



Post - Harvest Physiology and Quality Management of Commercial Fruit Crops

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Abstract

Post-harvest physiology and quality management is very important in making sure that high-quality commercial fruits are available between harvest and consumption. Fruits are living tissues that still subject themselves to different physiological, biochemical, and metabolic processes even after the harvesting process and thus play a significant role in affecting the shelf life, nutritional value, and the marketability of the products. The key physiological processes that cause rapid depreciation of fruits during post harvest handling include high respiration rates, water loss, ethylene production and senescence. In third-world countries, especially in India, fruits which are lost after harvesting constitute a significant percentage of the total production, which presents a great problem to food security, farmer earnings, and supply chain effectiveness. Knowledge of post-harvest physiology gives a scientific framework of the development of proper quality management strategies. Fruits that are classified into climacteric and non-climacteric ones can aid the design of crop-specific handling, storage and ripening procedures. The pre-harvest factors, maturity of harvest, and post-harvest environment have very strong effects on quality attributes like color, firmness, flavor, texture, total soluble solids, acidity, and nutritional composition. Poor harvesting practices, mechanical damages, temperature extremes and poor storage facilities hasten the decay of quality and augment fungal microbial degradation. Best quality management practices during harvesting should vary to harvesting on the right stage



of maturity, fast pre-cooling, sorting and grading, and application of appropriate post-harvest treatments. The cold storage, controlled atmosphere storage, modified atmosphere; packaging as well as ethylene management techniques are among the technologies that considerably extend the shelf life of commercial fruits without compromising the sensory and nutritional quality of the products. Besides this, novel technologies like edible coating, biopreservatives, smart packaging, and digital monitor systems are becoming significant in the current fruit supply chain. Integrated post-harvest management also minimises both quantitative and qualitative losses as well as improving value addition, competitiveness and export potential of commercial fruit crops. To attain sustainable production systems in fruits, there are mandatory infrastructural support after harvest, implementing high-tech technologies, and enhancing awareness of all concerned stakeholders. The current paper outlines the principles of post-harvest physiology and presents the major quality management practices required in limiting losses and delivering safe, healthy, and quality fruits to customers.

Introduction

Commercial fruit crops hold a critical status in the horticulture sector of both the world and India as it is high in nutritional value, economically significant, as it provides income and employment to farmers. Fruits contain abundant vitamins, minerals, antioxidants, dietary fiber and bioactive compounds thereby being indispensable to human health and nutrition. As the demand of fresh and quality fruits increases with the population increase, urbanization and shift in dietary habits, post-harvest management has become more urgent than ever. Nevertheless, a considerable percentage of fruits grown in the world is wasted immediately after picking, poor storage, and proper transportation systems leading to loss of money and availability to the consumers.

The study of physiological and biochemical change of fruits after harvesting is the study of post-harvest physiology. Fruits are also harvested at different levels of maturity unlike field crops and in spite of being separated with the parent plant, they keep respiring and undergoing metabolic processes. The respiration, transpiration, ethylene production, ripening, and senescence of fruits are processes that mostly contribute to the shelf life and quality of the fruits during storage and



marketing. These processes occur at different rates and in different degrees in relation to different fruit species and are determined by genetic variables, pre-harvest environment, and post-harvest environment. These physiological processes cannot be well understood scientifically and thus come up with effective strategies to preserve the quality of fruit and increase the shelf life. In India and other developing economies, it is estimated that post-harvest losses in fruits are quite high, and usually between 20 and 30 percent, the main cause of this being due to poor cold chain infrastructure, ineffective packaging and poor market linkages. These losses do not only influence the profitability of farmers but also pressure natural resources and countries' food systems. Deterioration of quality in the process of handling after harvest also reduces export capacity of fruits, because the quality and safety standards required in the international markets are very high.

Post-harvest quality management is a concept that covers various types of practices and technology designed to minimize losses and maintain the desirable quality attributes of foods, appearance, texture, flavor, and nutritional value. Some of these practices are harvesting when at ideal maturity, handling to prevent mechanical damages, management of temperature and humidity, proper storage methods and effective transportation mechanism. The use of modified atmosphere storage, modified atmosphere packaging, handling of ethylene and application of environmentally friendly treatment in post harvest technologies has greatly enhanced the marketability and storage life of commercial fruits.

