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Antibacterial Nanofibrous Film Encapsulated with 4-terpineol/β-cyclodextrin Inclusion Complexes: Relative Humidity-Triggered Release and Shrimp Preservation Application

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Abstract : Antimicrobial active packaging enables extensive biological effects to improve food safety. However, the efficacy of antimicrobial packaging hinges on factors including the diffusion rate of the active agent toward the food surface, the initial content in the antimicrobial agent, and the targeted food shelf life. Among the possibilities of antimicrobial packaging design, an interesting approach involves the incorporation of volatile antimicrobial agents into the packaging material. In this case, the necessity for direct contact between the active packaging material and the food surface is mitigated, as the antimicrobial agent exerts its action through the packaging headspace atmosphere towards the food surface. However, it still remains difficult to achieve controlled and precise release of bioactive compounds to the specific target location with required quantity in food packaging applications. Remarkably, the development of stimuli-responsive materials for electrospinning has introduced the possibility of achieving controlled release of active agents under specific conditions, thereby yielding enduring biological effects. Relative humidity (RH) for the storage of food categories such as meat and aquatic products typically exceeds 90%. Consequently, high RH can be used as an abiotic trigger for the release of active agents to prevent microbial growth. Hence, a novel RH - responsive polyvinyl alcohol/chitosan (PVA/CS) composite nanofibrous film incorporated with 4-terpineol/β-cyclodextrin inclusion complexes (4-TA@β-CD ICs) was engineered by electrospinning that can be deposited as a functional packaging materials. The characterization results showed the thermal stability of the films was enhanced after the incorporation due to the hydrogen bonds between ICs and polymers. Remarkably, the 4 wt% 4-TA@β-CD ICs/PVA/CS film exhibited enhanced crystallinity, moderate hydrophilic (Water contact angle of 81.53°), light barrier property (Transparency of 1.96%) and water resistance (Water vapor permeability of 3.17 g mm/m2 h kPa). Moreover, this film also showed optimized mechanical performance with a Young’s modulus of 11.33 MPa, a tensile strength of 19.99 MPa and an elongation at break of 4.44 %. Notably, the antioxidant and antibacterial properties of this packaging material were significantly improved. The film demonstrated the half-inhibitory concentrations (IC50) values of 87.74% and 85.11% for scavenging 2,2-diphenyl-1-picrylhydrazyl (DPPH) and 2, 2′-azinobis (3-ethylbenzothiazoline-6-sulfonic) (ABTS) free radicals, respectively, in addition to an inhibition efficiency of 65% against Shewanella putrefaciens, the characteristic bacteria in aquatic products. Most importantly, the film achieved controlled release of 4-TA under high 98% RH by inducing the plasticization of polymers caused by water molecules, swelling of polymer chains, and destruction of hydrogen bonds within the cyclodextrin inclusion complex. Consequently, low relative humidity is suitable for the preservation of nanofibrous film, while high humidity conditions typical in fresh food packaging environments effectively stimulated the release of active compounds in the film. This film with a long-term antimicrobial effect successfully extended the shelf life of Litopenaeus vannamei shrimp to 7 days at 4 °C. This attractive design could pave the way for the development of new food packaging materials.

Keywords : controlled release, electrospinning, nanofibrous film, relative humidity–responsive, shrimp preservation
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