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BIOTECHNOLOGICAL SOLUTIONS FOR RECYCLING SYNTHETIC FIBERS

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Abstract

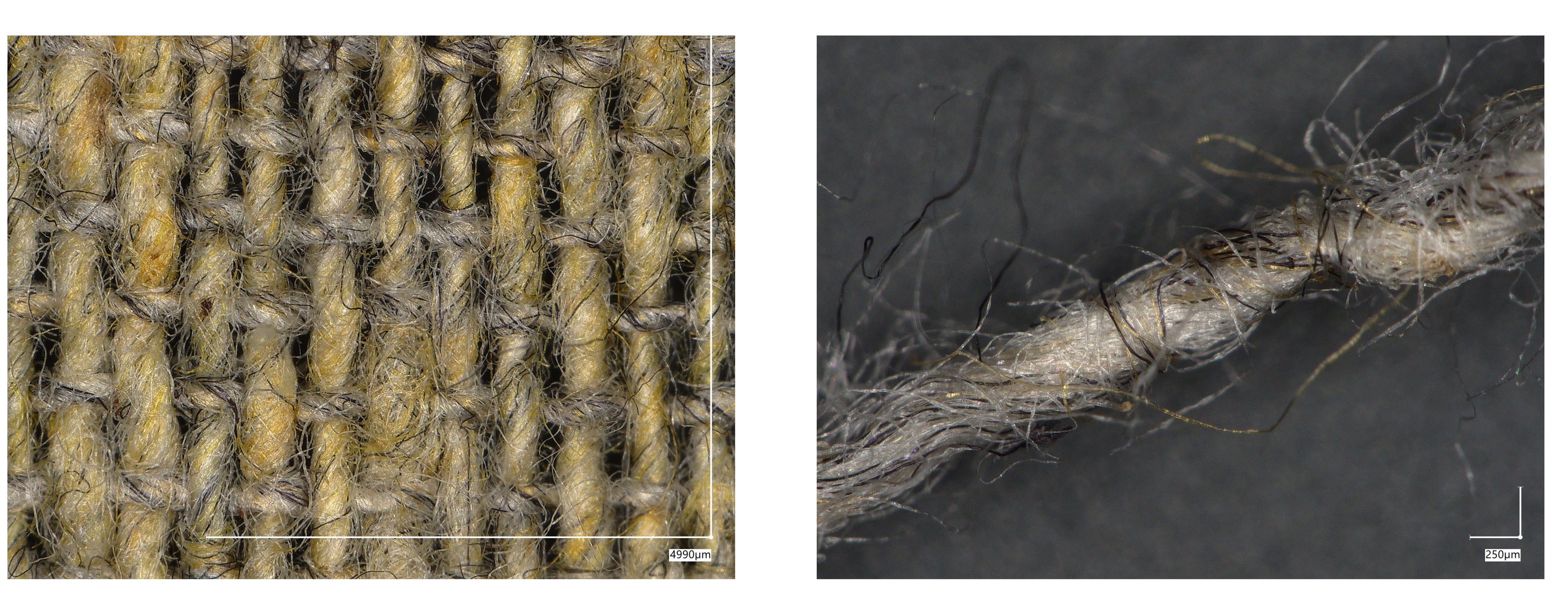
Biotechnology offers the potential for selective depolymerization of natural and synthetic fibers, isolation of components or recovery of monomers. This progress solves the problems associated with the regeneration of monomers from synthetic fiber blends, especially when contaminated or mixed fibers are involved. In addition, the recycling of used fiber products into higher value products not only keeps waste out of landfills, but also creates economic opportunities and reduces the need to produce new synthetic fibers. Synthetic fibers can be recovered by mechanical or chemical recycling, but biotechnological solutions with enzymes offer a better environmentally friendly alternative to harsh chemicals by selectively breaking down certain chemical bonds in polymers to obtain purer monomeric building blocks. Efficient biotechnological recycling, however, depends on the specific polymer, as different enzymes, microbial colonies, fungal hyphae, etc. can process different man-made fibers. This short review provides an overview of the possibilities of biotechnological solutions for synthetic fiber recovery.

Introduction

With growing environmental concerns, the textile industry faces pressure to reduce its ecological impact. The prevalence of synthetic fibers has resulted in slow degradation and increased waste [1,2]. Textile recycling involves mechanical and chemical processes, breaking down polymers or physically reprocessing fibers [3-5]. However, not all methods are sustainable. Biotechnological approaches are emerging, using microorganisms in bioreactors for large-scale recycling [6,7]. For instance, Marqués-Calvo et al. used fungal lipases and bacteria to degrade PET plastics [8], while Mohanan et al. explored microbial and enzymatic degradation of synthetic textiles [9]. This review focuses on mechanical and biotechnological solutions for synthetic fiber recycling, addressing challenges, and highlighting sustainable applications, especially enzymatic degradation, and innovative microbial approaches [10].