Post-Harvest Physiology

Post-harvest physiology is a branch of horticultural science that is concerned with physiological, biochemical as well as metabolic changes that occur on fruits after harvesting. Because of the life processes, fruits are not ended at harvest; but it is a new stage where the internal processes in the fruit take place until senescence and ultimate decay. The mechanism of these post-harvest modifications is fundamental in the design of proper handling, storage and quality management techniques of commercial fruit crops. The main goals of post-harvest physiology include the preservation of the fruit quality and the shelf life through the regulation of biological activities of



respiration, transpiration, ethylene synthesis, ripening, and senescence. Fruits lose water and nutrients provided by the parent plant after harvest, and therefore they are very sensitive to the environment. Any irregularity in the temperature, humidity and gaseous composition may cause a rapid increase in metabolic activities that cause rapid quality degradation. The post-harvest physiology is scientific understanding of how these factors affect the behavior of fruits and how they can be affected to delay the degradation process.

Respiration is among the most significant physiological processes that are examined under post-harvest physiology. It entails the degradation of carbohydrates and organic acids among other substrates in the presence of oxygen to give energy, carbon dioxide, and water. Respiration rate has a direct relationship with the shelf life of fruits; the faster the rate of respiration, the faster the food is depleted and the storage period is brief. Tightly linked with respiration is transpiration meaning loss of water in the surface of fruits. Over transpiration causes loss of weight, wilting and shriveling of fruits and loss of freshness especially in fruits with thin peels. Fruits ripening is another important concept in post harvest physiology since it is a complex process that entails physical, chemical, and sensory alteration of fruits in order to make them palatable. Ripening involves color changes because it involves degradation of chlorophylls and pigment and synthesis, softening of tissues because of degradation of cell walls, starch into sugars, acidity turning down, and the formation of characteristic aroma and flavor. Ethylene is a natural plant hormone that is of key importance in the process of regulating the process of ripening particularly in climacteric fruits like banana, mango, and apple. The study of post-harvest physiology focuses on ethylene biosynthesis, its mechanism of action and how to manipulate its impacts to delay or coordinate the process. The last stage of fruit development is senescence which is marked by reduced metabolic efficiency, membrane permeability and is prone to microbial infection. The senescence process occurs as the process of ripening is replaced by a loss and decay in quality. The physiological investigations after harvest are intended to slow down the process of senescence by maximizing storage facilities and using appropriate treatments.



Post-harvest physiology also takes into account the effect of pre-harvest conditions, including cultivar, climate, soil nutrition, and cultural practices on post-harvest behavior. Different types of fruits can have a different respiration rate, a different ripening process, and a different response to storage depending on the conditions in which they are grown. Post-harvest physiology therefore comes in as an intermediary between fruit production and post-harvest management which offers a scientific basis to minimize losses, improve quality, and increase the economic value of commercial fruit crops.

Fruits According to the Ripening Behaviour

Commonly used classifications of fruits include climacteric and non-climacteric on the basis of how these fruits mature. It is a basic classification in the post-harvest physiology because it can be used to understand the ripening process as well as developing proper post-harvest handling, storage and marketing strategy. Fruits closely relate the ripening behavior with the variation of the respiration rate and production of ethylene during post-harvest, which largely determines the shelf life and quality.

Climacteric fruits have rapid rise in rate of respiration and a sharp rise in ethylene synthesis during the ripening process. This is referred to as the climacteric rise and is actually the beginning of the process of ripening and goes on even after the harvesting period. The capability of the climacteric fruits to mature off the plant is one of the most important characteristics of the fruits and enables them to be picked just at the mature but unripe stage. The usual typical examples of the climacteric fruits are banana, mango, apple, papaya, pear, peach, plum, and tomato. Ethylene is a ripening hormone present in these fruits and a cascade of biochemical reactions which occur include the process of breaking down starch to sugars, softening of tissues, colour formation and production of flavour and aroma compounds.

Climacteric fruits have increased flexibility in harvesting and marketing in terms of post-harvest management. They can be picked prematurely in order to survive the long trip of transport and then be ripened in a controlled manner with the use of ethylene or ethylene releasing substances. Nevertheless, when ethylene exposure or storage conditions are too high, ripening and



senescence may occur too fast resulting in a shorter shelf life. Thus, climacteric fruits require management of ethylene by low temperature storage, controlled atmosphere or incorporation of ethylene inhibitors to preserve their quality.

