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Valorization of Agro-Industrial Residues in the Development of Biodegradable Films

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The increasing consumption of petroleum-derived polymers and the low recycling rate of synthetic plastics have intensified environmental impacts, driving the development of biodegradable alternatives. In this context, the valorization of agro-industrial residues emerges as a promising strategy for the partial or total replacement of conventional polymers with renewable, low-impact materials. Among the large-scale residues, coffee husk, rich in fibers and bioactive compounds with antioxidant and antimicrobial potential, and rice husk, a source of cellulose capable of producing highly crystalline nanocellulose efficient as a reinforcing agent, stand out. Recent studies have demonstrated that the incorporation of coffee husk extracts into polylactic acid (PLA) films, either through chloroform extract (0.2, 0.4, 0.6 g) or oil obtained via Soxhlet with hexane (3 and 6 g), improved oxygen barrier properties (PLA-C3: 8 $cm^3 \cdot mm/(m^2 \cdot d \cdot 0.1$ MPa); PLA-06: 13 $cm^3 \cdot mm/(m^2 \cdot d \cdot 0.1$ MPa)), increased antioxidant activity (PLA-C3: 44.62%; PLA-06: 46.12%), and enhanced food preservation potential. In another study, the addition of rice husk nanocellulose (1% w/w) to polyvinyl alcohol (PVA) films significantly increased the elastic modulus (295.45%) and tensile strength (29.6%) compared to pure PVA, while reducing solubility (13.7% versus 60.3% for pure PVA) and water vapor permeability (339 $g/m^2 \cdot 120$ h versus 410 $g/m^2 \cdot 120$ h for pure PVA). Both studies employed solvent casting processing, structural analyses (FTIR, XRD, SEM), and tests of mechanical, thermal, and barrier properties. In summary, the use of agro-industrial residues in the production of biodegradable films adds value to low-cost by-products and generates more sustainable functional materials, aligned with the principles of the circular economy and global sustainability goals.

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