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Scaling-up biodesign – weaving logic of mycelium-based-composite architecture

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Abstract

Mycelium-based composites (MBC) proved to be the one of the first biofabricated materials that can be implemented directly in architectural and interior design settings. The study presents a novel method of MBC biofabrication, which functionalises filaments of MBC stabilised by textile-net tubes as weft, woven on the cotton string warp. Cotton strings are arranged spatially by hanging to allow for three-dimensional formations and physical gravity-based finding of the optimal form. The demonstrators are the subsequent upscaling attempt after initial small-scale (30–60 cm height) proof-of-concept prototypes (Biale et al., 2026), which proved feasible. The goal of the study was to understand better the interplay and interdependencies of the process's parameters in all of the biofabrication phases (filament production, assembly, water transfer and skin formation during growth, contamination prevention, drying and shrinking) in the (case of bigger demonstrators 120 cm height) cultivated in semi-sterile conditions. The study has developed an understanding of which aspects become more significant as the element's size increases and has verified the feasibility of this biofabrication method for future upscaling efforts.

Impact statement

The work shows grassroot experimentations in the development of the novel, textile facilitated and textile inspired, filament based, scaleable, moldless, fabrication method for mycelium-based composites in architectural applications.

Introduction

There has been a recent surge of interest in the mycelium-based composite as a material that can be easily fabricated using a low-energy setup. In the initial experiments, the fabrication of the MBC elements predominantly followed the simplified methodology for inert materials (casting in plastic moulds), without acknowledging growth-related features as design opportunities. The overarching goal of this research is the development of a material-driven biofabrication technique that treats growth as the design driver, unfolding new spatial, physical, and aesthetic opportunities for the upscaling of MBC construction. The experimentation draws on the craftsmanship of textile production techniques, which allow for the transformation of linear into surfaces or volumes with technique-inherent porosities. The work sees potential in developing MBC construction methods that leverage inherent porosity to utilise mycelial skin formations (air mycelium) more effectively, supporting better material utilisation and optimisation (Gomaa *et al.* 2024) and potentially enabling self-healing futures (Elsacker *et al.* 2023).

The demonstrators are testing, in the enlarged scenario (Figure 1), the custom construction method, which has proven successful in past smaller-scale prototypes ('stool' (30 cm height) and 'coffee table' (60 cm height)) (Figure 2) (Biala *et al.* 2026, Kühner *et al.*, 2025).

Due to the large spaces and high volumes of mycelium materials required for upscale experimentation, research of this type is usually relatively rare in typical microbiology laboratories. We take advantage of the available, unique infrastructure of architecture schools' digital fabrication laboratory, paired with the grassroots biolab, which made such experimentation possible.

Fabrication and cultivation

The study presents a novel method of MBC biofabrication, which functionalises filaments of MBC stabilised by textile-net tubes as weft, woven on the cotton string warp. Cotton strings are arranged spatially to allow for three-dimensional formations and physical gravity-based finding of the optimal form. Two architectural demonstrators were developed: funnel column and dome (Figure 1).

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Figure 1. Demonstrators: column and dome.



Figure 2. First small-scale prototypes, 2024.

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Figure 3. Process steps of filament preparation.

