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Properties of thermoplastic blends: starch–polycaprolactone

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Abstract

Different compositions of wheat thermoplastic starch (TPS) and polycaprolactone (PCL) are melt blended by extrusion and injected. Different properties are determined: mechanical properties (tensile and impact tests), thermal and thermomechanical properties (DSC and DMTA) and hydrophobicity (contact angle measurement). A large range of blends is analysed with different glycerol (plasticizer):starch contents ratios (0.14:0.54) and various PCL concentrations (up to 40 wt.%). From the behaviour of each polymeric system, it is possible to analyse the relationship properties of each component proportion on the blends. The ageing of the system is studied and shows a structural evolution of the material after injection during several weeks. We have noticed a fairly low compatibility between both polymeric systems. Finally, the addition of PCL to TPS matrix allows to overcome the weakness of pure TPS: low resilience, high moisture sensitivity and high shrinkage, even at low PCL concentration, e.g. 10 wt.%.

Keywords: Blend; Thermoplastic starch; Polycaprolactone

1. Introduction

An important number of biodegradable polymers (biopolymers) exist that are derived from both synthetic and natural sources [1–3] but most of them are quite costly. Growing environmental concerns have created an urgent need to develop new biodegradable materials that have comparable properties with today's polymeric materials at an equivalent cost. The utilisation of agricultural products in plastic applications is considered as an interesting way to reduce surplus farm products and to develop non-food applications. For years, our laboratory has studied and developed low cost biopolymers such as starch-based materials, obtained from renewable resources. Several authors [4,5] have shown the possibility to transform native starch into thermoplastic resin-like products under destructuring and plasticization conditions. Thermoplastic starch (TPS) is processed like synthetic plastics through extrusion and injection units. Unfortunately, TPS is a very hydrophilic product. Some authors [6] tried to modify the starch structure, e.g. by acetylation, to reduce the hydrophilic character of the chains. This chemical process results in inferior mechanical properties and greater product cost [7]. In addition, some authors [8,9] have described changes in the mechanical properties of TPS in relation with the crystallinity and the contents of plasticizer and water, during ageing.

Moisture sensitivity and critical ageing have lead to the necessity to associate TPS with another biopolymer, to preserve the biodegradability of the final blend. Association between polymers can be blends or multilayer products. Multilayers can be obtained by coating [10] or by coextrusion [11] processes. However, in each case, it is necessary to appraise the compatibility between the different biopolymers through blend analysis. Blending TPS with other polymers has been commonly used [2–5,10,12–25]. Research groups [2–5,12] have developed blends with synthetic polymers such as polyethylene leading to non-fully biodegradable materials. To maintain the biodegradability of the blend, known biopolymer components include [2,3,13–25]: aliphatic polyesters like polycaprolactone [15–21] (PCL), polylactic acid [3] (PLA), polyhydroxybutyrate-co-valerate [15–17,22–24] (PHBV), polyesteramide [25]. Some starch-based blends have been commercialised like Mater-Bi [12,19] (Novamont-Italy) or Bioplast [13] (Biotec-Germany).

PCL has been chosen among the different biopolymers commercially available and widely produced. Previous studies have shown that PCL/TPS blends are readily biodegradable [3,19,20]. According to Bastioli et al. [19],

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