Utilization of organic nanofillers from renewable resources in the recycling of poly(lactic acid)

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The massive production, and consumption, of fossil fuel-based plastics represents an environmental problem, derived for the inadequate management of the wastes. Among the proposed alternatives for solving this issue is the utilization of bioplastics, such as poly(lactic acid) (PLA). PLA is an aliphatic polyester produced from renewable resources, which has gained a fair amount of interest, especially in food packaging applications, due to its biodegradability, biocompatibility, safety in food contact and good optical and mechanical properties (Auras et al., 2010). Such interest in PLA has caused an increase in the global production of this bioplastic, exceeding 200000 t in 2014 and with a projected growth of 10 %/year until 2021 (Aeschelmann and Carus, 2017).

The low environmental impact of PLA does not imply that its massive production is exempt of problems. The need of large surfaces of arable land and the inadequate management of PLA wastes could generate a negative effect on society and environment. Therefore, it is important to propose methods for the valorization of PLA wastes, among which is mechanical recycling (Beltrán et al., 2018a).

Mechanical recycling allows reducing the consumption of raw materials and energy, thus diminishing the environmental impact of PLA. However, previous studies point out that mechanical recycling leads to the degradation of PLA, along with a reduction of some key properties in packaging application (Beltrán et al., 2018a). Therefore, it is necessary to pose methods that allow improving the performance of recycled PLA, such as reactive extrusion or the incorporation of organic and inorganic fillers and nanofillers (Beltrán et al., 2018b).

Organic fillers and nanofillers obtained from renewable sources, such as cellulosic materials, starch and chitin, have been studied in recent years as potential fillers for virgin PLA, due to its biodegradability, availability and moderate cost. For instance, cellulose nanocrystals have attracted a fair deal of interest because of their capacity for improving the thermal, mechanical and rheological properties, without greatly increasing the environmental impact of the material. However, an accurate surface functionalization is needed because the high surface functionality of these fillers can lead to agglomeration during processing, resulting in biocomposites with poor properties (Shaghaleh et al., 2018). Recently, a work conducted by Tesfaye et al. showed that the addition of silk fibroin nanocrystals (SFNC) leads to an improvement of the thermal stability of PLA, even during reprocessing (Tesfaye et al., 2016). Another organic filler which has raised some attention is keratin, which is the most abundant protein in epithelial cells and constitutes one of the most important biopolymers.

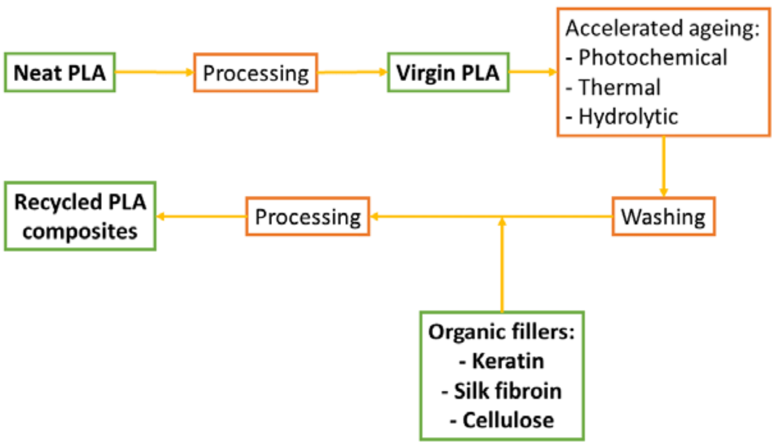

Figure 1. Scheme of mechanical recycling of PLA and the introduction of organic nanofillers

These works highlight the ability of organic fillers to improve the properties of PLA. However, there is little data about the utilization of organic fillers for improving the performance of mechanically recycled PLA. Therefore, the main aim of this work is to introduce organic fillers in a mechanically recycled PLA matrix to eventually improve its properties, and thus its recyclability.

Figure 1 shows a scheme describing the process employed for achieving such objective. A commercial grade of PLA was subjected to a mechanical recycling process including a first processing step (which involve an extrusion and a compression molding process), an accelerated aging (consisting in photochemical, thermal and hygrothermal aging) that simulates the degradation of the plastic during the service life, a demanding washing step and, finally, a second melt processing step. Different organic nanofillers, such as keratin, SFNC and chitosan were added during the second processing step. Then, the resulting materials were characterized using intrinsic viscosity measurements, differential scanning calorimetry (DSC), Fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM).

Finally, the effects of the organic fillers on the thermal stability, mechanical and optical properties of the mechanically recycled PLA were studied using thermogravimetric analysis (TGA), microhardness measurements and UV-Vis spectroscopy.

The results indicate that a correct selection of organic fillers can allow a cost-effective improvement of the properties of the recycled PLA, with a moderate environmental impact. Thus, the use of such organic fillers can result in an increase in the recyclability of PLA.

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