Chapter 14

Postharvest Handling of Fruits and Vegetables

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Abstract

Horticultural commodities including fruits, vegetables, and ornamentals are highly perishable. After harvest, they undergo continuous changes in their morphological structures and biochemical composition, which consequently lead to the quantitative and qualitative losses, throughout the supply chain. Postharvest losses in horticultural commodities have been estimated to be 5-25% in developed and 20-50% in developing countries. However, the magnitude of these losses varies with crop, cultivars, pre-harvest management and postharvest handling practices. Both pre-harvest, as well as postharvest factors, have significant contribution in the reduction of these losses in fresh produce. Growers, as well as handlers, must understand the biological and environmental factors that are involved in deterioration and postharvest losses. Similarly, understanding the mode of application of available postharvest technologies is also important to ensure delivering best possible quality at market and having maximum returns from these highly perishable commodities. This chapter focuses to improve the understanding of the readers about the concept of quality of fresh horticulture commodities; nature and extent of postharvest losses; basic principles in postharvest handling and management; latest advances in the

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postharvest technology of fruits and vegetables; and finally marketing of fresh horticultural produce.

**Keywords:** Fruits, pre-cooling, postharvest losses, quality, shelf life, storage.

### 14.1. Introduction

The word “quality” comes from the Latin word “qualitias” means attributes. According to International Organization for Standardization (ISO), quality is defined as "The totality of features and characteristics of a product or service that bears its ability to satisfy stated or implied needs". Thus, quality of fresh horticultural crops such as fruit, vegetables, and ornamentals means a combination of attributes or criteria that give a particular value to that horticultural commodity. For example, value as food for fruits and vegetables and esthetic gratification for ornamentals. The word quality can be used in different forms in relation to various types of horticultural produce including external quality, internal quality, physical quality, biochemical quality, eating quality, shipping quality, and market quality or consumer quality. Persons involved in various steps of postharvest supply chain use this term in their own perspectives. For the producer, the quality of commodity means higher yield, good appearance with minimum defects; for a shipper, good quality means good appearance with a capacity of being transported from orchard to market without physical injuries; whereas, for consumers, the good quality fruits and vegetables should be good looking, firm with good flavour. Thus, grower, handler, shipper, retailer, and consumer may not share the same perception regarding the quality of fresh produce.

In general, quality criteria for fruits and vegetables include both external and internal features of that commodity. Important quality criteria for determination of fresh horticultural commodities include: visual appearance (size, weight, volume, shape, colour, gloss), defects (external, internal, morphological, physical, mechanical, physiological, pathological and entomological), texture (firmness, hardness, softness, crispness, succulence, juiciness, mealininess, grittiness, toughness, and fibrousness), nutritional value (dietary fiber, carbohydrates, lipids, proteins, vitamins, minerals), and safety (naturally occurring toxicant, chemical residues, heavy metals, mycotoxin, microbial contamination) (Kader 2002).

Advancement in postharvest technology and logistics has increased the international trade of fresh horticultural commodities. Based on climatic conditions in various regions of the world, the global trade has now made it possible to have a year-round supply of fruits, vegetables, and ornamentals. The increased international trade of fresh produce has, however, increased the market competition and demand for quality assurance system through a certain specified system of quality standards.

At the global level, the Codex Alimentarius Commission, which was established by FAO and WHO in 1963, develops harmonized international food standards, guidelines, and codes of practice to protect the health of the consumers and ensure fair practices in the food trade. While these standards are taken as a reference globally, but these are not mandatory and individual organizations can develop their own standards for the produce of their interest.
Due to increased awareness about health hazardous effect of the excessive and uncontrolled use of pesticides, the concept of safety has become prime importance among consumers of fresh produce (Wills et al. 2004). More recently, new dimensions like environmental, ethical and social responsibility are also being included in the quality standards. Although currently, the new initiatives like Fair Trade and GLOBALGAP Risk Assessment on Social Practices (GRASP) etc., are being primarily promoted by the Western supermarkets, but it shows how the quality would look like globally in near future.

14.2. Quality Assurance Systems

The process of maintaining any horticultural commodity to an acceptable quality level up to the expectation of the consumer is known as quality control (Kader 2001). Whereas, quality assurance is a system, which ensures the quality control has been done effectively to maintain the specific quality standards for any commodity (Hubbard 1999). Different markets have their own criteria for quality control and quality assurance. In general, quality assurance ensures that the produce meets a specified set of standards with respect to that product itself as well as the processes involved in its production, distribution, and processing. A range of terms synonymously being used for quality and quality assurance for horticultural commodities include quality metasystem (Caswell et al. 1998), quality management system (Noelke and Caswell 2000), quality assurance (Unnevehr et al. 1999), quality assurance system (Morris 2000), quality system (Morris and Young 2000) and farm assurance (Morris and Young 2000). Identification of hazards, documentation of practices, certification audits, and approval are important characteristics of a quality management system (QMS) (Caswell et al. 1998).

According to ISO, quality assurance means “all those planned and systematic actions necessary to provide adequate confidence that a product or services will satisfy given a requirement for quality”. Hence, a QAS is defined as “organizational structures, procedures, and recourses needed to implement quality assurance (Sterns et al. 2001). However, QMS incorporate quality assurance and required management principles to drive continued improvement (Morris and Young 2000). QMS involves all component of an organization from executive manager to workers for continued improvement. QAS has different objectives depending upon who controls them. For example, farm specific quality assurance systems (e.g. Global GAP) are defined and managed at the individual farm level; industry quality assurance system is defined and managed at processing and retail level e.g. Hazard Analysis Critical Control Points (HACCP), British Retail Consortium (BRC), Global Food Safety Initiative, International Featured Standards (IFS), Safe Quality Food Institute (SQFI) etc. Whereas, some generic-international quality assurance systems (ISO 9000, 14000, and 22000) are defined and managed by independent standard organizations e.g. ISO; each of these requires third party audits.
14.3. Postharvest Losses

The term postharvest losses mean a measurable quantitative and qualitative loss in a given produce, once it is harvested. Fruits and vegetables generally contain 65 to 95 percent water, which makes them highly perishables. After harvest, if not handled properly in the supply chain, fresh horticultural produce exhibit tremendous postharvest losses. These losses can occur during any of the various phases of the postharvest handling system. These losses may include physical losses as well those which can make these commodities unsuitable either for human consumption or for sale. From an economic point of view, the sum of losses in quantity and quality of the products inevitably means loss in money (for growers) or value for money (consumer). From management perspectives, the most important aspects are to understand the critical stages, the quantity of loss and the causes of product deterioration. Lack of proper understanding of nature, as well as extent and causes of these postharvest losses, results in a huge economic loss, not only to the growers at the farm level but also to all stakeholders throughout the supply chain. Therefore, the reduction of postharvest loss in fruits and vegetables is mandatory to ensure food security throughout the world. It will be more efficient to reduce postharvest losses than investing in increasing productivity. Hence proper postharvest handling of fresh horticultural produce is a significant mean to increase food availability, on a sustainable basis.

