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From Waste to Wonder: Sustainable Packaging to Extend the Shelf Life of Button Mushrooms

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Button mushrooms (*Agaricus bisporus*) are a global culinary favorite, valued for their delicate flavor, high nutritional contentand versatility in cooking. However, they are also one of the most perishable fresh produces, with a shelf life of just 1–3 days at room temperature and about a week under refrigerated conditions (Falahati *et al*., 2025; Joshi *et al*., 2018). Button mushrooms have a very high moisture content, typically ranging from 85–95%, and lack a protective cuticle layer.This combination makes them extremely vulnerable to quality deterioration after harvest.They are highly prone to microbial contamination, which can cause spoilage.Enzymatic browning is another common issue that reduces their visual appeal and softening of tissues further shortens their shelf life.As a result, substantial post-harvest losses are reported globally.For farmers and traders, this results in economic losses; for consumers, it leads to reduced access to fresh and nutritious food; and for the environment, it causes an increase in food waste, which contributes to greenhouse gas emissions.To slow down the deterioration process, the mushroom industry commonly relies on conventional plastic packaging materials such as polyethylene and polypropylene films. These plastics provide good mechanical strength, effective moisture control, and are cost-efficienthowever, they are fossil fuel–derived and can persist in the environment for centuries (Koller, 2019; Ahmadi *et al*., 2020). This presents a challenge in balancing the need to preserve food quality with the responsibility to protect the environment. With increasing global awareness of the harmful impacts of plastic pollution, the food industry is under pressure to develop sustainable packaging solutions that maintain product freshness without causing environmental harm.

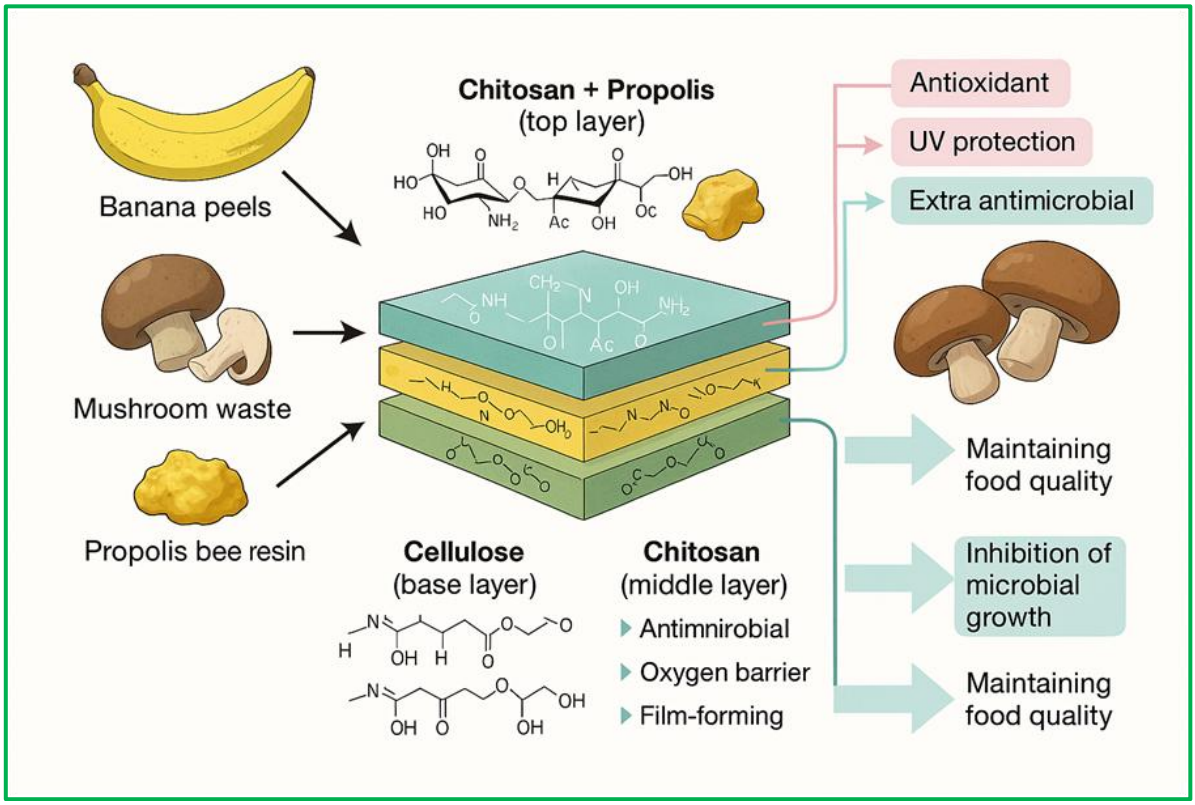
This challenge has inspired the idea of tackling both food spoilage and plastic waste in a single solution, with the approach focusing on converting agricultural byproducts into biodegradable, eco-friendly packaging materials that aim to reduce reliance on conventional plastics while keeping food safe and fresh.Every day, vast quantities of organic waste are generated worldwide. Juice vendors discard large amounts of banana peels, which are rich in natural fibres, while mushroom farms similarly dispose of stalks and trimmings after harvest. These waste streams contain valuable compounds that can be transformed into sustainable packaging materials.

