BIODEGRADABLE POLYMER-WOOD FLOUR COMPOSITES: MAIN PROPERTIES AND BIODEGRADABILITY

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Abstract – During the last years, a considerably increasing rate of attention has arisen on biodegradable polymers. In the meanwhile, the use of wood-plastic composites (WPC) has grown in importance, especially in the United States. The combination of biodegradable polymers and wood-based fillers allows obtaining the typical advantages achievable with the use of WPCs, with the further advantage of the biodegradability and compostability of the matrix (and not only of the filler). In this work, the characterization and the biodegradability assessment of Mater-Bi®-wood flour composites have been carried out.

Introduction

Recent years have witnessed an increasing rate of interest in biodegradable polymers, either in academia and industry [1, 2]. On the other hand, the use of wood-plastic composites (WPC) has grown in importance, especially in the United States, thanks to their main characteristics, related to the minimization of costs and environmental impact, the satisfying aesthetic features, the interesting mechanical properties [3]. The main drawback in using WPCs is the lack of a complete biodegradability (typically, the polymer matrices used are not biodegradable, but come from the well-known oil sources). The use of biodegradable polymers allows solving the issue.

In particular, Mater-Bi® is a quite interesting kind of biodegradable polymer. It is known to be derived from vegetable sources (especially corn starch) and to be compostable [1]. Some works on Mater-Bi/wood flour biocomposites evidenced a significant increase in the rigidity and the thermomechanical strength of the materials, but also an increase in the sensitivity to environmental humidity [4, 5].

In this work, a complete study on a Mater-Bi/wood flour system has been carried out. In particular, the effect of the processing technique (extrusion, injection molding) on the rheological, mechanical, morphological properties has been investigated, and a complete biodegradability assessment has been carried out.

Experimental

The Mater-Bi used in the work was kindly supplied by Novamont (Italy), and the composition is proprietary. The measured MFI was 46g/10 min (5kg load).

The wood flour (WF) was kindly provided by La.So.Le. (Italy) (average particle diameter 150-200 µm, average L/D ≈ 2.8). WF was dried in a ventilated oven at 70 °Cfor 10 hours before processing.

The neat polymer and the polymer-WF composites (15% w/w) were prepared according to two different techniques: a) extrusion, performed in a OMC (Italy) corotating twin-screw extruder (D = 19 mm, L/D = 35, temperature profile ranging from 90 °C to 125 °C), and b) injection molding, performed on the pellets obtained by the twin-screw extruder in a Sandretto (Italy) µ30 press (140 °C, pressure of 900 bar). The samples for the subsequent tests were directly obtained in this case while, in the case of the materials produced by the extruder, the pellets were compression-molded into sheets by using a Carver (USA) laboratory press. The specimens were then directly cut off the sheets.

The flow curves were determined by means of a Rheometric Scientific (USA) SR-5 plate-plate rheometer. Mechanical characterization included tensile tests, performed according to ASTM D882 by using an Instron (USA) 3365 machine.

The biodegradation assessment was based on weight loss monitoring of the samples immersed in an active sewage sludge reactor, belonging to a municipal wastewater treatment plant. In particular, the samples were dried and weighed before their immersion, and their average surface roughness (R_a) was detected as well, by means of a Zeiss E35A surface measuring station. Every week, samples of each preparation were taken out of the active sludge, washed, sterilized, dried and weighed. Monitoring was carried out both in winter and summer conditions.

SEM analysis was performed both on the samples before and after immersion, on a Philips (The Netherlands) ESEM XL30 apparatus.

Results and Discussion

The determination of the flow curves allowed observing the effects of the presence of the filler and of the processing. Both in the filled and in the unfilled systems, processing caused a significant decrease in the viscosity compared to the virgin material, and this was more evident in the injection-moulded material. This result is reasonably due to thermomechanical stresses during processing, which lead to a partial breaking of the macromolecular chain scission. The presence of the wood flour led to a significant increase of the overall

viscosity and to yield stress phenomena. This is probably due to the presence of fiber-matrix gel-like structures at the lowest shear rates.
The morphological investigation carried out by means of SEM evidenced that the extruded Mater-Bi has many small aggregates, while the morphology of the injection moulded material is smoother and compact. This is probably due to the high pressure achieved during the operation. As regards the composites, the differences were more limited, however no fibre pull-out was observed.
As for the mechanical properties, separate considerations must be done for unfilled and filled systems.
In the former, significant differences were found between extruded and injection moulded samples, especially for the elastic modulus and the tensile strength. The injection moulded samples, in fact, showed significantly lower values, and this can beexplained considering the longer processing procedure underwent by the injection moulded material. The addition of the wood flour led to a significant increase of the rigidity (elastic modulus) and to a reduction of the ductility (elongation at break) while, for the tensile strength, the situation was slightly more complicated. This, in fact, decreased in the extruded samples, while increased in the injection moulded ones. This may be explained considering that the latter showed a more compact morphology. In other words, the mechanical properties depend on several factors, depending in turn on the morphology of the systems and thus on the processing.
As for the biodegradability the results must be, for sake of clarity, commented separately for the unfilled and the filled systems.
In the former, the extruded material underwent higher weight loss (and thus, biodegradation) rates than the injection molded one (fig. 1). This was found to be related to the smoother and more compact bulk morphology and surface smoothness of the samples obtained by injection molding, rather than by extrusion and compression molding. An important effect of the environmental temperature was found as well: the samples immersed during the summer period exhibited significantly higher weight losses than the counterparts immersed in the winter period.

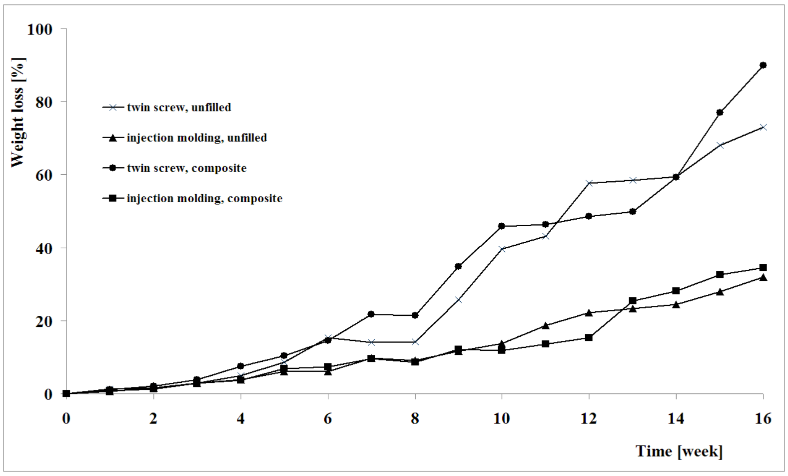

Figure 1 – Weight loss of unfilled and filled samples in active sludge

As for the composites, similar patterns were observed regarding the influence of processing technique and environmental temperature (fig.1). An interesting result was found concerning the biodegradation rates, which were significantly higher than in the unfilled counterparts. This is probably due to the fact that wood fibers can act as a support for bacterial growth [6].

References

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