14.4. Nature and Extent of Losses

A measurable qualitative and quantitative loss along the supply chain, starting at the time of harvest till its consumption or other end uses is known as a postharvest loss (Buzby and Hyman 2012). The quantitative or physical loss means a reduction in actual weight and volume which can be easily measured. These losses are often reported in the range of 20-40%. Whereas, the qualitative loss is mainly concerned with the cosmetic and nutritive value of the products and involves complex evaluation. Qualitative losses such as loss of nutritive value, loss of calories, loss of consumer acceptability, and loss of edibility of produce are more difficult to measure than quantitative losses of fresh fruits and vegetables.

Postharvest losses in developing countries occur mostly during the field to the market stage, with the smallest share at the consumer level. Contrarily, in developed countries, losses are more at consumer level which is also sometime referred to as food waste. Thus, from management perspectives, in developing countries, the reduction of quantitative losses during postharvest supply chain is of higher priority than their qualitative losses. However, in developed countries, more focus is on reducing qualitative losses where consumer dissatisfaction with the quality of fruits and vegetables results in a greater percentage of the total postharvest losses (Kader 2005).
14.5. Causes of Deterioration of Perishable Produce

Several factors are responsible for deterioration and postharvest losses of fresh horticultural produce such as physical, physiological, mechanical and hygienic conditions (Kader 2002). Fruits and vegetables exhibit short storage life because of their highly perishable nature and metabolic rates (Ferguson et al. 1999). Some other factors such as insect pest and disease attack are also responsible for the postharvest loss of fruits and vegetables. Among these causes, the pathological damage (Pratella 1994) is the most serious followed by mechanical injury (Martinez-Romero et al. 2002). Pathological rots together with mechanical injury cause maximum damage to the perishables (Zhang et al. 2010). Sometimes an attack of insects and birds at the pre-harvest stage are also responsible for the mechanical injury in fruits and vegetables.

An environmental condition in the storage such as gaseous balance, control of temperature and relative humidity also greatly influence the postharvest losses of fresh horticultural produce (Khan and Singh 2008). Inappropriate storage conditions lead to various types of physiological and biochemical deterioration which consequently becomes reasons for pathological attacks in stored fruits and vegetables. Therefore, postharvest loss of fruits and vegetables can be studied as primary and secondary causes. Primary causes of postharvest loss in fresh horticultural produce include mechanical, physiological, pathological or environmental factors. Whereas, lack of proper harvesting techniques, poor transportation facilities, inappropriate storage conditions, poor marketing infrastructure, lack of proper legislation and their implementation are generally considered as secondary causes of postharvest losses (Kader 1984).

Mechanical postharvest losses of fresh fruits and vegetables are caused by careless handling during harvesting, packing, transportation and storage. Mechanical bruising and cracking of fruits and vegetables make them more prone to attack by organisms and significantly increase the rate of water loss and gaseous exchange. After harvest, losses may occur during various pack house operations such as mechanical damage, impact damage, abrasion, excessive brushing, inappropriate waxing and poor packaging etc. Inappropriate packaging (bally packing in wooden crates) and transportation practices (careless loading/off loading, over loading) have also been reported to cause significant post losses in mangoes (Malik et al. 2008).

Various microorganisms such as fungi, bacteria, and yeast also cause significant quantitative and qualitative losses in fruits and vegetables. Among them, maximum damage is caused by fungi and bacteria. The succulent nature of fruits and vegetables and readily available food (sugars) make them easily invaded by these organisms. Mostly, the source of infections can be disease coming from the field (e.g. anthracnose and stem end rot causing fungi), contaminated washing water, contact with unhygienic equipment, packaging material and storage environment. The most common fungal pathogens causing damage to the fresh horticultural produce include *Alternaria*, *Botrytis*, *Diplodia*, *Monilinia*, *Phomopsis*, *Rhizopus*, *Pencillium*, *Fusarium*, *Sclerotinia*, and *Ceratocystis*. While, *Erwinia* and *Pseudomonas* are important bacteria causing extensive damage during the postharvest stage of various

Among storage conditions, temperature, relative humidity, the composition of gasses play an important role to reduce postharvest losses (Ali et al. 2004; Khan et al. 2008; Ali et al. 2016b). High temperature and relative humidity increase respiration rate and consequently breakdown of stored food reserves with the development of off-flavor (Kader 2002). Concurrently, high temperature and humidity during storage also encourage microbial decay. Inappropriate storage conditions also become the cause of physiological disorders such chilling and freezing injuries that are more commonly observed in tropical and subtropical fruits and vegetables following low-temperature storage. Each horticultural commodity has specific heat requirement during processing (Lurie 1998; Mansour et al. 2006) and excessive or insufficient heat during various pack house operations, improper cold storage temperature and undesirable gaseous composition of controlled atmosphere storage lead to tissue breakdown (Yahia 2009; Zhou et al. 2002).

14.6. Management of Postharvest Losses

Fresh horticultural produce exhibits short postharvest storage and shelf life. Due to high perishable nature, these crops need to be handled with care after harvest. Few of the reported strategies to minimize undesirable changes during postharvest handling of horticultural commodities and to increase their shelf and storage life with better quality include pre-cooling (Martinez-Romero et al. 2003a), cold storage (Khan et al. 2012; Plich and Michalczyk 1999; Ullah et al. 2015), postharvest heat treatment (Abu-Kpawoh et al. 2002), exogenous application of calcium (Valero et al. 2002), polyamine (Khan et al. 2008; Perez-Vicente et al. 2002; Razzaq et al. 2014), aminoethoxy vinylglycine (AVG) (Jobling et al. 2003), oxalic acid (Razzaq et al. 2015; Shafique et al. 2016), L-cysteine (Ali et al. 2016a) and 1-methylcyclopropene (1-MCP) (Dong et al. 2001; Khan and Singh 2007, 2009; Martinez-Romero et al. 2003b; Martinez-Romero et al. 2003c; Razzaq et al. 2016; Salvador et al. 2003; Serek et al. 1994; Ullah et al. 2016). Development of new cultivars with improved flavours and better nutritional quality and shelf-life are being given high priority in developed countries. Strategies for reducing postharvest losses in developing countries include the application of improved harvest and postharvest handling systems including advanced packaging of produce and maintenance of cool chain throughout the supply chain of fresh horticultural commodities for better quality and safety assurance. These strategies can be better implemented by overcoming the socioeconomic constraints in developing countries such as inadequacies of infrastructure, poor marketing systems, weak R&D capacity and integration among producers, handlers and marketers or exporters.
14.7. Factors Affecting Shelf Life and Quality

14.7.1. Pre-harvest Factors

It is important to understand that the quality of fruits and vegetables can only be maintained, not improved, after harvest (Kader 2002). Numbers of pre-harvest factors influence shelf life and quality of fresh produce. The most important among them are genotype, mineral nutrition, irrigation water quality, proper insect pest and disease management etc (Ferguson et al. 1999; Lee and Kader 2000).

