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ORIGINAL RESEARCH

Biodegradable composites of recycled thermoplastic starch and sawdust: the effect of cellulose nanofibers, nanoclay and temperature

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Abstract
Studies were performed on the effects of small amounts of cellulose nanofibers and nanoclay particles on mechanical, physical and morphological properties of biodegradable composites of recycled thermoplastic starch biopolymer and regular mixed industrial sawdust of Iranian wood species including rush, walnut and hornbeam. To this aim, nanoparticles at 0, 3, and 5 wt% were added to the prepared biodegradable composites. Mechanical, thermal, water absorption and thickness swelling tests were performed according to their corresponding standards. In addition, to investigate the effects of working temperature on derived characteristics of the resulting composites, the selected mechanical tests were performed at various temperatures ranging from 23 to 80 °C. For validation of the results obtained from the physical tests, scanning electron microscopy was also utilized to examine the morphologies of the nanocomposites. The results showed that adding nanoparticles improved tensile modulus by 50%, tensile strength by 110%, flexural modulus by 115%, and flexural strength by 18%. Adding 5 wt% nanocellulose fibers showed better results than 3 wt% addition, while in the case of nanoclay, the trend was reverse. No significant change was observed for impact strength. Glass transition temperature was increased from 90 to 123 °C depending on the amount of nanoparticles. Water absorption and thickness swelling were reduced by around 20%. It was also observed that at elevated temperatures nanoparticles led to greater stability of the composite structure. From the results of this study it can be concluded that cellulose nanofibers and nanoclay particles can be successfully used for improving the mechanical and physical characteristics and performance of the biodegradable WPCs made of thermoplastic starch and industrial sawdust. Furthermore, since the effect of adding each of these nanoparticles on mechanical and physical performance of WPCs is different, the results of this study can be used to decide on selection of the type and amount of nanoparticles for fabrication of a product for a desired application.

Keywords Biodegradable nanocomposite · Cellulose nanofiber · Nanoclay · Thermoplastic starch · Sawdust

Introduction

Despite plenty of undeniable benefits that advances are made in synthetic polymer technology in improving human life, abundant use of non-degradable plastic materials and high volume of wastes have led to many environmental problems for human and wildlife. With the depletion of oil resources in near future, these problems will double because the main primary raw materials of these products will also be scarce. Hence, the interest of researchers in design and use of biodegradable polymers, based on sustainable materials, has greatly increased [1–6].

Among the natural biodegradable polymers, starch is a good choice for producing biodegradable thermoplastics. Starch is a multi-purpose and inexpensive polymer with

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