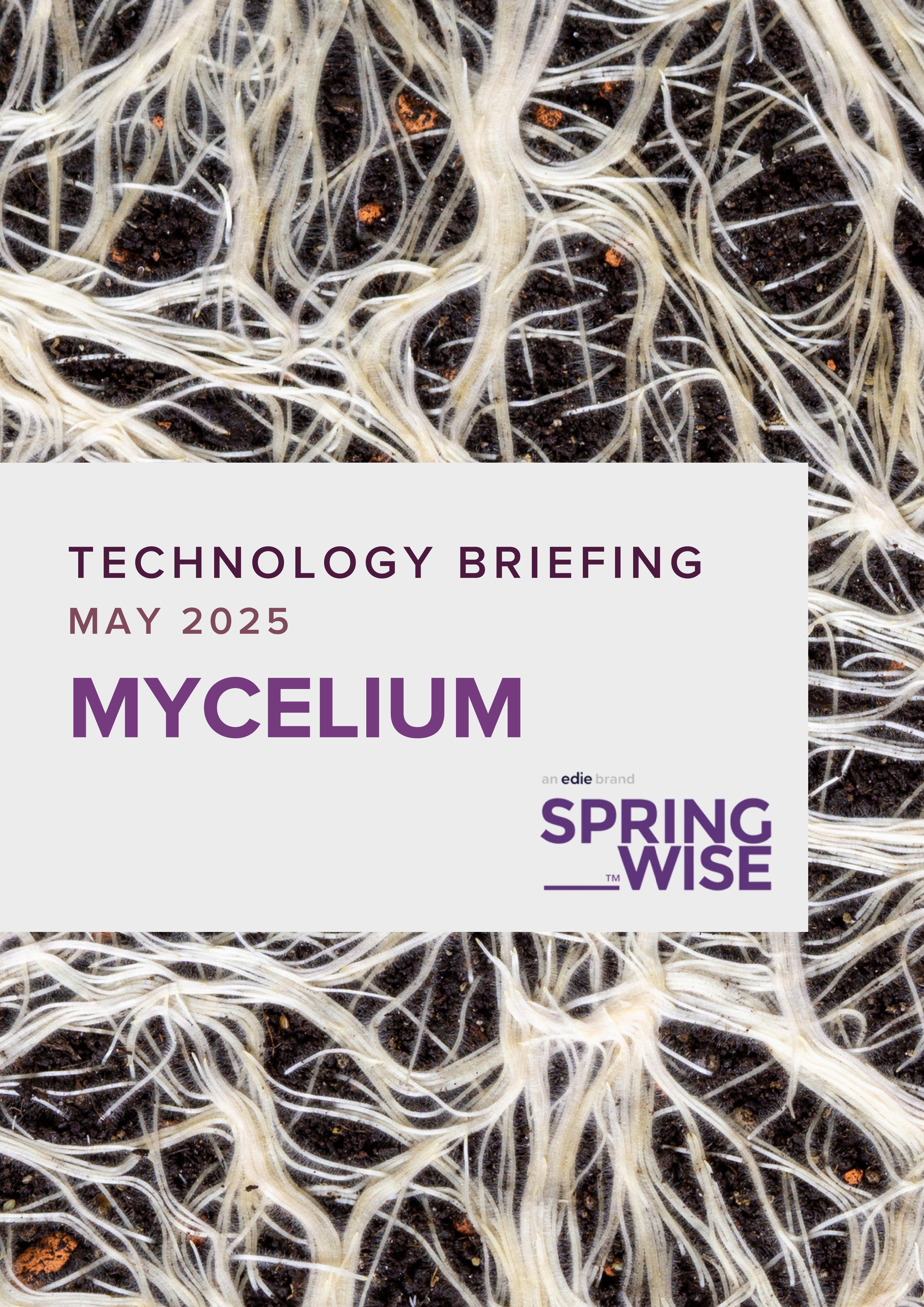


TECHNOLOGY BRIEFING

MAY 2025

MYCELIUM

an edie brand

SPRINGWISE™

FUNGI – AN AGE-OLD INNOVATION

A new generation of innovators are tapping into the power of filamentous fungi.

Photo credit: © andreymuravin from Getty Images via Canva.com

Most people are used to buying button, field, or chestnut mushrooms from the supermarket, and we may even stretch to portobello, shiitake, or oyster varieties for fancier meals. But mushrooms are just one part of the fungus – the fruiting body used in reproduction – and many fungi don't produce mushrooms at all.

We also don't fully appreciate all the unseen things that fungi do for us – and have done for millennia. One group of fungi, yeasts, are critical for making bread, cheese, beer and many other food products. Fungi also play an important role in medicine, such as by providing us with antibiotics, not least penicillin.

So, if fungi have played a role in the economy for so long, why are we talking about them as something innovative?

About this briefing

This briefing provides an introductory overview of the emerging field of mycelium. Our editorial team has pulled together insights from academic review articles and from our conversations with experts. Mycelium technology can be used across many industries – from food and packaging to fashion and construction – so this piece is relevant to readers with a broad interest in sustainable innovation.

Typically, where we have used fungi not as food but as a workhorse for industry, we have relied on single-celled fungal organisms. However, scientists have long known that filamentous fungi – a broad group of species, including those that produce edible mushrooms – can do much more than contribute to a tasty risotto.

Filamentous fungi are made up of 'hyphae', thread-like cells that grow into branching networks of filaments, which we call 'mycelium' – the focus of this technology briefing. Mycelium produces many interesting and useful chemicals. These are typically secreted from the tips of the hyphae and are used in nature for tasks like breaking down the organic matter that acts as the fungus's food.

Photo credit: © Niknami / Adobe Stock

As is often the case with innovation, this ability has not gone entirely unnoticed by industry. As long ago as 1919, Pfizer began producing citric acid from a filamentous fungi species – an ingredient with applications in the food, pharmaceuticals, and chemical industries. However, until recently, there hadn't been as much attention paid to filamentous fungi as other types of useful organisms, such as yeast and bacteria.

This is changing. In both academia and the private sector, mycelium has become a trendy solution for tackling environmental challenges in everything from fashion to construction. This has been driven, in large part, by the need to replace products derived from petrochemicals with circular alternatives – a task that fungi are particularly well-placed to contribute towards.

In this note, we take a look at some of the opportunities and challenges associated with mycelium solutions. With the help of experts in the field, we outline some of the key points organisations need to understand if they are to explore mycelium as a serious and scalable climate solution.

Matthew Hempstead
Commissioning Editor

This is the launch edition of our technology briefing feature series. We have made it freely accessible, but future editions will be available exclusively to Springwise members. To become a member click here, and you will also get unrestricted access to our full database of over 15,000 innovations. We'd love to hear your feedback on the content and format of this feature. Please email comments to matthew@springwise.com

Mycelium basics

Mycelium is often likened to the roots of plants. In nature, mycelium networks spread out through the soil, breaking down organic matter into nutrients. Unlike animals that must first ingest (i.e. swallow) their food before they can digest it, the reverse is true for fungi – their food must first be broken down into simple molecules that can be absorbed through the walls of their cells. Fungi do this by secreting powerful chemicals, known as enzymes, and these can be leveraged by humans.