Genetic influence

The quality of seed or plant material is an important factor that controls the yield, quality and postharvest life of the fruits and vegetables. Susceptibility and intensity of diseases, insect pest infestation and physiological disorders can be minimized by correctly choosing the genotype for a given environment. Breeding programs have allowed desired traits to be introduced into cultivars and rootstocks to improve varieties with better quality and resistance towards pests, pathogens and varying environmental conditions. Genetic engineering serves as a key tool for identifying and blending traits of interest for developing cultivars with desired characteristics.

Genetic influence is also observed in terms of respiration rate of fruits and vegetables once they are harvested. After harvest, several fruits and vegetables show typical respiratory climacteric (a phenomenal increase in the rate of respiration along with ethylene production), while the others do not. On this basis, horticultural crops are generally divided into two groups, i.e. climacteric and non-climacteric crops (Table 14.1). This classification helps in adopting compatible strategies in their postharvest handling and storage.

Environmental factors

Interaction of temperature and light, wind and rain are important environmental factors influencing yield and quality of fresh produce. Temperature varies with different agroecological zones and crops are cultivated accordingly in the temperate, sub-tropical and tropical regions. Apple requires a cool climate and specific chilling hours to break dormancy before fruit bud initiation. Similarly, chilies thrive best in climates with a long warm and frost-free growing season. Light is also an important factor which determines the time of harvest. For example, fruits in the outer canopy of mango and citrus trees which are exposed to sunlight tend to mature earlier than those in the inner canopy (Khan et al. 2009). Low light intensity limits photosynthetic activity. Similarly, strong winds, especially during early fruit development period (4-6 weeks), cause physical damage resulting in skin blemishes in citrus fruit, which downgrade its marketing grade. Humid and raining weather generally favours activity of microorganisms and spore germination. During rainy weather, fruit set is generally poor because of limited pollinator’s activity as well as washing out of pollen grains from stigma surface. If rainfall occurs after pollination in date palm, the process has to be repeated many times for sufficient fruit set.
Table 14.1 List of climacteric and non-climacteric fruit and vegetable crops.

<table>
<thead>
<tr>
<th>Climacteric</th>
<th>Non-climacteric</th>
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<td>Apple</td>
<td>Black Berry</td>
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<td>Avocado</td>
<td>Cacao</td>
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<td>Apricot</td>
<td>Cashew apple</td>
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<td>Banana</td>
<td>Carambola</td>
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<td>Bariba</td>
<td>Cabbage</td>
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<td>Blue Berry</td>
<td>Cherry</td>
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<td>Breadfruit</td>
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<td>Cherimoya</td>
<td>Cranberry</td>
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<td>Durian</td>
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<td>Feijoa</td>
<td>Dates</td>
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<td>Egg Plant</td>
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<td>Guava</td>
<td>Grape</td>
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<td>Jackfruit</td>
<td>Grapefruit</td>
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<td>Kiwifruit</td>
<td>Honey dew melon</td>
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<td>Mango</td>
<td>Jujube</td>
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<td>Mangosteen</td>
<td>Java plum</td>
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<td>Muskmelon</td>
<td>Lemon and limes</td>
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<td>Mamey apple</td>
<td>Lettuce</td>
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<td>Nectarine</td>
<td>Litchi</td>
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<td>Papaya</td>
<td>Longon</td>
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<td>Passion fruit</td>
<td>Loquat</td>
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<td>Persimmon</td>
<td>Mandarin</td>
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<td>Pear</td>
<td>Okra</td>
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<td>Peach</td>
<td>Olive</td>
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<td>Plum</td>
<td>Orange</td>
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<td>Quince</td>
<td>Eugenia sp</td>
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<td>Rambutan</td>
<td>Peas</td>
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<td>Sapote</td>
<td>Pepper</td>
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<td>Soursop</td>
<td>Pineapple</td>
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<td>Sweetssop</td>
<td>Pomegranate</td>
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<td>Tomato</td>
<td>Prickly Pear</td>
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<td>Raspberry</td>
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<td>Strawberry</td>
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<td>Summer Squash</td>
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<td>Spinach</td>
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<td>Tamarillo</td>
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<td>Water Melon</td>
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Cultural practices

Nutritional status of fresh produce is an important factor in its ultimate quality at harvest and subsequent postharvest life. Imbalanced nutrition can result in disorders that diminish postharvest quality and storage life. Nitrogen application is considered to directly influence quality as excessive dose stimulates vegetative growth and delays fruit maturation and development of optimum colour and flavour. Various studies show the positive role of calcium in improving shelf life and quality of fruits and vegetables (Kader 2002). In mangoes, a negative correlation between flesh Ca and B contents and postharvest disease development (stem end rot) during storage has been recently reported (Malik and Amin 2014), implicating the critical role of
nutrition for long distance shipment of mangoes. Thus, a balanced application of macro and micro nutrients, according to the requirement of plant and soil profile, is imperative to attain the best possible quality and quantity.

Similarly, irrigation is another important factor which must be taken into account as timing and quantity of water influences quality at harvest. Cutting-off irrigation or over-irrigation can be detrimental depending on the tolerance of plant towards water stress. Over irrigation in citrus can cause depletion of oxygen (suffocation) in the root zones leading towards the death of the entire tree. This is why intercropping in citrus with high water requiring crops is not recommended. Moreover, uneven irrigation management can cause a reduction in yield and quality (shape disorders, wilting, cracking, spots and rots). Withholding irrigation prior to harvest is generally practiced in mangoes in order to increase fruit dry matter contents, which are correlated with postharvest quality and shelf life.

Canopy management in tree crops can directly improve the quality at harvest as well as postharvest life. Judicious removal of unwanted, infested, overlapping and dead branches not only allows air and light penetration but also keeps a tree more fruitful and with reduced disease pressure. Better tree hygiene and canopy management are particularly important in reducing the quiescent infections (stem end rot, anthracnose) which cause significant losses at a postharvest phase in mango (Malik and Amin 2014) and other fruit crops. Similarly, crop load can be controlled by fruit thinning which results in better sized and quality fruit.

14.7.2. Harvest Factors

Maturity

Maturity at harvest is the most important factor that determines storage life and final product quality as well as consumer acceptability. Stage of maturity at harvest has been reported to significantly affect the biochemical composition of fruits (Meredith et al. 1992). Immature fruits and vegetables are susceptible to mechanical damage with inferior quality upon ripening. Likewise, overripe fruit is soft, mealy and develop insipid flavour soon after harvest. Vegetables, if allowed to over mature may become too fibrous or full of seeds that reduce its eating quality. Too early or too late harvested fruits are more susceptible to physiological disorders and result in shorter storage life than fruit harvested at proper maturity (Kader 1999). Maturity indicators are crop and variety specific and the assessment procedure could be subjective, objective, destructive or non-destructive. Maturity parameters including external (size, colour, shape, firmness, skin smoothness etc.) internal (acidity, soluble solids content, dry matter percentage, starch content, juice percentage etc.), physiological (ethylene production) along with time bound (days after full bloom, heat units etc) (Reid 2002; Khan 2016). For example, citrus maturity is locally assessed on the basis of fruit colour, although in some countries criteria used is juice contents. In, mango visual maturity indicators include smoothness of skin, raised shoulder development, and fullness of sinus. While flesh colour is generally regarded as the most consistent indicator of mango maturity. Apples and pears are harvested by counting the days from full bloom to harvest. Some melons develop an abscission
layer which is a clear indication of optimal maturity. Tomatoes are harvested when seeds are developed, and on the basis of different colour break stages depending upon intended market. The solidity of lettuce and cabbage is an important textural maturity indicator. Similarly, compositional changes (starch, sugar, acid, juice content, astringency) are very helpful in deciding the time of harvest. Pickers should be trained in assessing the proper maturity stage of produce.

