UNIVERSITY OF CAMBRIDGE

Mycelium-Algae Bio-Composite Packaging

Tan Hui Hui, Lok Yi Hang

Priority Topic Area: **Responsible Production, Innovation and Industry**

1 – Aim: Mycelium-algae bio composite as alternative packaging materials for polyurethane (PU) and expandable polystyrene (EPS)

PU and EPS are widely used for packaging fragile goods due to their lightweight, durability, and shock-absorbing properties. However, their non-biodegradable nature, lack of recycling infrastructure, and reliance on a linear economy contribute significantly to environmental pollution, posing risks to biodiversity. In 2022, global demand reached 33 million tonnes, yet recycling rates remained below 14%. A sustainable alternative is **mycelium-based bio-composites**, which are biodegradable and eco-friendly. Reinforcing them with algae enhances water repellence, making them a viable replacement for conventional short-lifespan packaging materials and promoting a shift toward a circular economy.

Properties	Polyurethane (PU)	Expandable polystyrene (EPS)	Mycelium bio-composite	Algae
Density / kg m^{-3}	38.2	12 -50	178.5	50 - 150
Moisture retention (%)	5.2	≈ 0	30	16.3
Sound absorption coefficient	0.6 - 0.9	0.13	0.2275	0.565
Thermal conductivity / W $m^{-1}K^{-1}$	0.0336	0.069950	0.053984	0.2905
Limiting Oxygen Index (O_2%)	21.3	19	23	23.5
Compressive strength / kPa	240	150	262.3	10.8

Table 1: Comparison of the materials properties, with boxes highlighted in green as more favourable, followed by light green, yellow and finally red as the least favourable material.

