



Impact of Rootstocks on Postharvest Quality and Phytochemical Composition of Fruits

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Grafting is one of the oldest and most widely used horticultural techniques, practiced for centuries to improve plant performance and adaptability. In grafted plants, the scion determines fruit characteristics such as shape, color, and flavor, while the rootstock provides anchorage and regulates water and nutrient uptake. Traditionally, rootstocks have been selected for their resistance to soil-borne diseases, tolerance to abiotic stresses such as salinity, drought, and flooding, and their ability to control tree size and vigor. However, advances in horticultural research have revealed that the influence of rootstocks extends far beyond these basic functions.

Postharvest losses remain a major challenge in global fruit production, often accounting for 20–40% of total production depending on crop and handling practices. Losses occur due to mechanical damage, rapid ripening, physiological disorders, water loss, and microbial decay. Improving postharvest quality and extending shelf life are therefore critical objectives for growers, traders, and the food supply chain. At the same time, consumers are becoming increasingly conscious of the nutritional and functional value of fruits, particularly their phytochemical content and antioxidant potential.

Recent studies have demonstrated that rootstocks can significantly influence fruit texture, flavor, storage behavior, and biochemical composition through complex rootstock–scion interactions. These interactions affect physiological processes during fruit development and continue to influence fruit behavior during postharvest storage. Understanding how rootstocks regulate postharvest quality and phytochemical accumulation is essential for developing sustainable fruit production systems that meet both economic and nutritional demands.

Rootstocks and Their Functional Role in Grafted Plants

Rootstocks form the underground portion of grafted plants and serve as the primary interface between the plant and its growing environment. They are responsible for the absorption and transport of water, minerals, and nutrients from the soil to the aerial parts of the plant. Through vascular connections at the graft union, rootstocks communicate with the scion via hydraulic, nutritional, hormonal, and molecular signals. Different rootstock genotypes exhibit variations in root architecture, nutrient uptake efficiency, water use efficiency, and tolerance to environmental stresses. These differences influence scion growth, flowering, fruit set, and fruit development. Rootstocks also affect carbohydrate partitioning, mineral distribution, and hormone balance within the plant, all of which play a role in determining fruit quality. In addition, rootstocks influence the transport of phytohormones such as cytokinins, auxins, gibberellins, and abscisic acid. These hormones regulate key developmental processes including cell division, fruit growth, ripening, and senescence. As a result, rootstock–scion interactions have long-term effects on fruit quality attributes that extend into the postharvest period.

Influence of Rootstocks on Postharvest Quality

Fruit Firmness and Texture

Fruit firmness is one of the most important indicators of postharvest quality, as it affects resistance to mechanical damage, consumer acceptability, and storage potential. Rootstocks influence fruit firmness through their effects on cell wall composition, calcium uptake, and enzymatic activity related to cell wall degradation. Studies in apple, pear, sweet cherry, peach, and plum have shown that fruits grown on dwarfing or semi-dwarfing rootstocks often exhibit higher firmness compared to those produced on vigorous rootstocks. Enhanced calcium uptake associated with certain rootstocks strengthens cell wall structure and delays softening during storage. Reduced activity of cell wall-degrading enzymes such as polygalacturonase and pectin methylesterase has also been linked to improved firmness in fruits from specific rootstock combinations. Improved firmness not only extends shelf life but also reduces bruising and damage during harvesting, handling, and transportation, thereby improving overall market quality.

Shelf Life and Storage Performance

Shelf life is a critical postharvest attribute influenced by respiration rate, transpiration, ethylene production, and susceptibility to physiological disorders. Rootstocks can significantly affect these processes by regulating plant water status and stress responses during fruit development. Fruits grown on stress-tolerant rootstocks often exhibit slower respiration rates and reduced ethylene production, resulting in delayed ripening and senescence. In crops such as tomato, melon, avocado, citrus, and apple, appropriate rootstock selection has been shown to extend shelf life and maintain quality during both ambient and cold storage. Rootstocks that improve water use efficiency and reduce oxidative stress also enhance resistance to chilling injury during cold storage. This is particularly important for fruits destined for long-distance transportation and export markets, where extended storage periods are unavoidable.

Soluble Solids Content and Acidity

Soluble solids content (SSC) and titratable acidity are major determinants of fruit flavor and consumer preference. Rootstocks influence sugar accumulation and organic acid metabolism by altering photosynthate production, translocation, and metabolic activity in the scion. Several studies have reported that specific rootstocks enhance SSC by improving carbohydrate transport from leaves to fruits. Rootstocks may also influence enzyme activity involved in sugar metabolism, leading to increased sweetness. At the same time, rootstocks can modulate organic acid synthesis and degradation, affecting acidity levels. A balanced ratio of sugars to acids is essential for desirable flavor. Fruits with higher SSC and moderate acidity are generally preferred by consumers and fetch higher market prices.

Weight Loss and Water Relations

Postharvest weight loss occurs mainly due to water loss through transpiration and leads to shriveling, loss of firmness, and reduced visual appeal. Rootstocks influence fruit water relations by regulating plant water uptake and transport during fruit development. Fruits produced on rootstocks that maintain better plant water status often show lower postharvest weight loss. Improved cuticle development and reduced transpiration rates contribute to enhanced postharvest appearance and extended shelf life. Reduced weight loss is particularly important for fresh market fruits where visual quality strongly influences consumer choice.

