Bread waste + fungi = yarn

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The production of new materials from fungi is an emerging research area. In a research project at the Swedish School of Textiles at the University of Borås, wet spinning of fungal cell wall material has shown promising results. In the project, fungi were grown on bread waste to produce textile fibers with potential in the medical technology field.

Photo Ida Danell

Sofie Svensson's project addresses, among other things, the UN's Global Goals 9, sustainable industry, innovation, and infrastructure, and Goal 12, sustainable consumption and production, as the project aimed to use sustainable methods in a resource- and cost-effective way, with less impact on people and the environment.

Sofie Svensson, who recently defended her dissertation in the field of Resource Recovery, explained:

“My research project is about developing fibres spun from filamentous fungi for textile applications. The fungi were grown on bread waste from grocery stores. Waste that would otherwise have a significant environmental impact if discarded.”

The novelty of the project lies in the method used – wet spinning of cell wall material.

“Wet spinning is a method used to spin fibres (filaments) from materials such as cellulose. In this project, cell wall material from filamentous fungi was used to produce fibres through wet spinning. The cell wall material from the fungi contains various polymers, mainly polysaccharides such as chitin, chitosan, and glucan. The challenge was to spin the material. It took some time initially before we found the right conditions”, explained Sofie Svensson.

Graphic: Elias at Pixabay

Antibacterial properties

Filamentous fungi were cultivated in bioreactors to produce fungal biomass. Cell wall material was then isolated from the fungal biomass and used to spin a filament, which was tested for its suitability in medical applications.

"Tests of the fibers showed compatibility with skin cells and also indicated an antibacterial effect", said Sofie Svensson, adding:

"In the method we worked with, we focused on using milder processes and chemicals. The use of hazardous and toxic chemicals is currently a challenge in the textile industry, and developing sustainable materials is important to reduce environmental impact."

What is the significance of the results?

"New materials from fungi are an emerging research area. Hopefully, this research can contribute to the development of new sustainable materials from fungi", explained Sofie Svensson.

Interest from the surrounding community has been significant during the project, and many have had a positive attitude toward the development of this type of material.

When will we see products made from these fibers?

"This particular method is at the lab scale and still in the research stage", she explained.

The doctoral project was conducted within the larger research project *Sustainable Fungal Textiles: A novel approach for reuse of food waste.*

Photo collage showing pieces of bread waste left for drying, filamentous fungi under microscope, prototypes of fungal yarn, leather like material and plastics. Researchers Alice Lind, Sofie Svensson and Kanishka Wijayarathna in the Biotechnology lab, holding bags of harvested fungal biomass. Photos by Kanishka Wijayarathna (bread waste), Erik Norving (prototypes), Andreas Nordin (researchers) and Sofie Svensson (microscope).

What is the next step in research on fungal fibers?
"Future studies could focus on optimizing the wet spinning process to achieve continuous production of fungal fibers. Additionally, testing the cultivation of fungi on other types of food waste."

How have you experienced your time as a doctoral student in Resource Recovery?
"It has been an intense period as a doctoral student, and I have been really challenged and developed a lot."

What is your next step?
"I will be taking parental leave for a while before taking the next step, which is yet to be decided."

Sofie Svensson defended her dissertation on 14 June at the Swedish Centre for Resource Recovery, University of Borås.

Read the dissertation: Development of Filaments Using Cell Wall Material of Filamentous Fungi Grown on Bread Waste for Application in Medical Textiles

Opponent: Han Hösten, Professor, Utrecht University

Main Supervisor: Akram Zamani, Associate Professor, University of Borås

Co-Supervisors: Minna Hakkarainen, Professor, KTH; Lena Berglin, Associate Professor, University of Borås

Source: University of Borås, Solveig Klug

Abstract of the dissertation

There is a need for new sustainable textiles to reduce the problems related to the production of current textiles, including the use of nonrenewable resources, shortages of cotton, and the use of harmful chemicals. Bio-based materials developed from natural biopolymers are attracting increasing interest as sustainable alternatives to fossil-based materials. Biopolymers are produced by living organisms such as plants and microorganisms. The cultivation of filamentous fungi results in fungal biomass that is rich in biopolymers. In fungal biorefineries, food waste can be valorized via fungal cultivation, resulting in a broad range of value-added products.

In this study, filaments were designed from the cell wall material of filamentous fungi grown on bread waste and evaluated for application in medical textiles. The developed route for filament production uses benign processes and reuses food waste. Fungal biomass has long, branched threads called hyphae, microfibers with 2–10 µm diameters, which create a strong and flexible network (mycelium). These characteristics, along with the properties of biopolymers in the fungal cell wall, make mycelia a promising candidate for the creation of novel materials. The fungal cell wall, isolated from fungal biomass (mycelia), consists of a matrix of biopolymers, including chitin, chitosan, and glucan. The aim was to directly utilize the cell wall material for developing filaments without needing extensive purification of these biopolymers.

Fungal biomass was obtained by cultivating an edible filamentous fungus (Rhizopus delemar) with a cell wall rich in chitosan and chitin. Submerged cultivation using bread waste as a substrate was demonstrated on multiple scales, from 0.2 L shake flasks to a 1.3 m3 bioreactor. First, a protein hydrolysate was recovered from the fungal biomass via mild enzymatic treatment. The protein hydrolysate exhibited potential as an emulsifier and foaming agent. The never-dried cell wall material was isolated using alkali treatment for fila-

ment production. Hydrogels formed from the cell wall material after the addition of lactic acid. Hydrogel formation was attributed to the protonation of the amino groups of chitosan present in the cell wall. The hydrogels were wet spun into monofilaments using ethanol as the coagulation agent. The wet-spinning procedure resulted in the alignment of fungal microfibers along the monofilament axis, following which the coagulated monofilaments were collected from the coagulation bath and dried. The produced monofilaments were characterized regarding their morphology, mechanical properties, antibacterial properties, biocompatibility with fibroblasts, wound healing, and degradation behavior. The mechanical properties of monofilaments included a tensile strength of 106 MPa and elongation at break of up to 28%. The fungal monofilaments are suggested as suitable candidates for applications in medical textiles owing to their biocompatibility with human fibroblast cells and their antibacterial and wound-healing properties.

This method was also applied to another strain of edible filamentous fungi (Aspergillus oryzae), wherein the cell wall mainly comprises chitin and glucan. The cell wall material obtained from A. oryzae was subjected to deacetylation and freeze–thaw pre-treatments to achieve gelation, and the formed hydrogels were successfully wet spun into monofilaments.

The work presented in this thesis introduces the potential of the valorization of bread waste into value-added products based on a biorefinery concept utilizing different edible fungal strains. This process focuses on scalability and environmental benignity. This study contributes to the development of novel biomaterials and fungal proteins obtained from fungal cell walls for application in medical textiles and food products, respectively