A range of non-destructive technologies is also being tested for testing maturity and internal defects which include optics, radiation (X-ray, Gamma Rays, Near Infra Red), mechanics (acoustic), electromagnetic (Magnetic Resonance/Magnetic Resonance Imaging etc.) (Abbot 1999; Nicolai et al. 2007) with promising future.

**Procedure**

Each horticultural commodity has a standard and prescribed method of harvest (Fig. 14.1). Gentle digging, picking, and handling help reduce crop losses. Harvesting of fruits and vegetables is done with some specialized secateurs and clippers. For example, Kinnow mandarin (citrus) is harvested by using secateurs, in two-step procedure. In the first step, fruit is clipped off with a longer pedicle which is then cut back near to the button. Likewise, mangoes should be picked by using special cut n hold type poles to avoid breaking of the stem which results in sap burn injuries. Sap burn injury in mango has been identified as the prime quality issue by consumers in different markets (Collins et al. 2006) which significantly downgrade its market value. To overcome this issue, fruit is carefully picked and then de-sapped using special physical or chemical methods. In contrast, apples and pears are easily harvested by a manual twist near natural break point without the aid of any tool.

![Fig. 14.1 Harvesting of fruits in the field: (A, B) harvesting through manually operated lifter, (C) manual harvesting, (D, E) unloading of fruit in the field bin, (F) sorting in the field, and (G) tool used for harvesting fruit.](image-url)
Environmental conditions at harvest

In general, harvesting should be done early in the morning or late afternoon, during summer. Harvesting during the hotter part of the day accelerates water loss, ripening and early senescence in comparison to early morning or late afternoon harvest. Harvested produce should be kept under shade in the field when immediate transportation is not possible. Avoid harvesting on a rainy day as pathogenic spores show high movement in splashy and rainy conditions. In the case of citrus, harvesting and handling of fruit under such conditions can result in the development of oleocellosis (rupturing of peel oil glands causing skin blemish). Presently, regular online updated weather forecast can assist the growers to plan the harvest operations accordingly.

Mechanical injury and impact

Undoubtedly, one of the most important factors in reducing postharvest losses of fresh produce is by avoiding injuries (Fig. 14.2). Picker should not be wearing pointed or sharp accessories (ring, bracelets) during harvest operations that can wound the produce. It is important that picker keeps their fingernails trimmed, and preferably wear cotton gloves. Fruits and vegetables are highly perishable commodities with high susceptibility to bruising and mechanical and impact injuries. Rough handling, dropping fruit from a height or over filling the collection bin can easily damage and misshape the fruit. Pulling fruit off the tree may also cause injury. These bruises and injury points provide entry sites to pathogens and thus favours development and spread of disease.

Fig. 14.2 Different types of container and bins used for harvesting and storage of fruits and vegetables (A) harvesting bag, (B) harvesting mulberry cane basket, (C) harvesting plastic basket, (D) plastic bin, (E) wooden bin, and (F) reusable plastic crates.
Secateurs are often used for harvesting and a picker can easily cut and place produce into picking bags without dropping. Sometimes, in the case of tall trees, fruits are out of reach. Under such situations, two pickers should work together, one can harvest the fruit using a cut-n-hold pole and the other can gently place into the crate. All harvesting tools either manual or mechanical must be used carefully without damaging the produce. A general malpractice in Kinnow orchards is to lean the ladder against the tree or climbing on a tree, which causes damage to the tree. Self-supportive ladders serve the perfect substitute to harvest fruit away from reach. Mechanical harvesting is mostly used for vegetables that are grown below ground that requires well-trained personnel. Operating at wrong depth can cause damage to edible root portion (carrot, radish, potato). Leafy vegetables need to be chilled in clean water at harvest to maintain quality and prevent wilting.

14.7.3. Postharvest Process

A good packaging facility including building, equipment and sanitation have a significant impact on the postharvest life and quality of fresh horticultural crops. Best packaging practices include proper sorting and culling of produce, maintaining detectable free chlorine in cleaning water, and exclusion of pathogens and pests (insects, birds, and rodents) from packing house. Good sanitation and housekeeping are integral components of standard operating procedures in a modern pack facility (An and Lee 2006; Cha and Chinnan 2004; Macnish et al. 1997). Pack house should also have adequate lighting. All food contact surfaces should be regularly cleaned during processing and packaging operations to reduce the risk of contamination with dirt or microorganisms (Yahia 2009). There should be separate rest rooms for workers, which should not open directly into the main processing areas. Workers should have access to adequate supplies (hand soap, cleaning detergent, disposable towels, clean water etc) as well as proper training of personal hygiene, sanitary practices, and food handling techniques.

Sorting

Sorting is an important operation carried initially in the field when loading bins for field transport and at the pack house before processing. In the field, sorting is carried out to eliminate highly infested and defected fruit which do not meet any market requirement. Such fruits should be buried in the soil. Dumping off disease and insect pest infested fruits are part of the good orchard management practices, to reduce insect pests and diseases. On arrival at pack house, re-sorting is carried out manually and by mechanical means to ensure uniformity in colour, size, and grade.

Washing

The main purpose of washing is to remove all dust impurities adhering to the surface of fruits and vegetables. In processing units, washing nozzles uniformly spray water over the fruits at a constant pressure. As the fruit moves over the roller, it is washed and brushed. From food safety perspective, quality of washing water is critical, since all the produce comes is direct contact with water. As a rule of thumb, the wash water used for fruits and vegetables should be of potable (drinking) quality. In a food quality assurance system, it is mandatory to get wash water quality tested for
microbial and chemical contaminants, from an ISO (17025) accredited lab. Use of chlorine (100-150 ppm) helps reduce the risk of microbial contamination; however, it is important to monitor its concentration since the accumulation of dirt (soil, organic matter) in wash water results in a reduction of free chlorine concentration. Further, any detergent used for washing must be of food grade. Some other sanitizing agents such as hydrogen peroxide, iodine, ozone and organic acids are used for cleaning of various horticultural products. Care must be taken that these products should be applied in an appropriate concentration for a particular commodity.

Grading

Commodities are graded on the basis of their size, shape and colour to attain good prices in the market (Fig. 14.3). Grading can be done manually or by automatic grading lines. Market grades of different commodities are also based on the skin blemishes. Each grade category has specific permissible limits with regard to the intensity of defects.

