Fabrication of polyvinyl alcohol-sodium alginate nanocomposite hydrogels reinforced with green synthesised silver nanoparticles for antimicrobial applications

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INTRODUCTION

Infectious diseases caused by potent microbes, the recent Covid-19 medical crisis, and increase in antibiotic resistant pathogens are serious medical and scientific challenges. These challenges pose a huge impact on the economy and health care systems of any country. There is an urgent need to development functional materials for immediate decontamination of surfaces. In this project, we have successfully fabricated a peelable nanocomposite hydrogel based on polyvinyl alcohol (PVA), sodium alginate and silver nanoparticles (synthesized using a green method). The hydrogel film was crosslinked with glutaraldehyde and zinc acetate and exhibited good antibacterial properties.

METHODS

Silver nanoparticles reinforced peelable hydrogel films and slabs comprising of PVA and sodium alginate were fabricated through in situ formation of nanoparticles using extracts of three different medicinally important plants such as Yerba mate, Hibiscus, and Matcha green tea. PVA and sodium alginate were crosslinked using glutaraldehyde (1 wt%), and zinc acetate solution, respectively. The physical and antibacterial properties of the prepared films were evaluated using established methods.

The PVA solution, initially constituted by dissolving 10g of polyvinyl alcohol in 200ml of water under agitation, was further enriched with 2g of sodium alginate and 0.07g of silver. Simultaneously, an extract preparation involved the dissolution of 1g of hibiscus, yerba mate, and matcha separately in 100ml of water each.

Subsequently, for the development of hydrogel films, 10ml of the individual hibiscus, yerba mate, and matcha solutions were amalgamated with 50ml of the PVA solution. To this mixture, 2 drops of sodium hydroxide (NaOH) and 1ml of glutaraldehyde were added. The resultant solution was then applied onto a petri dish previously treated with zinc, followed by another zinc application post-application.

RESULTS

In our investigation, we evaluated the antibacterial efficacy of hydrogels against three bacterial strains - E. coli, Pseudomonas aeruginosa, and Staphylococcus aureus - employing two distinct methods: the Disk Diffusion Method and the Broth Microdilution Method.

Initially, in the Disk Diffusion Method, 2 cm squares of hydrogels derived from matcha, mate, and hibiscus were tested against the bacteria. In this approach, no clear zones of inhibition were observed around the hydrogel samples when tested against any of the bacterial strains. [figure.1]

Subsequently, utilizing the Broth Microdilution Method revealed noteworthy findings that merit attention. The matcha hydrogel exhibited significant zones of inhibition against all three bacterial strains. Furthermore, the hibiscus hydrogel demonstrated substantial inhibition specifically against Staphylococcus aureus. Conversely, the mate hydrogel displayed inhibitory effects against Pseudomonas aeruginosa and Staphylococcus aureus, with reduced effectiveness against E. coli. [figure.2],[figure.3]

These results underscore the varying antibacterial properties of the hydrogels derived from matcha, mate, and hibiscus, as evidenced by their differential impacts on the tested bacterial strains in the Broth Microdilution Method. Further analysis and consideration of these outcomes are essential for elucidating the potential applications and implications of these hydrogels in antibacterial strategies.

Furthermore, in addition to the antibacterial testing, comprehensive swelling studies were conducted on the three distinct hydrogel samples. These investigations revealed a notable and significant increase in swelling behavior across all three hydrogel variants. The observed enhancements in swelling characteristics suggest a potential correlation between the structural properties of the hydrogels and their antibacterial efficacy, highlighting the multifaceted nature of these materials in biomedical applications.

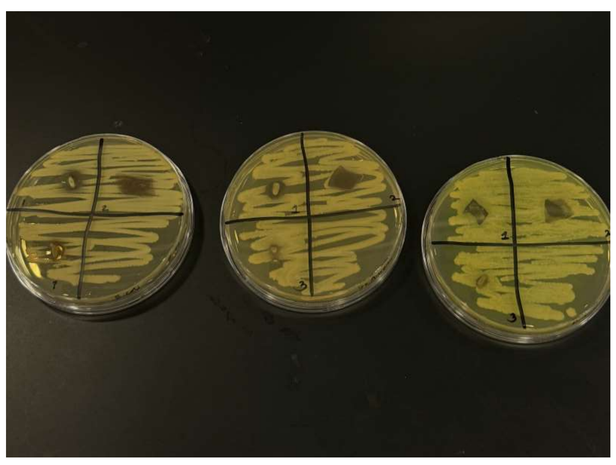

Figure.1

Figure.2

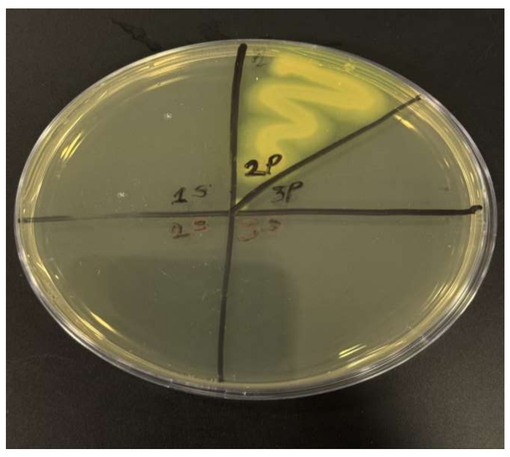

Figure.3

DISCUSSION

The development of functional materials for immediate decontamination of surfaces is of paramount importance, especially in the context of combating infectious diseases and addressing the challenges posed by antibiotic-resistant pathogens. In this study, we successfully fabricated a peelable nanocomposite hydrogel incorporating silver nanoparticles synthesized using a green method. The antibacterial properties exhibited by the hydrogel, crosslinked with glutaraldehyde and zinc acetate, hold promise for applications in antimicrobial surface coatings and medical devices.

The incorporation of silver nanoparticles, known for their antimicrobial properties, into the hydrogel matrix enhances its ability to combat a wide range of bacterial strains, as evidenced by the significant zones of inhibition observed in our experiments. Furthermore, the utilization of plant extracts from Yerba mate, Hibiscus, and Matcha green tea in the synthesis process adds a natural and sustainable aspect to the development of these functional materials.

SIGNIFICANCE OF THE PROJECT

The findings from this study have implications for the design of next-generation antibacterial surfaces, wound dressings, and medical implants, offering innovative solutions to combat infectious diseases and address the challenge of antibiotic resistance. Further exploration and optimization of these hydrogels could lead to the development of effective strategies for surface decontamination and infection control in healthcare settings.

CONCLUSION

In conclusion, our study demonstrates the successful fabrication of antibacterial peelable nanocomposite hydrogel films with promising antimicrobial properties. The differential responses of the hydrogels derived from Yerba mate, Hibiscus, and Matcha green tea against various bacterial strains highlight the importance of material composition in determining antibacterial efficacy. Moreover, the significant increase in swelling behavior observed across all hydrogel variants underscores the potential correlation between structural properties and antibacterial performance.