

Sustainable Nanoparticle Synthesis from Agro-Waste: Eco-Friendly Approaches

Seema Singh, Department of chemistry, Sardar Patel University, Balaghat, Madhya Pradesh

Abstract

The increasing demand for nanomaterials has encouraged the development of sustainable and environmentally responsible methods for nanoparticle synthesis. Agricultural waste, which is generated in large quantities from crop residues, fruit peels, husks, leaves, seeds, and other biomass materials, represents a promising and renewable resource for the production of nanoparticles. This study explores eco-friendly approaches for synthesizing nanoparticles from agro-waste, with emphasis on green chemistry, waste valorisation, and sustainable materials development. Agro-waste contains valuable phytochemicals, including polyphenols, flavonoids, proteins, sugars, and other bioactive compounds that can function as reducing, stabilizing, and capping agents during nanoparticle formation. Plant-mediated synthesis can reduce the dependence on hazardous chemicals, high-energy processes, and expensive synthetic reagents commonly associated with conventional methods. Various nanoparticles, including silver, gold, zinc oxide, iron oxide, and copper-based nanoparticles, can potentially be synthesized using extracts derived from agricultural residues. The physicochemical characteristics of the resulting nanoparticles, such as particle size, morphology, surface chemistry, crystallinity, and stability, depend on the type of biomass, extraction conditions, precursor concentration, pH, temperature, and reaction time. Advanced characterization techniques are essential for evaluating these properties and determining potential applications in antimicrobial materials, catalysis, agriculture, environmental remediation, sensing, and energy-related technologies. Despite its potential, challenges involving reproducibility, large-scale production, process standardization, waste variability, and comprehensive environmental assessment remain. Integrating nanotechnology with agro-waste valorisation can therefore support circular-economy principles while reducing agricultural waste and promoting sustainable production of functional nanomaterials.

Keywords: Agro-Waste, Nanoparticles, Green Synthesis, Sustainable Nanotechnology, Eco-Friendly Approach, Waste Valorisation, Green Chemistry, Biomass, Circular Economy, Nanomaterials.