![Fig. 14.3 Pictorial views of various pack houses in action: (A) citrus, (B) apple, (C) mango, and (D) cherry.](image)

Generally, produce should be clean and free from any visible foreign matter, smell and damage caused by pests or diseases. Moreover, commodity should possess the characteristic colour, flavour of variety, be at the proper stage of maturity/ripeness. The intensity of defects including blemishes, mechanical damage, objectionable
matter determines the grade. Slight superficial defects may be allowed in some grades. Codex quality standards for a number of fruits and vegetables have been developed, which can be customized to locally grown crops and varieties.

**Special treatments**

Edible films and coatings have been known to extend the shelf/storage life, and to improve the quality of perishable fruits and vegetables (Park 1999; Ahmed et al. 2009). The edible coatings act as a semi-permeable barrier for moisture and gasses and develop a modified internal atmosphere around the fruit. This modified atmosphere reduces respiration rate and retards ripening, senescence; reduce transpiration and weight loss (Basiouny and Baldwin 1997; Carillo-Lopez 2000). With increasing trend of fresh cut produce, antimicrobial agents are also being added to the edible composite films and coatings based on polysaccharides or proteins such as starch, cellulose derivatives, chitosan, alginate, fruit puree, whey protein isolated, soy protein, egg albumen, wheat gluten, or sodium caseinate (Valencia-Chamorro et al. 2011).

Use of wax coating is a commercial practice in citrus, while in mango it is not commonly used. Following types of waxes are commercially available.

- **Carnauba based waxes:** It is low shine, low-cost natural wax extracted from palm leaves.
- **Shellac based waxes:** These have the best shine and the most popular wax currently used.
- **Polyethylene based waxes:** Provide effective control of weight loss and reasonable shine.
- **Resin based waxes:** provide a good shine; however, they may cause rind injury to sensitive varieties of citrus fruit.

### 14.8. Packaging and Labeling

The aim of packaging includes identifying, protecting and conveniently handling the product during distribution and retail (Fig. 14.4-14.6). A number of packaging materials are being used for packing fruits and vegetables including wooden, jute, cardboard, polystyrene, polypropylene fabrics etc., depending upon several factors like the nature of product, process involved (pre-cooling etc.), mode of shipment (air, land route etc), market requirement and economic aspects etc. Likewise, the package size also varies from bulk pack (1000 kg) in crops like potato and onions etc to small consumer pack (100 grams) as in strawberry. Other important considerations in the choice of packaging material include properties like eco-friendly, biodegradability, and recycle ability etc. It is important to note that any wooden package or wooden pallets used for export must be treated against insect pests as per regulation of ISPM 15 (International Standard Phytosanitary Measure).
Fig. 14.4 Different types of packaging boxes being used for packing of various fruits in the international markets.

Fig. 14.5 Modern innovative and attractive fruit boxes with self-carrying handle or strap.
Traceability is the ability to trace any product back to its original source. Traceability for the export boxes would require references back to the exporting company, the packhouse, grower and the farm block, from where the fruit was harvested. Traceability has become a mandatory requirement in advanced countries. To maintain, traceability proper labeling is extremely important. Labels could be glued onto the box or it could be printed during the manufacturing of the box. The basic information on labels includes:

- The product name
- Quantity (count/net weight)
- Source (country of origin, name of grower, packer, shipper, exporter and a trace-back or tracking code)
- Special treatment on the fruits, if any (e.g. fungicide application).

After labeling, depending upon nature of the shipment, strapping of boxes and palletization is also done. For strapping, purpose, semi and fully automatic machines are used.

14.9. Storage

14.9.1. Pre-storage treatments

Pre-cooling

The temperature of produce at harvest affects their postharvest life and quality. Loss of quality occurs as a result of physiological and biological processes, which are influenced by high product temperature at the time of harvest. After harvest, it is necessary not only to cool the crops but also to do it as quickly as possible. The process of pre-cooling involves the removal of field heat to slow down the senescence processes that helps extend shelf life with maintained fruit quality. Pre-cooling of mango fruit has been reported to significantly reduce postharvest disease development and extend storage life in Pakistan (Malik and Amin 2014). Different
techniques used for pre-cooling include room cooling, package icing, hydro-cooling, vacuum cooling, and forced air cooling (Brosnan and Sun 2001).

**Chemical treatments**

Postharvest chemicals may include fungicides, insecticides, growth regulators, and ripening agents etc. It is extremely important for growers and shippers to check market restrictions like Maximum Residues Levels (MRLs), and registration of chemicals etc. For general guidelines, Codex standards provide MRLs for various chemicals; however, importing countries may have their own MRLs which could be more stringent.

One of the most important challenges in fresh produce supply chain is to keep postharvest disease development under control, especially during extended storage or long distance shipments. Where unavoidable, application of appropriate postharvest fungicides is needed. Postharvest fungicides are usually applied as dips, sprays, fumigants, treated wraps and box liners or in the wax formulation. Postharvest pathogens, which infect the produce before harvest, require the application of fungicides during production. Mangoes are usually dipped in hot water (52°C for 3-5 minutes) with or without fungicide for controlling postharvest diseases (anthracnose, stem end rot, and body rot). Likewise, in citrus, postharvest fungicides are commonly applied as wax formulation, for a successful shipment.

Exogenous application of methyl jasmonate (MJ) has been reported to influence the postharvest fruit quality parameters in both climacteric and non-climacteric fruit. MJ application improve fruit colour in apple, peach, raspberry and mango (Janoudi and Flore 2003; Khan and Singh 2007; Lalal et al. 2003; Shafiq et al. 2103; Wang 2003); increase aroma volatile production in mango and apple (Lalal et al. 2003; Li et al. 2006; Shafiq et al. 2013); enhance chlorophyll degradation, β-carotene biosynthesis as well as levels of total antioxidants in apple, mango, guava and papaya (Reyes and Cisneros-Zevallos 2003; Schreiner and Huyskens-Keil 2006; Wang 2003);

The AVG is a naturally occurring plant hormones which competitively and reversibly inhibit the conversion of SAM into ACC content (Boller et al. 1979). Pre- and postharvest applications of AVG have been investigated for improvement in yield and quality attributes of different climacteric fruits (Tareen et al. 2017; Palou and Crisosto 2003). Preharvest AVG-treated plum fruit showed ‘on tree’ delay in fruit maturity with improved taste and colour (Jobling et al. 2003). Pre-harvest application of ReTain™ (830 g ha\(^{-1}\)) to peaches extended the harvesting period with delayed fruit ripening and higher fruit firmness and SSC (Singh et al. 2003). Postharvest application of AVG reduced and delayed the endogenous ethylene production and fruit softening in ‘Patterson’ apricot (Palou and Crisosto 2003).

