https://doi.org/10.53230/tgm.1310-912X.2025.1001.11

DESIGN OF INNOVATIVE POLYMERIC MATERIALS AS BIOCONTROL AGENTS FOR SUSTAINABLE AGRICULTURE

Nasko Nachev, Mariya Spasova, Olya Stoilova
Laboratory of Bioactive Polymers, Institute of Polymers, Bulgarian Academy of Sciences
Akad. G. Bonchev St., bl. 103A, BG-1113 Sofia, Bulgaria
nachev_n@polymer.bas.bg

Introduction

Plant diseases caused by a wide range of phytopathogens – particularly fungi such as Fusarium, Phaeomoniel la, Verticillium, Botrytis, and Rhizoctonia – pose a significant threat to global agriculture, resulting in substantial crop losses and economic challenges. Fungi constitute the primary group of plant pathogens, causing numerous destructive diseases in crops. Current reliance on chemical pesticides offers short-term control but results in long-term environmental contamination and health risks to non-target organisms, including humans. This unsustainable cycle necessitates the development of effective, eco-friendly alternatives. Nanotechnology offers promising solutions, with electrospinning standing out as a versatile and efficient technique for producing micro- and nanoscale polymer fibers. These fibers have a large surface area and porous structure, making them ideal for encapsulating and protecting sensitive biological agents for use in eco-agriculture.

Experimental part

The following materials were used: Poly(L-lactide) (PLLA), chitosan oligomer (COS), low molecular weight chitosan (CS-LMW), and high molecular weight chitosan (CS-HMW). The beneficial microorganism Trichoderma asperellum was used as the biocontrol agent, and the pathogenic fungi Phaeomoniella chlamydospora and Phaeoacremonium aleophilum were used for antifungal testing. Dichloromethane, ethanol, and glacial acetic acid of analytical grade were used as received.

Results and Discussion

The electrospinning of PLLA produced fibers with a uniform and defect-free morphology. Subsequent coating of these fibrous mats with chitosan suspensions containing T. asperellum spores was effective, with the chitosan oligomer facilitating the most homogeneous distribution of spores across the material. Contact angle measurements revealed that the initially hydrophobic PLLA mat encountered a notable shift towards hydrophilicity after applying of the chitosan coating. Furthermore, the integration of the chitosan film notably enhanced the mechanical strength of the hybrid materials compared to the neat PLLA mat. The microbiological assessment was essential in confirming the bioactivity of the obtained materials. The PLLA mat coated with the oligochitosan and T. asperellum spores exhibited enhanced efficacy, demonstrating a strong antagonistic effect that resulted in the effective suppression of the targeted pathogenic fungal growth. Conclusions Novel hybrid biomaterials based on PLLA, chitosan, and T. asperellum spores were successfully developed. The spores were effectively incorporated into electrospun fibers resulting in biohybrid materials with strong biocontrol potential. These results demonstrate the promise of such materials as sustainable alternatives to chemical pesticides in crop protection.

Keywords: *electrospinning; chitosan; PLLA; plant diseases; eco-agriculture; biocontrol agents.*

Acknowledgments

This research was funded under the Grant BG-RRP-2.011-0005-C01 with financial support from the European Union-NextGenerationEU, Investment C2.I2 “Increasing the innovation capacity of the Bulgarian Academy of Sciences in the field of green and digital technologies”.