Synthesis and characterization of biologically active zinc compounds with different humic ligands

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Wound treatment is a significant healthcare expense, often referred to as a "silent epidemic" due to its widespread impact on patient well-being and mental health. An estimated 1-2% of the population suffers from chronic wounds. Effective wound healing requires a combination of systemic and local therapies, including zinc-containing medications. Zinc plays a crucial role in human physiology, acting as a cofactor for enzymes involved in cell membrane repair, growth, proliferation, and immune function, all essential for wound healing.

Recent research focuses on enhancing the properties of biologically active metals by using ligands to create hybrid molecules. Humic substances, natural compounds with immunostimulatory and antioxidant properties, have emerged as promising ligands for zinc-based wound treatments. These substances exhibit good biocompatibility and can be used as stabilizers or for synthesizing coordination compounds. Their varying biological activity allows for fine-tuning therapeutic applications across different wound healing stages.

The goal of this study was to create and characterize biologically active zinc compounds using fractions of humic substances with different ligand properties. The research synthesized three types of compounds: zinc oxide nanoparticles stabilized with coal-derived humic acids (HAs), zinc complexes with coal HAs, and peat-derived fulvic acids (FAs).

The coal HAs proved to be effective ligands for synthesizing zinc oxide nanoparticles. The process allowed control over nanoparticle size, and the moderate zinc release rate in hydrophilic gels made these nanoparticles suitable for use in wound dressings at the scarring (remodeling) stage, potentially replacing conventional zinc oxide ointments. Both humic and fulvic acids also showed promise as ligands for zinc complexes, with the ligand profile determining their biological activity.

FA-based zinc complexes stimulated monocyte differentiation into macrophages, promoting antibacterial activity, making them suitable for early wound healing stages. In contrast, HA-zinc complexes inhibited macrophage formation and exhibited anti-inflammatory properties, useful in later stages to prevent excessive collagen formation.

The research demonstrated that the three types of zinc-based compounds with humic ligands can be applied at different stages of wound healing, supporting faster recovery as confirmed by in vivo tests. This approach could lead to a range of zinc-based treatments tailored to specific healing stages, improving overall wound care.

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References

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