Development of Biodegradable Footwear Inputs from Mushroom Mycelium

Jillian Silverman, Huantian Cao, Kelly Cobb
University of Delaware, USA

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Apparel and footwear production and consumption contributes 21 billions of pounds of solid waste to landfills every year in the United States, comprising greater than 5.2% of the country's solid municipal waste (Council for Textile Recycling, n.d.). Many of the shoes sent to landfills contain toxic materials such as PVC, lead, and chromium, which may contaminate soil, air, and wastewater and pose significant risks to the environment and human health (McDonough & Braungart, 2002).

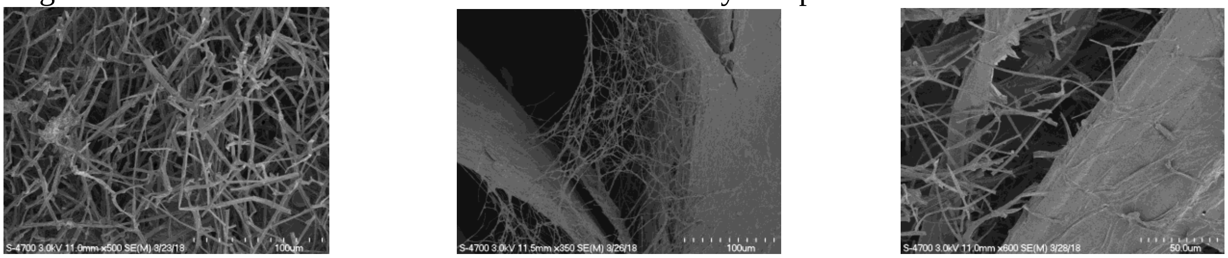
Bio-based materials have become increasingly popular in the fashion industry in the past few years, defined as "a material of which one or more of its components are sustainably grown and are fully renewable" and which help limit pollution and solid waste issues (Lelivelt, Lindner, Teuffel, & Lamers, 2015). Mycelium, the root structure of mushrooms, has been used to make composite materials for packaging, construction bricks, and shoe sole applications (Jones, Huynh, Dekiwadia, Daver, & John, 2017; Jiang Walczyk, McIntyre, & Chan, 2016). Grown on agricultural byproducts, mycelium acts as a natural binder, digesting and bonding to the surface of damp substrates as it grows (Jiang et al., 2016). Since all of the raw materials are natural, the mycelium composite is fully biodegradable (Holt et al., 2012).

The purpose of this research was to develop and evaluate mushroom mycelium composites that have a potential application for shoe soles. To offer a solution to problems of waste, pollution, human health concerns, and resource depletion, this research incorporated exclusively natural and non-toxic materials, and many of the inputs were locally sourced.

The experiment was a 4X2 design with two independent variables: mushroom species including reishi, oyster, king oyster, and yellow oyster, and natural fabric mats for reinforcement (with and without fabric). The growing procedure included mixing sawdust mushroom spawn with flour, psyllium husk, chicken feathers, and water for nutrition and structural support. The mixtures were put in 250 ml beakers and placed in a 25°C environmental chamber to grow for a week. The materials were then heated at 90°C to deactivate the spores, and cylindrical mycelium composites were developed.

The mycelium growth and interactions between mycelium and substrates were observed using a scanning electron microscope (SEM) (Hitachi, S-4700). The diameter, height, and weight of the composites were measured and the density of the composites was calculated. The compressive strength at 10% deformation was measured by a Tinius Olsen H5KT benchtop tester in accordance with the ASTM D1621 standard. There were five replications for each density and compressive strength test.

SEM images in Figure 1 exhibit that mycelium grew in the composite to form a fibrous matrix structure (a). The mycelium interweaves with chicken feathers (b) and textile fibers (c) to bond the composite components together. After mycelium growth, the loose materials in the original mixture turned into a cross-connected and sturdy composite.



a. King oyster mycelium b. Reishi bonding chicken feather c. King oyster bonding textile

Figure 1.SEM images of the composites

The density and compressive strength data of the mycelium composites are shown in Figure 2. Two-way ANOVA tests were conducted to determine the effects of mushroom species and fabric on density and compressive strength. For density, there was no significant interaction between fabric and species ($p = .117$), but the main effects of both species and fabric were significant ($p < .01$ for both variables). The fabric contributed to a lower density overall. A post hoc LSD test (significant at $p < .05$) separated species into three groups: (oyster = king oyster) > yellow oyster > reishi. For compressive strength, there was no significant interaction between fabric and species ($p = .938$) and no significant effect of fabric ($p = .162$), but the main effect of species was significant ($p < .01$). A post hoc LSD test (significant at $p < .05$) separated species into three groups: king oyster > oyster > (reishi = yellow oyster).

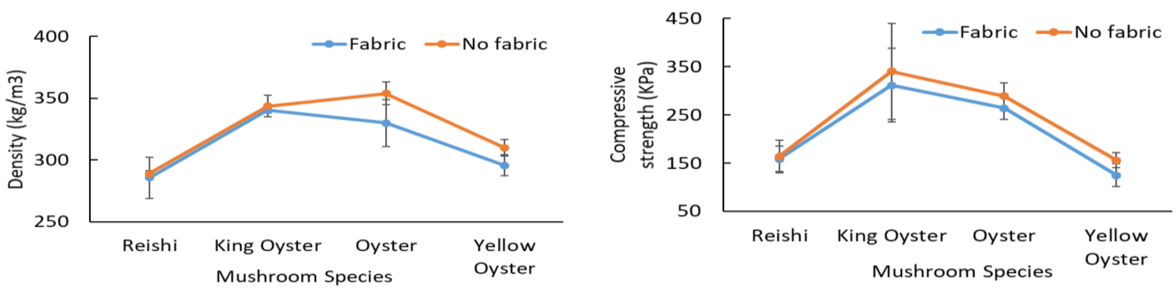


Figure 2. Density and compressive strength of mushroom mycelium composites

Mushroom mycelium composites were developed in this study. King oyster species provided the highest mean compressive strength of 340 KPa (no fabric) and 311 KPa (with fabric). Hessert et al. (2005) reported that while walking, the maximum foot pressures for young and old adults were 329 and 222 KPa, respectively, and the mean foot pressures for young and old adults were 89 and 62 KPa, respectively. This research provided support for the utilization of mycelium composites for shoe sole applications, particularly the king oyster species.

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