

Antifungal efficacy of metallic silica nanohybrids embedded in hydrogel formulations for enhanced dermatological applications

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Fungal skin infections pose a significant and escalating global health threat, emphasizing the need for innovative therapeutic approaches. The incorporation of metallic silica nanohybrids into polymeric hydrogel formulations presents a promising strategy to address these infections. In this study, we synthesized a nanohybrid by doping silver (Ag), copper (Cu), and cobalt (Co) separately into silica nanoparticles using the sol-gel method, followed by mechanochemical grinding to combine the metals in equal proportions. The resulting nanohybrids were incorporated into a hydrogel matrix made from a 2% (w/v) solution of sodium alginate and carboxymethyl cellulose. Gel formulations were prepared at concentrations of 2, 3, 4, 5, 10, and 15 mg/mL by dissolving the nanohybrid dispersions in the polymer blend, followed by cross-linking with 2M calcium chloride solution (20% (v/v)). Characterization of the gel formulations included Fourier-transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), Raman spectroscopy, and scanning electron microscopy (SEM) for structural and morphological analysis. Atomic absorption spectroscopy (AAS) quantified the loading capacity

of metal in each formulation. The band gap energy of the gels was measured and recorded at around 2.94 eV using UV diffuse reflectance spectroscopy, confirming the potential for radical scavenging under visible light. Swelling index and porosity measurements indicated that the 15 mg/mL gel formulation exhibited the highest values, with a swelling index of $717.10 \pm 19.35\%$ and porosity of $129.46 \pm 2.23\%$. Antifungal activity was evaluated using the agar overlay method, followed by colony count assays against *Candida albicans*, *Trichophyton rubrum*, *Microsporum gypsum*, and *Epidermophyton floccosum*. The 15 mg/mL formulation showed complete inhibition, with zero colony counts against all tested fungal strains. These findings underscore the promising potential of metallic silica nanohybrid-integrated hydrogel formulations as a highly effective and innovative therapeutic approach for treating dermatophytic and other fungal skin infections.

Keywords:

Antifungal activity, Metallic, Nanohybrids, Hydrogel, Band gap energy