



Botanical Approaches to Post-Harvest Preservation of Fruits and Vegetables

*Visman Kour, Neeraj Gupta and Priya Uday Shinde

Division of Post Harvest Management, Sher-e-Kashmir University of Agricultural Sciences & Technology, Chatha, Jammu-180009, J&K, India

*Corresponding Author's email: vismankour111@gmail.com

Post-harvest losses of fruits and vegetables represent a major challenge for global food security, particularly in developing countries where storage and transportation facilities are limited. Traditional preservation techniques often rely on synthetic chemicals, which may have negative environmental and health impacts. Botanical approaches using plant extracts, essential oils, edible coatings, and other plant-derived compounds have emerged as promising alternatives for sustainable post-harvest management. These natural substances possess antimicrobial, antioxidant, and physiological regulatory properties that help delay spoilage and maintain nutritional quality. Plant extracts such as neem, aloe vera, lemongrass, and garlic have shown effectiveness in reducing microbial growth and delaying ripening. Similarly, essential oils derived from aromatic plants like thyme, cinnamon, and rosemary are widely recognized for their antimicrobial properties. Advances in edible coatings and nanotechnology further enhance the preservation potential of botanical compounds by improving their stability and controlled release. This article reviews various botanical approaches used for post-harvest preservation of fruits and vegetables, their mechanisms of action, advantages, and future prospects.

Keywords: Botanical preservatives, essential oils, plant extracts, edible coatings, post-harvest technology, fruits and vegetables

Introduction

Fruits and vegetables play a crucial role in human nutrition as they provide essential vitamins, minerals, fiber, and bioactive compounds. However, they are highly perishable commodities due to their high moisture content and active metabolism. After harvest, fruits and vegetables continue to undergo physiological processes such as respiration, transpiration, and enzymatic reactions, which accelerate deterioration and lead to significant post-harvest losses.

Globally, post-harvest losses of fruits and vegetables can reach 30–40%, especially in developing countries where inadequate storage, transportation, and processing facilities contribute to spoilage (Kumar et al., 2023). Microbial infections, mechanical damage, and environmental conditions further contribute to these losses.

Traditionally, synthetic chemicals and fungicides have been used to control post-harvest diseases and extend shelf life. However, excessive use of chemical preservatives raises concerns regarding human health, environmental pollution, and development of resistant pathogens (Shahbaz et al., 2022). These concerns have led to growing interest in natural alternatives for food preservation.

Botanical approaches, which involve the use of plant-derived compounds such as extracts, essential oils, and natural coatings, are gaining increasing attention as safe and sustainable solutions for post-harvest management. These natural compounds exhibit antimicrobial,

antioxidant, and antifungal properties that can effectively delay spoilage and maintain the quality of fresh produce (Muthusamy et al., 2024).

Causes of Post-Harvest Losses in Fruits and Vegetables

Understanding the causes of post-harvest deterioration is essential for developing effective preservation strategies.

Microbial Spoilage

Fruits and vegetables are susceptible to various microorganisms including bacteria, fungi, and yeasts. Pathogens such as *Botrytis cinerea*, *Penicillium spp.*, and *Alternaria spp.* can infect produce during storage and transportation, leading to decay and loss of quality.

Physiological Changes

After harvest, produce continues to respire and metabolize stored nutrients. High respiration rates lead to rapid ripening, senescence, and deterioration of texture, flavor, and nutritional quality.

Moisture Loss

Transpiration results in water loss from fruits and vegetables, causing weight reduction, shriveling, and loss of freshness.

Oxidative Reactions

Enzymatic browning caused by enzymes such as polyphenol oxidase can degrade color and nutritional value of fruits during storage.

Botanical preservatives help address many of these problems by providing antimicrobial protection and reducing oxidative damage.

Plant Extracts in Post-Harvest Preservation

Plant extracts are natural substances obtained from leaves, roots, seeds, bark, or fruits of plants. These extracts contain various bioactive compounds including phenolics, flavonoids, alkaloids, and terpenoids, which possess antimicrobial and antioxidant properties.

Several plant extracts have demonstrated significant potential in extending the shelf life of fruits and vegetables.

Research shows that extracts from plants such as neem, aloe vera, lemongrass, ginger, and garlic can effectively inhibit microbial growth and delay ripening in fresh produce (Shahbaz et al., 2022). These extracts act by disrupting microbial cell membranes and interfering with metabolic processes.

Experimental studies have shown that applying plant extracts as coatings or sprays can improve the storage quality of tomatoes by reducing weight loss and maintaining firmness and color (Anjum et al., 2024).

Similarly, extracts from ginkgo biloba and anthocyanins have been shown to reduce enzymatic browning and maintain vitamin C content in stored litchi fruits (Li et al., 2021).

