Chapter 7
Preparation of Fruits for the Market

Introduction

After harvesting, fresh fruits are sold in different markets of India starting from local to distant markets within and outside the state. To get maximum profit from the produce, it is outmost important to have better preparation and presentation of fruits for the markets. Preparation includes all unit operations such as sorting, grading, postharvest treatments, precooling, and packaging. Preparation of fruits before marketing, if followed properly, fetches premium price for the producers and better quality for the consumers. It also reduces postharvest losses to a greater extent and increases marketing period of the fruits. Postharvest losses in fresh produce including fruits are very high due to living nature of the produce and deterioration in quality starts just after harvesting. On an average, this loss is estimated about 5–35 % in developed countries and 20–50 % in developing countries (Kader 2002). In order to reduce this loss, freshly harvested fruits must be prepared before sending to the markets. There may be many unit operations for preparation starting from assembling to final sale in the market. All operations play an important role in extending marketing period of fruits and reducing quality deterioration. The unit operations are described below.

Assembling

Assembling is collection of harvested fruits in a suitable container and bringing to pack house or any place where other unit operations are completed. In majority of fruit orchards, plastic crates are used for assembling and the same crates are transported to pack house where sorting, grading, precooling, pretreatments, if any, and packaging are carried out. During collection and assembling, care should be taken that fruits should not be thrown and hit the hard surface. It causes impact bruising. Crates with bubble sheet for cushioning should be used for this purpose.

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Fig. 7.1 Manual sorting and grading (*left*). Mechanical grader (*right*)

Sorting and Grading

Sorting and grading both are very important operations before marketing. These are done either in the orchard itself or in a pack house depending upon the facilities available. Sorting and grading are totally manual in India and depend on the type of fruits and trained labors. However, mechanical graders are also available (Fig. 7.1). At farmer's level, sorting is not a separate operation, but it is carried out during grading and packaging of fruits. However, on commercial scale, sorting is a separate operation performed by the people standing at both sides of the grader. This is a necessary operation before storage or packaging.

Washing

Washing of fruits is not very common in India, especially at farmer's level. Organized fruit business companies have created this facility in their pack house or at cold storage. Fruits are washed either before storage or before marketing, depending upon the company policy and nature of the fresh produce. Washing is also not necessary for all fruits like grapes and litchi. It is because washing removes natural wax from the grapes and adds browning to litchi, which is necessary for long shelf life and appearance. Fruits like apple, pear, plum, and guava are highly recommended for washing before storage. In pome fruits, washing before storage is found beneficial as it increases humidity of the storage chamber (Controlled atmosphere storage chamber) and reduces spoilage. Here, it is important to note that fruits should be stored in high-quality plastic bins or plastic crates only. Storage in corrugated fiber boxes (CFB) and in wooden boxes may be problematic if wet fruits are packed. Further, strength of CFB boxes will decrease if boxes are not moisture-proof and more fungal infection will occur in humid condition.

Washing is one of the most important postharvest treatments recommended for many fruits and vegetables. It not only decreases microbial load, but also removes field heat and increases shelf life of fruits and vegetables. Simply washing lettuce leaves in tap water reduced populations of micro-flora by 92 % (Adams et al. 1989). The advantage of this treatment largely depends on the purity of water used for washing.

Contaminated water used for washing can transmit diseases responsible for decaying the produce and adversely affects human health (Sanderson and Spotts, 1995). It is a well-established fact that upon washing, microbial load is drastically reduced in all commodities and therefore washing is highly recommended before consumption also. Washing of sponge gourd in tap water brought about more than 25 % reduction in bacterial population (Ahmad et al. 2003). Gomez et al. (2002) also reported that washing of cauliflower in tap water reduced about 25 % bacterial population. Wash water also acts as a medium for chemical applications on fresh produce. This operation is done again either before storage or after storage. Washing with different chemicals is mentioned in the following sections.

(a) Washing with chlorinated water
Chlorine treatment (100–150 ppm available chlorine) may be used in wash water to control inoculums build-up during harvesting and transportation to pack house. This operation is done either before packing or marketing or storage. Washing with chlorinated water reduces microbial load to a remarkable level. Many workers reported it in a wide range of fruits and vegetables. Garg et al. (1990) observed that dipping lettuce in water containing 300 ppm chlorine reduced total microbial counts by about 1000-fold. Ritenour et al. (2002) recommended a constant free chlorine concentration of 100–150 ppm maintained at a pH range of 6.5–7.5 for sanitizing purposes. Common sources of chlorine are sodium hypochlorite (NaOCl), calcium hypochlorite $Ca(OCl)_2$, and chlorine dioxide (ClO_2).