Polyamines (PAs) have been reported as an anti-senescence agent, and their application has been found to reduce the softening with the delay in senescence process in several fruits (Karmer et al. 1991). PAs retard the senescence by stabilizing cell membrane (Borrell et al. 1997) and inhibiting the activities of polygalacturonase and pectin esterase involved in the fruit softening (Martinez-Romero et al. 2002; Razzaq et al. 2014). Application of spermidine (0.1, 1.0 and 5.0 mM), spermine (2.0 mM) and putrescine (10 mM) 19 days before of harvest
significantly delayed the fruit softening in peach fruit (Bregoli et al. 2002). Pre-
storage dip applications of PAs retarded development of fruit softness and visual
colour, and reduced weight loss, thus improved overall storability of Kensington
Pride mangoes (Malik and Singh 2005).

Postharvest application of 1-MCP has been widely reported to affect endogenous
ethylene production in various fruit crops (Watkins 2006). 1-MCP blocks the
ethylene receptors and inhibits ethylene production to the extended period of time
(Sisler and Serek 1997). This potent compound, therefore, has been reported to
strongly influence the fruit ripening and improving the post-storage life of
climacteric fruit (Sisler et al. 1996). Apart from ethylene, 1-MCP has also been
claimed to has variety of effects on respiration rate, volatile production, chlorophyll
degradation and other colour changes depending on the species, cultivar,
developmental stage, time from harvest to treatment and number of applications
(Blankenship and Dole 2003; Khan and Singh 2007; Khan and Singh 2009; Razzaq
et al. 2016). Moreover, 1-MCP also delays the changes in SSC, TA, and SSC:TA
ratio in many climacteric fruits.

Nitric oxide (NO) is a multifunctional biomolecule involved in a variety of biological
plant functions such as stomatal movement, plant respiration, germination of seeds,
differentiation of cell and fruit ripening. Recent studies have reported that NO exhibit
antagonistic interaction with ethylene with the ability to suppress the biosynthesis of
ethylene by suppressing the activities of ethylene synthesis enzymes. This reduction
in ethylene production consequently delays fruit ripening with a reduction in fruit
softening. Its marked effects are more pronounced in non-climacteric fruits as
compared to climacteric ones.

**Intermittent warming**

Postharvest quality losses in stored fruits are mainly caused by the metabolic changes
and physiological disorders. In order to reduce the postharvest losses during cold and
controlled-atmosphere (CA) storage, application of intermittent warming during
storage has also been reported to exhibit beneficial effects in some crops (Fernandez-

**14.9.2. Types of Storage**

**Cold storage**

Low-temperature storage or cold storage is the most common method used to extend
the storage and shelf life of horticultural crops (Ullah et al. 2015; Wertheim 2005).
Stage of maturity at harvest and fruit temperature in the storage are the main factors
that affect the length of low-temperature storage period and occurrence of
postharvest physiological disorders (Plich and Michalczuk 1999). To decrease losses
during the low temperature storage period, and post-storage handling as well as to
ensure acceptable quality at the retail market, the product must be harvested at
appropriate maturity and stored at low temperature, but above the freezing point
(Hartmann et al. 1988). A general rule for vegetables is that cool-season crops should
be stored at cooler temperatures (0-3°C) and warm season crops at warmer
temperatures (7-14°C).
Controlled atmosphere storage

Controlled atmosphere (CA) storage involves altering the normal atmospheric composition of air around the fruit (Fig. 14.7), generally by lowering the O\textsubscript{2} concentration and increasing the concentration of CO\textsubscript{2} in the storage atmosphere (Mitchell and Kader 1989). Extensive studies have been done to investigate the effects of CA storage on the postharvest physiology and handling of fruits (Ali et al. 2016b; Chung and Shon 1994; Ke and Kader 1992; Ke et al. 1991; Wang and Vestrheim 2003). Beneficial effects of CA storage on extending the storage life of fruits include a reduction in the rate of respiration, ethylene production, colour changes and fruit softening while maintaining vitamins, sugars, and acids and inhibiting some physiological disorders and decay. Low oxygen CA storage has been reported to extend the storage life of different plum cultivars (Ke et al. 1991; Sive and Resnizky 1979). CA technology has been successfully employed in commercial sea shipment of Sindhi mangoes from Pakistan to Europe (Malik and Amin 2014). However, Kinnow mandarin showed sensitivity to low levels of oxygen, and thus CA application is not recommended.

![Fig. 14.7 View of commercial CA storage of apple: (A) CA room, and (B) Pallets of fruits before storage in CA.](image)

Modified atmosphere storage

Modified atmosphere packaging (MAP) creates a lower O\textsubscript{2} and high CO\textsubscript{2} atmosphere in the package, though this is not actively and precisely controlled like CA storage. Application of MAP has been reported to affect the postharvest quality in some fruit
crops, during storage (Khan and Singh 2008). Peach cultivar ‘Paraguayo’ stored at 2°C in non-oriented standard polyethylene films for 14 days maintained fruit firmness and quality without the development of wooliness and decay (Fernandez-Trujillo et al. 1998). Blueberries stored at 4°C in CO₂ permeable film exhibited higher scores for sensory texture and flavour compared to storage at 12°C (Rosenfeld et al. 1999). Use of MAP with low-density polyethylene film in carambola fruit held at 10°C markedly reduced the decline in fruit firmness and development of fruit colour, water loss and incidence of chilling injury (CI) (Ali et al. 2004). Application of micro-perforated polyethylene film has been reported to reduce the incidence of CI and rind breakdown during storage in citrus (Porat et al. 2004). In sweet cherries, use of MAP resulted in a reduction of water loss with better appearance during storage (Petracek et al. 2002). Modified atmosphere (MA) storage eliminated the CI symptoms of red spots in mangoes stored at 12°C (Pesis et al. 2000). MAP and low-temperature storage in loquats retarded the water losses and organic acid reduction for 2 months. Studies on locally grown mangoes (cultivars Sindhri and Sufaid Chaunsa) using X-tend film packaging showed significant improvement in storability and post-storage shelflife of mangoes as evidenced by reduced weight loss and disease development along with better-maintained fruit firmness. MAP studies on citrus showed that shelflife of washed lime and Kinnon can be significantly increased at ambient condition.

14.9.3. Storage Monitoring and Maintenance

Monitoring of storage environment is critical for successful storage of produce. Regular monitoring of storage temperature, relative humidity, ethylene, and carbon dioxide is required so as to take appropriate and timely measures before it can significantly impact the quality of the stored produce. Deviation in storage temperature should be within ±1°C of the desired temperature for the commodity being stored. Metabolic and respiration rate of the product is directly related to storage temperature. Temperature below or higher than the optimum range of commodity can lead towards chilling injury or cause deterioration by accelerating ripening. For most perishable commodities, RH should be around 85-95% in the cold storage facility and regularly monitored using a hygrometer or a sling psychrometer. In addition, commodities that are ethylene sensitive should not be stored together with those producing high ethylene. Storage rooms need to be vented when high levels of ethylene and CO₂ build up. Products packs should be stacked, aligned and spaced correctly to allow proper air circulation through them. Inspection of stored produce at regular intervals for signs of injury, water loss, damage or disease is very important to remove infected produce and prevent further spread of problems. Cold stores should also be regularly checked and maintained for gas leakage. Standard Operating procedures regarding sanitation and hygiene are to be strictly followed to reduce the risk of contamination to produce.