The ability to break down materials chemically is useful to us in numerous contexts (such as in advanced plastic recycling and pollution remediation). "Fungi know how to recycle very well and mycelium, in particular, excretes enzymes that are very efficient at recycling toxins," explains Joanne Rodriguez, CEO of Mycocycle, a startup that uses mycelium to upcycle waste building materials.

Because of their "unique and potent enzyme system", fungi are particularly good at breaking down really tough materials that other organisms struggle with, such as the lignocellulosic material found in woody biomass. This opens new possibilities for biochemicals and biofuels, which could one day replace petrochemical-based products. Mycelium also binds organic particles together as it degrades them, an ability that can be leveraged to create mycelium composite materials that consist of organic matter 'glued' together by mycelium filaments.

Finally, one specific type of fungi, mycorrhizal fungi, obtain sugars via beneficial relationships with plants, exchanging them, via their mycelia, for moisture and soil nutrients. These fungi help to maintain plant and soil health, which has positive impacts in areas such as nature-based carbon sequestration and agriculture.

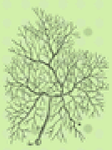
JARGON BUSTER

Filamentous fungi

Filamentous fungi is a broad term for a diverse group of fungal organisms. In nature, they play an important role in the ecosystem, as many species feed by decomposing dead organic matter.

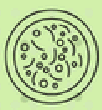
Hyphae

'Hyphae' are the basic cellular building blocks of filamentous fungi. They are elongated, thread-like cells that grow outwards from the tip.



Mycelium

As hyphae grow they repeatedly branch, creating complex networks of interconnected filaments, which is what we call 'mycelium'.

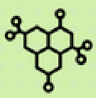


Culture medium

In many production processes, the mycelium is initially grown in a nutrient-rich substance called a culture medium, before being transferred to a substrate.

Substrate

The substrate is a mass of organic material that acts as food for the fungus, and through which the mycelium grows. Substrates can be made up of waste from human processes, creating promising possibilities for the circular economy.



Enzymes

As the mycelium penetrates the substrate, the tips of the hyphae secrete powerful chemicals called enzymes that break down the organic compounds on which the fungus feeds. These chemicals (as well as others produced by the fungi) have many potential useful applications in industry and beyond.

Mycelium applications

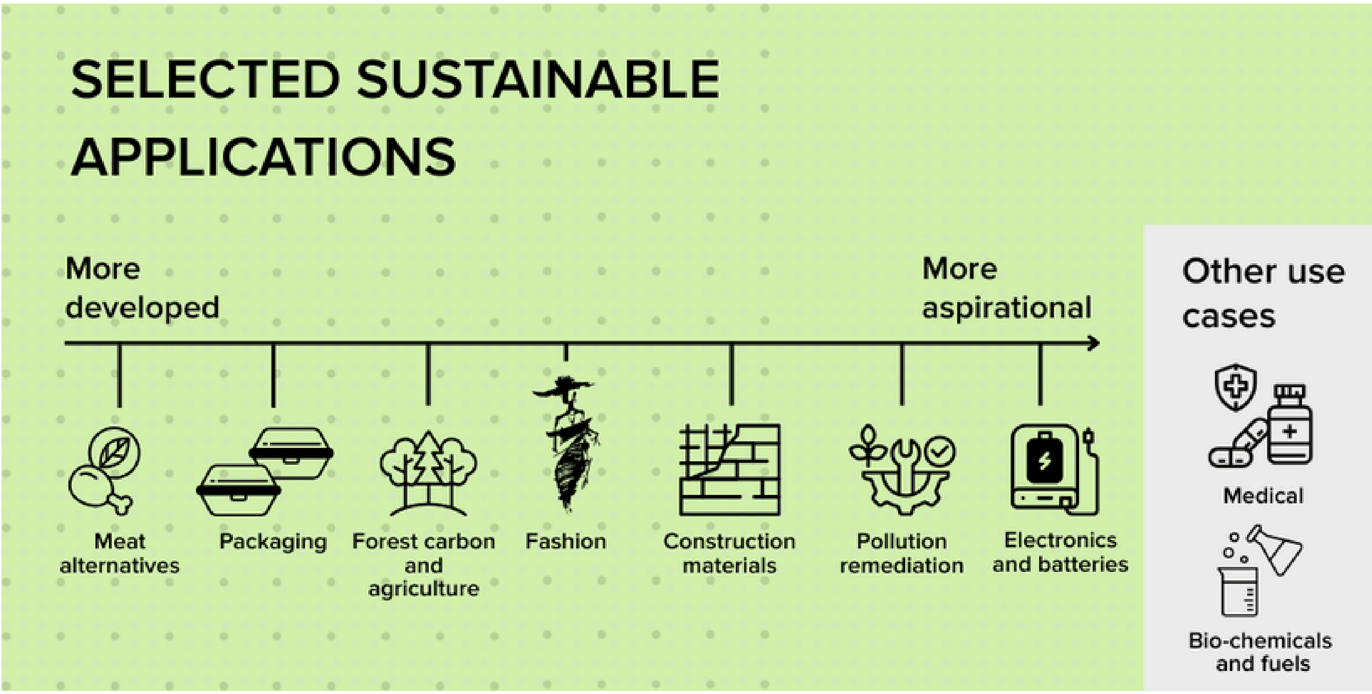
Mycelium can be used in a broad range of applications, some well-established, others more aspirational. “It all started with fungal innovations in alternative protein and packaging,” explains Susanne Gløersen, founder and CEO of The Future is Fungi Award, a global award recognising fungal science and startup innovation. “We have also seen a lot of sound insulation companies.”

Beyond this, other types of solution are emerging. “I love myco-remediation, which is cleaning soil and water with fungi, but it's still early days,” says Gløersen. “I also really like replacing petrochemicals in products. In cosmetics, homecare products, and food, we use surfactants made of petrochemicals, and we can replace those with fungi.”

The list below (far from exhaustive) outlines some of the key sustainability-focused applications for fungi and mycelium.

Alternative proteins

Quorn is perhaps the most established mycelium brand on the market, having been launched in the 1980s. However, there continues to be innovation in the use of fungi and mycelium for alternative proteins (a.k.a. meat replacements). A 2020 white paper, published in the journal Fungal Biology and Biotechnology, notes that if the hyphae of filamentous fungi are aligned and organised, they create a structure that looks like, and has the mouthfeel of, meat – particularly chicken. There are also other ways that mycelium can play a role in the development of meat alternatives. For example, they can be used as a support structure in cultivated meat production, where meat is grown from animal cells in a lab.



