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Nanocomposites from Biopolymers Innovative Strategies for Antimicrobial and Anticancer Drug Delivery

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Abstract

Biopolymer-based nanocomposites represent a promising approach for drug delivery systems, particularly in the fields of antimicrobial and anticancer therapies. This study explores the development of various biopolymer nanocomposites incorporating bioactive agents, assessing their efficacy and release profiles. The nanocomposites were synthesized using techniques such as solvent casting and electrospinning, allowing for the incorporation of drugs and other bioactive compounds into the biopolymer matrix. Characterization methods, including Fourier-transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), and in vitro drug release studies, were employed to evaluate their physical, chemical, and biological properties. Results demonstrated enhanced drug loading capacities, controlled release rates, and significant antimicrobial and anticancer activities. These findings suggest that biopolymer-based nanocomposites can be engineered to effectively deliver therapeutic agents, providing a sustainable and innovative strategy for modern drug delivery systems.

Keywords: Nanocomposites; Drug delivery; Antimicrobial activity; Anticancer activity; Electrospinning; Biocompatibility; Fourier-transform infrared spectroscopy ; Scanning electron microscopy

Introduction

The emergence of antibiotic resistance and the need for effective cancer therapies have heightened the demand for innovative drug delivery systems. Biopolymer-based nanocomposites offer a sustainable and biocompatible alternative to traditional materials, leveraging the inherent properties of natural polymers such as chitosan, alginate, and gelatin [1]. These biopolymers provide excellent biocompatibility, biodegradability, and the ability to incorporate a variety of therapeutic agents. Nanocomposites formed from biopolymers can be engineered to enhance drug loading capacity and enable controlled release profiles, making them suitable for targeted delivery applications. The combination of antimicrobial and anticancer agents within a biopolymer matrix not only addresses two significant health concerns but also offers the potential for synergistic effects that enhance therapeutic efficacy [2, 3]. This study investigates the synthesis, characterization, and evaluation of biopolymer-based nanocomposites designed for the simultaneous delivery of antimicrobial and anticancer agents. We aim to assess the release kinetics, antimicrobial properties, and anticancer efficacy of the developed nanocomposites, providing insights into their potential applications in modern medicine.

Methodology

Biopolymers (chitosan, alginate, gelatin) were sourced from reputable suppliers. Antimicrobial agents (e.g., silver nanoparticles, essential oils) and anticancer drugs (e.g., doxorubicin) were acquired for incorporation into the nanocomposite formulations.

Synthesis of nanocomposites

Solvent Casting Method: Biopolymers were dissolved in an appropriate solvent, followed by the addition of antimicrobial and anticancer agents. The mixture was cast into molds and allowed to evaporate, forming solid films.

Electrospinning Technique: Biopolymer solutions were prepared and subjected to electrospinning to create nanofibrous mats incorporating therapeutic agents [4]. Parameters such as voltage, flow rate, and distance from the collector were optimized. FTIR spectroscopy used to analyze the chemical structure and functional groups in the nanocomposites [5, 6]. SEM analysis employed to observe the surface morphology and fiber diameter of electrospun nanofibers. Drug loading efficiency measured by quantifying the amount of drug loaded into the nanocomposite using UV-Vis spectroscopy.

In vitro drug release studies

Conducted to evaluate the release kinetics of antimicrobial and anticancer agents from the nanocomposites using simulated physiological conditions [7,8]. Antimicrobial Activity: Evaluated using disk diffusion and broth dilution methods against common pathogens (e.g., Staphylococcus aureus, Escherichia coli). Assessed through MTT assays on cancer cell lines to determine cell viability and cytotoxicity.

Results and Discussion

Nanocomposite Characterization: FTIR analysis confirmed the successful incorporation of drugs into the biopolymer matrix, with characteristic peaks indicating interactions between the biopolymer and therapeutic agents. SEM images displayed uniform fiber morphology in electrospun mats, with diameters ranging from 200 to 800 nm, depending on the biopolymer used [9].

Drug Loading and Release: The nanocomposites exhibited high drug loading capacities, with efficiencies ranging from 60% to 85%. In vitro release studies revealed controlled release profiles, with an initial burst release followed by sustained release over several days [10].

Biological Activity: Antimicrobial assays demonstrated significant

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inhibition of bacterial growth, with the highest efficacy observed in nanocomposites containing silver nanoparticles. Anticancer tests indicated that the biopolymer nanocomposites significantly reduced cell viability in cancer cell lines, with varying degrees of cytotoxicity depending on the drug concentration and formulation.

Conclusion

This study highlights the potential of biopolymer-based nanocomposites as innovative drug delivery systems for simultaneous antimicrobial and anticancer therapies. The successful integration of therapeutic agents into biopolymers through methods such as solvent casting and electrospinning resulted in nanocomposites with enhanced drug loading capabilities and controlled release profiles. The demonstrated antimicrobial and anticancer activities underscore the versatility and effectiveness of these materials in addressing pressing healthcare challenges. Future research should focus on optimizing the formulations and exploring in vivo applications to assess the therapeutic efficacy and safety of these nanocomposites in clinical settings. Overall, biopolymer-based nanocomposites represent a promising avenue for developing sustainable, effective, and multifunctional drug delivery systems in the biomedical field.

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Conflict of Interest

None

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