Biotechnological Perspectives for Synthetic Fiber Recycling

Biotechnological methods harness microorganisms and enzymes to enhance synthetic fiber recycling, fostering sustainability in the textile industry. Enzymes like proteases, lipases, and cellulases target specific bonds in synthetic fibers, facilitating their breakdown into monomers and oligomers for further use, reducing environmental impact [11-13]. Microbial biodegradation employs bacteria and fungi, some engineered for enhanced fiber degradation, further expanding recycling capabilities [14-20]. Conventional synthetic fibers' persistence in landfills and the environment presents environmental issues, motivating the adoption of biotechnological solutions for recycling, aiding in closing the loop of synthetic fiber production and minimizing waste [21-24]. These biotechnological advancements promise to revolutionize synthetic fiber recycling and promote environmental conservation [25]. The microscopic image in Fig. 1 shows a textile fabric made from recycled polyester (PES) fibers, presumably mechanically recycled and consisting of 20% polyester and 80% cotton (see Fig. 1, shopping bag, Comco Plast CCC GmbH, Germany).



a) b)

Figure 1: Microscopic images of 20% polyester/80% cotton fabric (a) and warp yarn (yellow and black polyester fibers cover the white cotton fibers) (b).

Schematic representation

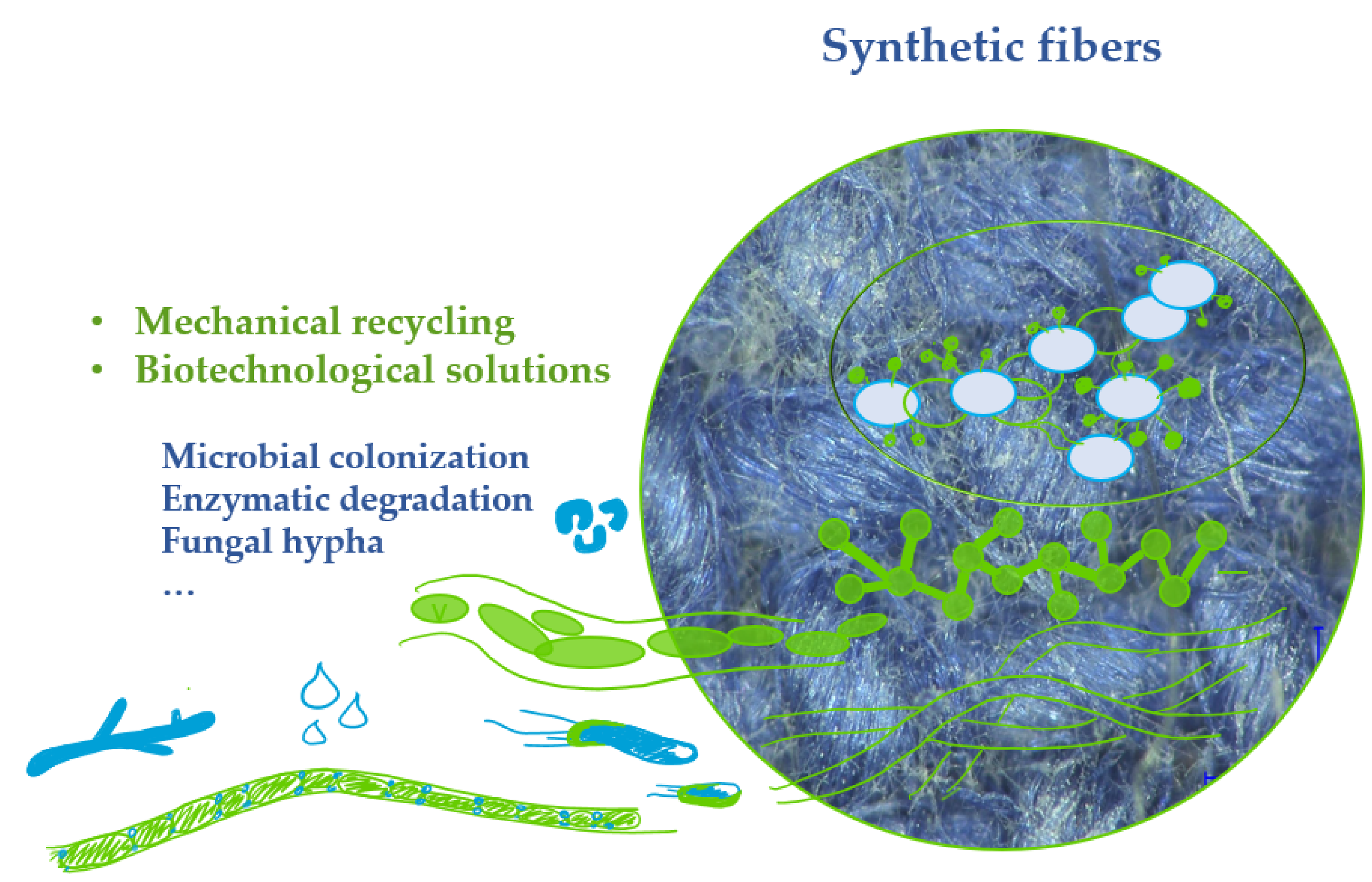


Figure 2: Schematic representation of the mechanical and biotechnological solution for recycling synthetic fibers.

Conclusion and Outlook

This short review discusses recent biotechnological advances in the treatment of synthetic fiber waste and the potential and limitations of mechanical and biotechnological solutions. Biodegradation is emphasized, highlighting the potential of enzymes for targeted degradation of synthetic fibers with minimal by-product formation. The integration of microbial consortia and genetically modified microorganisms offers innovative strategies to convert recalcitrant synthetic fibers into valuable resources. The use of fiber-degrading microorganisms in bioreactors enables large-scale recycling. Incorporating biotechnology into recycling concepts requires a holistic assessment that considers environmental protection and regulatory compliance. The potential of biotechnology is one of the most promising solutions for recycling synthetic fibers, supporting environmental sustainability and the transition to a circular economy.

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