

EFFECT OF MALEATION ON THE MECHANICAL PROPERTIES AND BIODEGRADATION OF LINEAR LOW DENSITY POLYETHYLENE- STARCH BLENDS

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Abstract— LLDPE grafted with maleic anhydride was blended with a bio-filler (starch- 5, 10 and 15 weight %). The biodegradation of the blends was established by subjecting the samples to biodegradation in a shake culture flask containing vibrios and soil burial. The extent of biodegradation was established by measurement of mechanical properties and weight loss. The morphology of the samples was carried out using scanning electron microscope. The maleation of LLDPE improved the mechanical properties. The reduction in tensile strength and weight of all the samples after biodegradation and after burial in soil suggests that the blends are partially biodegradable.

Keywords— maleation; bio-filler; biodegradation; vibrios

1. INTRODUCTION

Polyethylenes are of high commercial interest due to their wide range of physical and chemical properties. However, their use in polymer blends of technological interest has been limited due to their typical non-polar character leading to poor interfacial adhesion. To overcome this deficiency and to facilitate compatibilization with polar polymers, polyethylenes have been chemically modified through functionalization or grafting. This process introduces polar groups onto the polymer main chain as pendant units or short-chain branching [1]. It can be achieved by copolymerization of new monomers or by modification or blending of existing polymers [2].

Most research on the blends of starch and synthetic plastics has been focused on common plastics such as polyethylenes as the base materials. However, polyethylenes and starch are immiscible because of their differences in polarity; that

is, starch is hydrophilic whereas polyethylene is hydrophobic. To improve their compatibility, various attempts have been made to modify either starch or polyethylene [3-9].

More recently, an increased interest has been noticed in the use of polymers containing reactive groups (e.g., maleic anhydride) as compatibilizers [10-19]. Considerable studies have been carried out on maleic anhydride [9-13,20] grafting of polyethylene. It has been reported that anhydride groups could react with the hydroxyl groups in starch to produce chemical bonding, thus improving the dispersion of starch, the interfacial adhesion, and subsequently, the mechanical properties of the resultant blends. It is believed that the polar character of the anhydride causes affinity for the starch particles such that the maleated segments of polyethylene can serve as 'compatibilizer' [14,21-27].

Maleic anhydride grafted polyethylenes are generally produced using maleic anhydride (MA) in the presence of peroxide in a melt polymer processing process [9-10]. Maleic anhydride is, however, very volatile, toxic and strongly corrosive to the metallic

equipment used in the polymer melt processing [11]. It is generally accepted that the grafting of maleic anhydride (MA) on polyethylene proceeds via a free radical mechanism [28]. The free radicals produced from the thermal decomposition of a peroxide (e.g. DCP) abstract hydrogen atoms from the polyethylene backbones, thus the polymer free radicals are generated. The polymer radicals then attack the monomer MA resulting in the grafting of the monomer on the polymer backbones. Heinen et al. performed the grafting using ¹³C-enriched MA and found that MA attaches to the HDPE and LDPE backbones in the form of single succinic anhydride as well as short oligomers [28].

This paper reports the effect of maleation on the mechanical properties and biodegradation of linear low density polyethylenestarch blends.

2. EXPERIMENTAL

2.1 Materials

The film grade linear low density polyethylene (LLDPE 20FS010) used in this study was provided by Reliance Industries Limited, Mumbai, India. The bio-filler (starch, 300 mesh size) used in this study was provided by Jemsons Starch and Derivatives, Aroor, Kerala, India. The maleic anhydride used was supplied by Loba Chemie Pvt. Ltd., Mumbai, India and the dicumyl peroxide was supplied by Associated Chemicals, Edappally, Kerala, India.

2.2 Mixing

The compounds were prepared in a Thermo HAAKE PolyLab System equipped with roller type rotors. The mixing was done at a rotor speed of 30 rpm and at a temperature of 150°C. LLDPE was first melted for 2 minutes followed by the addition of bio-filler. Mixing was continued for a total duration of 8 minutes.

In the case of the maleated blends, initially the LLDPE was melted for 2 minutes and then grafted with maleic anhydride (1%) using dicumyl peroxide (0.25%) as the initiator. The bio-filler was then added and mixing was continued for a total duration of 8 minutes. Three compositions of LLDPE and LLDPE-g-MA with the bio-filler (5, 10 and 15 weight %) were prepared.

2.3 Preparation of test specimens

The test specimens were prepared from the compounds by moulding in an electrically heated hydraulic press for 5 minutes at 150°C under a pressure of 20MPa. After moulding, the samples were cooled under pressure.

2.4 Mechanical testing

The stress-strain properties were evaluated as per ASTM D-882 [29] in a Shimadzu Autograph AG-I series Universal Testing Machine at a crosshead speed of 50 mm/min using a load cell of 10KN capacity. An average of at least five measurements was taken to represent each data point.

2.5 Biodegradation studies

2.5.1. Using shake culture flask

Biodegradability of the blends was tested according to ASTM D 6691 [30] using a shake culture flask containing the selected amylase producing Vibrios. To prepare the inoculum the individual isolates of the consortium were grown overnight at 37°C at 120 rpm on an Orbitek shaker (Scigenics Pvt. Ltd, Chennai, India) in a nutrient broth (Himedia, Mumbai) of pH 7.0 ±0.3 with 1% NaCl. The cells were harvested by centrifugation at 5000 rpm (2292g) for 20 minutes, washed with physiological saline and then pooled. 5 ml of the pooled culture (OD₆₆₀ = 1) was used to inoculate 50mL amylase minimal medium [31] lacking starch. The strips of the LLDPE-starch and LLDPE-g-MA-starch blends previously wiped with 70% alcohol were added to this medium. Incubation was done in the Orbitek environmental shaker at 37°C and 120 rpm for a total period of 4 months with regular sampling. The medium without the inoculum with corresponding LLDPE-starch and LLDPE-g-MA-starch blends and subjected to the same treatment as above were used as controls. After 4 months

the percentage decrease in tensile strength and weight of the test specimens were measured for determining the degree of degradation.

2.5.2. Soil burial test

The soil burial test was also carried out for evaluating the biodegradability of the blends. The soil was taken in pots and the plastic strips were placed in it. The bacterial culture was supplied to the soil. Care was taken to ensure that the samples were completely covered with soil. The pot was then kept at room temperature. The percentage decrease in tensile strength was measured after thorough washing with water and drying in oven until constant weight to determine the extent of biodegradability.

2.5.3. Scanning electron microscopic analyses (SEM)

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