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Mechanical Characterization of Mycelium Composites Based on Hemp

Tennessee State University, a member of the Environmentally Responsible Transportation Center for Communities of Concern (ERTC[3]) consortium led by the University of Missouri-Kansas City, is studying the mechanical properties of mycelium composites.

The mycelium-based materials have been mainly produced from mushroom-forming fungi, which are known for their ability to colonize large areas in nature. Mycelium composite materials rely on the metabolism of the fungus to form cementing products (mycelium) that can bond a substrate material, which is typically a waste material. These composites grow by decomposing lignin and absorbing elements such as carbon and nitrogen. Mycelium grows gradually and forms a mycelial network that intertwines and binds the substrate to form a polymer. This cycle is shown in Figure 1.

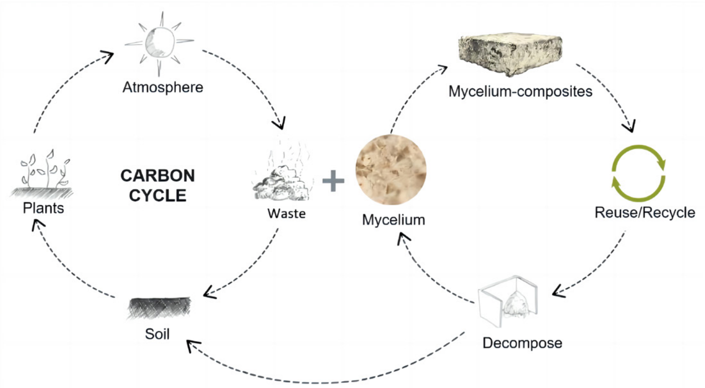

Figure 1. Diagram depicting how mycelium utilizes and reduces waste. Attias N,Danai O,Abitbol T,et al. Effect of agar concentration on structure and physiology of fungal hyphal systems, Journal of Materials Research and Technology, Volume 24,2023, Pages 7614-7623.

The global waste generation rate is soaring faster from 1.3 billion tons of waste generated in 1990 to 1.6 billion tons produced in 2009. It is expected to be around 2.2 billion tons annually by 2025. The inefficient recycling of nonbiodegradable wastes has resulted in the pollution of water bodies, landfills, fertile soils, etc. Recycling waste materials requires high energy consumption at the end of their lifetime. Additionally, waste generated by plastic materials poses a severe threat to the ecosystem, thus jeopardizing the lives of ocean and land creatures.

Therefore, it is essential to replace non-biodegradable products with biodegradable materials to minimize the environmental pollution and waste production. In response to this alarming rate of waste generation, research efforts have been made to provide alternative renewable technologies that can convert the present liability of waste into an ultimate sustainable resource for the future. For this purpose, the use of non-renewable resources must be reduced and replaced with renewable materials such as mycelium composites evaluated in this study.

Renewable mycelium-based materials have the potential to contribute to the new economy by replacing petroleum-based products such as plastics. These bio-based products of mycelium-based materials could be used for various applications in the construction of the transportation infrastructure.

Before this study, this research team evaluated hemp composites, another bio-based material and observed a critical relationship between mechanical properties of the material and curing conditions. Results indicated that hemp composites were not suitable for curing under high humidity conditions. Hemp composites were evaluated at different curing environments and curing times as shown in Table 1.

1d, 95%RH, Nature	*7d, 95%RH, Nature*	*14d, 95%RH, Nature*	*28d, 95%RH, Nature*
1d, 55%RH, Nature	*7d, 55%RH, Nature*	*14d, 55%RH, Nature*	*28d, 55%RH, Nature*
1d, 95%RH, Dried	*7d, 95%RH, Dried*	*14d, 95%RH, Dried*	*28d, 95%RH, Dried*
1d, 55%RH, Dried	*7d, 55%RH, Dried*	*14d, 55%RH, Dried*	*28d, 55%RH, Dried*

Table 1

Figures 2 and 3 show the bio-based hemp composites and their compressive strength values measured at different curing conditions and times. The three colors in each graph of Figure 3 represent the hemp-lime ratio in the mixtures. The green, orange, and blue lines represent a ratio of 0.2, 0.3 and 0.5, respectively.

