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Starch-based biodegradable blends: morphology and interface properties

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Abstract: In order to improve the properties of plasticized wheat starch (PWS) and to conserve its final biodegradability, PWS can be blended with biodegradable polyesters [polyesteramide, poly(ε-caprolactone), poly(lactic acid), poly(butylene succinate adipate) and poly(butylene adipate terephthalate)] which exhibit variable polar characteristics. This paper is focused on the analysis of the compatibility of these blends which vary according to their formulation. To understand the lack of affinity between the different phases, interface adhesion has been investigated by contact angle measurements to obtain the work of adhesion. From these determinations a forecast approach has been developed to predict blend compatibility. Blend structures were obtained by scanning electron microscopy observations. Blends show either a dispersed structure or a co-continuous morphology. Percolation thresholds (co-continuity) and full continuity regions were determined thanks to a method based on solvent extraction. Finally, rheological investigations have been carried out on the different biodegradable polymers to understand better the blend structure formation during the process.

Keywords: plasticized starch; biodegradable blends; interfacial compatibility; structure-properties relationship

INTRODUCTION

Advanced technology in petrochemical polymers has brought about many benefits to mankind. However, it is becoming more and more obvious that the ecosystem is considerably disturbed and damaged as a result of the non-degradability of disposal items. The environmental impact of persistent plastic wastes is becoming a more global concern, and alternative disposal methods are not boundless. Besides, the petroleum resources are limited. It is becoming important to find durable plastic substitutes, especially for short-term packaging and disposable applications. Starch may offer a substitute for petroleum-based plastics. Starch is a renewable and degradable carbohydrate. It can be obtained from various botanical sources (wheat, maize, potato, etc). Starch, by itself, has severe limitations due to its water solubility. Articles made from starch swell and deform upon exposure to moisture. Several authors[1,2] have shown that it is possible to transform native starch into thermoplastic resin-like products under destructuring and plasticization conditions.

Unfortunately, plasticized starch, also called 'thermoplastic starch' is a very hydrophilic material with limited performance. To overcome these difficulties and to maintain its biodegradability, one strategy consists in associating plasticized starch with another biodegradable polymer, such as an aliphatic polyester like polycaprolactone (PCL),[3–12] poly(lactic acid) (PLA),[13,14] poly(hydroxybutyrate-*co*-valerate) (PHBV),[3–5,15–17] poly(ester amide) (PEA),[12,18] or poly(butylene succinate adipate) (PBSA),[11,12] or an aromatic polyester like poly(butylene adipate terephthalate) (PBAT).[11,12] Some starch-based blends, such as Mater-Bi[7,19] (Novamont-Italy), are commercialized. The association of these biodegradable polymers makes it possible to improve the weaknesses of plasticized starch. Thus, one can obtain better mechanical properties, a significant improvement of the dimensional stability and a decrease in the hydrophilic character of starch.[10,11,18] Various strategies for increasing the performance of such associations are known, such as blending. In fact, blending polymers is easier and cheaper than synthesizing new macromolecules. Unfortunately, the main drawback is linked to the non-miscibility of polymers because of the differences in chemical structures. When demixing occurs, the phenomenon is conditioned by the properties of each phase and of the interface, ie by the interfacial energy that depends on the nature of the interactions.[20] Understanding the behaviour at the interface is essential because it governs the morphology of the blend and also its physical and

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