Processing-Microstructure-Properties Relationships in PLA/Talc Composite Films

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In polymer-based composites, the achievement of a homogeneous dispersion and distribution of the embedded fillers, leading to the establishment of a great polymer/filler interfacial region, is a mandatory requirement for obtaining materials endowed with superior properties.

Single-screw extruders (SSE) offer high production rates but typically suffer from poor mixing efficiency due to uneven shear rates and melt temperature distributions. To address this limitation, various screw designs have been developed to enhance dispersive and distributive mixing in SSE. In this work, PLA-based composites containing 5 wt% of talc were obtained by a two-step process involving the preliminary preparation of a masterbatch in a twin-screw extruder, followed by processing in SSE using two different screw in order to assess the possible effect of the different screw design. In particular, a C-screw, characterized by three-compression zones, and a barrier screw (hereinafter named as B-screw) were exploited. Additionally, a flat die followed by a calander with a three-roll sheet stack arrangement was exploited for the production of PLA/Talc films (thickness _~ 300 μm). The as-produced films were then characterized through morphological, rheological and mechanical analyses; furthermore, the possible application of the formulated films in the packaging field was evaluated by performing permeability tests.

Firstly, as far as the unfilled PLA is concerned, the processing through B-screw causes a decrease of the polymer viscosity as compared to the C-screw processed counterpart, suggesting a decrease of the material molecular weight likely due to some degradation phenomenon induced by the high shear promoted by the B-screw. Nevertheless, the composite processed through this screw configuration shows higher viscosity than the PLA/Talc_C-screw, indicating the obtainment of an enhanced extent of dispersion/distribution of the embedded fillers in this composite, leading to the establishment of a larger polymer/filler interfacial region. In fact, the morphological analysis performed through SEM observations revealed that in the case of the composite film processed using the B-screw the main dimensions of the dispersed talc particles are lower than those of the C-screw processed material. However, for both films a satisfactory dispersion/distribution of the embedded fillers was achieved, along with a well recognizable orientation along the casting direction. The noticed differences in the material microstructure induced by the processing affected the mechanical properties of the composite films. In particular, higher values of elastic modulus were obtained for the films processed through B-screw, likely due to the higher crystallinity content of this sample with respect to C-screw processed one, which also causes the obtainment of improved barrier properties. Similarly, the processing of the talc-containing composites through B-screw allows for achieving enhanced tensile modulus and lower oxygen transmission rate (OTR). These results can be explained considering the enhanced mixing efficiency of the SSE equipped with B-screw, which induces a better dispersion/distribution of the embedded talc particles. Furthermore, it appears that, due to the more effective dispersive mixing ensured by the B-screw, a more disordered array orientation of the talc flat-shaped particles is obtained, making more tortuous the pathway of the oxygen through the film, thereby promoting improved barrier properties.

Keywords: Single screw extrusion, calander, screw design, composites, films, oxygen transmission rate (OTR)

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