The maximum ordinate value of all the graphs in Figure 3 is 1400 kPa. It can be clearly seen that the compressive strength of the samples under 55% humidity environment can be increased by ten times as much as that of the samples cured under 95% humidity. The compressive strength of the samples can reach 1300 kPa at the highest. Results also indicated that drying the samples after curing can significantly improve the performance


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Figure 2. Hemp composites

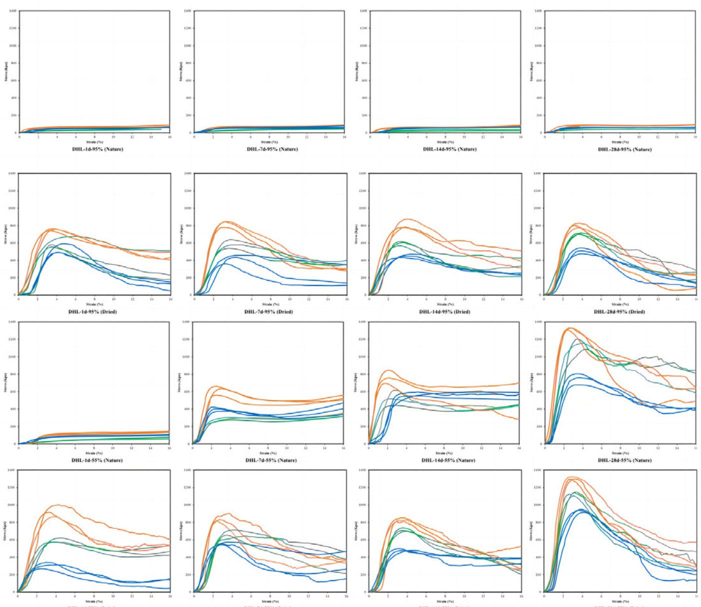
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Figure 3. Compressive strength of hemp composites

of the samples. However, after curing at 55% humidity for 28 days, the difference between the dried and undried samples were negligible, because the water inside the samples has been completely lost after curing at 55% humidity for 28 days.

The mycelium composites being evaluated in this study are similar to the hemp composites and their mechanical properties as well as their curing condition dependency will be compared to the earlier studied hemp composites.

The fungus will be cultured first to allow the mycelium composite to grow into a white hyphae state, as shown in Figure 4. As the mycelium continues to consume nutrients, it will continue to wrap around the hemp composite and finally form a block as shown in Figure 5.

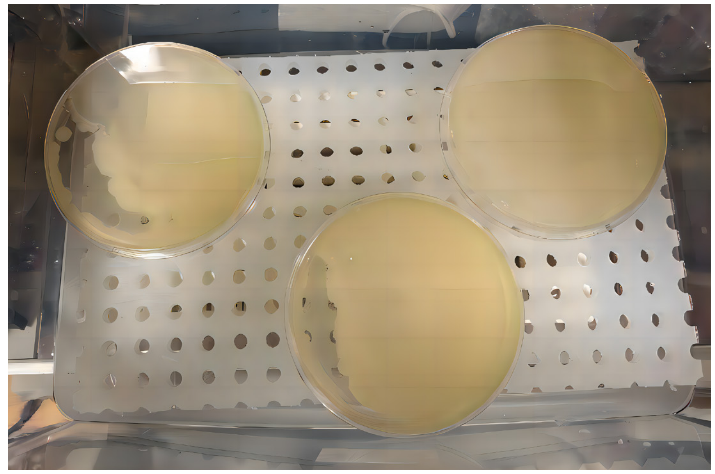
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Figure 4. Pleurotus ostreatus mycelium


Anastasia Cockerill

Figure 5. The mycelium fully incorporates into the plant substrate, forming a natural bio-composite foam. Anastasia Cockerill, Growing Together: Creating a Mycelium Based Gradient Material for Architectural Design,2020.

Further research will be conducted to achieve an optimal integration of mycelium with the hemp bio-base to enhance its mechanical properties. Leveraging their insights from previous studies that used hemp bio-base, the project team will also explore the potential of other underutilized bio-bases as viable substrates for mycelium growth. Use of waste materials as bio-bases for mycelium can lead to environmentally friendly construction materials with good mechanical properties that can support further development of our transportation infrastructure while preserving the environment.

About This Project

The project “Mycelium Composites Based on Hemp” is led by the Principal Investigator Dr. Catherine K. Armwood-Gordon, Associate Dean of College of Engineering and Associate Professor of Architectural Engineering, and Dr. Shihui Liu, Assistant Professor of Civil Engineering, at Tennessee State University. For additional information, please send inquiries to carmwood@tnstate.edu, and sliu1@tnstate.edu.

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