Utilization of olive tree pruning lignin: a sustainable and versatile raw material for industrial applications

I. Gómez-Cruz[1,2], P.L. de Hoyos-Martínez[1], M.d.M. Contreras[2], I. Romero[2], E. Castro[2], J. Labidi[1]

[1] Department of Chemical and Environmental Engineering, University of País Vasco, Donostia-San Sebastián, Gipuzkoa, 20018, Spain.
[2]Department of Chemical, Environmental and Materials Engineering, Universidad de Jaén, Jaén, 23071, Spain.
Keywords: deep eutectic solvents, industrial applications, lignin, olive tree pruning.
Presenting author email: igcruz@ujaen.es

In the face of growing environmental concerns and resource depletion, industries around the world are increasingly turning to green chemistry principles and biorefinery technologies to optimize resource utilization while minimizing waste generation (Silva et al., 2020). The sustainable use of lignocellulosic biomasses would contribute to the transition towards a sustainable circular economy and to the achievement of the Sustainable Development Goals (SDGs) adopted in the 2030 Agenda by the United Nations (UN) (Kobayashi and Nakajima, 2021) such as goal no. 12 "Responsible production and consumption". In addition, these actions would enable the preservation of the environment, economic prosperity and social welfare on a global scale.

Olive tree pruning (OTP) is a lignocellulosic by-product of olive cultivation rich in lignin generated in large quantities each year mainly in Mediterranean countries after the removal of unproductive branches of olive trees (García-Martín et al., 2020). Lignin is one of the most abundant natural aromatic biopolymers of complex and heterogeneous structure on earth, available in lignocellulosic biomass. The industrial interest of this compound has been increasing in recent years due to its low cost, its numerous properties (high carbon content, high thermal stability, biodegradability, antioxidant activity and favorable stiffness) (Zhu et al., 2020) and its multiple applications in the biofuels, biomaterials and food sectors (Gutiérrez-Villanueva et al., 2020).

Recently, biomass extraction by deep eutectic solvents (DES) has gained great interest due to its high lignin solubilization capacity (Soares et al., 2021). DES are mixtures of hydrogen bond donor (HBD) and hydrogen bond acceptor (HBA) species that exhibit excellent physicochemical properties (low toxicity, simple preparation, low cost, biodegradability, etc.) and allow higher or similar extraction yields to conventional thermochemical pretreatments (Contreras et al., 2023).

The objective of this work is to explore the potential of lignin extracted from OTP as a renewable and environmentally friendly resource for industrial applications following the biorefinery model and aiming at the circular bioeconomy of the olive sector.

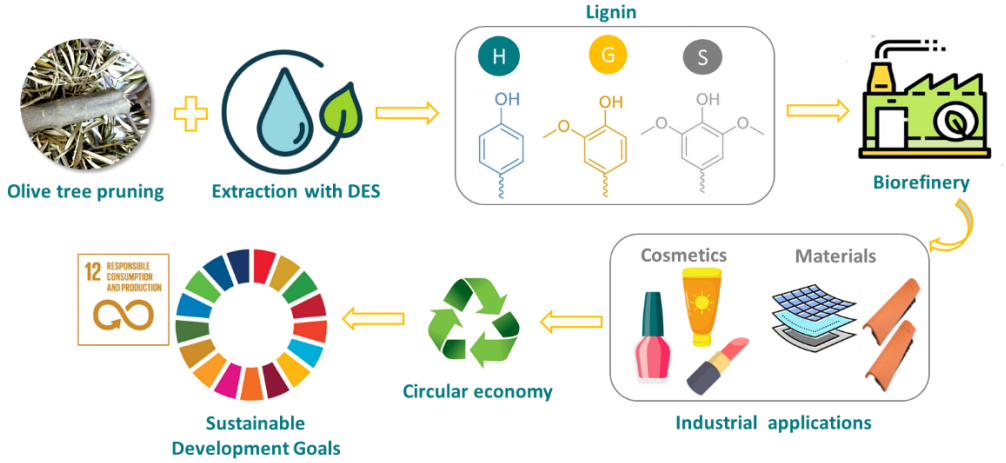

Figure 1. Scheme of work process followed for industrial applications of olive pruning lignin within the context of biorefineries following the circular bioeconomy model.