Mycelium shows promise as a meat substitute from a nutrition perspective, and fungi-based foods produce significantly less pollution than livestock farming, while also being more water efficient. The wider alternative meat market has struggled in recent years, and not everyone is convinced that alternative proteins are the most exciting mycelium application. "I'm not too focused on alternative protein," explains Gløersen. Nonetheless, there are exciting innovators working in this space, such as German company Kynda, which has created a plug-and-play solution for industrial partners to produce a range of meat alternatives and food products using mycelium.

Packaging

Another of the more established mycelium applications is packaging, particularly foam protective packaging that can replace polystyrene. These innovations take advantage of the inherent bonding properties of mycelium as well as its biodegradability. Mycelium packaging production typically uses custom growing chambers and moulds to shape the packaging into the desired shape. These moulds are often made in-house, meaning that startups in this space require expertise in 3D modelling and 3D printing.

$208.8 million

The forecast size of the mycelium packaging market by 2034

Estimates for the potential size of the mycelium packaging market vary, but at the top end, one market report forecasts that it could grow to $208.8 million by 2034. This is modest compared to the $25.67 billion the polystyrene market was calculated to be worth in 2024, but mycelium packaging has already been adopted by some big-name brands, such as Dell and IKEA. Ecovative Design is a key company in this space, while others include Dharaska Ecosolutions and S.Lab.

Beyond foam packaging, MadeRight is using fungi to turn waste materials into 'drop-in' additives that are mixed with traditional or bio-based plastics to create pellets compatible with existing manufacturing processes for both flexible and rigid packaging.

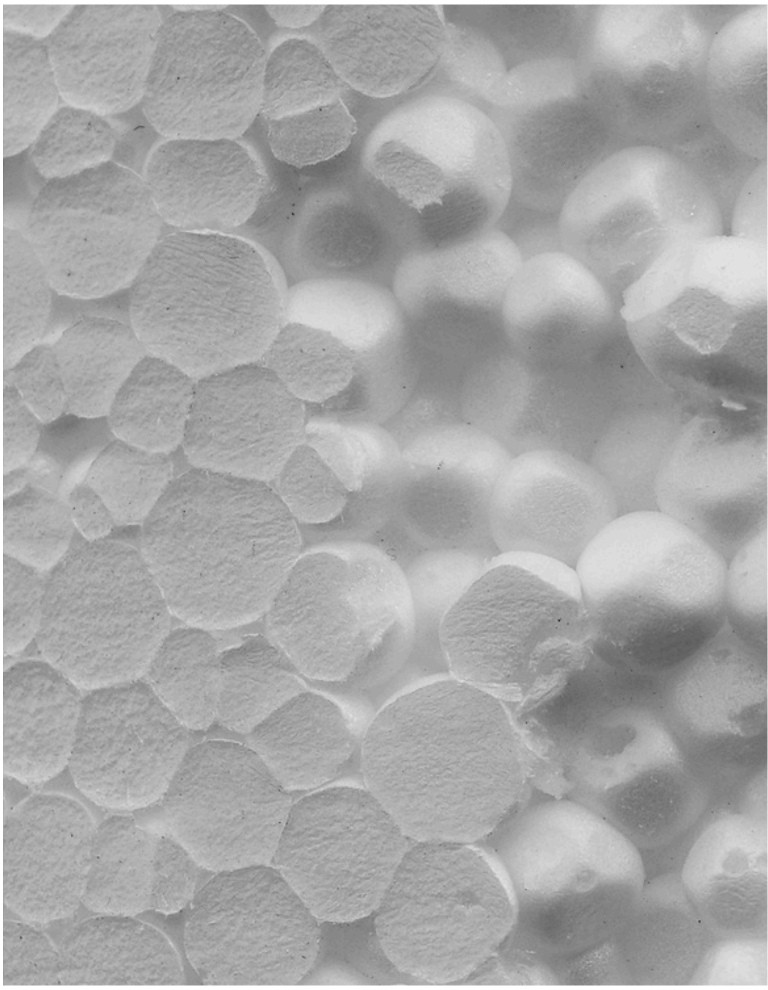


Photo credit: © Thanakon / Adobe Stock

Forest carbon and agriculture

More than 250,000 plant species are associated with mycorrhizal fungi, forming symbiotic relationships through their root systems. These fungi-plant connections are "vital for the soil structure, nutrient cycling, plant diversity, and ecosystem sustainability." In addition to keeping plants healthy, fungi play a crucial role in natural carbon sequestration, with University of Sheffield researchers finding that fungi store one-third of carbon from fossil fuel emissions. "Mycorrhizal fungi represent a blind spot in carbon modelling, conservation, and restoration," explains Professor Kate Field, a co-author of the study. "When we're thinking about solutions for climate, we should also be thinking about what we can harness that exists already," she adds.

> "Mycorrhizal fungi represent a blind spot in carbon modelling, conservation, and restoration."
>
> Professor Kate Field, University of Sheffield

Several startups are heeding this advice by using fungi to support nature-based solutions like tree-planting. Rhizocore turns fungi into pellets, which can be planted alongside saplings to boost the growth rates, resilience, and carbon-capturing potential of trees. Each pellet contains locally sourced fungi tailored to the specific planting site. Funga is another startup restoring forest soil with fungi. The company uses DNA sequencing and AI to generate profiles for a healthy fungal microbiome in around 1,000 different forests. This helps to identify the right combination of wild fungi for each location.

Like other plants, crops too form mycorrhizal relationships, yet soil fungi can be depleted by farming practices like over-tilling and commercial fertiliser use. Innovators are therefore also exploring fungi as a sustainable agriculture solution. Groundwork BioAg has developed Rootella, a family of mycorrhizal crop inoculants built on 30 years of research at Israel's Volcani Institute (ARO). These inoculants can be added to fields to boost crop resilience, increase water uptake, and reduce the need for expensive phosphorus fertilisers. The company also claims that Rootella can boost yields.

Photo credit: © thefarmer / Adobe Stock

Fashion

Another emerging application for mycelium is as a replacement for synthetic textiles and animal-based leather. “What we've seen over the last few years is that people are trying to match it [mycelium] against benchmarking materials, like leather, and there's real progress in achieving that,” explains Lars Dittrich of The Microbiology Research Group at Vrije Universiteit Brussel (VUB).

A 2025 literature review published in the journal Bioresources and Bioprocessing highlights that mycelium leather has a much shorter production period than animal leather, while also avoiding ethical issues associated with animal husbandry. The mycelium team at VUB currently has a strong focus on leather-like materials, and companies operating in this space include MycoWorks, developer of the ‘REISHI’ range of materials, which have been used in products such as furniture and fashion accessories.

The drawbacks of current mycelium leather include low mechanical strength, moisture sensitivity, and limited thickness. “What we focus on is really diving deep into the biology to address some of the issues with current mycelium materials,” explains Dittrich. “You can go really deep into the biology and address that.”