(b) Washing with water containing fungicides
Fungicides under permissible limit can be used during washing of fruits. This is necessary to control postharvest diseases. Many fruits like apple, pear, citrus, and banana are treated with permissible fungicides added in wash water before transportation to distant markets or storage. Ahmad et al. (2005) reported that Bavistin dip followed by packing of four fruits as a unit in a polyethylene film of 150-gauze thickness reduced spoilage in kinnow mandarin during 60 days of storage. Other workers have also reported that wash water containing fungicides reduced spoilage due to rots during storage (Kaushal and Thakur 1996; Pal et al. 1997; Shazia Hayat et al. 2013).

Postharvest Treatment with Ethylene Inhibitors/ Growth Regulator

Application of growth regulators or ripening inhibitors is commercially very important. These chemicals are applied easily through wash water. The most common chemicals are 1-MCP (1-methyl cyclopropene), AVG (Amenoethoxyvinyl glycine), 6-benzylaminopurine, silver nitrate, silver thiosulfate, cycloheximide, benzothiadiazole, etc. Yuan et al. (2010) observed 1-methyl cyclopropene inhibit ethylene production and/or action during ripening and storage of fruits. Similarly, application of growth regulators such as GA_3 or cytokinin can be effectively applied through washing. Downs et al. (1997) reported that application of cytokinin reduced broccoli floret senescence. Growth regulators also increase the postharvest life of fruits by retarding of ripening, senescence, by minimizing the rate of respiration, and by reduction in weight loss. Respiration may be slowed by application of growth retardants such as gibberellic acid (GA), kinetin, and silver nitrate (Siddiqui et al. 2014a, b; Gautam and Chundawat 1990).

Postharvest Treatment with Calcium Chloride

The postharvest application of $CaCl_2$ (2–4 %) or Ca $(NO_3)_2$ plays very important role in enhancing the storage and marketing period of fruits and vegetables by maintaining their firmness and quality. Calcium application delays aging or ripening, reduces postharvest decay, controls the development of many physiological disorders, and increases the calcium content, thus improving their nutritional value. Increase in calcium content of the fruits has been associated with reduced softening (Siddiqui et al. 2014b; Haggag 1987), decreased incidence of physiological disorders, and improved storage life (Rasese 1986). Similar results were also reported by Chahal and Bal (2003) in ber fruits. Calcium infiltration reduces chilling injury and increases disease resistance in stored fruits. Calcium compounds are known to extend the shelf life of several fruits by maintaining firmness, minimizing the rate of respiration, protein breakdown, and disease incidence.

Thermal Treatment

Thermal treatment means either hot water treatment (HWT), vapor heat treatment (VHT), or hot water rinse brushing (HWRB). Being a non-chemical method, the application of heat treatments to reduce postharvest decay or pest infestation is most popular for many fruits. However, the temperature and time are the most important factors to be considered during its application as tolerance to heat treatments may vary with the commodity, cultivar, and the maturity stage. Therefore, the selection of appropriate treatment regimes (temperature × time) is a crucial factor in determining the overall quality of the fruits.

Heat treatment is a must treatment for mango export. There are few countries where both or either of two treatments are prerequisite for export of mango fruits. This is also country specific, for example, mango export to the United States is only possible if hot treatment is done. This treatment (HWT) is the most common quarantine treatment option used by the mango industry all over the world to satisfy

Table 7.1 Hot water treatments for different fruits

Commodity	Pathogens	Temp. (°C)	Time (min)	Remarks
Apple	*Gloeosporium* sp. *Penicillium expansum*	45	10	Commercially not adopted in India
Grapefruit	*Phytophthora citrophthora*	48	3	Commercially not adopted in India
Lemon	*Penicillium digitatum* *Phytophthora* sp.	52	5–10	Commercially not adopted in India
Mango	*Colletotrichum gloeosporioides*	52	5	To kill fruit fly larvae
Orange	*Diplodia* sp. *Phomopsis* sp. *Phytophthora* sp.	53	5	For control postharvest diseases
Papaya	*Fungi*	48	20	For control postharvest diseases
Peach	*Monolinia fructicola* *Rhizopus stolonifer*	52	2.5	Limited application

requirements of USDA-APHIS for mango export to the United States from areas infested with fruit flies (Jacobi et al. 2001).

(a) Hot water treatment
Fruits may be dipped in hot water to control various postharvest pathogens (larvae, inoculums) and to improve peel color of a number of fruits (Table 7.1). In mangoes, the HWT is recommended at 50–52 °C for 5 min to kill fruit fly larvae and to control/reduce the microbial infection during marketing. This treatment helps in attaining uniform ripening within 5–7 days. Fruit should not be handled immediately after heat treatment. Cooling of fruit with water showers or forced air should be provided to bring the temperature back to their optimum temperature as soon as possible after completion of the heat treatment.

