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Comparative oxo-biodegradation study of poly-3-hydroxybutyrate-co-3-hydroxyvalerate/polypropylene blend in controlled environments

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ABSTRACT

The potential use of poly-3-hydroxybutyrate-co-3-hydroxyvalerate (PHBV) copolymer as a biodegradable additive in polypropylene (PP) has been explored. The melt blending technique was used to produce the blend of PHBV/PP (PB10). The degradation studies of PB10 were done in the field as well as in controlled laboratory conditions. The structural changes were studied using scanning electron microscopy (SEM), Fourier transform infrared (FTIR) spectroscopy, and thermogravimetric analysis (TGA). SEM micrographs showed the formation of agglomerates, pits, grooves, and holes on the treated films as a result of microbial activity. FTIR spectra indicated clear evidences of oxo-biodegradation of polymer chains due to an increase in carbonyl peak index. Thermogravimetric analysis confirmed that the thermal stability of PB10 was increased after soil burial. This study contributed toward the prospective commercial applications of PHBV for use in the food packaging industry.

1. Introduction

It can be argued that plastic is the most desirable material in our daily life due to its light weight, flexibility, and stability in the environment. The worldwide annual production of synthetic plastics used for manufacturing a wide range of products, from automobiles to commodity packaging, is 260 million metric tons (Lazarevic et al., 2010). However, changing demographics, increased usage patterns, and high production trends for synthetic plastics will result in a significant rise in the prevalence of plastic debris in the environment (Andrady, 2011). The amount of plastic in municipal wastes varies from 5 to 25% depending upon the density of the mixture. Polyolefin is recalcitrant to microbial degradation due to the lack of an active functional group, its hydrophobic nature, its high molecular weight, its branched structure, and the presence of additives (Arutchelvi et al., 2008). It has recently been reported that 25 million tons of synthetic plastic accumulates yearly in the environment, and the estimated time required for its degradation is 400 years (Preeti and Archana, 2011). More than 50% of plastic waste is comprised of polyolefins, and this is causing serious waste disposable problems in the environment (Sivan et al., 2006). Landfilling, burning, and incineration are the main techniques used for waste management. But there are serious health hazards associated with these strategies. Greenhouse gases and other toxic compounds are released into the environment during the incineration of plastics. The burning products of some additives present in plastics are suspected as possible carcinogens (Preeti and Archana, 2011). In the recycling process, it is difficult to sort the wide variety of plastics; in addition, recycling changes the materials' properties, which limits their applications. Furthermore, when plastics are deposited as landfill, the surrounding areas are often heavily polluted (Oehlmann et al., 2009). In Europe, due to the serious environmental concerns associated with the use of synthetic plastics, the demand for biodegradable plastic is between 50,000 and 100,000 tons and it is predicted to rise significantly in coming years (Wolf et al., 2005).

Polyhydroxyalkanoates (PHAs) are the most fascinating class of polyesters. The microorganisms belonging to 90 different genera are reported to produce PHAs as intracellular energy and carbon storage compounds from renewable resources under nutrient stress conditions (Chanprateep, 2010). Polyhydroxyalkanoates have 150 different types of monomers, which results in diversification of their properties and functions (Hazer and Steinbüchel, 2007). They are biodegradable, nontoxic, biocompatible, and environmentally

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Table 1
The comparison of mechanical properties of topilene and PB10 films.

Sample	Ultimate tensile strength (MPa)	Elongation at break (%)
Topilene	31.06 ± 3.43	13.49 ± 2.69
Aged PB10 (34 months)	18.54 ± 4.56	2.67 ± 5.43

friendly thermoplastics. The microorganisms present in soil secrete polyhydroxybutyrate (PHB) depolymerases and break down the ester bond of PHB; converting it into water-soluble products and carbon dioxide under aerobic conditions (Sridewi et al., 2006). Whereas, in anaerobic conditions methane, water and carbon dioxide are produced (Verlinden et al., 2007).

There are widespread applications for PHAs in various sectors of life. PHA products are not used as much as they could be in packaging films, due to their high production costs as compared to those of the other synthetic plastics. In order to address this issue, PHA is blended with other synthetic plastics. The development of green composites or blends by the melt blending technique is an innovative approach to lessen the hazards associated with the use of synthetic polyolefins. It also offers new opportunity by utilizing the existing polymers to obtain materials with new desirable properties such as amphiphilicity, biodegradability, and better mechanical and thermal properties (Chen and Wu, 2005; Mir et al., 2011). There are studies on the blending of poly-3-hydroxybutyrate (PHB), poly-3-hydroxybutyrate-co-3-hydroxyvalerate (PHBV), poly-3-hydroxybutyrate-co-3-hydroxyhexanoates (PHBHHx), and poly-hydroxyoctanoates (PHO) (Renard et al., 2004) with poly-caprolactone (PCL) (Casarin et al., 2011), rubber (Bhatt et al., 2008), polypropylene (PP) (Goncalves et al., 2009), and starch (Godbole et al., 2003).

