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Advances in biopolymer-based nanocomposites for sustainable packaging applications

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The global demand for sustainable packaging materials has accelerated the development of bio-based polymer alternatives to conventional plastics. Biopolymer-based nanocomposites have emerged as a promising class of materials due to their biodegradability, mechanical strength, and tunable physicochemical properties. This study explores the formulation, characterization, and performance evaluation of starch–cellulose nanofiber (CNF) reinforced biopolymer films designed for food packaging applications. The nanocomposites were produced using solvent casting, followed by controlled thermal curing to improve interfacial bonding. Mechanical testing showed that incorporation of 3–5% CNF significantly enhanced tensile strength and elasticity compared to pure starch films, while maintaining flexibility.

Barrier property analysis revealed a 40–55% reduction in oxygen permeability, indicating strong potential for extending food shelf life. Water vapor transmission rates also decreased due to improved polymer network density. Structural analysis using FTIR and SEM confirmed a uniform CNF dispersion and hydrogen bonding between polymer chains, which contributed to the improved performance. Biodegradation tests demonstrated complete decomposition within 45 days in controlled compost conditions.

The findings highlight that biopolymer nanocomposites represent a viable pathway toward eco-friendly packaging that meets industrial performance standards. Further work is underway to scale-up production and explore active packaging functionalities, including antimicrobial incorporation. The study demonstrates that combining natural polymers with nanotechnology offers a sustainable solution to plastic pollution while supporting circular economy goals.

Biography

Elena Martinez is an Associate Professor of Materials Science at the University of Barcelona, specializing in biopolymers, nanocomposites, and sustainable packaging engineering. Her research focuses on developing eco-friendly alternatives to petroleum-based plastics and improving biodegradability without compromising mechanical performance. She has authored over 45 peer-reviewed publications and collaborates with European industries on bioplastic commercialization. Dr. Martinez is a strong advocate for circular bioeconomy strategies and has received multiple awards for her contributions to green materials innovation.

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