These waste streams are valuable sources of high-quality biopolymers, particularly cellulose obtained from banana peels and chitosan derived from mushroom waste such as *Pleurotus* spp. (Strnad & Zemljič, 2023). Cellulose is prized for its excellent film-forming ability, mechanical strength, and biodegradability, while chitosan offers notable antimicrobial activity and good barrier properties. Once extracted and purified, these two biopolymers can be blended to form a strong, eco-friendly packaging base. To further enhance functionality, propolis — a resinous substance collected by bees and renowned for its potent antimicrobial

and antioxidant properties (Yong & Liu, 2021) — can be incorporated into the formulation. The combination of these components enables the development of a biodegradable multilayer packaging film with extended shelf-life potential for perishable foods. This approach not only adds value to agricultural waste but also promotes sustainable packaging innovations that reduce dependence on conventional plastics.

The novelty lies in the way these three natural materials complement one another: cellulose is abundant, edible, biodegradable, and provides excellent mechanical strength and moisture resistance (Liu *et al*., 2021); chitosan is a cationic polysaccharide with antimicrobial activity, oxygen barrier properties, and film-forming capability (De Carli et al., 2022); and propolis is rich in polyphenols and flavonoids, enhancing antioxidant capacity and providing UV-blocking properties (Bodini*et al*., 2013). While each material is valuable on its own, their combination in a multilayer structure offers strength, flexibility, microbial protectionand antioxidant functionality — precisely what perishable foods like mushrooms require. The multilayer films are produced using a layer-by-layer casting technique: a cellulose base layer provides strength, a middle chitosan layer delivers antimicrobial protection, and a top chitosan–propolis layer offers additional antioxidant and UV resistance. This structure creates an effective barrier against moisture loss, oxygen ingressand microbial contamination, thereby slowing browning, softening, and nutrient degradation in mushrooms.

While the current work focuses on extending the shelf life of button mushrooms, the technology can be applied to other perishable produce such as strawberries, leafy greens, and cut flowers. The benefits are multifaceted: longer shelf life reduces post-harvest losses; using biodegradable materials addresses plastic waste concerns; valorizing agricultural residues adds value to what is usually discarded; and local sourcing of raw materials can reduce packaging costs. In addition, this approach aligns with the United Nations Sustainable Development Goals — specifically SDG 2 (Zero Hunger) and SDG 13 (Climate Action). By integrating waste valorization with food preservation, this research demonstrates that sustainable solutions are not only possible but practical. Transforming banana peels, mushroom waste, and bee propolis into biodegradable packaging addresses three global challenges at once: food waste, plastic pollution, and agricultural residue disposal. In the near future, the fresh produce in your shopping basket could be wrapped in packaging born from waste — packaging that protects both the food you eat and the planet you live on.



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