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# Physiological Changes during Post-Harvest Storage of Fruits and Vegetables

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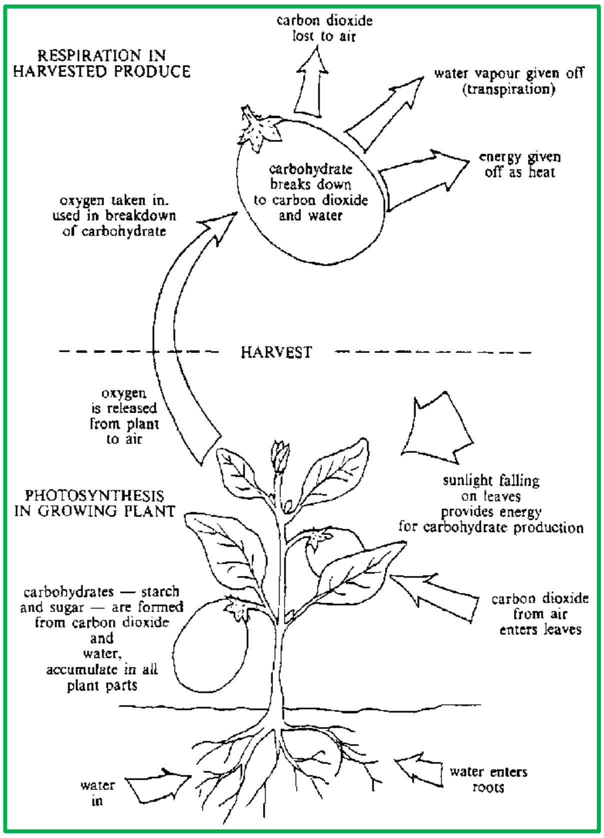
Fruits and vegetables play a vital role in global horticulture, not only because of their high economic importance but also due to their essential contribution to human nutrition and overall health. They serve as natural sources of vitamins, minerals, dietary fibre, sugars, organic acids, antioxidants, and numerous bioactive compounds that support normal physiological functions. Regular intake of fruits and vegetables has been widely linked with a lower risk of non-communicable diseases, including cardiovascular disorders, diabetes, obesity, certain types of cancer, and respiratory illnesses. These protective effects are largely attributed to the presence of naturally occurring phytochemicals such as phenolics, carotenoids, flavonoids, and antioxidant vitamins (Elhadi, 2019). Postharvest losses result from both physical quantity reductions and quality deterioration that occur from the time of harvest until consumption. Even after harvest, fruits and vegetables remain biologically active, and their metabolic processes continue, making them highly perishable in nature. A combination of physiological, biochemical, and microbial factors—such as respiration, water loss, ethylene-induced ripening, senescence, and microbial infection—collectively accelerates quality decline and leads to significant economic losses. The quality of horticultural produce cannot be improved once harvesting has taken place, as all desirable characteristics are formed while the produce is still attached to the parent plant. After harvest, fruits and vegetables are cut off from the continuous supply of water, nutrients, and photosynthates provided through the vascular system. As a result, they rely solely on their stored reserves of carbohydrates, proteins, and lipids to maintain metabolic activities, which gradually become depleted, ultimately leading to progressive quality deterioration. Postharvest physiology and related technologies are essential for prolonging shelf life and preserving the quality of horticultural produce. Postharvest physiology deals with the study of metabolic activities such as respiration, transpiration, ethylene synthesis, and susceptibility to microbial attack that continue after harvest. In contrast, postharvest technologies—such as temperature management, controlled or modified atmosphere storage, chemical interventions, and the application of edible coatings—are designed to regulate these physiological processes, slow down senescence, and reduce postharvest deterioration (Saltveit, 2019).