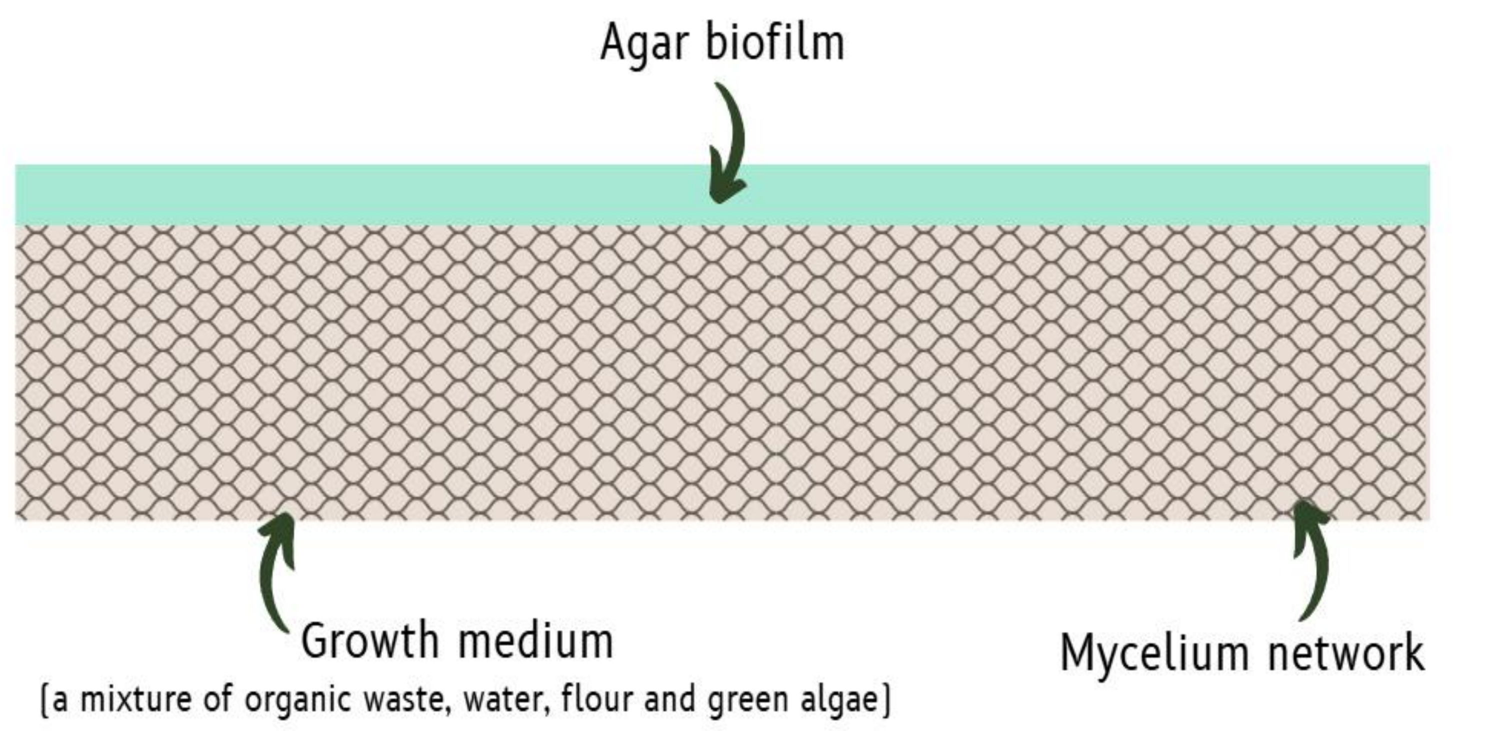

Figure 1: Illustration of coating of agar derived from algae on the surface of mycelium network

2 – Methodology: Enhancing Mycelium-Based Biocomposites - Algae Integration for Improved Water Resistance and Growth Efficiency

Research shows that mycelium-based polymers possess high mechanical strength due to their interconnected hyphal network. However, prolonged moisture exposure reduces their hydrophobicity, and production time is constrained by fungal growth rates.

To address these challenges, this study proposes **integrating algae with fungi to enhance water resistance and accelerate fungal growth.** Specifically, **coating** mycelium polymers with agar derived from algae to improve hydrophobicity, while **algal compounds would stimulate fungal development.** This approach aims to optimise large-scale production efficiency, making mycelium-algae bio-composites a more durable and scalable alternative for industrial packaging.

3 – Outputs: Predicted Performance and Environmental Benefits of Mycelium-Algae Biocomposites for Packaging

The mycelium-algae bio-composite exhibits promising properties that could make it a viable alternative to PU and EPS for packaging applications.

- **Density** can be **varied through compression**, allowing **customization** for different packaging needs.
- **Moisture resistance** improves significantly when a **thin lamination film** is applied.
- Interestingly, bio-composites with lower water resistance tend to have higher biodegradability, offering **flexibility in packaging lifespan** based on industrial or consumer requirements.
- The material also demonstrates higher sound absorption compared to EPS, indicating **better sound insulation capabilities.**
- The presence of aromatic compounds like lignin from agricultural waste and phosphorus in mycelium contributes to significant char formation, **enhancing fire resistance.** In contrast, EPS and PU are non-fire-retardant, highly flammable, and release toxic gases when burned.
- The comparison of key properties reveals that the mycelium-algae bio-composite has a **higher compressive strength (262.3 kPa)** than EPS (150 kPa) and **comparable moisture retention (16.3%)**, **sound absorption (0.565)**, and **thermal conductivity (0.053984 W m-1K-1)**.

These findings suggest that mycelium-algae bio-composites offer **enhanced properties** over traditional materials, such as better sound insulation, fire resistance, and biodegradability, making them a sustainable packaging solutions.

4 – Benefit to society

- By utilising abundant and cost-effective renewable materials, mycelium-based composites can significantly **reduce carbon emissions**— 0.37kg CO2 per kg compared to 2.7kg CO2 per kg PU and 6.9kg CO2 per kg EPS.
- Unlike starch-based biodegradable packaging, mycelium-algae bio-composites can degrade in both home and industrial composting **without requiring specific conditions**. This reduces landfill waste, curbing methane emissions, besides minimising soil and groundwater contamination.
- Additionally, it **supports circular economy** by repurposing agricultural waste as nutrients for fungal growth, while packaging waste decomposes naturally after use.

This solution benefits not only the packaging industry but also waste management and environmental conservation.

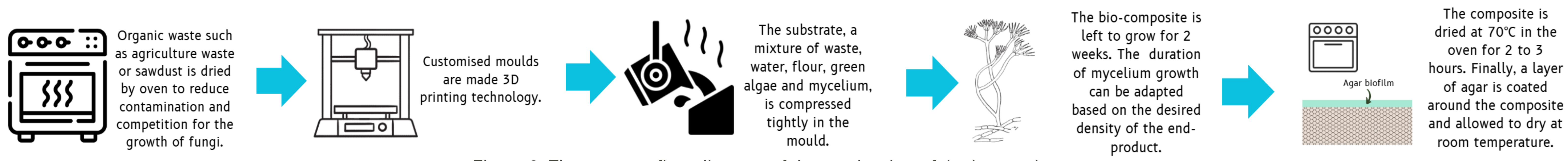

Figure 2: The process flow diagram of the production of the innovation.

5 – Next steps

Research will focus on optimising mycelium polymer coatings for better water resistance while maintaining biodegradability, ensuring both durability during use and efficient degradation after disposal.

Following this, life cycle assessment and prototype testing will be conducted to evaluate performance and environmental impact.

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