Chemical and physical compatibilization strategies of bioactive compounds from potato crops and polymer matrix

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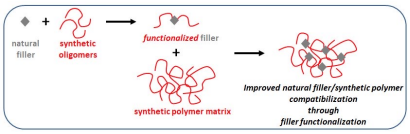
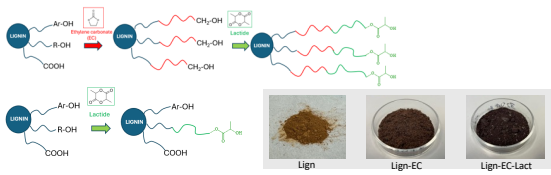
Introduction

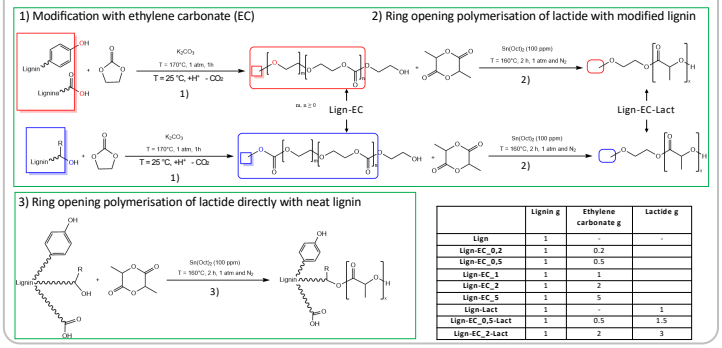
The ever-increasing amount of agricultural and food waste produced requires strategies for valorization and use to reduce its environmental impact in the perspective of a circular economy. Potato by-products are present in significant quantities in European countries and are therefore of great relevance. Potato derived bioactive compounds, such as starch and lignin, can be used in the production of polymer blends/composites and films for smart food packaging. Polylactic acid (PLA) was chosen as reference polymer with the aim of improving its thermal and mechanical response as well as imparting it smart properties. Lignin has been chemically modified in the first step with ethylene carbonate [1], while in the second step with oligomeric PLA branches, [2], to improve its dispersibility/miscibility with PLA polymer matrix. An alternative pathway has also been implemented to enhance biomolecules/polymer miscibility. More in detail an A-B-A triblock copolymer was synthesized as compatibilizer, being A polylactic acid segments and B an ad hoc oligomer with a chemical structure resembling the lignin one.



Synthesis

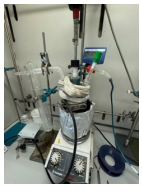
Chemical functionalisation of Lignin

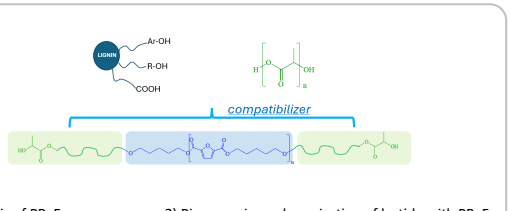




	Lignin g	Ethylene carbonate g	Lactide g
Lign	1	-	-
Lign-EC_0,2	1	0.2	
Lign-EC_0,5	1	0.5	
Lign-EC_1	1	1	
Lign-EC_2	1	2	
Lign-EC_5	1	5	
Lign-Lact	1	-	1
Lign-EC_0,5-Lact	1	0.5	1.5
Lign-EC_2-Lact	1	2	3

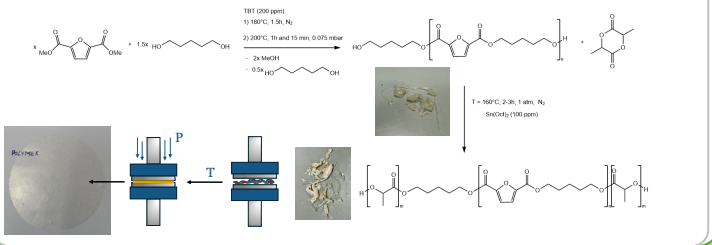
Physical compatibilization: synthesis of poly(pentamethylene furanoate)-poly(lactic acid) triblock copolymer



