Starch- and Alginate-Based Biofilms Reinforced with Banana Fiber-Derived Microcrystalline Cellulose for Sustainable Packaging

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Abstract:
The increasing environmental impact of non-biodegradable petroleum-based plastics has created an urgent need for sustainable material systems for packaging and related applications. Among the available candidates, polysaccharide-based films reinforced with bio-derived cellulose have attracted considerable attention because of their biodegradability, renewability, and potential for property tailoring through matrix hybridization and filler engineering. In this study, two interconnected investigations are presented within a unified materials-design framework. The first examines the influence of microcrystalline cellulose (MCC) loading on the properties of starch-, sodium alginate-, and starch/alginate-based biofilms. The second focuses on the modification of the selected matrix system by incorporating chitosan or carrageenan as functional secondary biopolymers in order to further tailor structural, physicochemical, thermal, and antibacterial characteristics. Biofilms were fabricated by solution casting using glycerine as plasticizer. In the first part, different matrix compositions and MCC loadings were prepared to evaluate the role of cellulose reinforcement in single and hybrid polysaccharide systems. In the second part, the most suitable matrix was further hybridized with varying amounts of chitosan or carrageenan while maintaining a fixed MCC content. The developed films were characterized by thickness, density, tensile testing, water absorption, swelling, solubility, and water vapor-related measurements. Fourier transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), X-ray diffraction (XRD), energy-dispersive X-ray spectroscopy (EDX, where applicable), and thermogravimetric analysis (TGA) were employed to assess structural, morphological, compositional, and thermal features. Selected formulations were

additionally subjected to antibacterial evaluation. The study is intended to establish a systematic basis for the development of cellulose-reinforced polysaccharide biofilms for biodegradable and potentially active packaging applications.

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