Because of their natural origin and minimal toxicity, plant extracts are considered safe alternatives to synthetic chemical preservatives.

Essential Oils as Botanical Preservatives

Essential oils are volatile aromatic compounds extracted from plants such as herbs, spices, and flowers. They contain active components including thymol, carvacrol, eugenol, and cinnamaldehyde, which exhibit strong antimicrobial and antioxidant activity.

Essential oils have been widely studied for their application in post-harvest preservation of fruits and vegetables.

For example, essential oils from plants such as thyme, cinnamon, basil, rosemary, eucalyptus, and lemongrass have been reported to inhibit the growth of spoilage microorganisms and extend shelf life (Kumar et al., 2023).

The antimicrobial action of essential oils is mainly due to their ability to disrupt microbial cell membranes, leading to leakage of cellular contents and inhibition of enzyme activity (Patrignani et al., 2015).

In addition to their antimicrobial properties, essential oils also exhibit antioxidant effects that help prevent oxidative deterioration in fruits and vegetables.

Studies suggest that spice and herb oils can act as effective natural preservatives and may reduce the need for synthetic agrochemicals in post-harvest management (Muthusamy et al., 2024).

Botanical Edible Coatings

Edible coatings are thin layers of edible material applied to the surface of fruits and vegetables. These coatings act as protective barriers that reduce moisture loss, regulate gas exchange, and inhibit microbial contamination.

Plant-based edible coatings prepared from aloe vera gel, starch, alginate, and pectin have been widely used for preserving fresh produce.

Aloe vera gel coatings have shown strong antimicrobial properties and can effectively maintain the texture, color, and nutritional quality of fruits during storage (Ghosh et al., 2024).

When essential oils or plant extracts are incorporated into edible coatings, their antimicrobial effectiveness increases significantly (Antunes et al., 2012).

Biopolymer-based coatings also help reduce weight loss and delay senescence in fruits and vegetables during storage (Devi et al., 2021).

Nanotechnology and Advanced Botanical Preservation

Recent advancements in food technology have integrated botanical compounds with nanotechnology to improve preservation efficiency.

Nano-emulsions containing essential oils enhance stability and allow controlled release of antimicrobial compounds, which helps maintain fruit quality during storage (Wang et al., 2025).

Nano-coatings and nano-packaging materials can modify gas permeability, inhibit microbial growth, and maintain physiological quality of produce during storage (Shan et al., 2023).

Chitosan-based coatings combined with plant extracts have also shown promising results in reducing microbial contamination and improving shelf life of fruits and vegetables (Popescu et al., 2022).

Advantages of Botanical Approaches in Post-Harvest Preservation

1. **Eco-friendly and biodegradable:** Botanical preservatives are derived from natural plant sources and are biodegradable, which reduces environmental pollution compared to synthetic chemical preservatives.
2. **Antimicrobial properties:** Many plant extracts and essential oils contain bioactive compounds that inhibit the growth of bacteria, fungi, and other microorganisms responsible for post-harvest spoilage.
3. **Antioxidant activity:** Botanical compounds such as phenolics and flavonoids help reduce oxidative damage and delay enzymatic browning in fruits and vegetables.
4. **Safe for human health:** Plant-based preservatives generally leave minimal harmful residues on food products, making them safer for consumers compared to synthetic chemicals.
5. **Maintains nutritional quality:** Botanical treatments help preserve vitamins, minerals, and other nutrients in fruits and vegetables during storage.
6. **Reduces moisture loss and weight loss:** Edible coatings made from plant materials help control transpiration and prevent dehydration of produce.
7. **Delays ripening and senescence:** Botanical coatings regulate gas exchange and respiration rates, which slows down the ripening process.
8. **Improves shelf life of produce:** The use of plant extracts and essential oils can significantly extend the storage life of fruits and vegetables.

9. Reduces post-harvest losses: By preventing microbial decay and maintaining quality, botanical approaches help reduce overall food losses.
10. Consumer preference for natural products: With increasing demand for organic and chemical-free foods, botanical preservation methods are more acceptable to consumers.

Future Prospects

Despite the promising potential of botanical preservatives, several challenges remain. These include variability in plant extract composition, potential changes in flavor or aroma, and difficulties in large-scale commercial application. Future research should focus on developing improved formulations, combining botanical compounds with advanced technologies, and evaluating their long-term safety and effectiveness.