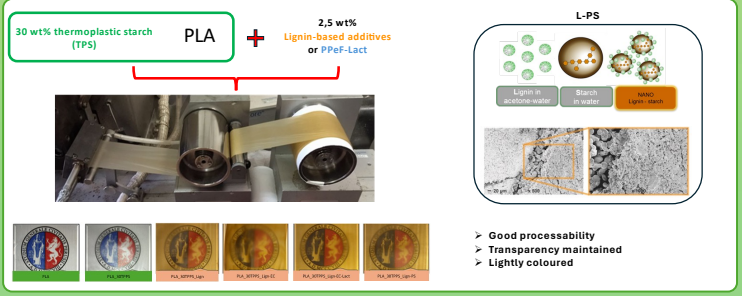


1) Synthesis of PPeF

2) Ring opening polymerisation of lactide with PPeF



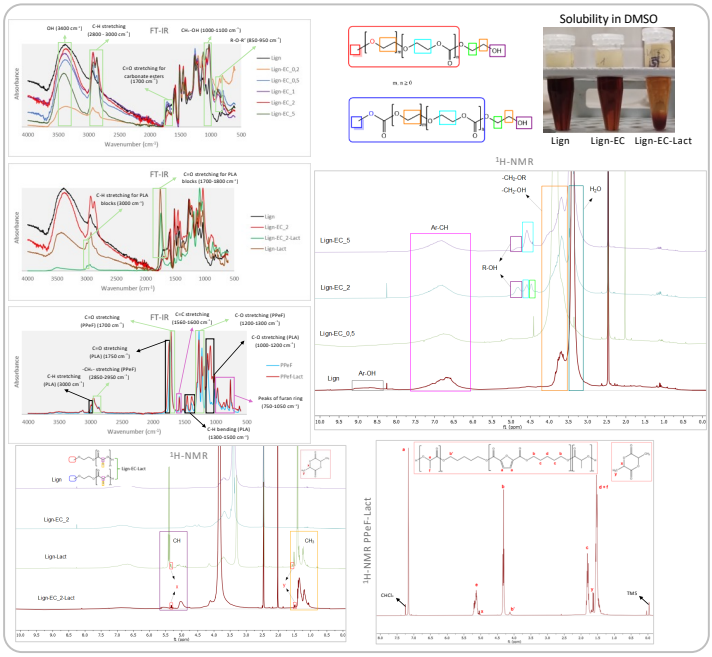
Film preparation



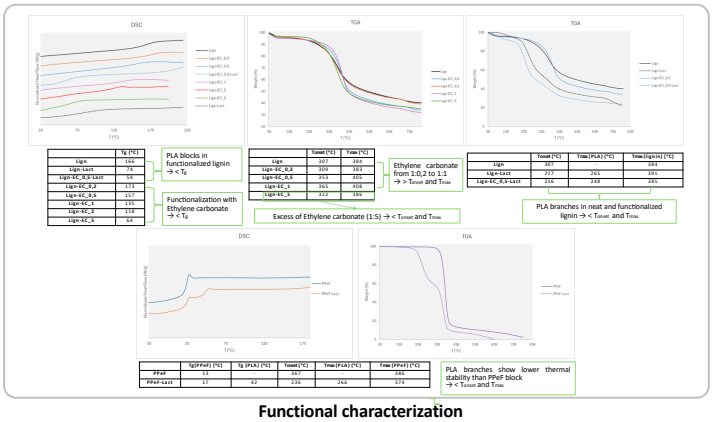
- Good processability
- Transparency maintained
- Lightly coloured

Characterization

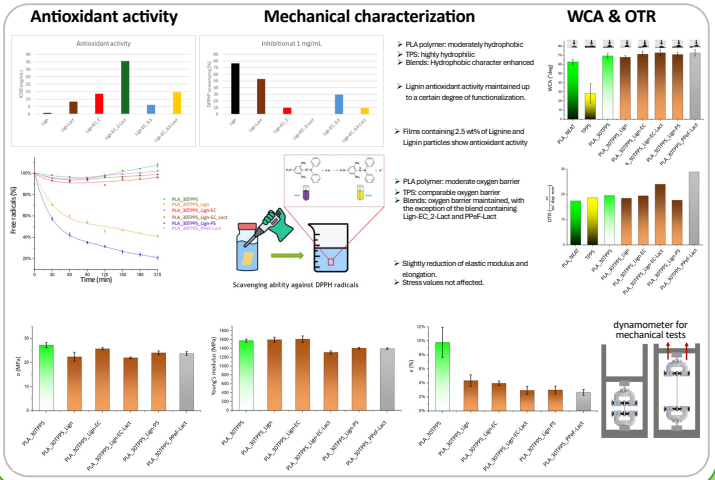
Molecular characterization



Thermal characterization



Functional characterization



Conclusions & future perspectives

- Successful **chemical modification** of Lignin with ethylene carbonate and lactide.
- Successful **functionalization** of neat Lignin with lactide.
- Lignin antioxidant ability maintained up to a certain degree of functionalization.
- The formulations with 2.5 wt%. of lignin-based additives improved functional properties such as **antioxidant activity, oxygen barrier and surface wettability compared to the matrix (due to lignin hydrophobicity).** In general, for samples with lignin-based and PPeF-Lact additives, mechanical properties, such as **σ** and **Young's modulus** remain still the same or have a little decrease, while ε decreases more then 50% respect to PLA_30TPPS reference sample.
- Future developments for the project may be the possibility of **testing further chemical modifications of the lignin to improve compatibility between the two matrices of PLA and TPPS.** In parallel, it is planned to consider the **use of copolymers with different structures compatible with the two homopolymers.**

Acknowledgments

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P4PACK: Pulp, Plants and Peels byproducts from Potatoes as ingredients for plastic blends in PAckaging applications. (Prot. 20223TTKEL)

References
[1] Duval, A., & Avérous, L. (2017). *ACS Sustainable Chemistry & Engineering*, 5(8), 7334-7343. [2] Bianchi, E., et. al (2023). *Biomacromolecules*, *24*(5), 2356-2368.