Chapter 2
Synthesis of Bio-Nanocomposite Materials:
Thermal and Mechanical Study

Basavaiah Chandu
https://orcid.org/0000-0002-3964-276X
Acharya Nagarjuna University, India

Venkata Sai Sriram Mosali
https://orcid.org/0000-0003-2240-798X
Colorado State University, USA

K. K. C. Satish Babu
Acharya Nagarjuna University, India

Syed Akhil
https://orcid.org/0000-0002-5600-7362
Nanyang Technological University, Singapore

ABSTRACT

Synthetic polymers and their composites are excellently suited to numerous applications, but their overexploitation has caused environmental pollution. Therefore, the need to replace them with sustainable and biodegradable materials is a critical issue that needs to be addressed urgently in order to reduce pollution. Natural polymers such as cellulose, starch, proteins, chitosan, and polylactic acid are promising alternatives to synthetic polymers since they are abundant, cost-effective, biodegradable, and exhibit good mechanical and thermal properties. However, the fabrication of these natural polymers into long-lasting goods is challenging due to their poor

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mechanical and thermal stability and excellent water absorption properties. Thus, the fabrication of composites of these bio-polymers represents an ever-intriguing research area for material scientists to achieve thermally stable bio-nanocomposites with low water absorption and enhanced mechanical properties. This chapter focuses on the synthesis methodologies of bio-nanocomposites and their mechanical and thermal properties.

4.1 INTRODUCTION TO BIO-NANOCOMPOSIES

The awareness in society towards the importance of renewable products to control environmental pollution has increased the demand for biodegradable and environmentally friendly materials. Non-renewable inorganic, ceramic, and synthetic polymer materials take several years to degrade, which contributes to environmental pollution due to long-term accumulation. As a result, the quest for renewable materials has created excellent opportunities for material science researchers to develop novel materials from natural, renewable resources for sustainable development. Natural polymeric materials like cellulose, starch, proteins, polysaccharides, and biomolecules like polylactic acid, polyvinyl alcohols, etc, are biodegradable, renewable, abundantly available at low cost, and biocompatible. These natural polymers are therefore considered superior alternatives to synthetic polymers for sustainability. However, their poor mechanical properties, low thermal stability, and high water adsorption ability restrict their practical applications. To address these limitations and reduce dependence on synthetic polymers, bio-nanocomposites have been developed. These are the materials in which a biological polymer matrix is reinforced with nanomaterials sized between 1-100 nm in any dimension.(Ray & Bousmina, 2005) Bio-nanocomposites are prepared with three main components: a biopolymer matrix, reinforcements from renewable sources, and nanosized fillers. In light of these environmental and practical benefits, bio-nanocomposites have gained increasing attention as viable alternatives to conventional polymer systems. Bio-nanocomposites can be broadly classified based on the source and type of the biodegradable polymer matrix, as shown in Fig. 4.1. Several natural, inorganic, and synthetic nanomaterials with good mechanical and thermal stability are used as fillers to tailor their performance. Although nanofillers are used in small quantities, their presence significantly influences the properties of the composite, while their impact on overall biodegradability remains minimal. The development of bio-nanocomposites directly supports global sustainability goals by promoting the use of renewable inputs, reducing reliance on fossil-based polymers, and enabling the creation of functional materials with a minimal environmental footprint. Beyond biodegradability, the significance of bio-nanocomposites lies in their potential to

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