Mycelium could also be used to create other types of textiles, fabrics, and clothes. VUB PhD candidate Annah-Ololade Sangosanya showcased a mycelium jacket at this year’s Milan Design Week, using the opportunity to prove that mycelium-based textiles can be scaled up to complex fashion products.

Meanwhile, My-Fi is developing ‘myco-fibres’ made of chitin, a natural polymer that is a key component of the cell walls of mycelium. Chitin has a similar structure to cellulose, which is the building block of traditional natural textile fibres.

As with mycelium packaging, a key benefit of mycelium textiles is their biodegradability, which promises to address some of the environmental impact associated with today’s non-biodegradable synthetic fibres.

“What we focus on is really diving deep into the biology to address some of the issues with current mycelium materials.”

Lars Dittrich, Vrije Universiteit Brussel

Photo credit: © Supranee / Adobe Stock

Construction materials

Beyond the clothes we wear, innovators are exploring how mycelium can be used as a building material. Mycelium's ability to bind together the biomass it feeds on makes it possible to create mycelium-based composites. These 'MBCs' combine the mycelium itself with feedstock materials that can be sourced from waste streams, creating a circular solution. Shaped into bricks or panels, MBCs could be used as an alternative to carbon-intensive building materials in multiple applications.

A 2025 review article published in the journal Biotechnology Advances highlights that MBCs offer recyclability and low-energy production, in addition to providing a use for typically unrecycled waste. They also have further beneficial properties such as fire resistance.

On the other hand, a current limitation of mycelium-based materials is their typically low tensile strength. As a result, they are mostly being used for applications such as thermal and acoustic insulation, rather than more structural use cases. In 2017, architect Dirk Hebel and engineer Philippe Block used a composite provided by Indonesian company MYCL to create a self-supporting structure called the MycoTree. However, in general, more research and development is needed for high-strength applications. Smart species and substrate selection can enhance mycelium's performance properties, as can genetic and biochemical modification, suggesting that there is scope for future development in this vein.

Startups developing mycelium-based insulation include Biohm, MycoTile, and Mykor. Meanwhile, Mycocycle is taking a slightly different approach. The company takes waste streams originating from the built environment – such as floors, ceilings, and walls – and uses fungi to convert them into a new bio polymer additive material.

From the innovation library

Startups from our databse featured in this section include:

- Kynda
- Funga
- S.Lab
- Groundwork BioAg
- Dharaska Ecosolutions
- Biohm
- MadeRight
- Rhizocore

The Springwise Innovation Database contains over 15,000 innovations. For unlimited access, become a member today.

Photo credit: © exclusive-design / Adobe Stock

Pollution remediation

For millions of years, fungi have played a crucial waste management role within ecosystems due to their ability to break down dead biomass, including more complex compounds like lignin. Innovators are now leveraging this ability to tackle human-made pollutants in both soil and water, a process known as 'mycoremediation'.

"Fungi have an inherent ability at which they excel, which is using pollutants as a food source – because that's their niche in ecology," explains Max Nijman, co-founder and CTO of MycoFarming, a startup operating in this emerging field. "We harness that power of fungi to tackle a wide range of pollutants, mostly in waters. That can be anything from fertiliser residues like nitrates and phosphates to more difficult to solve problems like oil, PFAS, microplastics, and pesticides."

> "Fungi have an inherent ability at which they excel, which is using pollutants as a food source."
>
> Max Nijman, MycoFarming

Mycoremediation works through multiple mechanisms, such as biodegradation, biosorption, and bioaccumulation. In biodegradation, the powerful enzymes produced by mycelium break down persistent pollutants into less harmful molecules. In biosorption, the mycelia bind pollutants onto their cell wall, reducing their bioavailability and toxicity. In bioaccumulation, toxins are slowly absorbed into the tissues of the fungus, effectively removing them from the environment.

One of the exciting features of mycoremediation is that it can produce useful end-products, such as food, feedstock, or fertiliser, thereby turning harmful waste into something valuable.

Beyond MycoFarming, which primarily focuses on water pollution, other mycoremediation startups include Novobiom, which won the startup prize at the Future is Fungi Award, alongside another mycoremediation solution. The company is focusing on soil remediation at industrial and brownfield sites. In addition to tackling recalcitrant soil pollutants (a.k.a. those that don't easily degrade naturally), the startup's solution is implemented on-site. This means it enables customers to avoid the costs and carbon emissions associated with shipping contaminated soil to a centralised treatment facility.

Photo credit: © konoplizkaya / Adobe Stock

Emerging frontiers

At the bleeding edge of mycelium technology are a range of applications that are only now being fully explored by researchers and innovators.

For Lars Dittrich at VUB, one exciting area of development is the creation of materials where the fungi remain alive in the finished product. This can create interesting new properties, such as the ability for a mycelium material to heal itself. “Self-healing is the next frontier, because, at the moment, we treat the organism in a way where it makes the material but then it’s inactivated as it’s in use,” he explains. “Over the longer term, it's that question of the livingness of the material. Is that something we can tap into much more?” At the Venice Biennale in 2023, the VUB team demonstrated the potential of living materials by displaying ten sheets of mycelium material at different stages of self-repair.

Another, slightly unexpected, frontier application for mycelium is in electronics. According to the Bioresources and Bioprocessing review article, this is because branching mycelia can act as conductors or electrical components, while different geometries (shapes) of mycelium can compute various logical functions. Hi-tech applications in biocomputing and biosensing, while at an early stage, are currently being pursued by institutions like the Unconventional Computing Laboratory at the University of the West of England.

Another avenue of innovation is the use of fungi to create biodegradable batteries and energy storage systems. Researchers at the Swiss Federal Laboratories for Materials Science and Technology, for example, have created a fuel cell for small electronics that uses two types of fungal yeast to convert nutrients into energy.* One of the two complementary yeast species was used for the battery’s anode, while the other was used as the cathode. Another research team, led by Jens Laurids Sørensen of Aalborg University, won the science prize at the 2023 Future is Fungi Award for its work using fungi to produce molecules for an aqueous battery that stores renewable energy.

Finally, according to the white paper in Fungal Biology and Biotechnology, fungi hold much promise for next-generation biomanufacturing, and specifically the upgrading of wood waste streams into next-generation biochemicals and biofuels. Many waste substrates from the wood supply chain, such as pulpwood, wood shavings, and recycled paper, are unsuitable for traditional chemical upgrading due to challenges such as low purity and the need for costly cleaning processes. Filamentous fungi, however, can selectively transform desired target compounds, even when they are contained within complex mixtures.

Mycelium has very broad potential across multiple sectors. The next section explores some of the factors that determine the performance and success of mycelium innovations.

* Yeasts are not filamentous fungi, so including yeast-based batteries under the banner of mycelium is not strictly accurate. Nonetheless, they are an interesting area of innovation.

