From Textile Waste Powder to Flexible Bio-Based Polymeric Films: A Scalable Circular Materials Approach

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Abstract

The increasing volume of textile waste generated by the fast fashion industry has created an urgent need for sustainable and value-added recycling strategies. In particular, colored cellulosic textile wastes present a significant challenge due to sorting difficulties, dye contamination, and limited recycling routes. In this study, an environmentally friendly and chemical-free mechanical process was developed to convert colored cellulosic textile wastes into micron-sized powder without the use of water or chemical treatments. The obtained colored textile waste powders were subsequently utilized as sustainable reinforcing and coloring agents in the production of flexible bio-based composite films. The main objective of this study is to develop flexible, leather-like, sustainable composite structures by transforming textile waste into high-value functional materials. The composite formulations were prepared using poly(vinyl alcohol) (PVA, Mw 70,000), agar, glycerol, and acetic acid. Different amounts of textile waste powder were incorporated into the composite formulations to investigate the effect of waste powder amount on the structural, mechanical, thermal, color, and swelling properties of the resulting leather-like films. Due to the intrinsic color of the recycled textile powder, darker green shades were obtained with increasing waste content, eliminating the need for additional synthetic colorants and contributing to a more sustainable production approach. The produced films were characterized through comprehensive analyses including mechanical testing, Fourier Transform Infrared (FTIR) spectroscopy, differential scanning calorimetry (DSC), light microscopy characterization, color measurement, and swelling behavior analysis. FTIR analysis was used to evaluate possible intermolecular interactions between the polymer matrix and textile waste particles, while DSC analysis provided information regarding the thermal transitions and thermal stability of the composites. Light microscopy was employed to investigate the dispersion and surface morphology of the waste particles within the matrix. Swelling tests were conducted to evaluate the water absorption behavior and dimensional stability of the films. The results demonstrate the potential of colored textile waste powders as sustainable functional fillers and coloring agents for the development of flexible bio-composites with leather-like characteristics. This approach not only supports circular economy principles by valorizing textile waste, but also offers a promising pathway for the production of eco-friendly materials for textile, fashion, and accessory applications.

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