14.10. Transportation

After packaging and processing, fresh horticulture produce is either stored at appropriate storage conditions or transported to wholesale or retail markets.
Throughout the postharvest handling and transportation, ownership and traceability of produce must be maintained. Every care should be taken to minimize the risk of microbial contamination and any abuse in temperature maintenance during transit (Kader 2002). Use of specialized vehicle must be ensured to maintain the integrity of the product. Fresh fruits and vegetables are transported in refrigerated vehicles for land routes and local markets, while marine containers are used for offshore distant marketing. Air freight is generally used for highly perishable and costly products. If refrigerated transport is not available, then try to avoid exposure of fresh produce to high temperature as much as possible and transport at a cooler time. In all above modes of transportation, fresh produce is susceptible to losses in their quality. Physical factors such as initial product quality, produce temperature before and during transport, humidity and water loss, atmospheric composition, transportation of mix loads, physical injury during transportation have a significant impact on the effective transportation with minimum postharvest losses (Ryall and Pentzer 1982; Vigneault et al. 2009).

To keep the produce in optimum condition during transportation, adequate temperature control, and air circulation system is important to ensure produce quality. Among them, most important are the cooling capacity of transporting vehicle. It should be noted that marine containers are not meant for precooking of produce, they can only maintain the temperature if produce has already been pre-cooled closer to the required temperature during transportation. In addition to the refrigeration system, circulation of cool air is also very important to regulate and maintain the required temperature during the transportation. Better heat removal and uniform circulation of temperature either top or top air delivery are key features of a good air circulation system (Vigneault et al. 2009; Yahia 2009). Another important consideration is venting or air exchange of containers during transportation. Specific volumes of air needed to be exchanged/replaced to exclude high levels CO₂ and ethylene accumulated due to continuous respiration of produce loaded in the container. For example, in 40 feet reefer container of Kinnow mandarin, local industry has a practice of venting set at 25m³/h, while for mango, Maersk shipping company recommends 30m³/h. In the case of controlled atmosphere containers, venting is set at zero, since the gaseous environment is precisely maintained as per settings through the CA-system.

14.11. Ripening

14.11.1. Ripening Process

After harvest or storage, mature fruit undergoes a natural process of fruit ripening, which involve numerous physical, physiological and biochemical changes. Change in fruit colour is the most obvious physical sign, while biochemical changes include SSC, TA, and aroma volatile production. The physiological changes occur in respiration rate, ethylene production, and fruit firmness. These and many other changes in physicochemical properties, brings the mature fruit from hard, sour with unacceptable texture, taste and flavour to more a favourable state of consumption (Kader 1999) Most of the stone fruits adopt climacteric-ripening pattern, in which
ethylened triggers the ripening and senescence process with reduction in the fruit weight, firmness, texture, aroma production and occurrence of off-flavour and decay (Giovannoni 2001). Commercially, fruits are harvested at a mature stage prior to ripening, so that they can withstand the postharvest handling.

14.11.2. Ethylene Management Strategies

Ethylene (C₂H₄) is a natural plant hormone associated with the growth, development, ripening and aging of many plants. This phytohormone is said to promote ripening in climacteric fruits including banana, pineapple, tomato, mango, melon, and papaya. It is produced in varying quantities depending on the type of produce. Non-climacteric fruits ripe on the tree and do not undergo a rise in ethylene activity after harvest. Climacteric fruits harvested before ripening initiation at their physiological maturity can be stored and ripened successfully. The climacteric rise in ethylene production within the fruit coordinates several changes including peel colour development (green to yellow), chlorophyll degradation, flesh softening, and an increase in SSC and carotenoids along with a decrease in titratable acidity. The firmness of fruits and vegetables has been reported to decrease with the exogenous treatment of C₂H₄ (Kader 1985). Consumer acceptability depends upon uniformity in ripening and colour as it is said that a consumer eats with his eyes (Saks et al. 1999). In commercial ripening facilities, ethylene is applied at a concentration of 10 ppm (trickle system) to 100 ppm (shot method), at specified temperature and duration, depending on the crop and cultivar. For ripening purpose, ethylene gas is available in cylinders as 4% C₂H₄ in nitrogen. In many developing countries, traditionally, calcium carbide (CaC₂) is used as a ripening agent in the local market due to ease of its availability and low price. When dissolved in water, carbide produces acetylene gas. However, health hazards have surpassed its benefits and its usage as a ripening agent is banned (Singh and Janes 2001) including in Pakistan. It is also considered a threat because it may contain traces of arsenic and phosphorus hydride (Delpierre, 1974). On the other hand, ethylene being a natural hormone does not pose any health hazards for the consumers. It has been reported that exogenous application of ethylene helps in the uniform ripening of fruit (Medlicott et al. 1988). In order to extend the shelf life of fresh produce, effective ethylene management strategies are needed. These include: 1) avoiding injuries and bruising of produce, 2) maintaining high level of sanitation (dumping of rotten fruits and vegetables); 3) avoid other sources of ethylene production; 4) segregation of high ethylene producing items (apples, avocados, bananas, melons, peaches, pears, and tomatoes) from ethylene-sensitive ones (broccoli, cabbage, cauliflower, leafy greens, lettuce, etc.), during storage and transportation; 5) Flushing of storage environment with fresh air/N₂; 6) Use of ethylene absorbing filters; 7) Oxidation of ethylene (oxidized to CO₂ and water), using ozone gas (difficult to use, risk of injuries, carring of pipes etc.) and use of other chemicals (ethylene biosynthesis and action inhibitors (AVG, AOA, 1-MCP etc) as reported in various literature.
14.12. Marketing

Marketing could be defined in many ways. According to Mariam-Webster dictionary, the process or technique of promoting, selling, and distributing a product or service is known as marketing (http://www.merriam-webster.com/dictionary/marketing). Moving the harvested produce from the farm to the customer in good condition and at right time is extremely important for a successful and sustainable supply chain. Products are prepared according to the specifications of the importer or destined markets.

14.12.1. Domestic Marketing

The schematic diagram given below represents typical mango supply chain (Fig. 14.8). Other products in domestic markets are also having more or less similar intermediaries in the supply chain. In general, a contractor buys the product from the grower and sells it to the middle man where product flows from wholesaler to retailer and ultimately the consumer. Less perishable vegetables including potatoes and onions are packed into sacks or mesh nets. While highly soft and perishable fruits including strawberries, peaches, plums and cherries are field packed into corrugated cardboard boxes. They are more susceptible to damage and need to be gently packed in a way that something can help cushion the produce. On arrival to the destined auction market, the highest bidder buys the product. At times, retailers buy the product in bulk quantity and sell them in small units. Most of the produce is domestically marketed. In the case of Kinnow mandarin and mango, A-grade fruit is usually exported, while B grade goes in the domestic market. In Pakistan, agricultural markets including fruits and vegetable markets are still regulated by the government; however, efforts are underway to allow establishing markets under private sector.