On the contrary, non-climacteric fruits do not show a significant rise in the rate of respiration or production of ethylene when they are allowed to ripen. The harvest of these fruits should be done when the fruits are fully ripe or almost at the point of ripening because the fruits do not exhibit any or very minimal capacity to undergo the ripening process after harvest. Citrus fruits, grape, strawberry, cherry, pineapple, litchi, pomegranate, and watermelon are examples of non climacteric fruits. Ripening-related processes like the development of the color, the build-up of sugars and improvement of the flavor take place in these fruits mostly when the fruit remains to be connected to the plant.

The non-climacteric fruits are to be treated differently after harvest because when poorly harvested or stored, one cannot reverse quality losses since such losses may arise in a short duration of time. Ethylene is not of much use in the ripening process hence exogenous use of ethylene does not enhance the ripening of non-climacteric fruits. Nonetheless, even these fruits can be susceptible to ethylene, which could lead to undesired effects like degreening, softening, or more damage to rot.

Post-harvest Physiological alterations in Fruits

Fruits are still metabolically active after harvest and still continue to experience various physiological and biochemical processes that have a great impact on their shelf life, quality and marketability. Fruits do not have water and nutrients since they are no longer attached to the parent plant; therefore, they are very reliant on their reserves as well as the immediate environment. The significant physiological processes that take place in the fruits after harvesting consist of respiration, transpiration, ripening, ethylene production, and senescence. It is necessary to understand these changes so that they can be dealt with in order to have a successful post-harvest management of commercial fruit crops. The most essential physiological process that determines post-harvest life of fruits is respiration. It entails oxidation of stored



carbohydrates, organic acids and other substances into energy to be used in sustaining cellular processes. In the process of respiration, oxygen is used and carbon dioxide, water, and heat are emitted. An increased respiration rate will result in an increased depletion of the food reserves and therefore reduced shelf life. Climacteric fruits have a sharp rise in respiration during ripening referred to as the climacteric rise, whereas non-climacteric fruits have a more steady respiration rate. Temperature, the levels of oxygen, carbon dioxide and mechanical injury play a great role in determining the rate of respiration in the harvested fruits.

Transpiration can be defined as the loss of water by fruits through the skin or natural openings of a fruit. Water loss is one of the big contributors to quality deterioration after harvest resulting in loss of weight, wilting, shriveling and loss of firmness. Fruits that have thin skins like grapes and berries, lose moisture more readily than those that have a thicker peel. Transpiration is enhanced by high temperature, low relative humidity and benefit of increased air movement. Keeping the humidity at the optimum and applying the right packaging materials would minimize the loss of moisture and maintain freshness. Ripening is a complicated and synchronized procedure of a sequence of physiological and biochemical alterations of immature fruits into edible and palatable commodities. The ripening process involves the development of color because cell wall component degradation leads to softening of tissues, enzymes break down the cell wall components, starch is converted into sugars, acidity is reduced and typical flavor and aroma compounds are produced. Ripening is highly linked to rising ethylene production and respiration in climacteric fruits and there is no climacteric escalation in ripening in non-climacteric fruits.

The production of ethylene has been at the focal point of controlling the post-harvest alterations, especially in climacteric fruits. Ethylene is a natural plant hormone that speeds up the process of ripening and senescence as it activates a number of metabolic pathways. The behavior of fruits can be greatly affected by ethylene even in minor quantities. Thus exposure to ethylene during the storage and transportation process has to be strictly regulated to avoid premature ripening and loss of quality. The last post-harvest life cycle is senescence, a stage of progressive breakdown in the organization and efficiency of cells. In senescence, there is a decline in membrane integrity,



reduction in enzyme activity and increased vulnerability of fruits to physiological disorders and effects of microbial infections. This eventual demise results in deterioration and inedible crops.

Fruit Ripening and the Role of Ethylene.