(b) Vapor heat treatment
This treatment proved very effective in controlling infection of fruit flies in packed boxes. The boxes are stacked in a room, which are heated and humidified by injection of steam. The temperature and exposure time are adjusted to kill all stages of insects (egg, larva, pupa, and adult), but fruit should not be damaged. A recommended treatment for citrus, mangoes, papaya, and pineapple is 43 °C in saturated air for 8 h and then holding the temperature for further 6 h.

(c) Hot water rinse brushing
The HWRB is a new system that can be used for heat treatment of fruits. In this system, the fruits roll over to brushes directly into the pressurized recycled hot water rinse at temperatures between 48 and 63 °C for 10–25 s. The HWRB system is being used in Israel and several other countries in commercial packing lines for various types of fruits as well as vegetables.

Jing et al. (2010) reported that HWRB treatments significantly reduce the epiphytic microbial population on fruit surface, decay development, and weight loss in strawberry. Strawberry fruits treated with HWRB (60 °C) showed less decay than the control fruits, and cold storage could enhance the effect of HWRB treatments.

Fumigation (Sulfitation)

Fumigation with sulfur dioxide gas (SO_2) is successfully used for controlling post-harvest diseases of grapes (especially for powdery mildew by *Botrytis cinerea*). This treatment is having great commercial application on many fruits by different ways.

(a) Fumigation by grape gourd
This is a commercial practice used in grapes and approved by all quality control agencies of the world. The main purpose of this pad is to control powdery mildew, a disease most common in grapes. This purpose is achieved by placing grape guards (sodium or potassium metabisulfite impregnated pads) into individual boxes of fruit to give a slow release of SO_2.

(b) Fumigation by sulfur powder
The SO_2 fumigation is used to prevent discoloration of skin or peel of litchi fruits. This is a commercial practice followed in India for domestic market. In case of litchi fumigation, sulfur powder is burnt in a closed room having ceiling fan for fast circulation of sulfur fumes inside the room for 40–45 min and an exhaust fan to expel the fumes outside the room after circulation period is completed. Litchis are kept in perforated crates of 10 kg capacity for better fume circulation touching almost all fruits. In general, *550–600 g* sulfur powder is sufficient for *1000 kg* of litchi fruits. Sulfur powder is kept on a paper piece in 3–4 places and allows it to burn. Immediately after sulfur fumigation treatment, litchi fruits turn in uniform yellow color. Now precooling is followed by fumigation and then storage at *low temperature* (*3–5 °C*). Transportation by reefer van is necessary for sulfited litchi. During storage and marketing, sulfited litchi again regains its original color up to some extent (Fig. 7.2). Sulfited litchi is packed either in perforated polyethylene pouches or punnets. The sulfitation

Fig. 7.2 Litchi fruits fresh; sulfited litchi; reappearance of color

treatment can also be achieved by placing the boxes of fruit in a gas-tight room where SO_2 gas is injected by SO_2 cylinder at a recommended concentration.

(c) Fumigation by paper pads
Paper pads or wraps impregnated with biphenyl fungicides are commonly applied to citrus fruits. The chemical vaporizes slowly, protecting the fruit from fungal infection. This has limited use on commercial scale.

Waxing

Waxing is another important postharvest treatment widely used in fruits and vegetables. These waxes are edible and reported by many workers as a promising postharvest treatment to extend the shelf life of many fruits as in mango (Abbasi et al. 2011; Singh et al. 2012), Kinnow (Ahmad et al. 2005), and sweet orange (Shahid and Abbasi 2011). The beneficial effects of waxing mainly include an improved appearance, less moisture loss and shriveling, reduced postharvest decay, and a longer shelf life (Fig. 7.3). Waxing of fruits and vegetables is a common postharvest treatment used all over the world. In some fruits and vegetables, it is mandatory also like apple, pear, capsicum, etc. Fruits and vegetables possess an outer protective epidermis, covered by a natural waxy cuticle layer containing the polymer cutin (Lequeu et al. 2003).

In recent years, coatings of some edible materials like lipid-based coatings, polysaccharide-based coatings, protein-based coatings, composite and bilayer coatings, etc. have been applied on the skin of different fruits and vegetables in order to reduce moisture loss, restrict oxygen entrance, lower respiration, and retard ethylene production (Baldwin et al. 1995). However, the main aim of waxing from commercial point of view is to make external appearance glossy and attractive. This is an important quality attribute of almost all fruits and vegetables. It is the first quality attribute that a buyer notices. Attractive peel color of any fresh produce is the most powerful attribute for price fixation and market acceptance. The second aim of waxing is to supplement the natural wax on the surface of a commodity, which is removed during harvesting, cleaning, and packing. Waxing consists of applying a

Fig. 7.3 Waxed apple

thin layer of edible wax on the surface of the product either by dipping, brushing, or spraying. The benefits of waxing, methods of application, and detrimental effects if applied in excess are described below in details.

