

Green Synthesis of Nanoparticles Using Plant Extracts: A Sustainable and Eco-Friendly Approach

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Abstract: Nanotechnology has emerged as an important area of scientific research because nanomaterials exhibit distinctive physical, chemical, optical, catalytic, and biological properties compared with their bulk counterparts. Conventional methods for nanoparticle synthesis frequently involve hazardous chemicals, high energy consumption, expensive equipment, and the generation of undesirable by-products. Consequently, green synthesis has gained considerable attention as an alternative approach for producing nanomaterials using renewable biological resources. Among the different biological methods, plant-mediated synthesis is particularly promising because plant extracts contain phytochemicals that can facilitate the reduction of metal ions and the stabilization of the resulting nanoparticles. Compounds such as polyphenols, flavonoids, terpenoids, alkaloids, proteins, sugars, and organic acids may participate in nanoparticle formation, depending on the plant species and extraction conditions.

The present review examines the principles, mechanisms, synthesis procedures, characterization techniques, and potential applications of nanoparticles synthesized using plant extracts, with particular emphasis on literature published up to December 2019. Silver, gold, zinc oxide, copper oxide, and iron oxide nanoparticles are discussed in relation to their synthesis and potential applications in antimicrobial technology, environmental remediation, catalysis, agriculture, and biomedical research. Important synthesis parameters, including pH, temperature, extract concentration, precursor concentration, reaction time, and mixing conditions, are also considered. Although plant-mediated synthesis offers advantages in terms of reagent selection, operational simplicity, and the possibility of reducing hazardous chemical inputs, challenges remain regarding reproducibility, particle-size control, mechanistic understanding, toxicity assessment, and industrial scalability. The review concludes that standardized extraction protocols, comprehensive physicochemical characterization, life-cycle assessment, and systematic safety evaluation are necessary to establish the environmental and technological benefits of plant-mediated nanomaterial production.

Keywords: Green synthesis, nanoparticles, plant extracts, phytochemicals, nanotechnology, biosynthesis, silver nanoparticles, environmental sustainability.