Conclusion

In conclusion, botanical approaches offer an effective and sustainable method for the post-harvest preservation of fruits and vegetables. Fresh produce is highly perishable due to physiological activities and microbial spoilage, which often lead to significant losses during storage and transportation. Traditional preservation methods commonly rely on synthetic chemicals, but concerns regarding environmental safety, human health, and chemical residues have increased the need for natural alternatives. Plant-based preservatives such as plant extracts, essential oils, and edible coatings have shown great potential in extending the shelf life of fruits and vegetables. These natural substances contain bioactive compounds with antimicrobial and antioxidant properties that help inhibit microbial growth, delay ripening, and maintain the nutritional quality of produce. Botanical coatings such as aloe vera and plant-derived films also act as protective barriers that reduce moisture loss and protect fruits from environmental damage. Recent developments in technologies such as nano-emulsions and biopolymer coatings have further improved the effectiveness of botanical preservation methods. Although challenges such as standardization, sensory effects, and large-scale application still exist, botanical approaches remain promising alternatives to chemical preservatives. Overall, the use of botanical preservation techniques can contribute to reducing post-harvest losses, improving food quality, and supporting sustainable agricultural practices. Continued research and technological advancements will further enhance the practical application of these natural preservation methods in the future.

References

1. Anjum, S., Naveed, Z., Anees, M., Sarwar, M., Mustaq, Z., Tariq, M. R., Ashraf, M., & Gulraiz, C. Z. (2024). Evaluation of different plant extracts as a postharvest management strategy for enhancement of shelf life in tomato fruit. *Journal of Agriculture and Biology*.
2. Antunes, M. D. C., & Cavaco, A. (2010). The use of essential oils for postharvest decay control. *Flavour and Fragrance Journal*.
3. Antunes, M., Gago, C., Cavaco, A., & Miguel, M. (2012). Edible coatings enriched with essential oils and their compounds for fresh and fresh-cut fruit. *Recent Patents on Food, Nutrition & Agriculture*, 4(2), 114–122.
4. Devi, L. S., Purkayastha, M., Mukherjee, A., & Kumar, S. (2021). Biopolymer-based films and coatings: Emerging technologies to extend shelf-life of fruits and vegetables. *Prayogik Rasayan*.
5. Ghosh, M., Hemanth, P., Rahman, M., Kardile, N. B., Gaikwad, S. T., & Kumar, S. (2024). Advancement and effectiveness of *Aloe vera* (*Aloe barbadensis* Miller) and sodium alginate based natural coatings for extending the shelf life of fruits and vegetables. *European Journal of Nutrition & Food Safety*.
6. Kumar, V., Singh, A. P., Yadav, H., Pathak, S., & Srivastava, R. K. (2023). Essential oils uses in post-harvest management of fruits and vegetables: A review. *International Journal of Minor Fruits, Medicinal and Aromatic Plants*.

7. Li, L., Yan, X., & Li, J. (2021). The prolonging effect of natural plant extracts on the storage period of postharvest litchi. *Korean Journal of Horticultural Science and Technology*.
8. Meghachitra, S., Sumathi, T., Irene, V., Jeyakumar, P., & Sharmila, R. C. (2025). Edible coatings: A sustainable approach to protect perishable fruits and vegetables. *Plant Science Today*.
9. Muthusamy, L., Balakumbahan, R., Rajangam, J., Sathiyamurthi, S., Anitha, T., Muthusamy, D., & Velmurugan, T. (2024). Spice and herb oil as potential alternative to agrochemicals in postharvest management of fruits and vegetables. *Discover Applied Sciences*.
10. Patrignani, F., Siroli, L., Serrazanetti, D., Gardini, F., & Lanciotti, R. (2015). Innovative strategies based on the use of essential oils and their components to improve safety, shelf-life and quality of minimally processed fruits and vegetables. *Trends in Food Science & Technology*, 46, 311–319.
11. Popescu, P., Palade, L., Nicolae, I., Popa, E., Miteluț, A., Draghici, M., Matei, F., & Popa, M. (2022). Chitosan-based edible coatings containing essential oils to preserve the shelf life and postharvest quality parameters of organic strawberries and apples during cold storage. *Foods*, 11.
12. Shahbaz, M., Arshad, M., Mukhtar, K., Nabi, B. G., Goksen, G., Starowicz, M., Nawaz, A., Ahmad, I., Walayat, N., & Manzoor, M. F. (2022). Natural plant extracts: An update about novel spraying as an alternative of chemical pesticides to extend the postharvest shelf life of fruits and vegetables. *Molecules*, 27.
13. Shan, Y., Li, T., Qu, H., Duan, X., Farag, M., Xiao, J. Q., Gao, H., & Jiang, Y. (2023). Nano-preservation: An emerging postharvest technology for quality maintenance and shelf life extension of fresh fruit and vegetable. *Food Frontiers*.
14. Wang, Y., Shaukat, M., Farhan, M., & Pan, J. (2025). Role of essential oil nanoemulsion and biopolymer-based edible coatings on postharvest quality preservation of fruits and vegetables during cold storage. *Journal of Horticultural Science & Technology*.