We have extracted PHA from *Bacillus cereus* FA11 strain (Masood et al., 2012). This PHA is used to synthesize a biodegradable blend with PP by the melt blending technique. The biodegradation studies were carried out using a consortium of *B. cereus* strains

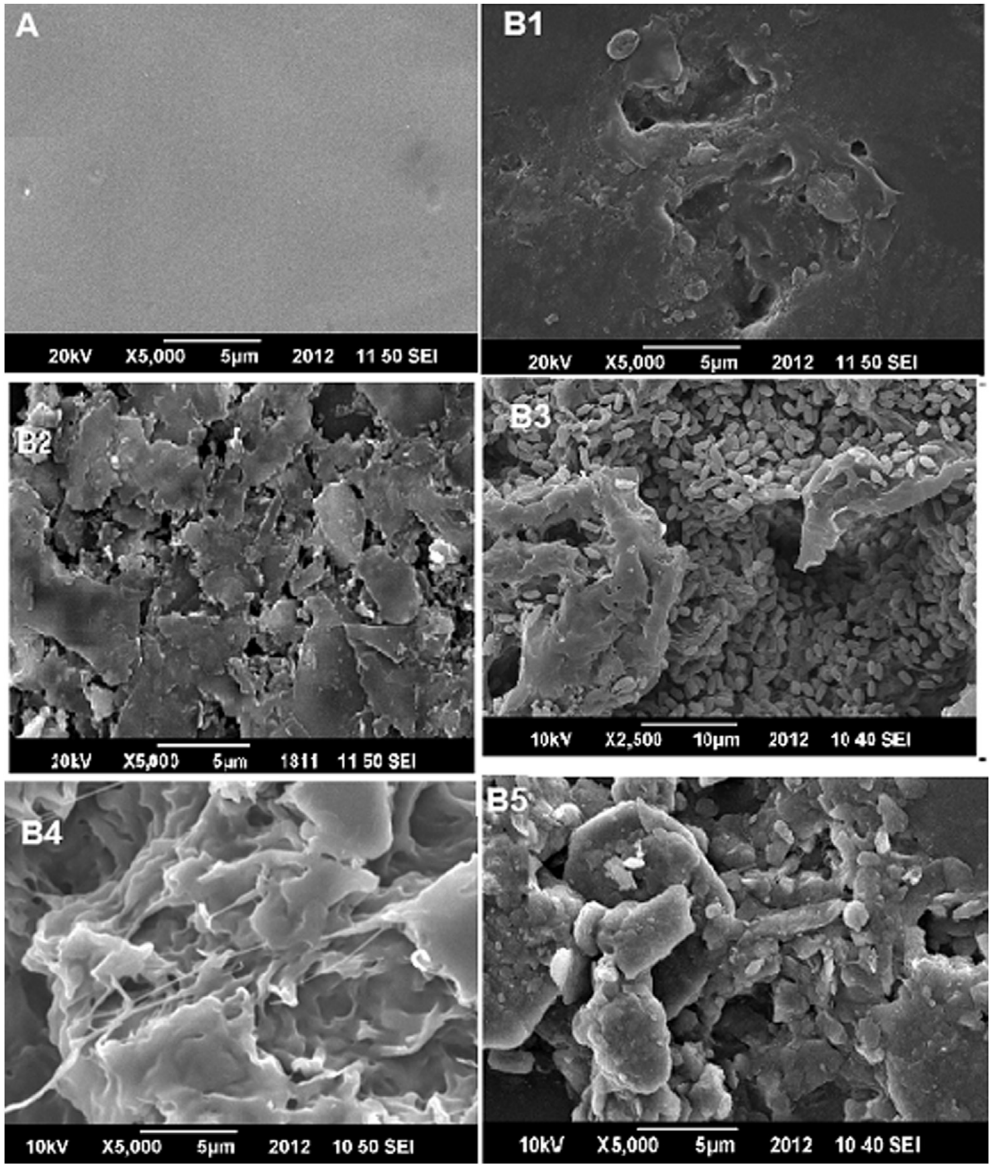

Fig. 1. Scanning electron micrographs of PB10 (A1): control; treated by bacterial consortium; (B1): at pH 8; (B2): 45 °C; (B3): lactose; (B4): 28 days; and (B5): PB10 films buried in soil for 120 days.