

Sustainable Nanoparticle Synthesis from Agro-Waste

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Abstract

The increasing generation of agricultural waste and the growing demand for sustainable nanotechnology have created opportunities for developing environmentally friendly approaches to nanoparticle synthesis. This study explores the potential of agro-waste as a sustainable and cost-effective resource for the green synthesis of nanoparticles. Agricultural residues such as fruit peels, crop residues, husks, seeds, leaves, and other biomass contain various bioactive compounds, including phenolics, flavonoids, proteins, carbohydrates, and organic acids, which can act as reducing and stabilizing agents during nanoparticle formation. The use of agro-waste can reduce dependence on conventional chemical reducing agents and minimize waste disposal problems, thereby supporting the principles of green chemistry and circular economy. The study reviews the major methods involved in the preparation, characterization, and optimization of nanoparticles synthesized using agricultural waste-derived extracts. Parameters such as pH, temperature, reaction time, extract concentration, and precursor concentration can influence nanoparticle size, morphology, stability, and yield. Agro-waste-mediated nanoparticles have potential applications in areas such as antimicrobial materials, agriculture, environmental remediation, catalysis, food packaging, and healthcare. Despite these advantages, challenges related to reproducibility, standardization, scalability, and consistent physicochemical properties remain. Overall, sustainable nanoparticle synthesis from agro-waste offers a promising approach for converting agricultural residues into value-added nanomaterials while reducing environmental impacts and promoting resource efficiency.

Keywords: Sustainable Nanotechnology, Agro-Waste, Green Synthesis, Nanoparticles, Agricultural Residues, Green Chemistry, Circular Economy, Bioactive Compounds, Waste Valorisation, Environmental Sustainability.

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