Popular science summary

In a world where organic waste is underutilized and excess plastic pollutes the environment and food, scientists are looking for solutions that are aligned with the principles of the circular economy. The project addresses these challenges by focusing on a deeper understanding of the biological and material processes that occur during the fermentation of kombucha in the presence of biodegradable 3D scaffolds, lignocellulosic additives and natural pigments. The aim is to gain new knowledge on the influence of scaffold geometry, surface activation, and the composition of the fermentation environment on the growth of SCOBY, the properties of the biocellulose it produces as well as effectiveness of kombucha fermentation.

SCOBY is a natural symbiotic matrix of acetic acid bacteria and yeast, which creates a layered biocellulose structure during kombucha fermentation. This automatic process leads to the formation of durable, bioactive cellulose films, which have application potential, among others, in food science and functional materials. The project will analyze the influence of selected lignocellulosic additives, such as coffee grounds, vegetable pomace, tea or fermented vegetable and fruit juices on the bioactive properties of the fermentate and the structure and physicochemical characteristics of the produced biocellulose. Phenolic compounds, fiber and natural dyes present in these additives can affect both the growth dynamics of SCOBY and its functional value (e.g. antioxidant activity), color and microstructure. Fermentation will be carried out in the presence of biodegradable 3D scaffolds made of ecological polymers (PLA, TPS), which adopt diverse, nature-inspired geometries, including honeycomb or Voronoi system. These structures are designed to support the development of SCOBY, but also to modify its final morphology and mechanical properties of the resulting materials. Before fermentation, the scaffolds will be subjected to physicochemical activation using non-thermal methods, such as cold plasma or ultrasound, and after the process is completed, various drying techniques (microwave, radiant, convective or hybrid) are used to fix the structure and preserve bioactive properties. The obtained composites will be the subject of research in terms of potential use in the food industry as intelligent packaging films, indicator membranes monitoring food quality (e.g. by changing color in response to pH or temperature), and also as biodegradable disposable materials with increased durability and controlled permeability to gases and water.

The project includes four main stages, starting from the fermentation of kombucha with lignocellulosic additives, through the integration of SCOBY with biodegradable 3D scaffolds, to the drying processes and evaluation of the obtained materials. The effect will be the development of basic relationships between material and process parameters and the final properties of composites. The aim is to gain fundamental knowledge necessary for the further development of this class of materials and their future applications. The project will use advanced research methods, including atomic force microscopy (AFM), infrared spectroscopy (FTIR) and UV-Vis, crystallinity analysis (XRD), thermal property studies (DSC, TGA), as well as mechanical tests, wetting angle measurements and evaluation of antioxidant activity of the fermentate and its components. In parallel, the analysis of the biodegradability of composites in conditions similar to the environmental conditions will be conducted.

The research will allow for a better understanding of the relationships between the microbiological and material aspects of the fermentation process and the properties of the obtained product. The project emphasizes the use of local and waste resources, the development of technologies consistent with the "zero waste" strategy and interdisciplinarity combining biotechnology, engineering and microbiology. In addition to the scientific dimension, the project also has an educational character, inspiring a new perspective on food, organic waste and their potential in creating functional materials of the future. SCOBY is no longer just a component of a fermented drink and becomes a carrier of knowledge, a research tool and an example of a natural component that can be used in environmentally friendly materials engineering. Thanks to the synergy of fermentation, microbiology and material sciences, the project will also enable the exploration of the fundamental mechanisms of food preservation and extending its shelf life. Bioactive properties of plant additives and their interactions with the SCOBY matrix can potentially affect the inhibition of microbial growth, which is crucial in the context of food safety. At the same time, these studies create space for controlling the properties of materials by modifying fermentation parameters and additive composition, enabling the creation of structures adapted to specific food products and storage conditions. The project opens new directions of basic research in biotechnology, showing that waste and microorganisms can be a source of knowledge necessary to develop future solutions in the field of food quality and durability.