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Biotechnological upcycling of blended textile waste

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Large amounts of textile waste are still mainly discarded in landfills or incinerated. Therefore, novel approaches for keeping these materials in a circular application are urgently needed. Textiles often consist of blended fibers that can improve certain properties but at the same time represent a challenge in recycling processes. 65% of textile fibers are synthetic (mainly polyester and polyamide) that are often blended with natural and biobased cellulosic fibers (such as cotton and viscose) [1].

For textile-to-textile recycling pure materials are required which introduced the necessity of fiber blend separation. By application of cellulolytic enzymes, the cellulosic fibers are specifically targeted and hydrolyzed into the monomer glucose [2]. Thereby, pure synthetic fibers could be recovered for mechanical characterization and further reprocessing. Recovered polyester was confirmed to be suitable for reprocessing into textile fibers [3] and mechanical characterization of recovered polyamide as well showed comparable properties to virgin material in this study.

Enzymes can be separated after hydrolysis by membrane filtration which enables application of pure glucose solution on one hand and re-application of the enzymes on the other hand still showing 95% of the initial activity as well as equal process performance in terms of glucose concentration after five cycles (Figure 1).

The glucose monomer from the textile separation was applied as substrate for microbial production of two different biopolymers, polyhydroxybutyrate (PHB) and bacterial cellulose (BC) by *Cupriavidus necator* and *Komagataeibacter sucrofermentans*, respectively. High PHB content (up to 60%) was obtained inside the cells and as well comparable BC yield in comparison to standard cultivating conditions. Characterization of the obtained biopolymers through gel permeation chromatography (GPC), Fourier transform infrared (FTIR) spectroscopy, and electron microscopy as well showed equal properties (Figure 2). Produced biopolymers can eventually be reintroduced to the textile industry closing the cycle and developing towards a real circular bioeconomy.

In conclusion, the biotechnological approach presents an opportunity of specifically separating blended textile waste for recycling of the non-depolymerized fraction and as well convert the hydrolysate into valuable biopolymers.

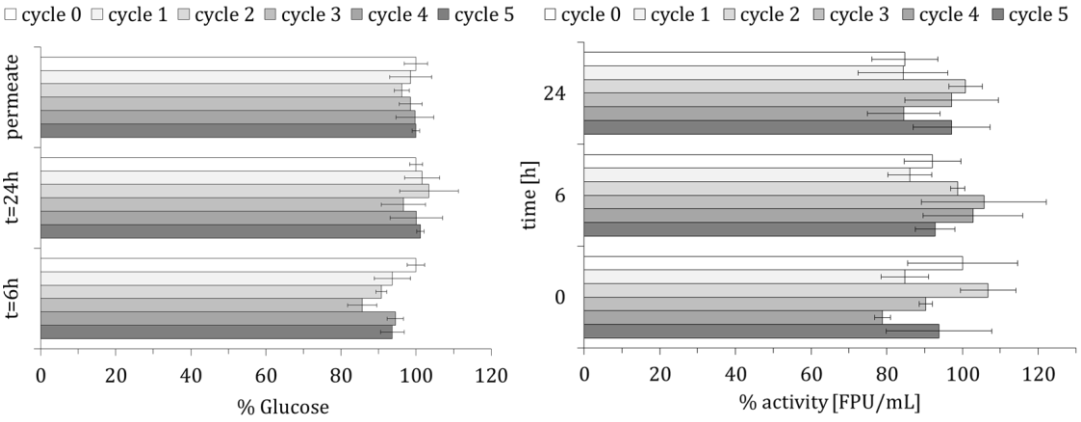

Figure 1 glucose obtained during enzymatic hydrolysis of cellulose for 5 recycling steps of enzymes (A) and cellulolytic activity during each cycle (B).

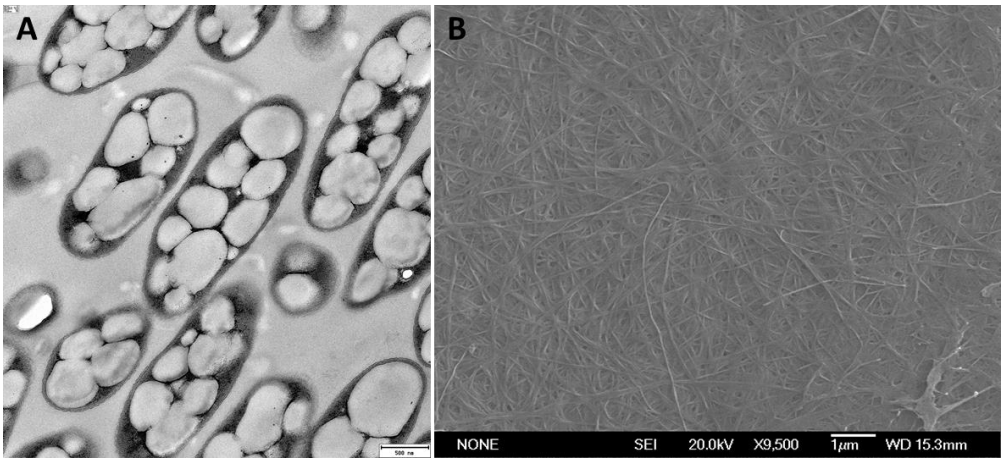

Figure 2 Electron microscope image of intracellular PHB granules from *C. necator* (A) and BC membrane from *K. sucrofermentans* (B) grown on textile waste hydrolysate.

Sources

[1] Textile Exchange (2024). Distribution of textile fibers production worldwide in 2022, by type. Statista. https://www.statista.com/statistics/1250812/global-fiber-production-share-type/#statisticContainer

[2] Quartinello, F., Vecchiato, S., Weinberger, S., Kremenser, K., Skopek, L., Pellis, A., & Guebitz, G. M. (2018). Highly Selective Enzymatic Recovery of Building Blocks from Wool-Cotton-Polyester Textile Waste Blends. *Polymers, 10*(10), 1107. https://www.mdpi.com/2073-4360/10/10/1107

[3] Gritsch, S. M., Mihalyi, S., Bartl, A., Ipsmiller, W., Jenull-Halver, U., Putz, R. F., Quartinello, F., & Guebitz, G. M. (2023, 2023/01/01/). Closing the cycle: Enzymatic recovery of high purity glucose and polyester from textile blends. *Resources, Conservation and Recycling, 188*, 106701. https://doi.org/https://doi.org/10.1016/j.resconrec.2022.106701