Success factors

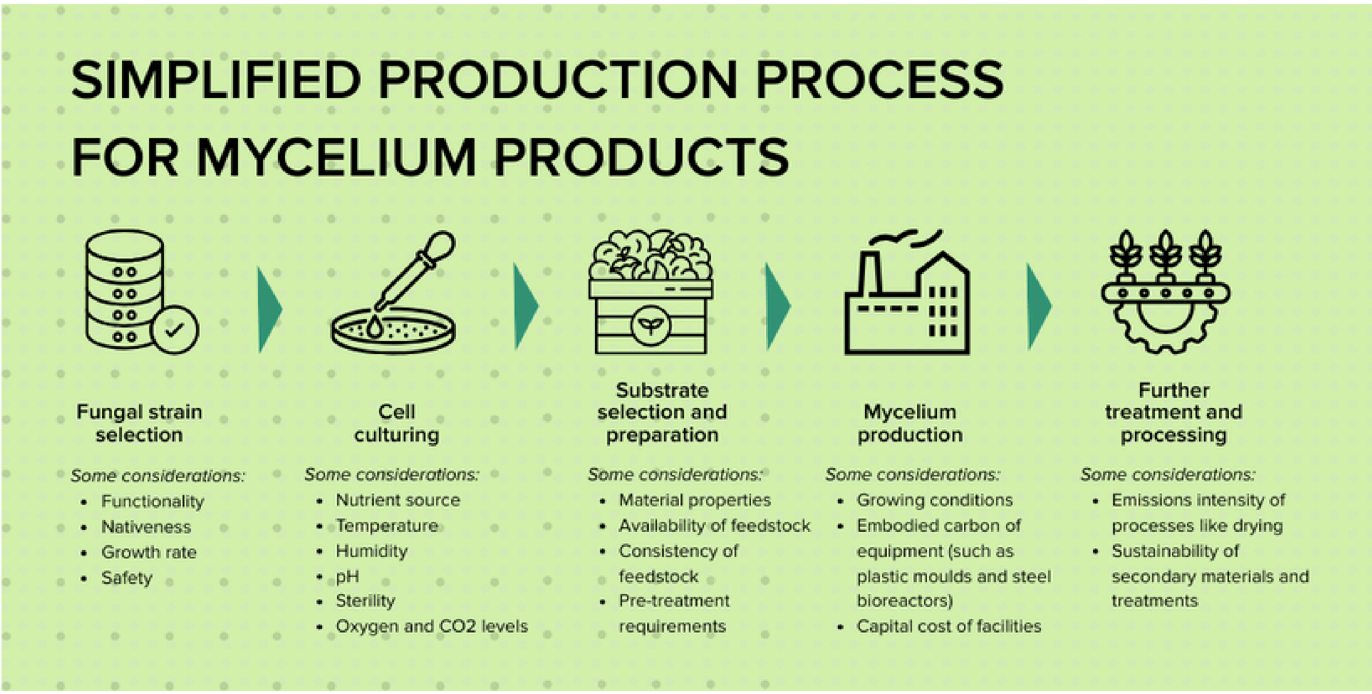
In addition to appreciating the potential applications of fungi-based solutions, it's important to understand the commercial and environmental factors that determine whether a mycelium innovation will be successful. To simplify significantly, the properties of mycelium-based products are a function of the species of fungi, the substrate, the growing conditions, and any further manufacturing processes required to finish the product.

Outlined below are some of the key considerations that mycelium innovators (and those looking to partner with them) should take into account.

Species selection

Fungi are a kingdom of organisms on the same rung in the taxonomic hierarchy as animals and plants. They therefore come in a huge range of shapes and sizes, and the selection of the right species (or combination of species) for the right application is a key element of any mycelium innovation.

"We use a wide range [of species], from oyster mushrooms for simple stuff like nitrates and phosphates ...to other totally unrelated mushrooms that are more suitable for plastic, PFAS, and medicine, for example," explains Max Nijman of MycoFarming. "We have built a giant catalogue of fungi that are capable for a wide range of applications."



The importance of species selection is reflected in the emergence of a new category of company that aims to support innovators working in this space. "We see startups building fungal discovery platforms: finding new fungal types that we can use for industry," explains Susanne Gløersen of The Future is Fungi Award. One of these is Oxford-based Really Clever, which pinpoints specific types of fungi and matches them to potential commercial applications.

An important factor in species selection is nativeness, particularly in applications such as mycoremediation, agriculture, and nature-based carbon sequestration, where fungi are being introduced into the wider environment. Like all organisms, fungi have evolved to live in specific habitats. "What works in the Netherlands does not necessarily work in Latin America or Africa," explains Nijman.

In addition to impacting the effectiveness of the end-product, nativeness is also important from an environmental perspective, as it's vital that any fungi introduced into an ecosystem do not become invasive or environmentally harmful in their own right.

Beyond identifying promising species in nature, innovators can also enhance the properties of naturally occurring fungi using a range of chemical, physical, and molecular biological protocols. This makes it quicker and easier to develop fungi with desirable traits for various applications.

Matching species and substrate

For applications like mycelium leather, textiles, and construction materials, matchmaking fungi with the perfect substrate material is crucial for determining the end product's properties.

"One of the main tasks is having your input material, the food for the fungus, matched to the right fungus, and then having the right processes developed to obtain an optimal result," explains VUB's Lars Dittrich.

The ability to mix and match different fungal strains and substrates makes it possible – in theory at least – to create products with extremely diverse properties. The Biotechnology Advances review article highlights that: "The development of MBCs [mycelium-based composites] is marked by vast possibilities due to the diversity of fungal species and substrate types, each contributing unique characteristics to the final material." The species-substrate match is therefore one of the main bases on which mycelium companies compete.

Meanwhile, companies that use mycelium to recycle specific waste streams face a similar challenge: identifying species that can tackle particularly tricky materials. Mycocycle, for example, uses two species of fungi. The first works on most of the materials the company deals with. However, to tackle rubber, the startup developed a second, which was adapted from an organism found growing naturally on the material. "We were able to swab it and see what was growing on there," explains Joanne Rodriguez.

The production process

The conditions in which the mycelium is grown play a further important role in the success of a mycelium-based product. Typically, the fungi are initially grown in a nutrient-rich culture medium before being transferred to the substrate. Controlling conditions during both of these stages is essential. Factors like pH, temperature, and humidity must be optimised, while the fungi need to receive the right nutrition when they are being cultured. It's also crucial that sterility is maintained to prevent contamination. "We work really hard to figure out the dynamic of temperature, pH, and food for it [the fungus] prior to giving it to the waste," explains Rodriguez. Optimal growing conditions vary by species type, and, alongside the species-substrate match, they are an important area of intellectual property in the sector.