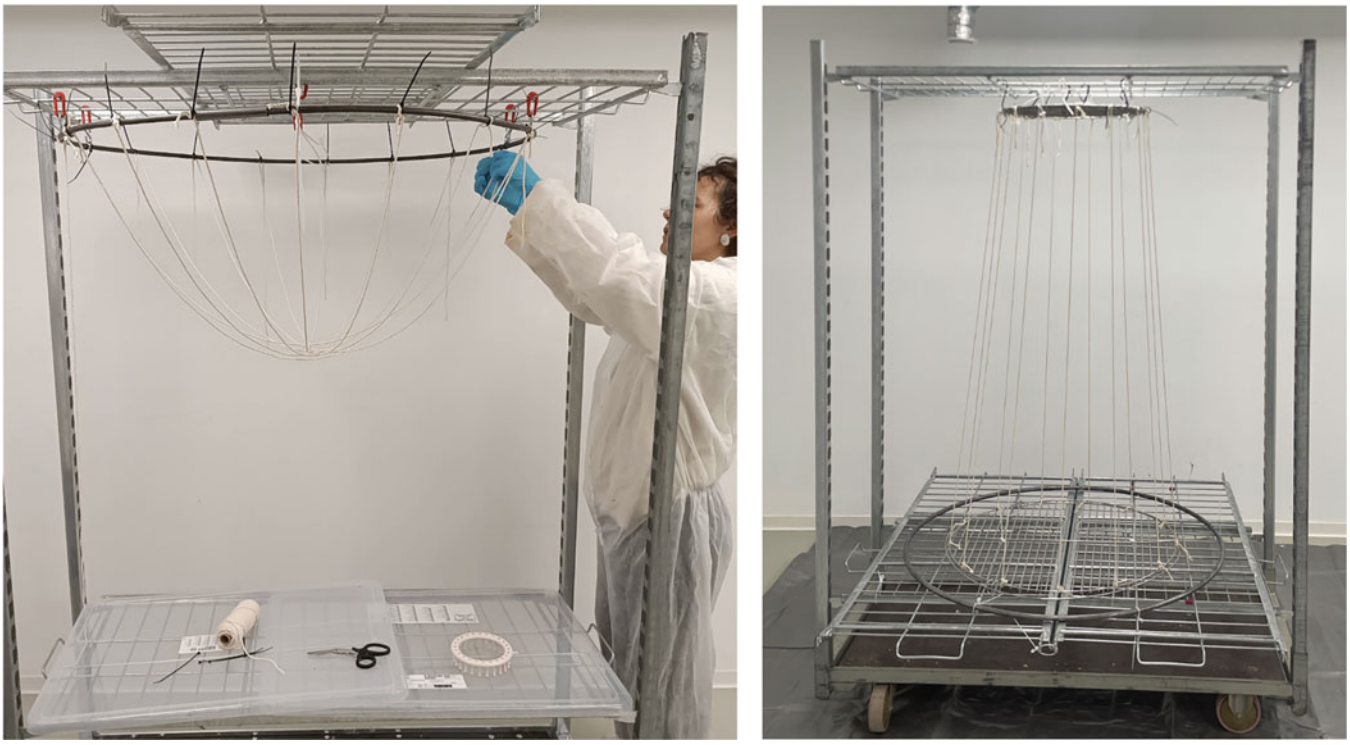


Figure 4. Scaffold preparation: DC trolleys as framework, and strings attached to metal loops.

The experiment aims to better understand the interplay and interdependencies of the process's parameters in all of the production phases (filament production (Figure 3), assembly (Figures 4, 5 and 6), water transfer and skin formation during cultivation (Figure 7), contamination prevention (Figure 8), drying and shrinking (Figure 9) in the case of upscaled demonstrators and semi-sterile growth conditions (mechanically ventilated room with HEPA filter, no sanitary sluices, not a clean room).

The main research questions were:

- How many layers of the filaments on top of each other are possible without pressing the material out of the net tubes or other significant distortions?
- Would handling necessary for the assembly allow for contamination-free cultivation?
- Would water transfer in the vertical direction (in a column demonstrator) compromise effective growth?

Filaments preparation

Filaments consist of Ganoderma lucidum pre-grown substrate (mix of soft and hard wood in unknown proportion, provided by the sawmill) stabilised by the external outer net tube (Nobanetz® Netzschlauchverband, 25 m, Gr. 0,5 Zehe). To limit contamination during hand preparation of filaments (Biala and Ostermann 2022, Kühner 2023), a semi-automated filling process was introduced.

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Figure 5. Weaving process of the column.

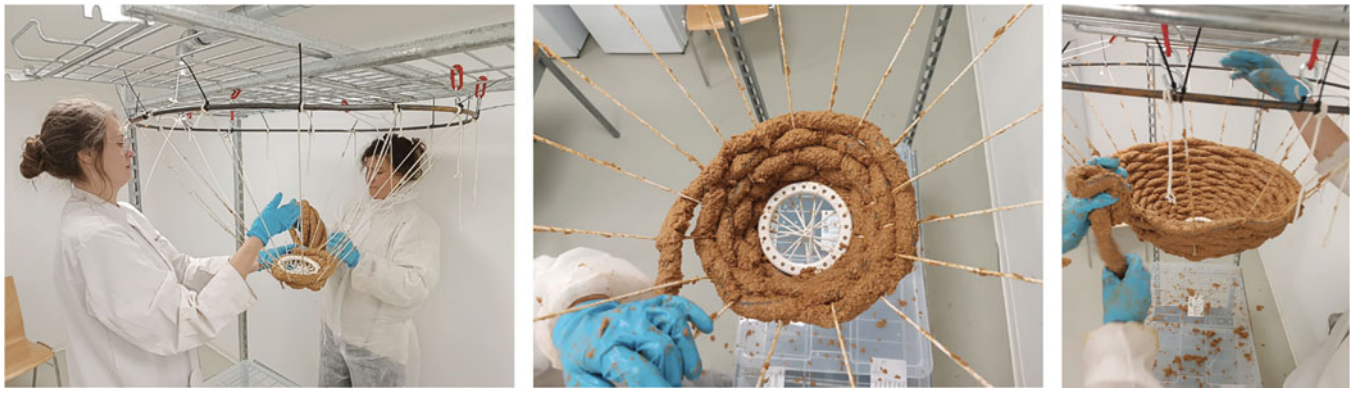


Figure 6. Weaving process of the dome.



Figure 7. Wrapping and sealing with painting plastic foil and tape.

Pre-grown substrate was shredded using a garden shredder (Remarc Elektro-Häcksler SUMMERTIME 2.1) and supplemented with additives (2% guar gum, 8% wheat flour, 70% tap water), providing the viscosity necessary for automated extrusion with the sausage-making machine (VEVOR Electric Sausage Stuffer 25L). Introduction of the equipment (shredder and sausage stuffer) minimised manual handling of the material and shortened this phase by 90% compared to the hands-only process (Figure 3).

