



Research article

PERFORMANCE ENHANCEMENT OF CITRIC ACID–CROSSLINKED BAMBOO–STARCH FILMS: EFFECT OF BAMBOO POWDER DOSAGE

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ABSTRACT

The performance limitations of starch-based biodegradable films remain a major barrier to their application in food packaging, particularly in terms of mechanical strength, moisture sensitivity, and antimicrobial functionality. In this study, citric acid–crosslinked bamboo–starch composite films were developed and systematically evaluated to elucidate the effect of bamboo powder dosage on the film's structure and performance. To the best of our knowledge, this study is the first to systematically evaluate the effect of bamboo powder dosage (3–6 g) in citric acid–crosslinked bamboo–starch films and correlate dosage-dependent changes with mechanical, barrier, morphological, and antibacterial performance. Bamboo powder loadings of 3, 4, 5, and 6 g were incorporated into a gelatinized potato starch matrix using citric acid as a food-grade crosslinker, with a neat starch film serving as the control. The films were characterized for mechanical, chemical, morphological, barrier, and antibacterial properties. Tensile strength increased markedly with the incorporation of bamboo, reaching a maximum of 9.65 MPa at 6 g of bamboo, representing a 170% improvement over the control (3.57 MPa). However, elongation at break decreased due to restricted polymer chain mobility. FTIR analysis confirmed the formation of an ester bond between starch, bamboo cellulose, and citric acid, indicating enhanced crosslinking efficiency with increasing bamboo content. SEM observations revealed optimal filler dispersion at moderate bamboo loading, whereas higher dosages led to fiber agglomeration and structural heterogeneity. Moisture content decreased progressively from 21.57% in the control to 9.96% at 6 g of bamboo, indicating reduced moisture retention as bamboo incorporation increased. Antibacterial evaluation against *Escherichia coli* showed a dose-dependent increase in inhibition activity, with the largest antibacterial ring radius (3 mm) observed for the highest bamboo loading. Overall, citric acid–crosslinked bamboo–starch films exhibit improvements in mechanical strength, moisture-related properties, and antimicrobial activity, highlighting their strong potential as sustainable active food packaging materials, with the bamboo dosage serving as a critical design parameter.