From an environmental perspective, maintaining consistent growing conditions requires climate control, which can be energy intensive. It's therefore important that processes are as efficient as possible, utilising renewable energy where possible. What is more, mycelium manufacturing facilities often utilise materials that have significant embodied carbon. For example, a particular sustainability challenge associated with mycelium-based composites is the use of moulds made from plastic. These factors must all be factored in when calculating the sustainability of mycelium solutions across their entire lifecycle.

Further treatment and processing

Once the mycelium has been grown and harvested, it is typically subject to a range of further processes, such as drying and chemical treatments. This is particularly important in fashion applications (where customers expect a particular look and feel) and construction (where innovators use post-processing to boost material properties).

"A lot of the material that is out there is grown with the organism, but then there's a lot of processes after to make it as good as it looks," explains VUB's Lars Dittrich. "It's not just mycelium, in the same way that leather is not just the skin of an animal." This post-processing has implications for sustainability as it not only consumes energy but can also involve the use of materials, such as plastic coatings, with a high environmental impact.

Because of this, the mycelium team at VUB is focused on optimising the core mycelium material to try and reduce the need for post-processing. "What we focus on is really this core of how well we can work with biology to make the raw material as good as possible to then not have all those other steps and coatings," explains Dittrich.

To optimise the benefits of switching to mycelium-based products, innovators need to consider sustainability across the entire value chain. In Dittrich's words: "It really matters what the feedstocks are, and how we grow the organism. We need to avoid making this, on paper, sustainable material in an unsustainable way."

These success factors point to some of the challenges with mycelium, which will be explored in the next section.

Challenges

As with all new technologies, innovators must overcome some key challenges if mycelium solutions are to reach the mainstream. The various applications outlined in this briefing note are all different from one another, and each face specific hurdles. However, there are some higher-level issues that cut across all (or many) of the different areas of development.

Skills and expertise

One important challenge when scaling mycelium technologies is the need for relevant skills – in university departments, in startups, and in corporates. Beginning at the academic level, a BBC headline from 2023 claimed that "fungi are underloved and understudied", and the Fungal Biology and Biotechnology white paper points out that: "The science on filamentous fungi has always been lagging behind that on many other microorganisms, such as yeast and bacteria." With millions of species of fungi, all with their own unique characteristics, the research community on any given species is relatively small and fragmented. To tackle this, initiatives like the Future is Fungi award aim to boost interest in mycology (the science of fungi) by shining a light on fungi innovations, including those at the university level.

Beyond academia, it's also vital that startups seeking to commercialise mycelium technology have the right mix of skills. "It's a trade-off between having a novel idea that fixes a problem and knowing what you need to do," explains Max Nijman of MycoFarming. He therefore underlines how important it is to "have a good, versatile, diverse team." Fortunately, he adds, "the one power that startups have is that they can attract talent."

Meanwhile, at the corporate level, it's important that companies can access appropriate skillsets when determining which mycelium innovators to partner with. "We need scientists to assess this," explains Susanne Gløersen of The Future is Fungi Award. Some of these skills will come from corporates bringing talent in-house, and Gløersen is confident that, "since we're moving to a bioeconomy, many companies will hire more people with biology backgrounds." However, collaboration will also play a key role. For example, Gløersen told Springwise that The Future is Fungi has plans to establish "industry verticals where we bring corporates, startups, and scientists together for knowledge sharing and cooperation."

Photo credit: © russcom / Adobe Stock

Consistency and standardisation

Mycelium is a living system, so mycelium-based manufacturing processes are impacted by the inherent randomness of biology. This makes it difficult to achieve standardised outputs – something that is particularly problematic given that many mycelium products aim to replace existing materials and must therefore match established performance standards. This challenge of consistent quality is particularly acute in certain applications, such as fashion and construction materials.

Challenges at a glance

- Filamentous fungi have traditionally been understudied compared to other types of industrially relevant organisms. There is therefore a need to build interest at the academic level, and skills within startups and larger organisations.
- Mycelium-based manufacturing is impacted by the inherent randomness of biology, so processes must be carefully controlled to achieve sufficient consistency of outputs.
- As with other areas of deep tech, mycelium technology comes with high up-front capital costs.
- Consumer taste preferences and expectations for blemish-free products are a hurdle for some mycelium applications.

With mycelium being such a new field, part of the problem is a lack of standardised guidelines for species selection and production parameters. Collaboration to establish these frameworks would go a long way towards solving this problem.

There is a further consistency challenge when it comes to inputs, particularly for mycelium startups working with waste streams. "We control what we can control because the waste comes in and we don't know [what it will contain]," explains Joanne Rodriguez of Mycocycle. One of the things often found in feedstocks is other organisms, and Mycocycle employs a dedicated mycologist to understand the contaminants that regularly occur and develop mitigation strategies to deal with them. "It's not if something comes in with it, but how do we respond to that," explains Rodriguez.

Photo credit: © VisualCrafter / Adobe Stock

Scalability and capital costs

A key challenge for mycelium innovation is scalability – "corporates need scale," as Gløersen puts it. However, this scale does not come cheap, and many mycelium startups face high capital costs when they move towards commercialisation. "There's so much capex needed to have industrial capacity," explains Gløersen, who herself has a background in venture capital. "It's not right that startups should be the one having all these capacities – they fundraise so much to build it."

The review article on mycelium-based composites in Biotechnology Advances similarly raises the issue of capex: "Uncertainties in scalability result from significant capital investments, particularly for the extensive space and controlled environment needed in large-scale fermentation setups."

Capital costs are a common issue across hardware startups, but as outlined in the next section, collaboration and the reuse of existing infrastructure could help to make it more manageable.

Photo credit: © thithawat / Adobe Stock

Mycelium innovators must also decide whether to build new types of manufacturing system or tailor their solutions to slot into existing processes. As Lars Dittrich of VUB puts it: "Do we create a material that really fits seamlessly into the existing manufacturing process of the product, or are there things that change due to some positive benefits of the material?"

Consumer acceptance

A final challenge affecting some categories of mycelium innovation is consumer acceptance. As highlighted above, organically grown materials are susceptible to imperfections, which consumers conditioned to expect blemish-free products may not accept. Mycelium also inherently has a different aesthetic to other materials, which may clash with customers' existing expectations and preferences.

For applications like forestry and agriculture, meanwhile, adopting mycelium-based products represents a departure from long-established practices in industries with narrow profit margins. Mycelium solutions could therefore be perceived as risky, creating resistance to their implementation.

To tackle these challenges, it's important that those working to develop mycelium solutions invest sufficient time and resources into educating consumers about the benefits and properties of mycelium products.

While there are undoubtedly hurdles to scaling mycelium solutions, the next section will explore the flip side: the opportunities available for organisations seeking to leverage and optimise mycelium technology.

Opportunities

While there are naturally challenges involved in scaling up a novel technology like mycelium, there are also same under-explored opportunities that can help to expedite and optimise the process. As with the challenges, there are more granular opportunities for each specific application, but some general themes emerge.

