Chapter 9
Innovations and Applications of Bio-Nanocomposites in Sustainable Food Packaging:
Biodegradable Materials With Nanotechnology for Enhanced Safety, Functionality, and Environment

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ABSTRACT

The rising demand for sustainable food packaging has spurred advancements in bio-nanocomposites, which blend biodegradable biopolymers like starch, cellulose, and PLA with nanomaterials such as nanoclays, cellulose nanocrystals, carbon-based materials, and metal oxide nanoparticles. This combination enhances mechanical strength, thermal stability, and barrier properties, making them ideal for modern packaging. This chapter reviews synthesis methods—including solution casting, melt blending, and in situ polymerization—and explores their impact on material properties. Key functionalities such as antimicrobial activity, biodegradability, and shelf-life extension are discussed, along with emerging applications in active and intelligent packaging. Challenges like nanoparticle dispersion, polymer compatibility, and scalability are addressed. Future prospects include multifunctional systems, bio-derived nanomaterials, and advanced fabrication techniques. This chapter offers a comprehensive overview of bio-nanocomposites in sustainable food packaging.

INTRODUCTION

Food packaging is an essential component of the global food supply chain, playing a critical role in ensuring food safety, quality, and freshness throughout its storage and transportation (Aydın et al., 2024; Mahunu et al., 2024). As the world's population grows and consumer demand for convenience increases, packaging requirements have become more sophisticated, focusing not only on preserving food but also on maintaining its nutritional value and sensory attributes (Pascall et al., 2022; Ncube et al., 2021). Traditional packaging materials, primarily derived from petrochemical-based plastics, have dominated the market for decades due to their affordability, durability, and functional versatility (Hussain et al., 2024). However, these materials come with significant drawbacks, most notably their environmental impact. Non-biodegradability, limited recyclability, and the growing problem of plastic pollution have created an urgent need for alternative packaging materials that align with the principles of sustainability and environmental stewardship (Stanley et al., 2025).

In this context, bio-nanocomposites have emerged as a transformative innovation. These materials are engineered by integrating biopolymers, derived from renewable resources such as starch, cellulose, chitosan, and polylactic acid (PLA), with nanoscale fillers, including nanoclays, cellulose nanocrystals (CNCs), carbon-based nanomaterials, and metal oxide nanoparticles (Matin et al., 2024). The incorporation of nanomaterials addresses the inherent limitations of biopolymers, such as their relatively poor mechanical strength, thermal stability, and barrier properties, which