Commodities that are generally waxed include citrus fruits such as mandarins, oranges, pomelos, apples, and pineapples. For pineapples, waxing ameliorates chilling injury, especially if pineapples are transported under refrigerated conditions. Methods of waxing include dipping, foaming, brushing, and spraying. Some commodities may not be suited to a particular method of waxing owing to their morphology (Esguerra and Bautista 2007).

Benefits of Waxing

(a) Improved appearance
Fruits and vegetables that are waxed generally have more attractive and fresh appearance. This fresh appearance of wax produce persists for quite a longer period than unwaxed. As discussed earlier, the appearance attracts consumers more than any other attributes as buyers initially judge the quality of a product based on external appearance only. Waxing can also improve the internal color of certain commodities. Mahajan et al. (2005) observed improved appearance in coated kinnow fruits even after 24 days of storage.

(b) Less moisture loss
The cell wall of fruits and vegetables is covered with cuticle, which acts as a barrier to moisture loss. This outer layer possesses tiny pores or natural passage allowing water loss through transpiration. Coating partially covers these pores and reduces both respiration and transpiration. However, some water vapor can move through the pores and micro-cracks in the cuticle. During the process of waxing, a tightly adhering thin film of the coating substance is applied to the surface of the fruit. The wax coating partially blocks the pores in the cuticle, which significantly reduces the amount of water vapor loss from fruits and vegetables which results in product shriveling and/or wilting. Marketing of such products which have suffered significant moisture loss becomes very difficult. Generally, when any fresh produce has lost 10 % or more of its original weight, it will not attract consumers. This amount of moisture loss typically lowers the grade of the product or makes it completely unmarketable. Application of a thin layer of wax coating can reduce product weight loss by 30–40 %, as noticed by Chaudhary et al. (2004) in kinnow mandarin and Bisen and Pandey (2008) in Kagzi lime.

(c) Good eating quality
On the basis of consumer's acceptance and sensory quality, it is observed that wax-coated fruits and vegetables retain better fruit quality as compared to non-waxed fruits at higher temperature (Mahajan et al. (2005)). Ladaniya (2001) found taste score was highest in fruits of "Musambi" sweet orange (*Citrus*

sinensis) treated with Sta-fresh 451 wax and Wang et al. (2004) revealed that due to the waxing, eating quality was good without unpleasant taste in fruits of Jincheng orange variety.

(d) Less economic loss and reduced postharvest decay
Water is the principal component of all fresh fruits and vegetables. It usually constitutes between 80 and 90 % of a product's fresh weight. Once harvested, the fresh product begins to lose moisture from the processes of transpiration and respiration. The rate of moisture loss varies among commodities. This results in weight loss, which is highly undesirable as it is directly related to economic loss. Growers often sell their fresh products based on weight and will obtain less economic return with increasing amounts of weight loss. Also, there is a loss by rotting and spoilage. Waxing reduces weight loss to a great extent. A fungicide can also be added to the wax emulsion to provide protection against decay.

(e) Reduces ripening and senescence (longer postharvest life)
Edible coatings reduce ripening and senescence in fresh produce and thus increase shelf life and marketing period, which is a well-established fact as reported by many workers in many fruits such as in mango (Abbasi et al. 2011; Singh et al. 2012), sweet orange (Shahid and Abbasi 2011), and banana (Abbasi et al. 2004). The science behind this is that waxing creates a modified atmosphere inside each product in which the oxygen content decreases and the carbon dioxide content increases (Kader et al. 1989). Therefore, these coatings create modified atmosphere in each product and reduces weight loss during transport and storage (Cuq et al. 1995). Many workers reported that Modified Atmosphere Packaging (MAP) technology is used for extending the shelf life of fresh fruits and vegetables (Ladaniya 2001; Wasker and Gaikward 2005; Sharma et al. 2012). This results in a reduction in the product's respiration rate and an increase in postharvest life. The higher CO_2 and lower O_2 concentration delayed ripening process by maintaining slow degradation of Polysaccharides (Abbasi et al. 2004). This could be due to delay in ripening and senescence.

(f) Less susceptibility to chilling injury
Fruits and vegetables of tropical origin are susceptible to chilling injury (CI), which occurs frequently during storage at lower temperature than optimum. The amount of CI depends on the temperature and duration of exposure to low temperature. Waxing reduces the severity of CI and allows for storage of CI-sensitive commodities at slightly lower temperatures. However, waxing does not eliminate CI on the susceptible commodities. The commercially available waxes are citra shine, Sta-fresh, Sta-fresh 451, 960, Semperfresh, Carnauba wax, etc. Import of insect-based waxes such as Shellac wax-coated fruits is not allowed in India. Coatings may be applied by either dipping, brushing, or spraying on the fruits and vegetables. Different countries have their own rules and regulations for the use of coatings on horticultural produce.