Fig. 14.8  Relationship of various mango supply chain components. Modified from Collins et al. (2006).
14.12.2. Export Marketing

Fruits and vegetables remain high in demand in both local and international markets (Fig. 14.9). Export through air freight allows the product to reach the destination in a timely manner and is mostly adopted for commodities with a short postharvest life span. Alternatively, use of sea freight technology has been proven to be economical which allows transportation of much larger volumes of export.

Fig. 14.9 Supermarkets showing increasing demands for organic and certified food and quality, the high priority in the modern markets.
However, sea freight is only applicable for commodities that can withstand long term storage without loss in quality. Less perishable commodities including onions and potatoes are mostly exported by road to neighboring countries. However, China has allowed mango export by road using a 20 ft reefer container through Sust border. Due to the proximity of Middle East, it remains as main markets for Pakistani produce. Russia/Russian states are an important market for Kinnow and potato, while EU/UK is a second biggest market (after the Middle East) for Pakistani mangoes. Main issues of Pakistan produce in export markets are low quality, with poor packaging, and low market prices. According to Agricultural Sector Linkages Program (ASLP) studies, in order to establish successful export supply chains, the following are the key points.

- Focus on meeting customer and consumer needs
- Membership and the relationships among members
- Information and communication flows
- Product integrity systems, including logistics and distribution
- Ability to create and distribute value

14.12.3. Export Market Access Treatments

In order to gain access to the international markets, compliance with regards to specified sanitary and phytosanitary (SPS) standards is mandatory. Currently, the major quarantine concerns in fresh produce are fruit fly and canker (Bacterial disease). Adaptation of good agricultural practices at field level along with crop specific postharvest quarantine treatments is mandatory. Quarantine measures include irradiation, vapour heat, hot water and cold treatment. Type of quarantine treatment depends upon the nature of crop and requirement of the importing country. In Kinnow mandarin, most of the countries accept a cold quarantine treatment of 2.2°C, for 16 days for disinfestations of a fruit fly. The treatment can be done in the container while in transit. In the case of mango, China requires one-hour hot water treatment at 48°C, while Iran requires it for 75 minutes at 46°C. Irradiation (400 gray) is an approved quarantine treatment against fruit fly, for export of mangoes to the USA. However, at the present, mangoes are to be treated in the USA, after arrival. Japan is the only country, which requires a vapour heat treatment of mangoes for allowing its import. With emerging issues and consumer concern, it has become imperative to closely monitor residue levels of chemicals being used, and it must meet the MRLs of the importing country. Moreover, the chemical product being used must be registered and allowed for usage into the importing country. Commodity traceability is the key to consumer satisfaction and confidence. Commodities are required to be prepared (processed, treated, packed) according to trends that are internationally recognized and accepted.
14.13. Postharvest Problems

14.13.1. Diseases

Postharvest diseases reduce product quality and quantity in a way that it becomes unsaleable (Fig. 14.10). Infection of fruits and vegetables by postharvest pathogens can occur before, during or after harvest. Infections that occur before harvest and then remain quiescent until some point during ripening are particularly common amongst tropical fruit crops. Anthracnose (*Colletotrichum gloeosporioides*) is the most serious postharvest disease, widely spread in tropical and sub-tropical fruits such as mango, banana, and avocado. Anthracnose infects at early as well as a mature stage but symptoms mostly appear as the fruit starts to ripen. Similarly, stem end rot (*Phomopsis citri*) of citrus result from quiescent infections in the stem button of fruit. Brown rot (*Monilinia* sp.) is a common disease in most fruits from the temperate zones including plum, peach, cherry, apricot and apples. Fruit rot may occur before harvest but often occurs postharvest.

In developing an effective control strategy for postharvest diseases, it is important to maintain a high level of hygiene at all stages during production and postharvest handling to minimize the sources of inoculum for postharvest diseases. Use of appropriate fungicides in combination with heat treatments has demonstrated good disease control. Postharvest exposure to heat (>38°C) treatment is used for disinfestations of a large number of fresh horticultural crops (Lurie 1998). The sensitivity of these crops to high temperature has been reported to depend upon pre-harvest weather conditions, cultivar, the rate of heating and subsequent storage conditions (Paull and Chen 2000). After postharvest heat treatment, ethylene sensitivity is irreversibly inhibited due to rapid loss of ACO activity (Lurie, 1998). High temperature has been reported to induce resistance against chilling injury (CI) (Lurie 1998), to control postharvest diseases (Barkai-Golan and Phillips 1991), and to delay ripening (Mitchell 1986).

Fig. 14.10  Disease development in mango fruit, collected from different orchards, after four weeks of storage.
14.13.2. Disorders

A simple difference between diseases and disorders is that the diseases are caused by pathogens, while disorders are the result of non-pathogenic factors (Fig. 14.11). Fungi and bacteria cause most of the postharvest disease in fruits and vegetables. An unfavorable pre- and postharvest factors especially nutritional imbalance, moisture loss, temperature stress and atmospheric stress are important triggers of postharvest disorders. Fruits and vegetables show various browning symptom that has been attributed to deficiencies in some mineral constituents of the produce.

Fig. 14.11  Fruits with various problems: (A) mango fruit fly, (B) mango stem end cavity, (C) sap burn injury in mango, (D) litchi fruit without pericarp browning, (E) litchi fruit showing symptoms of pericarp browning, (F) fruit fly attack on peach, (G) wind blemishes on citrus fruit, (H) blemish on Kinnow due to attack of thrips, (I) variation in apple fruit size, (J and K) attack of codling moth in apple, and (L) blemish in apple.
Bitter pit of apple is a nutritional disorder associated with deficiency of calcium or excess of potassium (Snowdon, 2010). For controlling nutritional disorders, fertilizers must be applied according to the requirement of soil and plant. Granulation is a disorder in citrus which is characterized by large and hardened fruit with dry juice vesicles. Frequent irrigation or standing water in the root zones and delaying harvest increases the chances of this disorder. Greening in potato is a physiological disorder which can be controlled by avoiding long term exposure to light. Long term storage of commodity below critical temperatures can induce chilling injury (CI) disorder, especially in tropical and subtropical crops. Common CI indicators include, off flavours, browning of flesh tissue, discoloured pitting on the skin, usually due to the collapse of the cells beneath the surface (Raison 1985). The symptoms of CI normally occur while the produce is at low temperature, but sometimes will only appear when the produce is removed from the chilling temperature to a higher temperature. The simplest way to avoid CI is to ensure that product stored at a safe temperature at which chilling does not occur. However, exposure to chilling storage temperature followed by short-term exposure to a higher temperature (intermittent warming) have been reported to prevent developing of chilling injury. This is termed as a conditioning treatment and effectively employed to prevent several disorders including the black heart in pineapple, woolliness in peach and flesh browning in plum.

References