Scaffold preparation

Scaffolds were determined by the elements already available in the lab: DC trolleys with metal wire, wire grill racks (45 and 75 cm in diameter), and metal hoops (90 cm in diameter).

For the funnel column, cotton strings were tensioned between the top and bottom grill racks attached to the trolley's shelves, spaced 150 cm apart. For the dome, the strings were tightly attached to the metal hoop on the trolley's shelf above. At the

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Figure 8. To prevent the spread of contamination, the spots were washed off by spraying water.



Figure 9. The dome was turned upside down after drying.

bottom, the 'oculus' from the plastic circular knitting loom was put on the strings to provide regular spacing of the string arrangement.

Strings had to be provided in odd numbers to ensure proper offset of the woven layers (13 strings per column; 17 strings per dome). Strings before attachment were washed with tap water. The metal scaffolds were wiped with alcohol (Figure 4).

Weaving

Both structures were woven by two people: one person moving the filament between the strings and the second providing the precise positioning and overlap. The weaving process of each demonstrator took about 1 hour. The elongation of the strings resulted in the formation of a funnel-shaped column. The first 15 cm reached a flat position, but thereafter the curvature was evenly distributed. In the dome case, the round shape formed as expected. We observed that friction between the filaments and the strings limits filament sliding, reducing the load on the lower layers of the filaments.

The structures were woven until easy hand access was possible (15 cm from the top attachment points). At the end of the weaving, the cotton strings were covered with a mycelium-based paste to prevent contamination (Figures 5 and 6).

Cultivation and tending

The ready demonstrators, together with the scaffolds, were wrapped in painting foil, taped with paper tape, for easy maintenance opening. According to the structure, flat plastic boxes were placed to catch the released solution, as expected. Tap water was sprayed on the foil to increase the humidity. They were checked daily to monitor growth progress (Figure 7).

After one day, a large amount of brown liquid droplets is being released from the structure. They are only present on the upside-down part of the structures. After another day, the droplet spots start to be covered by the mycelial skin, forming the spikes. The droplet locations and the puddles of released solution are where the contamination spots were observed. The phenomenon was much more intensely visible in the dome demonstrator.

To prevent the spread of contamination, the spots with the first signs of black points were washed off by spraying tap water and scraping them away with the toothpicks. If the contamination could not be easily removed (only on the three mycelial spikes), the whole spike was torn off. Within 2 days, the removed spikes grew over with the flat mycelium skin (Figure 8).

In the demonstrator column, after 1 day, mycelial skin formation was observed more intensively in the top part, creating a colour gradient from brown to beige. After 3 days, the difference was no longer visible.

Structures grew for 4 days at 28 degrees Celsius.

Drying

Growth was stopped when the first signs of primordia formation were observed. The foil was removed, the room temperature increased, and the room's ventilation system was installed. Both demonstrators were air-dried at 35 degrees Celsius using convection heaters placed in the isolated room. Air movement was provided by home ventilators and the room's mechanical

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Figure 10. The column is solid, hollow and free-standing.

ventilation. As the room (40 m^2) was used for drying multiple other MBC probes in parallel, the pieces could remain in this condition for 2 weeks (Figure 9).

The final dimensions of the pieces were:

Dome: 78 bigger diameter, 18 cm oculus, 34 cm height; 8.02 kg

Column 40 cm upper diameter, 68 cm lower diameter, 112 cm height; 14.54 kg (Figure 10).

Conclusion

The described work demonstrates that the proposed method allows for growing architectural elements with mycelium-textile hybrid filament. The method allows for easy creation of gravity optimised forms, profiting from the coherent formation of mycelium skin. The contamination challenge can be easily overcome regardless of the big scale of experimentation and semi-sterile conditions. The proposed paste recipe allowed for layering more than 30 layers

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Figure 11. Outlook and insight on the upscaling efforts currently done.

without major deformations with water transfer within structure not causing major issues.

The study has developed an understanding of which aspects become more significant as the element's size increases (friction of the strings, shrinking, access for contamination inspections) and has verified the feasibility of this biofabrication method for future upscaling efforts which are currently underway (Figure 11).

Data availability statement. Data sharing is not applicable to this article as no new data were created or analysed in this study.

Author contributions. E. Biala: Conceptualisation (equal), Methodology (equal), Investigation (equal), Resources (equal), Validation (equal), Visualisation (equal), Writing – Original Draft Preparation (lead), Review & Editing (lead), Project Administration (lead), Supervision (lead).
A-K. Kühner: Conceptualisation (equal), Methodology (equal), Investigation (equal), Validation (equal), Visualisation (equal), Writing – Review & Editing (supporting).
P. Baszynski: Investigation (equal), Resources (equal), Validation (equal), Visualisation (equal), Writing – Review & Editing (supporting).
M. Ostermann: Funding Acquisition.

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Competing interests. The authors declare that they have no competing interests.

Ethical standards. No ethical approval was required for the presented study as it did not involve human participants or animal testing.

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