(g) Increased shelf life
Postharvest treatments and storage conditions are equally important for quality maintenance during storage (Ahmad et al. 2005).

Wax Application Methods

Waxes may be applied in several ways, ranging from manual rubbing to automated application by roller brushes.

Rubbing

Liquid waxes can be applied by manually rubbing the commodity over a soft surface saturated with wax emulsion. A soft absorbent cloth or foam sheet or fine brush can be used as a soft surface. After application, the products should be left to air dry for about 15–20 min or under fan before packing. This is mainly for lab testing and for small lots only.

Dipping

In this method, wax is applied by dipping fruits or vegetables in a solution of wax. Dipping time and wax concentration are product specific. It is recommended to keep coated materials for few minutes before packing. It is also very important that the product surface should be completely dry before waxing by dipping method where melted wax is used. If not dry, the high temperature of the melted wax converts the surface moisture on the product into steam and forms pockets or blisters under the wax coating. The wax will then loosen and drop off.

Roller Brushing

Liquid waxes can be applied automatically on the surface of the commodity by using a series of roller brushes. The wax is dispensed on the roller brushes from the nozzles fitted just above it. The speed of application is adjustable. All roller brushes rotate which facilitates produce to spin and rotate over the roller, and in this process a thin layer of coating is applied evenly over the surface of the product. The brushes on the wax applicator should be fed continuously with the wax solution during the operation. It is always advisable to wash fruits and vegetables prior to waxing. Therefore, fruit should be damp in a water tank and pass through hot air blowing unit and over dry brushes and then finally through waxing unit. This is necessary in order to prevent wax dilution. The roller brushes should have at least 50–60 % horsehair to help spread the wax over the fruit. Brush speed should not exceed 100 rpm. The brushes should be kept soft by regular washing with hot water.

Specification of a Desirable Wax

- The selected wax material should provide a lasting shine.
- It must be manufactured from food grade materials.
- It should not develop any off-flavor.
- It should reduce moisture loss of commodity from 30 to 50 %.
- After application, wax should dry rapidly.
- It should be easy to clean and price should be less.

Types of Food-Grade Waxes

Several different raw materials are used as a base for formulating food-grade waxes. The most commonly used materials are paraffin, carnauba, and shellac. Less frequently used waxes include beeswax and candelila wax. Each of these raw materials has unique and different properties which determine its shine, gas permeability, and other physical characteristics. The waxes available commercially are already premixed and ready for immediate application with or without dilution. The amount of wax applied to each individual fruit or vegetable is very small. Upon application, it provides a thin continuous coating on individual fruits or vegetables.

Example of some commercial waxes

1. Paraffin wax
2. Carnauba wax
3. Bee wax
4. Shellac
5. Wood resin
6. Chitosan

Paraffin (Candle Wax)

Paraffin is a petroleum-based wax obtained from the distillation of crude oil. It is solid at room temperature and must be heated at about 52 °C (125 °F) to melt. Temperature of the liquid wax influences the thickness of coating layer upon solidification. Paraffin wax is commonly used on cassava for export marketing. It can also be used on sweet potatoes, yams, coconut, and thick-skinned fruits like breadfruit.

Carnauba

Carnauba wax is obtained from the leaves of carnauba palm. On an average, 5–10 g of wax is obtained from each leaf. Carnauba is a moderate glossy wax. It imparts much better shine to the product than paraffin wax, but less than shellac. A carnauba wax coating is more permeable than shellac.

Shellac

Shellac is produced from the resinous secretions of lac insect (*Laccifer lacca*). This insect secretes the resin from its glands onto a host tree in the form of tiny platelets, which are gathered, crushed, washed, and purified into food grade wax called shellac. It is hard at normal temperatures but softens when heated. Shellac is a hard, tough resin that has good water resistance and produces high lustrous finishes. However, the waxed products are more likely to whiten or chalk upon removal from cold storage. Shellac is less permeable to gas exchange than carnauba and care must be taken to avoid over-application and possible product fermentation. It is the most popular wax currently used on citrus.

Trade name of some extensively used waxes

Trade name	Fruits
Tal-prolong	Banana, apple
Semper fresh	Guava, banana
Nutri-save	Apple
Brilloshine, Citrashine	Citrus fruits
Vapor gard	Mango
Waxol	Fruit
Ban-seel	Banana

Precooling

The rapid cooling of fresh produce from field temperature to its best storage temperature is called precooling. Precooling reduces field heat and hence reduces all physiological processes. Respiration is one of them. The lower the temperature of any fruit, the slower is its respiration rate and vice versa. There are four methods of precooling. These are forced air, hydro cooling, vacuum cooling, and icing. Each method was developed with specific crops in mind.

