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Postharvest Technology

Nano-Chitosan Herbal Coatings for Extending Cut Flower Vase Life

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Abstract: -

Cut flowers such as roses (Rosa spp.) and carnations (Dianthus caryophyllus) exhibit rapid postharvest deterioration due to microbial blockage of xylem vessels, water stress, oxidative damage, and ethylene-mediated senescence, leading to significant economic losses in the floriculture supply chain. This review highlights the application of nano-chitosan coatings enriched with bioactive herbal extracts, particularly neem (Azadirachta indica) and curcumin (Curcuma longa), as a sustainable strategy for extending cut flower vase life. Nano-chitosan, owing to its cationic nature and high surface area at the nanoscale, effectively suppresses microbial growth, maintains vascular integrity, and enhances water uptake. The incorporation of herbal extracts provides synergistic antimicrobial and antioxidant effects, stabilizes cellular membranes, and delays senescence through modulation of ethylene biosynthesis pathways. Experimental evidence demonstrates that nano-chitosan–herbal coatings can extend vase life from approximately 14 to 21 days, reduce microbial load at stem ends, improve fresh weight retention, and enhance antioxidant enzyme activity. These coatings offer an eco-friendly, chemical-free alternative to synthetic preservatives and are compatible with cold-chain management and other postharvest technologies. Overall, nano-chitosan herbal coatings represent a promising green technology for improving cut flower quality, shelf life, and commercial value while supporting sustainable floriculture practices.

Introduction:

Cut flowers, including commercially important species such as roses (*Rosa* spp.) and carnations (*Dianthus caryophyllus*), are highly perishable horticultural commodities that suffer rapid postharvest quality deterioration. The primary factors contributing to this decline include microbial colonization at the cut stem ends, vascular blockage by

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bacteria and fungi, water stress, and oxidative damage, all of which accelerate wilting, petal abscission, and loss of ornamental quality (Singh *et al.*, 2024). Freshness in these flowers is typically maintained for only a few days under conventional storage conditions, creating challenges for producers, distributors, and retailers in the floriculture supply chain. Rapid postharvest losses result in economic setbacks and reduced consumer satisfaction, emphasizing the need for innovative, sustainable postharvest strategies.

Cut flowers undergo senescence due to multiple interconnected factors. Microbial pathogens block xylem vessels, reducing water uptake and causing wilting. Reactive oxygen species (ROS) accumulate in petals and leaves, leading to lipid peroxidation, membrane damage, and accelerated senescence. Enzymatic degradation by polygalacturonase, cellulase, and pectinase further diminishes cell wall integrity, lowering flower firmness and aesthetic quality (Singh *et al.*, 2024).

Nano-chitosan coatings integrated with bioactive herbal extracts, such as neem (*Azadirachta indica*) and curcumin (*Curcuma longa*), have emerged as an effective natural solution for prolonging vase life (Kumar *et al.*, 2023). Chitosan, a biodegradable polysaccharide derived from crustacean shells, forms thin, uniform films on plant tissues. At the nanoscale, it exhibits enhanced surface area and bioactivity, creating a protective barrier against microbial invasion. The addition of herbal extracts enhances antimicrobial and antioxidant properties, stabilizes cellular membranes, and delays senescence (Patel *et al.*, 2024). By forming a nano-scale protective film along the flower stem, these coatings facilitate water absorption, maintain turgor, and reduce vascular blockage, offering a sustainable alternative to conventional chemical postharvest treatments.

Mechanism of Nano-Chitosan-Herbal Coatings and Postharvest Benefits

Chitosan is a cationic polysaccharide that exhibits antimicrobial activity by interacting with negatively charged microbial cell membranes, causing membrane disruption, leakage of intracellular contents, and inhibition of microbial proliferation (Singh *et al.*, 2024). When formulated as nanoparticles (~50–100 nm), chitosan demonstrates increased surface area, enhanced adhesion to stem tissues, and deeper penetration into xylem vessels, improving its antifungal and antibacterial efficacy.

Herbal extracts such as neem oil and curcumin are rich in phenolic compounds, flavonoids, and terpenoids, which inhibit fungal spore germination, prevent bacterial biofilm formation, and protect cellular structures from oxidative stress (Mehta *et al.*, 2023). These extracts act synergistically with nano-chitosan, lowering the minimum inhibitory concentration (MIC) required to control pathogens, with reported MIC values as low as 20 µg/mL.

Experimental studies on roses treated with 0.5% nano-chitosan and 0.1% neem extract showed a vase life extension from 14 days in untreated controls to 21 days in treated flowers (Patel *et al.*, 2024). The extension was associated with reduced microbial colony-forming units (CFUs) at the stem ends, maintained xylem vessel openness, and improved water transport. Physiological parameters such as fresh weight retention (85%) and chlorophyll content were significantly higher in treated flowers. Additionally, treated flowers exhibited reduced relative electrolyte leakage, indicating enhanced membrane stability, and higher activity of antioxidant enzymes, including superoxide dismutase, catalase, and peroxidase. Molecular studies revealed downregulation of ethylene biosynthesis genes ACS and ACO, delaying senescence signaling (Kumar *et al.*, 2023).

The coating is applied either as a dip or spray immediately postharvest, forming a nano-thin, water-permeable film that facilitates hydration while blocking pathogen entry. The natural composition ensures safety for consumers, environmental sustainability, and compliance with organic production standards, providing a chemical-free alternative to synthetic fungicides (Mehta *et al.*, 2023).

Integration with Postharvest Technologies

The effectiveness of nano-chitosan-herbal coatings can be enhanced through integration with other postharvest strategies. Cold chain management at 4–8°C, combined with the protective coatings, minimizes microbial growth and slows senescence. Modified atmosphere packaging (MAP) with reduced oxygen and elevated CO_2 further complements the coatings' effect by reducing respiration rates. Smart sensors for real-time monitoring of temperature, humidity, and microbial load can be integrated with AI-based predictive models to optimize transport and storage, ensuring maximum flower freshness.

Sustainability and Economic Impact

The adoption of nano-chitosan-herbal coatings supports sustainable floriculture by reducing the use of synthetic fungicides, minimizing chemical residues in the environment, and lowering ecological risks. Prolonged vase life reduces postharvest losses, increasing profitability for producers and retailers. Additionally, consumer preference for chemical-free, eco-friendly flowers enhances market value, making this technology commercially advantageous.

Future Directions and Technological Prospects

Future research may focus on multi-functional nano-chitosan coatings with antifungal, antibacterial, and antioxidant properties in a single formulation. Stimuli-responsive coatings that release antimicrobial agents in response to microbial proliferation, humidity, or temperature changes are under exploration. Expansion of applications to edible flowers and other ornamental species, combined with scalable green synthesis methods, could increase industrial viability. Integrating bioinformatics, AI, and sensor technologies can allow real-time shelf-life prediction and optimal postharvest management strategies (Singh *et al.*, 2024; Patel *et al.*, 2024).

Conclusion

Nano-chitosan coatings enriched with herbal extracts provide a highly effective, sustainable, and eco-friendly approach for extending the vase life of cut flowers. By combining antimicrobial, water-retention, and antioxidant properties, these coatings reduce microbial growth, maintain vascular integrity, and delay senescence. This technology improves commercial value, reduces chemical usage, and aligns with environmental and consumer safety priorities. Integration of such green technologies into floriculture represents a forward-looking strategy for sustainable, high-quality flower production, benefiting both producers and consumers.

References

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