



Harmonizing nature and nanotechnology: Phytoextract-mediated synthesis of Ag-doped ZnO nanoparticles using *Lavandula stoechas* extract for environmental and biomedical applications

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Abstract

Nanoparticles, owing to their distinctive physical and chemical attributes, play pivotal roles in advancing nanomedicine and environmental technologies, particularly in the development of therapeutic systems and clean energy solutions. In this study, we achieved the synthesis of silver-doped zinc oxide nanoparticles utilizing Lavandula stoechas extract (LSE@Ag-doped ZnO nanoparticles) for the first time. The characterization of nanoparticles involved Energy-dispersive X-ray (EDAX), Dynamic Light Scattering (DLS), Ultraviolet–visible (UV–Vis), Field Emission Scanning Electron Microscopy (FESEM), Fourier-transform infrared (FT-IR), Transmission Electron Microscopy (TEM), and X-Ray diffraction (XRD) analyses. XRD and TEM results illustrated

a crystalline structure, spherical shape, and a size range of approximately 45–65 nm for the synthesized nanoparticles. The photocatalytic property of LSE@Ag-doped ZnO nanoparticles was assessed through the degradation of gentamicin. Optimization reactions, encompassing nanocatalyst dosage, light source, and antibiotic concentration, were conducted to achieve maximum degradation efficiency. Remarkably, under optimal conditions, LSE@Ag-doped ZnO nanoparticles exhibited a remarkable 93.7% degradation of gentamicin in just 100 min. Additionally, the antifungal and antibacterial properties against both Gram-negative and Gram-positive strains were investigated. Notably, the highest antibacterial activity was observed against Klebsiella pneumoniae, Proteus mirabilis, Escherichia coli, and Staphylococcus aureus strains with concentrations of 250, 125, 62.5, and 250 µg/ml, respectively. Furthermore, the anticancer potential of LSE@Ag-doped ZnO nanoparticles against the HT-29 cancer cell line was explored, revealing an IC₅₀ value of 21.37 µg/ml. Additionally, the nanoparticles demonstrated potent antioxidant capabilities, with a 79.8% DPPH removal percentage for LSE@Ag-doped ZnO nanoparticles. These findings underscore the multifaceted properties of the synthesized nanoparticles, holding promising prospects for applications in both medical and environmental sciences.