AI and big data

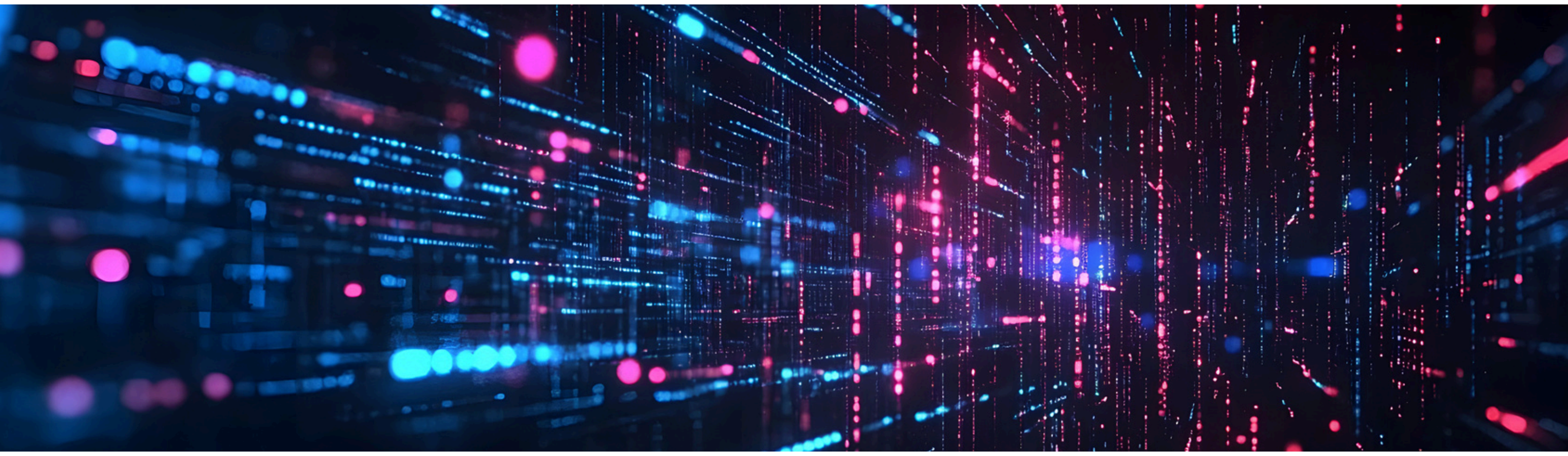
Recent years have seen seismic developments in the use of AI, and these breakthroughs could be applied to mycelium innovation – just as they are transforming many other sectors. "I'm very sure we will see much more use of AI," explains Susanne Gløersen of the Future is Fungi Award.

Several parts of the mycelium value chain are susceptible to AI optimisation. With millions of species found in nature, identifying specific fungi for a commercial application is something of a 'needle in a haystack' problem. However, AI systems can streamline this process through their ability to quickly and accurately analyse large data sets, such as image libraries and DNA 'bar codes'.

What is more, AI can facilitate the digitisation and automation of biomanufacturing processes using filamentous fungi. According to a 2023 review article in the journal Bioresource Technology: "With the current digital transformation within the biomanufacturing sector, the interest of automating fungi-based systems has intensified." The article highlights that AI and automation can boost yields and reduce labour costs, while machine learning can uncover complex interactions that take place during fungi cultivation. Meanwhile, 'soft sensors' (software systems that process multiple measurements together) can further facilitate our understanding of the dynamics of bioprocessing.

> "I'm very sure we will see much more use of AI."
>
> Susanne Gløersen,
> The Future is Fungi Award

Photo credit: © PixPacks / Adobe Stock



Commercial collaboration

Collaboration between startups and corporates holds much promise for unlocking the scalability of mycelium products – particularly if the deeper-pocketed party is willing to contribute towards the capital cost of equipment and facilities. “I would encourage corporates to think about this as a collaboration across the value chain,” explains Gløersen.

What questions should larger organisations be asking of potential startup collaborators? “The golden goose with startups is traction, actual market traction, because there are a lot of ideas that are out there, but you need to prove that it works,” explains Max Nijman of MycoFarming.

For Mycocycle’s Joanne Rodriguez, transparent and realistic discussions about the capacity and capabilities of mycelium are central to any effective collaboration. “I think we want it [mycelium] to be the end-all, be-all, and sometimes, as a result, we don't talk about those challenges efficiently enough,” she explains.

> “The golden goose with startups is traction, actual market traction, because there are a lot of ideas that are out there, but you need to prove that it works.”
>
> Max Nijman, MycoFarming

For her, understanding the challenges and what the startup is doing about them is the key consideration for potential partners: “Where are those companies making the investment of time to overcome the challenges?”

As with any climate innovation, sustainability claims, particularly those related to biodegradability and end-of-life, need to be sufficiently interrogated to avoid the risk of greenwashing.

Repurposing infrastructure

One thing that could help to facilitate corporate-startup collaboration is the possibility of leveraging existing infrastructure to help scale mycelium solutions. “Some of them [corporates]... have infrastructure capability already – they have fermentation technology,” Gløersen explains.

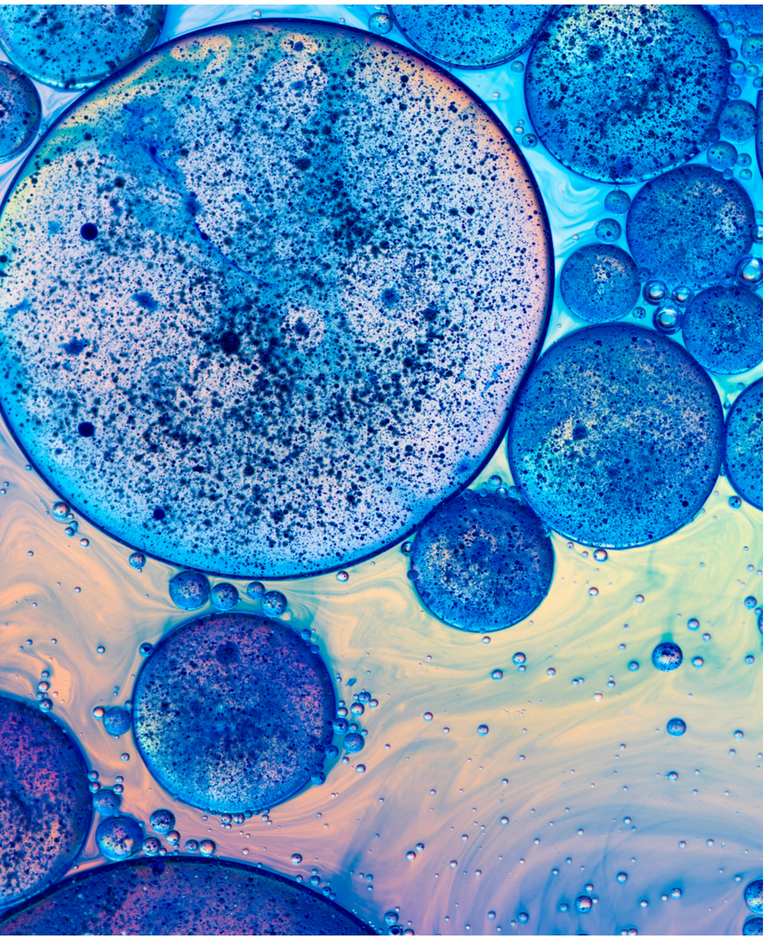
An example of a partnership exploring this possibility is a tie-up between alternative protein startup Infinite Roots and Bitburger Brewery Group. Not only is Infinite Roots using brewers spent grain as a feedstock – it is also repurposing brewery infrastructure for its production process. Another key mycelium company, Ecovative, has also demonstrated that its AirMycelium technology can be deployed in existing infrastructure with minimal modification.