## Physiological Status of Fruits and Vegetables After Harvest

The physiological status of fruits and vegetables at the time of and after harvest has a direct impact on their postharvest performance and storage potential. Appropriate storage and transportation conditions are critical for controlling physiological activities and minimizing quality losses. Processes such as respiration, transpiration, ethylene production, and disease incidence are strongly influenced by external factors including temperature, relative humidity, atmospheric composition, and light, which together determine the postharvest longevity of horticultural produce (Kahramanoglu, 2017). Among the various physiological processes, respiration intensity, ethylene evolution, and moisture loss through transpiration are regarded as the key factors governing postharvest quality. These processes have a profound effect on textural integrity, color development, flavor characteristics, nutritional composition, and the overall marketability of horticultural produce.

## Respiration and Its Role in Postharvest Deterioration

Respiration is a fundamental metabolic activity in which stored biochemical compounds are oxidized to generate the energy needed for cellular maintenance. Following harvest, fruits and vegetables remain metabolically active, continuing to utilize oxygen while releasing carbon dioxide, water, and heat. This energy-producing process depends on the degradation of carbohydrates, proteins, lipids, and organic acids through interconnected pathways, including glycolysis, the tricarboxylic acid cycle, and the electron transport system.




Although respiration is essential for cellular survival, elevated respiration rates accelerate senescence by rapidly depleting stored reserves, thereby shortening shelf life. One mole of glucose oxidized during respiration yields approximately 686 kcal of energy, emphasizing the magnitude of reserve depletion associated with high respiratory activity.

**a. Respiratory Patterns in Fruits**

Fruits are commonly grouped into climacteric and non-climacteric categories based on their respiratory patterns during ripening. Climacteric fruits, including banana, apple, mango, guava, and papaya, are characterized by a distinct increase in respiration rate known as the climacteric peak, which occurs alongside a sharp rise in ethylene production. In contrast, non-climacteric fruits such as citrus, grape, pineapple, and olive show a steady decrease in respiration after harvest and do not exhibit a respiratory surge. The climacteric rise occurs in well-defined stages and is closely associated with ethylene-regulated ripening events. For example, research on mango has shown a continuous increase in physiological weight loss along with a prominent respiratory peak around the ninth day of storage, after which respiration gradually declines (Janave, 2007).

**b. Respiration Rate and Storability**

Storability of horticultural commodities is inversely related to their rate of respiration. Produce with higher respiratory activity tends to have a shorter shelf life, while those with lower respiration rates generally retain quality for longer periods (Brummell and Toivonen, 2018). Leafy vegetables such as spinach, broccoli, peas, and mushrooms exhibit rapid respiration and therefore deteriorate quickly. In contrast, commodities like apples, citrus fruits, onions, and potatoes respire more slowly and possess better storage potential (Saltveit, 2019).

**c. Influence of Temperature on Respiration**

Temperature is one of the most critical environmental factors influencing the rate of respiration in harvested produce. In accordance with the Van't Hoff principle, the speed of biological reactions typically increases two to three times for every 10 °C rise in temperature. As a result, reducing storage temperature is one of the most effective approaches for slowing respiratory activity and prolonging shelf life (Saltveit, 2019). For example, produce that can be stored for about 100 days at 0 °C may deteriorate within approximately 13 days at 20 °C and as little as 4 days at 40 °C.

## Transpiration and Physiological Weight Loss

Transpiration is the process by which harvested fruits and vegetables lose water through evaporation, resulting in physiological weight loss, shriveling, wilting, tissue softening, and a decline in market quality (Kader, 1992). Water loss from produce occurs through multiple pathways, including stomata, the cuticular layer, epidermal tissues, and surface structures such as trichomes. Since fresh fruits and vegetables generally contain more than 90–95% water, they are particularly vulnerable to dehydration after harvest (Diaz-Perez, 2019). Storage conditions characterized by high temperature, low relative humidity, and elevated metabolic activity greatly accelerate transpiration losses. Experimental findings indicate that untreated mango fruits may lose up to 26.41% of their weight after 12 days of storage, whereas wax-coated fruits experience significantly lower physiological weight loss. Similarly, pomegranate arils stored at 5 °C under 96% relative humidity exhibit minimal moisture loss, while the highest transpiration losses are observed at 22 °C and 76% relative humidity (Mandal et al., 2018).

