From Waste to Strength: Leveraging Synergistic Effects to Enhance Sustainable Composite Bioplastics Through Upcycling Shrimp Shell Waste

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The annual generation of 3.8 million tons of shrimp shell waste contributes to environmental toxicity, and microplastics from conventional plastics cause adverse health impacts. To combat these issues, this project creates sustainable composite bioplastics through upcycling shrimp shell waste, and further leverages synergistic effects to enhance their performance. First, a novel green extraction process was developed to extract functional chitin from shrimp shell waste without any processing hazard. Next, the formulation of binary and ternary composite bioplastics was systematically optimized to enhance mechanical strength and water resistance. The results demonstrated the reinforcement benefit of incorporating chitin and synergistic effect in ternary bioplastics to significantly improve performance with over 110% increase in mechanical strength and over 80% increase in water resistance. The bioplastics were further characterized by Scanning Electron Microscopy (SEM) and Fourier Transform Infrared Spectroscopy (FTIR). SEM imaging revealed uniformity, compact structure, and microfibril structure to enhance performance. Meanwhile, FTIR spectra indicated the enhanced intermolecular interactions among composite components to improve performance. The biodegradability of bioplastics was modeled using first-order degradation kinetics with half-life determined to be 36 days. Moreover, functional prototype products were developed, demonstrating real-life applications. The reprocessability of bioplastic products was further proved, enabling a fully closed-loop material cycle. This project highlights a sustainable material design strategy for upcycling food waste into high-performance composite bioplastics with real-life functionalities and closed-loop circular economy.

Awards Won: