

Circular design of innovative elastomers from agro-industrial residues

Paula Lorena Bucci¹, Adrian Pedrosa Valbuena², Alberto Blanco Rodriguez³, Maria Teresa Fernandez Peña⁴, Esteban Cañibano Alvarez⁵

¹ CIDAUT, Spain. paubuc@cidaut.es

² CIDAUT, Spain. adrpel@cidaut.es

³ CIDAUT, Spain. albbla@cidaut.es

⁴ CIDAUT, Spain. maifer@cidaut.es

⁵ CIDAUT, Spain. estcan@cidaut.es

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Abstract

We establish an integrated process platform that upgrades lignin-rich streams from agro-industrial residues into circular, high-performance elastomers with industrial-grade performance. The route combines (i) hydrothermal fractionation/activation to tailor molar-mass distribution and phenolic functionality; (ii) green-catalyzed chemical modification (e.g., epoxidation and methacrylation) in alternative solvent systems; and (iii) solvent-free copolymerization and reactive extrusion under industry-relevant conditions. Segment-structured, bio-based architectures are designed to be compatibilized with PHA/PLA, prioritizing moderate processing temperatures and short cycle times. The platform is validated through rheology, DMA, tensile/tear, fatigue, abrasion, and thermal ageing, as well as functional tests in seals and flexible components. LCA and TEA are coupled to the development from the outset to minimize carbon footprint and costs, and to define circularity strategies (chemical recycling via transesterification and dynamic covalent bonds). The resulting materials exhibit properties comparable to or exceeding petrochemical (tunable modulus, low hysteresis, favorable compression set), together with relevant emission reductions. Overall, the concept demonstrates the technical and environmental feasibility of a continuous, statistically controlled process and supports scaling toward pilot operations (TRL 5–6).

Keywords:

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