**Ethylene Production and Its Physiological Effects**

Ethylene is a gaseous plant hormone that plays a key role in controlling fruit ripening and senescence. It regulates several ripening-related changes, including color development, tissue softening, aroma formation, and the accumulation of sugars. Ethylene is synthesized through the methionine pathway, in which methionine is converted to S-adenosylmethionine (SAM) and subsequently to 1-aminocyclopropane-1-carboxylic acid (ACC), with the final step catalyzed by ACC oxidase. Climacteric fruits generate relatively large quantities of ethylene during ripening, whereas non-climacteric fruits produce only small amounts. However, even very low concentrations of ethylene can trigger yellowing, accelerated senescence, and quality deterioration in leafy vegetables and immature fruits.

## Postharvest Diseases and Microbial Deterioration

Postharvest diseases are a major cause of losses in fruits and vegetables and can develop at various stages, including harvesting, handling, storage, transportation, and marketing (Singh et al., 2017). The vulnerability of horticultural produce to microbial infection is closely linked to its physiological status at and after harvest. Fungal pathogens such as *Alternaria*, *Botrytis*, *Penicillium*, *Colletotrichum*, *Rhizopus*, and *Aspergillus* are responsible for most postharvest decay, while bacterial groups including *Pseudomonas* and *Erwinia* also contribute significantly (Barkai-Golan, 2005). The high water content and abundant nutrients present in fruits and vegetables provide an ideal environment for the growth and spread of these microorganisms.

## Management Strategies to Reduce Postharvest Losses

Controlled atmosphere (CA) and modified atmosphere (MA) storage are widely used strategies for reducing postharvest losses in fruits and vegetables by adjusting the concentrations of oxygen, carbon dioxide, and ethylene around the stored produce. Lowering oxygen levels and increasing carbon dioxide within safe thresholds slows respiration and other metabolic processes, thereby delaying ripening and senescence. These atmospheric adjustments help retain textural integrity, flavor, and nutritional quality, and have been successfully employed across a wide range of horticultural commodities to enhance storage life and marketability (Kader and Saltveit, 2003). Vacuum packaging operates on a similar principle by removing air from the package, which limits oxygen availability and reduces respiratory activity as well as oxidative degradation. Studies on fruits such as guava have shown that vacuum and modified atmosphere packaging significantly improve shelf life and quality when compared with conventional storage methods (Rana et al., 2018). Beyond physical and atmospheric interventions, chemical treatments and edible coatings also play an important role in postharvest management. Chemicals such as 1-methylcyclopropene (1-MCP), salicylic acid, chlorine dioxide, and nitric oxide are commonly applied to suppress ethylene action, lower respiration rates, and inhibit microbial growth, thereby delaying ripening and decay without posing health risks (Guo, 2014). Edible coatings derived from lipids, polysaccharides, or proteins create a thin, semi-permeable barrier on the surface of fruits and vegetables that reduces moisture loss, limits gas exchange, and restricts pathogen invasion. These coatings have proven effective in maintaining postharvest quality and extending shelf life, offering an eco-friendly and consumer-acceptable approach to minimizing postharvest losses (Vaishali et al., 2019).

## Conclusion

A clear understanding of postharvest physiological processes is vital for reducing losses and strengthening food security. High rates of respiration, excessive ethylene activity, and uncontrolled moisture loss are among the primary factors that limit the storage life of fruits and vegetables. Maintaining suitable storage conditions—particularly optimal temperature, high relative humidity, and a well-regulated atmospheric environment—can markedly slow deterioration and preserve produce quality. An integrated approach that combines controlled atmosphere storage, vacuum packaging, chemical treatments, and edible coatings has proven effective in delaying senescence, limiting microbial spoilage, and conserving nutritional value. The adoption of scientifically based postharvest management practices not only enhances economic returns for producers but also plays an important role in improving global food availability and nutritional security.

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