Continuous manufacturing

On the technical side, there are further opportunities to optimise manufacturing processes for some mycelium applications. One possibility proposed in the Bioresources and Bioprocessing review article is a move towards continuous manufacturing.

Currently, many mycelium processes are batch-based, meaning that the substrate is inoculated with the fungi and then incubated in controlled conditions until a desired yield is reached. The mycelium is therefore harvested in discrete 'batches'. In continuous manufacturing, by contrast, the fungi are continuously fed growth substrate and harvested in a continuous flow, leading to higher throughput and greater consistency.

Photo credit: © Daco / Adobe Stock



According to the article's authors, continuous manufacturing allows for "a more efficient and scalable production system." They are therefore "convinced that the large-scale production and utilisation of mushroom mycelium will increase dramatically if even a partial continuous process is possible."

Discussion of the merits of batch-based versus continuous processes is reminiscent of developments in other sectors such as pharmaceuticals, where continuous manufacturing has become more popular in recent years for both commercial and environmental reasons.

Opportunities at a glance

- Big data and AI can help innovators with tasks like species selection, and automation can make mycelium-based production processes more efficient.
- Collaborations between startups and larger organisations can help to deliver vital capital investments.
- Many organisations have existing infrastructure that could be repurposed for mycelium applications at little cost.
- Moving to continuous (rather than batch-based) manufacturing processes could unlock efficiency and scalability.

Final thoughts

At the most basic level, mycelium is exciting as a climate solution because it has three fundamental abilities: it can break larger compounds down into simpler ones, it can bind organic material together, and it can act as a carbon sink. These adaptations are the result of millions of years of evolution and are useful to us as we tackle our interconnected planetary crises. They also allow for a wide range of potential applications across many sectors of the economy.

The big promise of mycelium is that it could enable us to create greener, cleaner industrial processes that consume less water and emit less carbon than our existing petrochemical-reliant systems. What's more, mycelium's biodegradability means that products made from it cause fewer problems at end-of-life, and fungi's ability to create value from waste could help to unlock the circular economy.

As with any new technology, commercial-scale adoption of mycelium is not a straightforward endeavour. Beyond the incremental technological optimisation that is likely to occur as more innovators dedicate themselves to mycelium, there is a specific need to focus on allocating human and financial capital where it is needed most.

The growth of interest in mycelium reflects a broader shift towards a bioeconomy that leverages living systems to create the products we rely on with less impact on the planet. According to McKinsey, as much as 60 per cent of the physical inputs to the global economy could, in principle, be produced biologically. The emerging ascendancy of biology will require professionals with expertise in life sciences to bring their skills to new settings, including industries where they haven't traditionally been involved. Mycelium is one of the technology areas where the rubber is hitting the road with this megatrend.

Second, mycelium solutions, with their significant capex requirements, reflect the growing importance of hardware and deep tech in the early-stage capital ecosystem. Scaling this type of solution is a very different task to building the software startups that have historically been the focus of Silicon Valley. Finding innovative ways to make capital investments, such as through partnerships with larger organisations or repurposing existing infrastructure, will be key to achieving mycelium's potential.

If these challenges can be met, then there's every possibility that we will live to see a world where many of the products in our daily lives are derived from mycelium.

About this briefing note

The purpose of this briefing note is to provide an introductory overview of the emerging field of mycelium technology, with the Springwise editorial team highlighting the key themes that emerged through their research. Information was sourced from a selection of academic articles, with a particular focus on literature reviews, as well as general desk research. Further insight came from in-person interviews with four experts. Interested readers are directed to the articles and organisations listed below for a more comprehensive understanding of the field. The Springwise editorial team has attempted in good faith to validate the information contained in this briefing note, but cannot make guarantees as to its accuracy or completeness.

If you have any feedback or further information to share on this topic, please contact: matthew@springwise.com

Key academic articles cited:

Camilleri, E., Narayan, S., Lingam, D., Blundell, R., Mycelium-based composites: An updated comprehensive overview, Biotechnology Advances 79 (2025). https://doi.org/10.1016/j.biotechadv.2025.108517

Hawkins, HJ., Cargill, RIM., Van Nuland, ME., Hagen, SC., Field, KJ., Sheldrake M., Soudzilovskaia, NA., Kiers, ET. Mycorrhizal mycelium as a global carbon pool. Curr Biol. 33(11):R560-R573 (2023). https://doi.org/10.1016/j.cub.2023.02.027

Meyer, V., Basenko, E.Y., Benz, J.P. et al. Growing a circular economy with fungal biotechnology: a white paper. Fungal Biol Biotechnol 7, 5 (2020). https://doi.org/10.1186/s40694-020-00095-z

Shin, HJ., Ro, HS., Kawauchi, M. et al. Review on mushroom mycelium-based products and their production process: from upstream to downstream. Bioresour. Bioprocess. 12, 3 (2025). https://doi.org/10.1186/s40643-024-00836-7

Wainaina, S., Taherzadeh, M., Automation and artificial intelligence in filamentous fungi-based bioprocesses: A review, Bioresource Technology 369 (2023). https://doi.org/10.1016/j.biortech.2022.128421

Interviewees

Joanne Rodriguez, Founder and CEO, Mycocycle

Lars Dittrich, Dissemination and Knowledge Valorisation Consultant, Vrije Universiteit Brussel

Max Nijman, Co-founder and CTO, MycoFarming

Susanne Gløersen, Founder and CEO, The Future is Fungi Award

Featured startups

Alternative proteins	Packaging	Forest carbon and agriculture	Fashion	Construction	Pollution remediation	Fungal discovery
Kynda	Dharaska Ecosolutions	Funga	My-Fi	Biohm	MycoFarming	Really Clever
Infinite Roots	Ecovative	Groundwork BioAg	MycoWorks	MYCL	Novobiom	
	MadeRight	Rhizocore		Mycocycle		
	S.Lab			MycoTile		

Photo credit: © ec0de / Adobe Stock