Proceedings of the 11th World Congress on New Technologies (NewTech'25)
Paris, France - August, 2025
Paper No. ICBB 114
DOI: 10.11159/icbb25.114

Enhancing Agaricus bisporus Shelf Life through Nanocellulose-Based Packaging Derived from Spent Medicinal Mushroom Substrate

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Extended Abstract

White mushrooms (*Agaricus bisporus*) are one of the most economically significant edible fungi globally, valued for their high nutritional content, particularly in protein and dietary fiber, and for their low fat and caloric levels [1]. However, due to their high respiration rate, moisture content, and lack of a protective epidermal cuticle, these mushrooms are highly perishable post-harvest. Browning, microbial contamination, and moisture loss significantly reduce their shelf life, leading to considerable economic losses in the supply chain [2]. Traditional plastic packaging is widely used to mitigate these issues, but it contributes to environmental degradation due to its non-biodegradable nature [3]. There is a growing demand for biodegradable and functional packaging solutions that are not only environmentally friendly but also capable of enhancing food preservation [4].

This study addresses the post-harvest preservation challenges of *A. bisporus* through the development of nanocellulose-reinforced starch-based films derived from spent mushroom substrate (SMS). SMS, an abundant agricultural byproduct from mushroom cultivation [5], serves as a sustainable source of nanocellulose. Nanocellulose was extracted via chemical pretreatment and mechanical processing and was subsequently incorporated into starch matrices at varying concentrations (0.2–1.0 wt%) to form biodegradable nanocomposite films.

The mechanical and thermal properties of the developed films were evaluated. Results indicated a significant enhancement in tensile strength and Young's modulus, particularly at the 1.0 wt% loading, as well as improved thermal stability when compared to native starch films. These enhancements are attributed to strong hydrogen bonding and uniform dispersion of nanocellulose within the polymer matrix, which reinforces the structural integrity of the films.

Furthermore, the antibacterial activity of the extracted nanocellulose was assessed against *Staphylococcus aureus*, *Escherichia coli*, and *Salmonella* spp., which are among the key bacterial species responsible for food spoilage [6]. The nanocellulose exhibited inhibitory effects, particularly against Gram-negative bacteria (*E. coli*). These findings suggest that the nanocomposite films offer not only mechanical and barrier advantages but also antimicrobial functionality.

To evaluate practical applicability, fresh *A. bisporus* mushrooms were packaged using the nanocellulose-starch films and stored under refrigerated conditions. Their quality parameters, including pH, firmness, color (browning), and sensory properties, were monitored over a six-day period. Mushrooms stored in nanocomposite films retained significantly higher quality attributes than those packaged in conventional polyethylene films. The superior performance is likely due to the films' enhanced moisture and oxygen barrier properties and their antimicrobial effects, which together delay microbial growth and oxidative browning.

This research highlights a sustainable and circular approach to food packaging by valorizing agricultural waste (SMS) into high-performance nanomaterials. The nanocellulose-reinforced starch films demonstrate strong potential as eco-friendly alternatives to conventional plastic packaging, with added value in food preservation, particularly for highly perishable produce like mushrooms.

Further research will focus on scalability, shelf-life extension over longer durations, and the evaluation of consumer acceptance and cost-effectiveness. This innovation aligns with the broader goals of reducing food waste, lowering plastic dependency, and promoting circular economy principles in the agri-food and packaging industries.

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