Hydro Cooling

Hydro cooling removes field heat and cool the produce with chilled water. The water used in hydro cooling is usually cooled by mechanical refrigeration. On a small scale, cold well water or ice may also be used depending upon the temperature requirement. The size of hydro cooling units varies depending on the size of the operation, but considerable refrigeration or large quantities of ice are required to keep the water at the desired temperature of 33–36 °F. The produce is cooled by a water bath or sprinkler system. The produce either is dumped in the bath or under the sprinkler or is left in bins or boxes. Small operations might have an ice-water tank in which to “stir” the vegetables for rapid cooling. Pay special attention to water quality. Unfiltered and unsanitized water can spread undesirable microorganisms.

Most vegetables and many fruits that can withstand wetting can be hydro cooled. Asparagus, celery, cantaloupes, green peas, leaf lettuce, peaches, radishes, and sweet corn can be cooled successfully with this method.

Forced Air Cooling

Forced air cooling is the best method of precooling, and it is a commercial practice used worldwide on many fruits to reduce field heat, disease development, softening, and weight loss of fresh fruit. However, the main purpose of precooling is removal of field heat from fresh produce. Forced air cooling is a powerful tool that allows perishable produce to be marketed over long distances because it can cool produce quickly after harvest. It is the primary cooling method used for fresh fruits and vegetables in California prior to placing them in longer term cold storage (Thomson et al. 2008).

In this method, cool air moves rapidly over a product to remove the field heat. Inside a cool storage room, fans pull air through the produce boxes and back into the cooling unit. When you design a cool room, provide enough refrigeration capacity and proper humidity control. These steps can prevent excess weight loss. Forced air units are affordable for many small-scale growers. Alternatively, an existing cold room can be augmented by making cooling tunnels using portable fans and tarps. Line up two rows of produce and set up a fan to draw air down the aisle between the rows. Cover the aisle with a sturdy tarp to force the system to draw air through the boxes of produce. Forced air cools most commodities effectively, but those best adapted to this method include berries, stone fruits, and mushrooms. Forced air cooling stages are shown in Fig. 7.4.

In forced air cooling system, mainly packed produce is placed in the cooling system and the box is covered with tarpauline so that direct hitting with cold air may not cause chilling injury. Therefore, slowly the heat is removed from the produce.

Fig. 7.4 A forced air coolers loaded with boxes (*left*) under loading (*middle*) empty (*right*)

Vacuum Cooling

Produce is placed in a vacuum tube and air pressure is reduced greatly. At lower atmospheric pressure, some water from the produce "boils" away as the produce uses its own heat energy to convert water to gas, thus lowering the product's temperature. Heat and moisture are removed from the vacuum tube by mechanical refrigeration. Commercial vacuum units usually cool the product to the proper storage temperature in less than 30 min. Units are available for cooling different amounts of product, from two pallets to a full truckload. Because of the high cost of this equipment, it might be more economical to do the cooling at a central location on a cooperative basis. Grower costs depend mainly on the volume cooled. Growers usually are able to recover costs by charging a fee per unit, in addition to the agreed purchase price of the produce. Lettuce and a few other vegetables can be vacuum-cooled effectively.

Icing

Crushed or slurry ice is placed directly into the produce box. This can be an effective way to precool individual boxes of certain vegetables. The produce can be cooled in a short time and the temperature maintained in transit. Broccoli, green onions, and some root crops most commonly are top iced.

Ripening Treatments

Ripening has revolutionized the world of bananas, mango, sapota, and other fruits. Ripening had a positive impact on consumer satisfaction and sales volume. A very important step in a successful fruit ripening program is to select fruits that were harvested at proper maturity stage. Fruit that was harvested immature will soften, and it will not develop a pleasing flavor. Temperature management is the key for ripening fruits and storage after ripening. All tropical fruits such as banana, mangoes, and sapota if stored at low temperature, sustained chilling injury. Ripening of mango and sapota are described here.

Mango Ripening

Mango maturity and ripeness are two different stages. Like all other fruits, mango also progresses from immature to mature stage. However, peel color is not a maturity standard in mango as it is in tomato, apple, and many other fruits. However, peel color is also taken as one of the maturity standards of mango in retail business by both sellers and consumers. An immature mango will eventually become softer, but its flavor will not improve and neither will consumer acceptance. Thus, an immature mango will be inferior in quality and there is no postharvest treatment that can improve it. Mangoes should be harvested at physiological mature stage to get optimum quality upon ripening.

Maturity at harvest is a critical factor for development of mango flavor. A mango harvested immature will not ripen normally and development of mango flavor is almost NIL. These mangoes never satisfy consumers even though peel color has turned yellow and may attract consumers. In Indian markets, arrival of mango of early variety Safeda (Banganpali) from Andhra Pradesh is a typical example of immature mango with uniform yellow color. In normal condition, this variety is supposed to attain maturity after 15^{th} of March every year. But it is available in the market from the first–second week of February and ripening treatment is given at terminal markets by wholesalers or sub-wholesalers. Retailers also do ripening before marketing, and in this way, they regulate market.