Susceptibility to Physiological Disorders

Physiological disorders such as internal browning, bitter pit, chilling injury, and flesh breakdown reduce fruit quality during storage. Rootstock selection has been shown to influence the incidence of these disorders by affecting mineral nutrition, stress tolerance, and metabolic balance. For example, rootstocks that enhance calcium uptake reduce the incidence of calcium-related disorders such as bitter pit in apples. Similarly, stress-tolerant rootstocks can reduce chilling injury and oxidative damage during cold storage, improving postharvest quality.

Rootstock Effects on Phytochemical Composition

Phenolic Compounds

Phenolic compounds are among the most important phytochemicals in fruits, contributing to antioxidant activity, color, flavor, and resistance to pathogens. Rootstocks influence phenolic accumulation by affecting nutrient availability, stress signaling pathways, and enzyme activity involved in phenylpropanoid metabolism. Fruits grafted onto rootstocks with higher nutrient uptake efficiency and stress tolerance often show increased phenolic content. Enhanced phenolic levels improve nutritional value and also contribute to better postharvest stability by reducing oxidative damage and delaying senescence during storage.

Flavonoids and Anthocyanins

Flavonoids and anthocyanins are responsible for fruit pigmentation and play a major role in antioxidant capacity. Rootstock–scion interactions can significantly affect the accumulation of these compounds, particularly in grapes, berries, cherries, plums, and citrus fruits. Rootstocks that induce moderate physiological stress often stimulate the synthesis of anthocyanins and flavonoids, resulting in deeper color and improved antioxidant properties. Improved pigmentation enhances visual appeal and market value while also increasing health benefits.

Carotenoids

Carotenoids are important pigments and antioxidants found in fruits such as citrus, mango, papaya, and tomato. Rootstocks can influence carotenoid biosynthesis by altering nutrient availability and metabolic activity. Increased carotenoid content enhances nutritional quality and contributes to improved color and antioxidant capacity.

Antioxidant Activity

Total antioxidant activity in fruits reflects the combined effects of phenolics, flavonoids, vitamins, carotenoids, and antioxidant enzymes. Rootstock selection can significantly influence antioxidant capacity by regulating mineral nutrition, stress tolerance, and oxidative metabolism. Fruits grown on rootstocks that reduce oxidative stress generally exhibit higher antioxidant activity. Enhanced antioxidant capacity not only improves nutritional value but also helps delay oxidative deterioration during postharvest storage.

Vitamin Content

Vitamins, particularly vitamin C, are essential nutritional components of fruits. Rootstocks influence vitamin accumulation by affecting metabolic pathways and nutrient transport. Several studies have shown that certain rootstocks enhance vitamin C content, improving both nutritional quality and postharvest stability.

Physiological and Biochemical Mechanisms Behind Rootstock Influence

The influence of rootstocks on postharvest quality and phytochemical composition is mediated through several interconnected mechanisms:

Water and Nutrient Uptake

Efficient absorption and transport of essential nutrients such as calcium, potassium, magnesium, nitrogen, and phosphorus improve fruit firmness, flavor, and biochemical stability. Calcium plays a particularly important role in maintaining cell wall integrity and reducing postharvest disorders.

Hormonal Regulation

Rootstocks regulate the transport and balance of phytohormones including cytokinins, auxins, gibberellins, and abscisic acid. These hormones influence fruit growth, ripening, ethylene production, and senescence, thereby affecting postharvest behavior.

Stress Modulation

Stress-tolerant rootstocks reduce oxidative stress by enhancing antioxidant defense systems. Reduced oxidative damage helps preserve fruit quality and phytochemical content during storage.

Metabolic and Molecular Signaling

Rootstock–scion communication involves molecular signals that alter gene expression and metabolic pathways related to sugar accumulation, organic acid metabolism, and phenolic biosynthesis. Advances in molecular biology have begun to reveal the complexity of these interactions.

Practical Implications in Horticulture

From a practical standpoint, rootstock selection should consider not only yield and vigor but also postharvest quality and nutritional attributes. Optimizing rootstock–scion combinations can help extend shelf life, reduce postharvest losses, and enhance phytochemical content.

This approach is particularly important for export-oriented fruit production systems, where long storage periods and transportation distances require fruits with superior postharvest performance. In addition, value-added horticultural products and functional foods benefit from fruits with enhanced antioxidant capacity and nutritional quality.

Future Perspectives and Research Needs

Despite significant progress, further research is needed to fully understand the molecular and genetic mechanisms underlying rootstock effects on fruit quality. Advances in genomics, transcriptomics, metabolomics, and phenotyping offer new opportunities to identify rootstocks with targeted effects on postharvest quality and phytochemical enrichment.

Developing rootstocks specifically designed to enhance nutritional quality and storage performance will be an important goal for future horticultural research. Integrating rootstock selection with sustainable management practices will support resilient and high-quality fruit production systems.

Conclusion

Rootstocks play a crucial role in shaping postharvest quality and phytochemical composition of fruits. Through their influence on nutrient uptake, hormonal balance, stress responses, and metabolic pathways, rootstocks can improve fruit firmness, shelf life, flavor, and nutritional value. A comprehensive understanding of rootstock–scion interactions enables growers and researchers to select optimal combinations that support sustainable production, reduce postharvest losses, and meet increasing consumer demand for high-quality and nutritious fruits. Continued research will further enhance the role of rootstocks in modern horticulture.

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