma, M., Lim, L.-T. and Kaur, G. (2026) 'Tailoring structure–property relationships of fungal mycelium for material applications: a process engineering approach for pure mycelium-based biomaterials', New Biotechnology, 91, pp. 156–169. doi:10.1016/j.nbt.2025.12.006.

Silm, M., Jiang, Q., Kisand, A., Bismarck, A. and Jones, M.P. (2026) 'Transforming textile waste into materials using fungi', Resources, Conservation and Recycling, 228, 108812. doi:10.1016/j.resconrec.2026.108812.

Sun, W., Tajvidi, M. and Hunt, C.G. (2023). Fungal Mycelia as Bioadhesives. In Biobased Adhesives (eds M. Dunky and K.L. Mittal). https://doi.org/10.1002/9781394175406.ch16

Trabelsi, M., Mamun, A., Klöcker, M., Brockhagen, B., Kinzel, F., Kapanadze, D. and Sabantina, L. (2021) 'Polyacrylonitrile (PAN) nanofiber mats for mushroom mycelium growth investigations and formation of mycelium-reinforced nanocomposites', Journal of Engineered Fibers and Fabrics, 16, 15589250211037982. doi:10.1177/15589250211037982.

Volk, R., Schröter, M., Saeidi, N., Steffl, S., Javadian, A., Hebel, D.E. and Schultmann, F. (2024) 'Life cycle assessment of mycelium-based composite materials', Resources, Conservation and Recycling, 205, 107579. doi:10.1016/j.resconrec.2024.107579.

Wattanavichean, N., Phanthuwongpakdee, J., Koedrith, P., Laoratanakul, P., Thaithatgoon, B., Somrithipol, S., Kwantong, P., Nuankaew, S., Pinruan, U., Chuaseeharonnachai, C. and Boonyuen, N. (2025) 'Mycelium-based breakthroughs: Exploring commercialization, research, and next-gen possibilities', Circular Economy and Sustainability, 5, pp. 3211–3253. doi:10.1007/s43615-025-00539-x.

Xue, J., Wu, T., Dai, Y. and Xia, Y. (2019) 'Electrospinning and electrospun nanofibers: methods, materials, and applications', Chemical Reviews, 119(8), pp. 5298–5415. doi:10.1021/acs.chemrev.8b00593.

Xu, W., Cheng, Q., Alam, W., Tian, Y., Deng, P., Niu, Z., Warsinger, D. and Li, T. (2026) 'Robust bio-textiles via mycelium–cellulose interface engineering', Advanced Functional Materials, 36(12), e17897. doi:10.1002/adfm.202517897.

Zada, M., Bairagi, S. and Menon, C. (2026) 'Electrospun nanofiber-integrated embroidered textiles for speed-independent RF-based motion sensing and triboelectric energy harvesting', Chemical Engineering Journal, 532, 174536. doi:10.1016/j.cej.2026.174536.

Zheng, W., Gao, Y., Zong, X. and Wang, J. (2025) 'Study on the properties and design applications of polyester–cotton matrix mycelium composite materials', Biomimetics, 10, 681. doi:10.3390/biomimetics10100681.