At the mature/unripe stage at harvest, mangoes are high in starches and acids and low in soluble sugars. During ripening, sugar content increases, mango firmness decreases, and acidity and starch concentrations decrease. Internal flesh color will develop from white or pale yellow to deep yellow or golden yellow. External skin color changes will also take place in some varieties. For example, the skin of the Safeda or Banganpali, Neelum, and Chausa variety will progress from green to a deep yellow upon ripening. Not all varieties show skin color changes during ripening. Malda or Bombai mango variety is a typical example where skin or peel color do not change upon ripening.

Ripening Procedure

Fruit should be ripened using controlled temperature and ethylene. First remove field heat (precooling of fruits up to 20–22 °C). Hold at this temperature, i.e., 20–22.2 °C (68–72 °F) and apply ethylene at 100 ppm for 24 h. After 24 h ethylene exposure, hold mangoes at this ripening temperature 20–22.2 °C (68–72 °F). Ethylene-treated mangoes kept at 20–22.2 °C (68–72 °F) will ripen in 3–9 days. Check ripening progress in the fruit for firmness and peel color until the required peel color and firmness are reached for marketing. During ripening, carbon dioxide levels should always be kept below 1.0 % by exchanging room air with outside air. Hence, open the door for once or twice for 5–10 min after every 24 h. Keep fan on continuously for better air circulation. Maintaining a relative humidity of 90–95 % will reduce potential water loss and mango shriveling due to continuous air circulation.

The ripening procedure may vary slightly on the demand, maturity level of fruits, and quarantine treatment (HWT). Ripening chamber should have high air flow (forced air) circulation inside the chamber. Generally, forced air circulation is must in the chamber or room for uniform mango ripening. Hence, maintaining uniform temperature, relative humidity, and air flow in the ripening room are three most important parameters for ripening.

Hot Water Treatment

Mangoes are grown in tropical climates. Many mango production areas have populations of fruit flies that are not allowed in European countries and Japan, the United States, and other countries. Importation of fruit from a fruit fly zone could carry the pest into these countries and threaten the domestic agricultural production. For this reason, many tropical fruits are required to go through some type of *quarantine treatment to eliminate* this risk. For mangoes, the most common protocol is *hot water treatment*. HWT is also called quarantine treatment. The fruit is submerged in hot water for sufficient time to control the risk of fruit fly. Ripening procedure after HWT is given below

- After HWT, precool the fruits 20–22 °C
- Hold at 68–72 °F (*20–22.2 °C*) *for sufficient periods* (*3–6 days*)
- No ethylene application is needed, although using ethylene on hot water-treated mangoes should not cause a problem
- *Hot water-treated mangoes kept at 20–22.2 °C* (68–72 °F) *will ripen in 3–6 days*
- Monitor progress and sample fruit for firmness until the ideal stage for marketing is reached

Handling After Ripening

Once ripen, mangoes will ideally be kept at (54–60 °F) 12–15.6 °C and 90–95 % relative humidity for no longer than 1 week.

Banana Ripening

Banana ripening is very similar to mango ripening. Maturity of banana also plays very important role of ripened fruit. This is a climacteric fruit, hence transportation is done at green mature stage and fruits are ripened at sales place. Major production site of banana is South India and consumption is in North India.

Ripening Procedure

Fruit should be ripened using controlled temperature and ethylene application. First separate hands, if bananas are in bunch. Ripening of bunch is not uniform and commercially not viable. Discard diseased, cut, damaged fruits and keep best quality in plastic crates. Always use plastic crates or bins for ripening. Now, stack the crates in the ripening chamber and remove field heat (precooling of fruits up to 20–22 °C). Hold at this temperature, i.e., 20–22.2 °C (68–72 °F) and apply ethylene at 100 ppm for 24 h. This ethylene application is called gassing. After 24 h of gassing, open the door for 5–10 min to remove CO_2 build-up. This is necessary because accumulated

Fig. 7.5 Ethylene cylinder for gassing (*left*), cooling system (*middle*), ripened banana ready for dispatch (*right*)

