Exploring organic waste materials as a source for new bio-based textile fibers

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Abstract:

The textile industry is experiencing a profound shift towards sustainability driven by demand and the urgent need to address environmental challenges. To find a more sustainable alternative to petroleum-based synthetic fibers, a new generation of bio-based textile fibers has been explored, based on the use of biomass and valorization of agri-food and industrial waste as feedstock [1],[2]. Inspired by this, this study aimed to develop new PLA fibers, by melt-extrusion, reinforced with two main organic wastes: lignin - one of the most abundant biopolymers on the planet, but currently one of the main residues of the paper industry, and spent coffee grounds (SCG) - the main residue generated by the production of the second most consumed beverage on the planet, coffee. Prior the melt extrusion, lignin was dried in an oven for 48 hours and then sieved using a 75 µm sieve. In the case of SCG, due to its particle's dimensions, it was decided to use only the liquid extract, obtained by conventional extraction, as described in reference [3]. By UV-Vis Spectroscopy, it was found that the SCG extract obtained was mainly composed of caffeine and chlorogenic acid and had a total phenolic compound of 62,2 µg GAE, determined using the Folin-Ciocalteu method. Both organic wastes were then mixed in different proportions with a specific PLA grade for textile fibers, using a double-screw extruder. The composition of the samples produced are summarized in Table 1.

Table 1. Composition of the produced samples of PLA reinforced with lignin and SCG extract.

Samples	PLA	(Lignin:SCG extract)
PLA	100% w/w	-
PLA-1	97.5% w/w	2.5% w/w (75%w/w:25%w/w)
PLA-2	97.5% w/w	2.5% w/w (50%w/w:50%w/w)
PLA-3	97.5% w/w	2.5% w/w (25%w/w:75%w/w)

The four samples, extruded in the form of monofilaments, with 1 mm of diameter, were then evaluated by Fourier Transform Infrared Spectroscopy (FTIR), Thermogravimetric analysis (TGA), and tensile tests. From the FTIR analysis, it was possible to confirm the incorporation of lignin, due to a small peak at 1510 and 1600 cm^{-1}, which is related to the C=C groups of the aromatic rings and at 2850 cm^{-1} related to the C-H bond of lignin. Based on the TGA, it was confirmed that the initial decomposition temperature of PLA increased from 270 °C to 330°C with the incorporation of 2.5% of lignin+SCG extract, in different proportions, which means that the thermal stability of the produced monofilaments was more stable than PLA alone. Finally, as seen from the mechanical properties presented in Table 2, the incorporation of lignin+SCG extract also improved the tensile strength, deformation, and Young's Modulus of PLA, especially for the conditions 2 and 3. This indicates that the incorporation of organic materials makes it possible to obtain mechanically resistant PLA fibers. So, based on these findings, the produced samples exhibit significant potential for use in textile fiber production across a wide range of applications. Further research will be necessary to assess the spinnability of these novel materials.

Table 2. Mechanical properties of the samples.

Samples	Tensile strength (MPa)	Deformation (%)	Young's Modulus (GPa)
PLA	69.81 ± 2.67	4.29 ± 0.03	0.95 ± 0.07
PLA-1	47.40 ± 4.02	5.17 ± 0.22	1.08 ± 0.05
PLA-2	69.32 ± 6.93	4.42 ± 0.35	1.39 ± 0.12
PLA-3	74.91 ± 2.27	4.40 ± 0.32	2.28 ± 0.11

Keywords: *Lignin, spent coffe grounds, PLA, bio-based fibers*

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