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ORIGINAL PAPER

Effects of various nanomaterials on the properties of starch/poly(vinyl alcohol) composite films formed by blow extrusion process

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Abstract Effects of various nanomaterials on the physical and mechanical properties of hydroxypropyl distarch phosphate/poly(vinyl alcohol) (starch/PVA) composite films fabricated by blow extrusion were investigated. The starch/PVA nanocomposite films were studied by differential scanning calorimetry (DSC), thermogravimetric analysis (TGA/DTG), FTIR, and scanning electron microscope (SEM). The nanocomposite films containing nano-$CaCO_3$ and organically modified montmorillonite (OMMT) showed the lowest and highest tensile strengths of 3.72 and 7.04 MPa, respectively. The film containing natural montmorillonite (MMT) exhibited the lowest elongation-at-break of 118.73 %. The film with OMMT exhibited the lowest water vapor permeability of 4.12×10^{-10} g m^{-1} s^{-1} Pa^{-1}. Addition of nano-TiO_2 to starch/PVA films resulted in a significant decrease in ΔE^* (increased clearness). Differential scanning calorimetry (DSC) indicated that the nanocomposite films exhibited higher glass transition temperatures (T_g) and lower melting enthalpy compared to the control film. Adding MMT and OMMT to starch/PVA blends increased the thermal stabilities of the films according to the TGA/DTG analysis. Agglomeration of particles was observed in the starch/PVA composite films containing nano-$CaCO_3$ and nano-TiO_2 while nano-SiO_2 and MMT dispersed well in the matrix. On the whole, OMMT was more compatible with starch/PVA blends and served as a better nanomaterial to prepare starch/PVA nanocomposite films which was superior to that of the other four nanomaterials.

Keywords Starch · Poly(vinyl alcohol) · Nanocomposite · Film blowing · Properties

Introduction

A growing public concern for the harmful effects of non-degradable plastic films on the environment has stimulated increasing research on biodegradable films as alternatives to conventional petroleum-based films [1, 2]. Starch, a cheap, renewable, and biodegradable material, has been widely studied to prepare biodegradable films. However, pure starch films exhibit some severe limitations such as poor mechanical properties and high moisture sensitivity [3]. To overcome these drawbacks, starch has often been blended with other biodegradable synthetic polymers, such as poly(lactic acid) (PLA), poly(ε-caprolactone) (PCL), and PVA, which show promise in food packaging applications.

Starch/PVA composite films are one of the most popular biodegradable plastics in packaging and agricultural applications [4–6]. Starch and PVA are polar substances that contain many hydroxyl groups (–OH). These hydroxyl groups tend to form inter-molecular and intra-molecular hydrogen bonds and improve the integrity of starch/PVA blends [7]. Many approaches have been designed to further improve the moisture barrier and mechanical properties of starch/PVA blends, i.e. acid modification and plasma treatment [8], adding cross-linking agents [9], blending plasticizers, such as the mixture of glycerol and urea [10], or adding nanoparticles [11–13].

Of these methods, biodegradable nanocomposites have attracted much attention because of their good moisture

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