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ORIGINAL PAPER

Mixed morphology nanocrystalline cellulose from sugarcane bagasse fibers/poly(lactic acid) nanocomposite films: synthesis, fabrication and characterization

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Abstract Fully green nanocomposite films with excellent mechanical properties were prepared using mixed morphology nanocrystalline cellulose obtained by the dual acid hydrolysis of sugarcane bagasse fibers as the reinforcing and poly(lactic acid) (PLA) as the matrix member. Sugarcane bagasse fibers were subjected to alkaline pretreatment and bleaching for de-lignification and partial acid hydrolysis resulting in the formation of microcrystalline cellulose (MCC). Nanocrystalline cellulose (NCC) was obtained by the dual acid hydrolysis of MCC using sulfuric acid and hydrochloric acid followed by ultrasonication. The nanocomposite films were solution cast from chloroform in varied compositions. Mixed morphology and surface topography characteristics of NCC and PLA/NCC films were established using microscopic studies. Changes in the functionality and molecular chemistry with subsequent treatments in the fibers were evaluated using FTIR. NCC exhibited better dispersion characteristics, increased crystallinity and rendered thermally stable from room temperature to 230 °C. Degradation profiles of samples were obtained from thermogravimetry, while the reinforcing effects of NCC in PLA were established by analyzing crystallization characteristics from X-ray diffraction studies. X-ray diffraction was utilized to estimate the increase in crystalline constituents and their state. The increase in tensile strength of the films confirmed the increased and effective positive interaction at the matrix–filler interfaces.

Keywords Nanocomposites · Nanocrystalline cellulose · Mixed morphology · Dual acid hydrolysis · Poly(lactic acid)

Introduction

In recent years, production of fully biodegradable materials derived from natural sources has garnered global interest in academic and industrial areas of materials research. One of the key areas of research is the development of innovative "fully green" composites with biodegradable matrices and fillers.

Polylactic acid (PLA) is a biodegradable and compostable thermoplastic polyester obtained usually by the ring opening polymerization of lactic acid, a product of the fermentation of renewable plant resources, such as starch and sugar [1]. PLA is one of the most promising alternatives to many petroleum-derived plastics. Current areas of PLA commercialization include packaging [2, 3] and medical applications [4, 5]. However, some property attributes to PLA, such as brittleness, low heat distortion temperature; high gas permeability and high cost have limited its widespread applications. PLA-based nanocomposites show remarkable improvement in the mechanical and physical properties compared to the pure PLA and its conventional macro- and micro-composites; incorporating small amounts, typically less than 5 wt%, of nanofillers into the matrix [6, 7].

Cellulose is one of the most abundant biopolymers on earth, occurring in all plant-based materials and serving as the reinforcing phase in the plants structures. The yearly supply of lignocellulosic biomass is approximately 200 billion metric tons worldwide. In the wake of growing environmental awareness, the demand for eco-friendly

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