Ethylene is a gaseous natural plant hormone that is important in the control of fruit ripening and senescence. Ethylene is unlike other plant growth regulators because it is a gaseous plant growth regulator and can be used at very low concentrations. Ethylene is regarded as the major ripening regulator in climacteric fruits during post-harvest physiology and the factor of significant impact on changes in quality in many non-climacteric fruits also. To achieve the best management of quality of commercial fruit crops after harvest, it is important to understand the role of ethylene. Plant tissues produce ethylene by the synthesis of methionine commonly referred to as the Yang cycle. This is the pathway that methionine undergoes to form the direct precursor of ethylene, 1-aminocyclopropane-1-carboxylic acid (ACC). ACC synthase enzyme and ACC oxidase enzyme are important in the regulation of ethylene production. The activity of these enzymes rises dramatically during the initiation of the ripening process in climacteric fruits and thus results in a rapid increase in ethylene production referred to as autocatalytic ethylene production. Ethylene initiates physiological and biochemical reactions related to the process of ripening in climacteric fruits like banana, mango, apple, pear, and papaya. Such changes involve increased respiration rate, softening of fruit tissues because of cell wall degradation, starch to sugar conversion, lowered organic acid formation and acquired characteristic color, flavor and aroma. Ethylene also triggers expression of ripening-related genes, which controls coordinated complex metabolic activities of fruit maturation. Ethylene generation after the process has been triggered is self-stimulating and therefore ripening is an irreversible process. In non-climacteric fruits like citrus, grape, strawberry, and pineapple, ethylene is not involved in the middle of the process of fruit ripening, and these fruits do not show any climacteric increase in respiration. Non-climacteric fruit can however also react to ethylene exposure in certain ways including degreening of citrus fruits, softening or senescence. Uncontrolled release of ethylene in storage may consequently cause unwanted effects in non-climacteric fruits.



It is important to manage the level of ethylene in fruits to improve their shelf life and to preserve their quality as a post-harvest management practice. Some of the measures that are used to control ethylene action include low-temperature storage, low oxygen and high carbon dioxide controlled atmosphere storage, and good ventilation to eliminate the built-up ethylene. Sometimes storage and packaging systems use ethylene absorbers and scrubbers, e.g. potassium permanganate-based materials. Also, there are ethylene action inhibitors such as 1-methylcyclopropene (1-MCP), which is currently used to slow down the process of ripening and senescence in climactic fruits.

Conclusion

Sustainable and profitable fruit production systems must involve the management of post-harvest physiology and quality. Fruits as living and extremely perishable goods will experience intricate physiological and biochemical post-harvest alterations that directly correlate with shelf life, nutritional and marketability. The rate at which quality deteriorates as well as the levels of post-harvest losses, are dependent on processes like respiration, transpiration, ripening, ethylene production, and senescence. The proper knowledge of these processes forms the scientific basis needed to come up with effective post harvest handling and management of commercial fruit crops. The understanding of fruits as being classified as climacteric and non-climacteric on the basis of ripening behavior has great pragmatic implications to harvesting, storage, transportation, and marketing of fruits. Climacteric fruiting plant species have the benefit of flexibly harvesting and managing the ripening process through the control of ethylene, whereas non-climacteric fruit species have to be harvested when they are optimally mature and handled with great care to retain their quality. Ethylene is a key to the control of the ripening process, especially in climacteric fruits, and its appropriate control allows to prevent senescence and spoilage and provide uniform ripening where required.

Proper management of quality post-harvest is an integrated strategy that includes pre-harvest management based on proper maturity of harvest, harvesting which carries the minimal force, rapid pre-cooling, proper storage, and efficient packaging and transportation. The commercial



fruits have had a lot of shelf life and their quality maintained due to the adoption of advanced technologies which include cold storage, controlled atmosphere and modified atmosphere system, ethylene inhibitors, edible coatings, and smart packaging. These technologies do not only reduce quantitative and qualitative losses, they also increase the value addition, market competitiveness as well as export potential. In the developing world such as India, losses during the harvesting of fruits continue to pose a significant problem in terms of poor infrastructure, inaccessibility of modern technology as well as lack of awareness with the players. In response to the reduction of losses and enhancement of income of farmers, strengthening infrastructure post-harvest, enhancing cold chain infrastructure and capacity building through training and extension programs are critical measures. Besides, the policy support and public-private partnership could be instrumental in enhancing efficient post-harvest practices quick adoption.

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