Development of New Competitive and Sustainable Bio-Based Plastics

Incorporation of nano-additives to PLA-PHB blends during extrusion

Within the frame of the NEWPACK project, the involved partners face the challenge of developing new bio-based and biodegradable blends for the packaging market sector. The use of two biopolymers like PLA and PHB and the preparation of optimized formulations represent part of the experimental work developed by Proplast during the first 18 months of the project. On one hand, blending them together was a valuable approach to overcome the shortcomings of both PLA and PHB. On the other hand, adding to the blends specific nano-additives can provide to the formulations improved performance, in terms of both physical and mechanical properties.

The preparation of PLA/PHB blends with nano-additives like **nano-whiskers of cellulose (CNWs)**, to increase the mechanical properties of the final blends, has been performing since the beginning of the project. In the first experimental steps, Proplast has prepared blends with CNWs, produced by partner Tecnalia. A preliminary experimental incorporation of a percentage of 1 wt.% of CNWs in several **PLA/PHB blend formulations** (100/0, 60/40 and 20/80) was performed, using a **lab-scale mixing equipment** and obtaining small amounts of materials. In order to evaluate if the presence of the nano-additives had affected the transparency of the produced blends and to verify if macroscopically macro-agglomerates of CNWs had been present, samples in a thickness range of 100-200 µm were compression-moulded using a **lab-scale compression equipment**. As it can be observed in the figure below, transparency has not been strongly affected by the incorporation of a small amount of CNWs. Moreover, no macro-agglomerates of these nano-fillers are detectable macroscopically in the prepared specimens.

Figure 1: PLA:PHB (60:40) blend with 1 wt.% CNWs and related compression moulded sample

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These preliminary activities were fundamental in order to perform a subsequent compounding phase using a **pilot scale equipment,** i.e. a co-rotating twin-screw extruder. This machine is considered the most efficient way to mix additives and thermoplastic polymers. The processing layout, in terms of screw profile, use of dosing unit, degassing, processing aid, has been tailored to the specific case of the project.

The selection of the formulations to be used for the incorporation of the nano-additives are the direct results of the Desing of Expertiment statistical analysis, built-up in order to investigate the influence of the reciprocal concentrations of the main components of the blends on their rheological and thermal properties. This study, performed in the previous task of the project, led to select the more interesting and promising formulations for the final application of the project.

For this second experimental phase, commercial biopolymers – **PLA** and **PHB** – and a specific plasticizer (**liquid lactic acid oligomer**) were used as polymer matrix. To these formulations, **CNWs in several amounts** (namely, 0.2 wt.%, 0.5 wt.%, 1 wt.% and 2 wt.%) have been added. From the PLA/PHB-based nanocomposites some **blown films** were obtained, using **a lab-scale blown film line**, equipped with a single screw extruder, as displayed in the figure below.

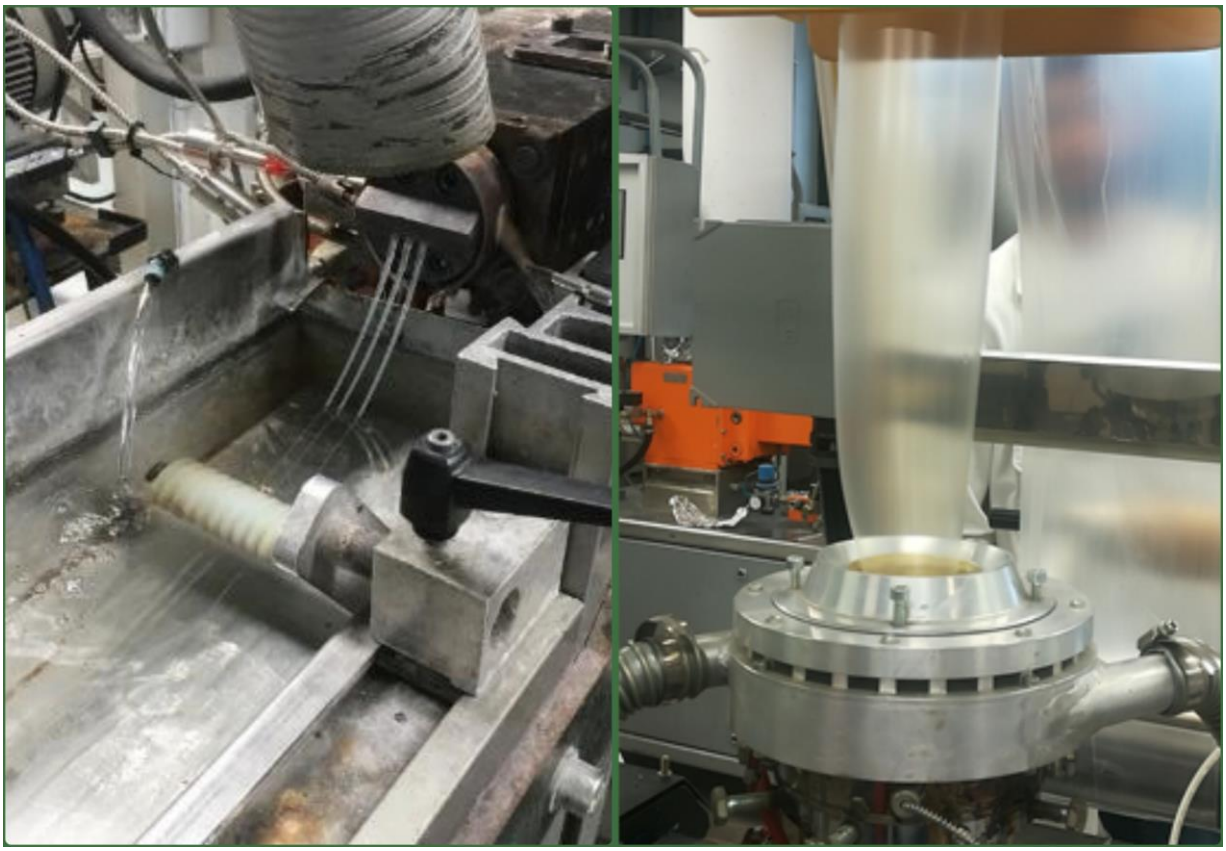

Figure 2: Experimental set-up for the preparation of PLA-PHB blends with the twin-screw extruder (left) and overview of the lab-scale equipment for the blown film extrusion (right)

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The same process has been performed adding to the polymeric formulations **encapsulated commercial natural extracts**, based on **olive oil leaves**, studied and selected by partners Tecnalia and Università Cattolica del Sacro Cuore (UCSC). Also, in this case, several amounts of the natural extracts (namely, 0.2 wt.%, 0.5 wt.%, 1 wt.% and 2 wt.%) were added to PLA/PHB blends in order to verify if an antimicrobial feature is obtainable even when the filler is added in the bulk of the polymer and not only as a coating. The obtained blown samples were reported in the figure below. Proplast, in collaboration with the other partners of the project, are testing these samples in order to evaluate the mechanical, thermal, optical and permeation properties.

Figure 3: Blown films of the PLA/PHB-based blends produced by Proplast (picture by Tecnopackaging)

This phase is preparatory in order to select the most promising formulations in terms of performance and it will lead to the preparation of blends using the PHB, experimentally synthetized within the project. This will allow **comparing the behaviour**, in terms of processability and performance, of the **commercial blends with the ones developed in the project**, creating a benchmark for the technical validation of the output of the project.

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