The chemical structure and unique properties of lignin make it an attractive component in the development of sustainable materials. The incorporation of lignin-derived components in composite materials improves their mechanical (strength and durability) and thermal (conductivity, density and specific heat) properties, reduces operating costs and minimizes environmental impact. These lignin-based materials find promising applications in various sectors, including automotive, construction, packaging and electronics (Yu and Kim, 2020) contributing to the development of sustainable and environmentally friendly alternatives to conventional materials. In

cosmetics, lignin derivatives exhibit excellent properties such as antioxidant, UV protection and antimicrobial activities, making them suitable candidates for skin care, hair care and personal care products (Antunes et al., 2023). Lignin-based ingredients offer natural alternatives to synthetic additives, meeting the growing demand for ecological and environmentally friendly formulations in the cosmetic industry.

This study shows that the utilization of lignin from OTP presents an attractive avenue to produce high value-added compounds for industrial applications in various sectors. Furthermore, this activity improves the sustainable efficiency of this waste from the olive oil industry by reducing the problem of waste processing and enables the development of technologies that contribute to energy savings and environmental protection by addressing the principles of the circular economy.

References

Antunes, F., Mota, I.F., Fangueiro, J.F., Lopes, G., Pintado, M., Costa, P. S., 2023. From sugarcane to skin: Lignin as a multifunctional ingredient for cosmetic application. International Journal of Biological Macromolecules, 234, 123592. https://doi.org/10.1016/j.ijbiomac.2023.123592

Contreras, M.d.M., Galán-Martín, Á., Seixas, N., da Costa Lopes, A.M., Silvestre, A., Castro, E., 2023. Deep eutectic solvents for improved biomass pretreatment: Current status and future prospective towards sustainable processes. Bioresource Technology, 369, 128396. https://doi.org/10.1016/j.biortech.2022.128396

García Martín, J.F., Cuevas, M., Feng, C.H, Mateos, P., Torres, M., Sánchez, S., 2020. Energetic valorisation of olive biomass; Olive-tree pruning, olive stones and pomace. Processes, 8(5), 511. https://doi.org/10.3390/pr8050511

Gutiérrez-Villanueva, A.R, Guirola, C., de Armas, A.C., Albernas Carvajal, Y., Villanueva, G., 2020. Valorización de la lignina en el concepto de biorrefinería (I). Centro Azúcar, 47(3), 95–105.

Kobayashi, T., Nakajima, L., 2021. Sustainable development goals for advanced materials provided by industrial wastes and biomass sources. Current Opinion in Green and Sustainable Chemistry, 28, 100439. https://doi.org/10.1016/j.cogsc.2020.100439

Silva, N.H.C., Morais, E.S., Freire, C.S.R., Freire, M.G., Silvestre, A.J.D., 2020. Extraction of high value triterpenic acids from *Eucalyptus globulus* biomass using hydrophobic deep eutectic solvents. Molecules, 25(1), 210. https://doi.org/10.3390/molecules25010210

Soares, B., da Costa Lopes, A.M., Silvestre, A.J.D., Rodrigues, P.C., Freire, C.S.R., Coutinho, J.A.P., 2021. Wood delignification with aqueous solutions of deep eutectic solvents. Industrial Crops and Products, 160, 113128. https://doi.org/10.1016/j.indcrop.2020.113128

Yu, O., Kim, K.H., 2020. Lignin to materials: A focused review on recent novel lignin applications. Applied Sciences, 10(13), 4626. https://doi.org/10.3390/app10134626

Zhu, J., Yan, C., Zhang, X., Yang, C., Jiang, M., Zhang, X., 2020. A sustainable platform of lignin: From bioresources to materials and their applications in rechargeable batteries and supercapacitors. Progress in Energy and Combustion Science, 76, 100788. https://doi.org/10.1016/j.pecs.2019.100788

Acknowledgements

I. Gómez-Cruz expresses her gratitude to the University of Jaén and the Ministry of Universities for the financial support of the Grants for the Recalibration of the Spanish University System for 2021-2023 in the Margarita Salas modality for the training of young doctors. J. Labidi would like to acknowledge the financial support from MCIN/AEI/ 10.13039/501100011033 and by “ERDF A way of making Europe”, project reference PID2021-122937OB-I00. F.