Development of a bioactive gauze dressing functionalized with herb-loaded nanoparticles to facilitate wound healing

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Abstract

Wound healing is crucial in healthcare due to its significant physiological and economic impacts on patients. Among wound dressings, gauze is the most widely used; however, it is associated with a high risk of bacterial wound infections that delay healing. Hence, enhancing its effectiveness remains critical. In Uganda, herbal medicines are still utilised in the treatment of wounds and other illnesses; however, they require high dosages and prolonged treatment, leading to poor patient compliance. Nanoencapsulation offers a promising solution by improving the drug's therapeutic effect through sustained release while minimising toxicity and dosage. The main objective of this study was to develop and evaluate a gauze dressing functionalized with herb-loaded chitosan nanoparticles for enhanced wound healing. This study explored the extraction of selected medicinal herbs (Bidens pilosa L., Ageratum conyzoides L., and Hoslundia opposita Vahl) using different methods and solvents with varying polarity. The extraction yield, in vitro antibacterial (on Staphylococcus aureus/Methicillin-Resistant Staphylococcus Aureus (MRSA), Enterococcus faecalis, Escherichia coli, Klebsiella Pneumoniae, and Pseudomonas aeruginosa), antibiofilm, and antioxidant activities, as well as phytochemicals present, were determined. The most efficacious extract was subjected to GC-MS and LC-MS analysis. It was nanoencapsulated in chitosan nanoparticles via the ionic gelation method, and optimisation was performed using Response Surface Methodology (RSM). The herb-loaded nanoparticles were evaluated for in vitro antibacterial activity and incorporated into the gauze dressing. Their in vitro antibacterial activity, in vivo wound healing in Wistar rats, water absorption, and retention capacity, as well as in vivo skin irritation in rabbits, were tested. High extraction yields were obtained for samples extracted with highly polar solvents. The methanol (100%) extract of H. opposita extracted by maceration, displayed better bioactivity (antibacterial, antibiofilm and antioxidant). The biological activity of the plants was attributed to the presence of various phytochemicals. The herb nanoparticles obtained were spherical with size 212 nm, zeta potential 40 mV, Polydispersity Index (PDI) 0.22, encapsulation efficiency 79.1% and loading capacity 9.82 %. Their in vitro drug-release profile showed sustained release of 50% over 24 hours, compared with 100% for the free extract. They exhibited enhanced antibacterial activity with minimum inhibitory concentrations (1.875 to 3.275 mg/mL) against S. aureus, MRSA, E. faecalis, E. coli, K. pneumoniae, and P. aeruginosa. Gauze incorporated with nanoparticles exhibited no antibacterial activity but significantly accelerated wound healing, achieving 93% wound closure by day 18 compared with 41% in untreated gauze. The dressing also exhibited improved water-holding capacity; no skin irritation was observed in rabbits, and its water absorption capacity remained unaltered. Extract fractionation identified rutin and 4111-acetylvitexin-211-O-rhamnoside as the possible major bioactive compounds in the methanol extract of H. opposita. In conclusion, integrating the H. opposita extract-loaded chitosan nanoparticles into gauze significantly enhanced wound healing, offering a promising advancement in wound care technology.

Description

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