Process Optimization of Green Chemistry Pathway for Fabric-to-Fabric Recycling of Cotton

Wies, Marley (School: Greenwich High School)

An estimated 92 million tons of textiles are discarded annually, yet fabric-to-fabric recycling accounts for less than 1% of production due to quality degradation and financial barriers. This research develops a green chemistry pathway for closed-loop recycling of cotton, strategically targeting cut-and-sew waste streams in which 16-21% of fabric is discarded. Utilizing aqueous sodium hydroxide, the process deweaves cotton fabric and despins yarns into spinnable staple fibers. Systematic optimization of process variables identified two optimal protocols: treatment in 4M NaOH at 50°C for 30 minutes achieved 71.63 ± 4.29% fiber recovery (n=4), while room-temperature processing for 120 minutes yielded 70.13 ± 3.04% recovery with lower energy expenditure at laboratory scale. Both protocols utilized presoaking and mechanical stirring at 300 rpm. Preliminary solvent reuse studies indicate potential for industrial waste reduction, as fabric deweaving was sustained over four consecutive cycles without solvent replenishment. Although recovered fiber staple length (2.17 ± 0.08 cm) was shorter than virgin cotton length (3.2-3.8 cm), fibers were successfully incorporated into yarns at 20% recycled content, which is approximately double commercial recycled cotton standards. FTIR spectroscopy confirmed desirable shifts from cellulose I to cellulose II. The re-spun yarns were woven into new fabric, completing the closed-loop cycle. This work aligns with Green Chemistry Principles of waste prevention, safer solvents, and energy efficiency. The approach establishes a fabric-to-fabric recycling pathway that offers an alternative to landfilling or downcycling, preserving material value while reducing dependence on environmentally intensive cotton agriculture.

Awards Won:
Third Award of $1,200