

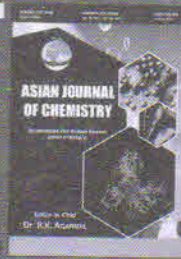


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Biogenic Synthesis and Characterization of Ag-Zn-CuO Nanoparticles using Peels of *Citrus limetta*: Evaluation of Dyes Degradation and Antibacterial Activity

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The synthesis of green nanomaterials by sustainable routes is gaining more attention as they hold potential for catalysis, environmental clean-up and biomedical applications. Herein, Ag-Zn-CuO trimetallic nanoparticles were green synthesised using *Citrus limetta* (mosambi) peel extract as a bioreducing and stabilizing agent. Phytoconstituents such as phenolics, flavonoids and tannins were present in the peels and help to reduce metal ions and shows capping properties. The formation of nanoparticles was reflected by a clear colour change and further established through UV-Vis spectroscopy, which showed typical SPR absorption bands at 388 nm (Ag), 324 nm (Zn) and 284 nm (CuO). Morphological investigation through FE-SEM reflected uniformly dispersed nanoparticles with irregular surface morphology and EDS ensured their trimetallic nature (84.73 wt.% Ag, 3.06 wt.% Zn, 12.21 wt.% Cu). XRD analysis confirmed crystalline structure by diffraction peaks for fcc Ag (111, 113), Zn (101) and CuO ($\bar{1}$ 13) with crystallite size of 16.15 nm on average as calculated from Scherrer's equation. Zeta potential analysis showed a mean value of -16.6 mV and thus moderate electrostatic repulsion to prevent aggregation and promote colloidal stability. Further catalytic application, in the presence of NaBH₄, nanoparticles degraded methyl red dye (78.69%) and Congo red dye (73.82%) in 180 min. Antibacterial activity exhibited strong inhibitory activity against *E. coli* (20 mm at 24 mg/mL). Biosynthesised Ag-Zn-CuO trimetallic nanoparticles possess effective dye degradation and antibacterial action, indicating their promise for usage in catalysis, environmental decontamination and biomedical applications.

Keywords: Trimetallic nanoparticles, Mosambi peel, Green synthesis, Congo red, Methyl red, Antibacterial activity.