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ORIGINAL PAPER

Reinforcement effect of poly (methyl methacrylate)-*g*-cellulose nanofibers on LDPE/thermoplastic starch composites: preparation and characterization

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Abstract The effect of cellulose nanofibers (CNFs) and poly [methyl methacrylate (MMA)]-grafted cellulose nanofibers (CNF-*g*-PMMA) on mechanical properties and degradability of a 75/25 low density polyethylene/thermoplastic starch (LDPE/TPS) blend was investigated. Graft copolymerization on CNFs was performed in an aqueous suspension by free radical polymerization using MMA as an acrylic monomer. In addition, a LDPE/TPS blend was reinforced by different amounts of CNFs (1–5 wt%) and CNF-*g*-PMMA (1–7 wt%) using a twin-screw extruder. A 61% grafting of PMMA on the surface of CNFs was demonstrated by gravimetric analysis. Moreover, after modification the X-ray photoelectron spectroscopy analysis showed a 20% increase of carbon atoms on the surface of CNFs and a 22.6% decrease in the oxygen content of its surface. The mechanical properties of the CNFs-modified composites were significantly improved compared to the unmodified nanocomposites. The highest tensile strength and Young's modulus were obtained for the composites reinforced by 3 and 7 wt% CNF-*g*-PMMA, respectively. The degradability of cellulose nanocomposites was studied by water absorption and soil burial tests. Surface modification of CNFs lowered water absorption, and soil burial test of the LDPE/TPS blend showed improvement in biodegradability by addition of CNF-*g*-PMMA.

Keywords Cellulose nanofibers · Surface modification · Methyl methacrylate · Polyethylene/starch blend degradability · Mechanical properties

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Introduction

Plastic products can bring about serious damage to the nature at the end of their life cycle due to their low biodegradability [1]. Therefore, the development of biodegradable plastics has been given more attention by scientists and producers. Among the materials used in packaging industry, the highest consumption is reported for polyethylene [2]. However, compared to other plastic materials, it has the highest resistance to degradation in the environment. To solve this problem, low density polyethylene (LDPE) with a higher rate of degradation was produced [3]. In addition, for this purpose PE was mixed with a biopolymer such as poly (lactic acid), poly (glycolic acid), starch, etc. [4]. Among these biopolymers, thermoplastic starch (TPS) has been widely used because of its biodegradability, availability, low cost and abundant sources [2]. However, the mechanical properties of PE are reduced by the addition of TPS [5]. Therefore, developing a method to enhance the mechanical properties of TPS blends would be a great challenge. Recently, cellulose nanofibers (CNFs) have been used widely to produce biocomposites because of such advantages as high modulus and strength, renewability, biodegradability and low cost [6–8]. However, the high polarity of cellulose has limited CNFs usage in nonpolar polymer matrices [9, 10]. Having plenty hydroxyl groups in its structure cellulose has the chance to involve in strong hydrogen bonds and form nanofibers agglomeration [6, 11]. In a previous study, Alidadi et al. [12] used CNFs as the reinforcement for the PE/starch composite. The polarity differences between PE as the matrix and CNFs leads to reduced mechanical properties. As evident in SEM images, an aggregation of CNFs has been observed in the composite. Therefore, incompatibility with hydrophobic matrices, sensitivity to processing temperature and absorption of water are the major shortcomings of CNFs