Harnessing Nature: Hydrogels Derived from Bacterial Cellulose and Chitosan for Biomedical Applications

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Abstract

Bacterial cellulose (BC) is a biopolymer with excellent mechanical strength and purity. However, its utilization in biomedical applications is hampered due to limitation in reactive functional groups. This work presents the development of semi-interpenetrating hydrogels (semi-IPNs) by combining BC with chitosan (Ch) and crosslinking with genipin (Gp), using a straightforward two-step strategy. First, an *in-situ* method was employed to incorporate chitosan directly into the BC matrix during *Gluconacetobacter xylinus* fermentation process. This was followed by an *ex-situ* crosslinking step, where the BC-Ch were immersed in genipin solution to enhance network stability and biocompatibility. FTIR study revealed new amide I and II bands and C–N stretching vibrations confirming the successful modification of BC with Ch. SEM analysis demonstrated that crosslinked BC-Ch-Gp hydrogels exhibited a compact, highly interconnected fibril network with improved porosity. Differential Scanning Calorimetry indicated the presence of free, bound, and intermediate water types, contributing to good water retention capacity of the hydrogels. Swelling studies revealed pH-responsive behaviours, with higher swelling at low pH for crosslinked samples and increased chitosan ratio further enhancing this response. Mechanical testing showed improved stiffness and reduced moisture content in crosslinked hydrogels, making them more suitable for biomedical environments. Antibacterial evaluation confirmed effective inhibition of *Escherichia coli* and *Staphylococcus aureus*. In vitro drug release studies using quetiapine fumarate showed sustained release profiles following the Higuchi model and a combination of non-Fickian and super case II transport, indicating controlled diffusion and matrix relaxation. Using non-pathogenic bacteria and coconut-derived media, this simple dual-method strategy produced safe, functional hydrogels suitable for applications in controlled drug delivery, wound healing, and advanced biomedical dressings.

Keywords: Bacterial cellulose; Chitosan; Genipin; Semi-IPN hydrogel; In-situ synthesis; Ex-situ crosslinking; pH responsiveness; Controlled drug release; Antibacterial