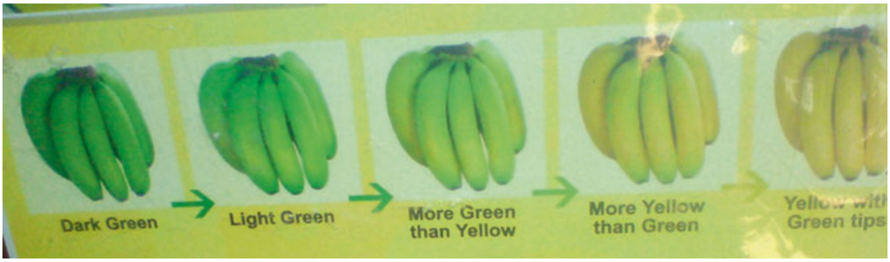

Fig. 7.6 Ripening stage based on color development in banana

CO_2 will reduce ripening process. Hold bananas at this temperature for 3 days. Bananas will ripen if kept at this temperature (20–22.2 °C) for 3–4 days. Check ripening progress in the fruit for firmness and peel color until the required peel color and firmness is reached for marketing. During ripening, carbon dioxide levels should always be kept below 1.0 % by exchanging room air with outside air. Hence, open the door for once or twice for 5–10 min after every 24 h. Keep fan on continuously, for better air circulation. However, continuous air circulation may results water loss and shrivelling. This problem may be sorted out by maintaining a relative humidity of 90–95 % with the help of humidifier.

The ripening procedure may vary slightly for better air circulation. Maintaining a relative humidity of *90–95 %* will reduce water loss and hence shrivelling from the fruits in the ripening chamber. Different components of ripening of banana are shown in Fig. 7.5 and color development in Fig. 7.6.

Handling After Ripening

Once ripen, bananas can be stored at 12–15.6 °C (54–60 °F) and 90–95 % relative humidity for 5–7 days. When to dispatch for markets depends upon the color developed after ripening. More green than yellow is the best stage for long distance journey (25–50 km); more yellow than green should be dispatched to a radius of less than 25 km. Whereas, yellow with green tips is ideal for immediate consumption.

Packaging

Packaging is considered as the first sales man in marketing language. It maintains the condition of fresh commodities during entire postharvest handling chain. A good packaging and packet is liked by all consumers. Buyers wanted to know exactly what they will get when they purchase a particular packet. Packaging also reflects the image and quality of any brand. Thus, a packet that is consistent in quality, appearance, and weight (sometimes a grade standard) throughout the season is desirable. Packages and presentation of produce in a package make it attractive to buyers. Poorly packed containers distract the consumer's eye from the quality of the produce. Attractive packing frequently encourages repeat purchase.

Packaging requirements vary from produce to produce and are based on perishable nature of the fresh produce and rate of respiration, transpiration, and ethylene production. On the basis of rate of respiration and ethylene production, there is a wide variation among fruits and vegetables (Tables 7.1). High-quality produce must be handled carefully during harvesting and packing. For packing in the field, you have to rely on skilled harvesters and packers and adequate supervision is needed. Atmospheric conditions cannot be maintained in field condition. In a packing shed, you must rely on skilled line workers and properly operating equipment. The cost of building and/or packing shed varies according to product needs and type of equipment. Though usually more expensive than field packing, packing sheds offer some advantages. Grading and packing can be done under well-supervised and less strenuous working conditions and with or without required machineries. The result often is a higher quality and more uniform pack than can be achieved in the field. Some crops, however, cannot absorb the additional costs of shed packing. Also, some products, such as berries, do not lend themselves to the additional handling required in packing sheds. If such handling is necessary, harvesters should select only clean, firm fruit that will allow extra handling.

When you choose a packaging container considering several functional criteria, the container must meet industry standards for size, volume, and strength and must allow for efficient cooling of the contents. In addition, be sure the container protects the product throughout distribution and is suitable for storing standard pallets. The package must present your product in a useful and attractive manner. Buyers usually expect new, unused containers. Sometimes, however, recycled produce boxes are acceptable for deliveries directly to a customer such as a restaurant. But keep in mind that recycled containers may have another farm's name printed on the outside, and your excellent job of production and handling may be attributed to that farm.

Some products are packaged in smaller units before being placed in the shipping carton. Apples and pears may be wrapped individually and placed on layer trays. Berries may be sold in pint or half-pint containers and covered with a clear plastic lid. Berries also may be sold in clear plastic, clamshell-type containers for easier handling. Shippers often use prepacking to provide additional protection for their product. Many retail buyers prefer prepacking of some products to reduce the amount of preparation and handling at the point of sale. With many types of fruit, such as apples and pears, a coded sticker is applied to each piece for easy identification by supermarket clerks. Be sure to check with potential buyers to determine their labeling requirements. Prepackaged produce is more expensive to prepare and ship than bulk produce, so your pricing should reflect the added cost.

When you pack produce destined for retail supermarket shelves, use an attractive package. A package that shows off the product and has an attractive label helps promote sales. Be sure to include your farm name, business telephone number, and address (where the product is grown) to help promote locally grown products. Take advantage of any local promotions or logos that identify products as locally grown. Advertise your farm website (you really should have one) to encourage buyers to check out your full line of products and to make future ordering easier.

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