Comparative Evaluation of Zinc Oxide Nanoparticles Synthesized via Green and Chemical Methods

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Antibiotic-resistant bacteria cause over 2 million infections annually in the US, driving the need for new antimicrobials. Zinc oxide nanoparticles (ZnONPs) are a promising solution, but conventional synthesis methods are often time-consuming and expensive. This study compares the synthesis, characterization, and antimicrobial properties of ZnONPs produced via simple green and chemical methods. Green-ZnONPs were synthesized using Spinach (Spinacia oleracea) and Swiss Chard (Beta vulgaris) extracts, while chemically-synthesized ZnONPs (Chem-ZnONPs) used polyethylene glycol and organic acids. NPs were characterized with UV-Vis, Raman, FTIR, DLS, SEM, EDS, and the Kirby Bauer disk diffusion test. UV-Vis analysis confirmed ZnONP formation with absorption peaks at 366–370 nm. SEM revealed Chem-ZnONPs as uniform nanospheres, while Green-ZnONPs showed greater polydispersity and aggregation due to residual organic material. DLS supported this, with Chem-ZnONPs showing the highest peak intensity at 250 nm, followed by Spinach-ZnONPs, and finally Swiss Chard-ZnONPs. Chem-ZnONPs outperformed Green-ZnONPs in size control and purity, while Spinach-ZnONPs are less aggregated with smaller sizes than Swiss Chard-ZnONPs. Disk diffusion against E. coli and S. epidermidis showed on average, Chem-ZnONPs were 13.5% more effective than Green-ZnONPs. Raman and FTIR spectra showed minimal differences among samples. While chemical synthesis produces smaller, purer, and more potent ZnONPs, green synthesis offers a viable and sustainable alternative. These findings emphasize the trade-offs between efficiency and sustainability, supporting further research into optimizing green synthesis for scalable antimicrobial applications.

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