Advancements in Post-harvest Management of Fruits and Vegetables

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1 Introduction

Fruits and vegetables have a significant role in human nutrition, especially as source of vitamins, minerals, dietary fibres and antioxidants. Increased consumption of variety of fruits and vegetables on regular basis is recommended because of associated health benefits which include reduced forms of cancer, heart disease and strokes besides some other chronic diseases.

2 Nutritional Importance of Fruits and Vegetables

Among horticultural crops, fruits and vegetables play a significant role in human nutrition, especially as sources of vitamin C (ascorbic acid), vitamin A, vitamin B_1 (thiamine) and B_2 (niacin), pyridoxine (vitamin B_6), folacin (vitamin B_9), vitamin E, minerals and dietary fibres. Their contribution as a group is estimated as 91 % of vitamin C, 48 % of vitamin A, 30 % of vitamin B9, 27 % of vitamin B6, 17 % of thiamine and 15 % of vitamin B_2 in the diets. Fruits and vegetables remain important source of nutrients in many parts of the world and offer advantages over dietary supplements because of low cost and wide availability. There is increasing evidence that consumption of whole food is better than isolated food components such as

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dietary supplements and neutraceuticals. For example threshold consumption of carotenoids rich fruits and vegetables is more effective than carotenoid dietary supplements in increasing LDL oxidation. Thus demand for fresh fruits and vegetables, inspite of emphasis on processing and value addition, needs to be met through advancement in post-harvest management techniques.

3 Post-harvest Losses Due to Injuries and Diseases and Pests

All horticultural crops including and fruits vegetables are living plant materials containing 65–95 % water. They continue their living processes even after harvest. Their post-harvest life depends on the rate at which they use their stored food reserves and the rate of their water loss. When food and water reserves are exhausted, these crops/produces die and decay. Anything that increases the rate of this process may make the produce inedible before it can be consumed.

Physical damage to fresh produce can come from a variety of causes, the most common being mechanical injury. The high moisture content and soft texture make fruits/vegetables susceptible to mechanical injury.

(a) ***Mechanical injury***

Fruits and vegetables as well as root crops are susceptible to mechanical injuries which can occur at any stage from production to retail marketing. Owing to their high moisture content and soft texture, the mechanical injuries could be because of:

- the product being dropped on hard surface during transportation, loading or unloading or during movement of transport system. Such injury is known as impact injury.
- vibration or abrasion injuries result when produce is able to move within a container because of vehicles with small wheels and poor/bad shock-absorbers, weak crates, bad roads, transmission vibrations, etc.
- compression injuries are caused by improper packaging or inadequate package performance resulting from over packaging of boxes/crates, too high stacking of crates, weak packaging, etc.
- puncturing injuries resulting from nails or splinters from the boxes/crates, fingers or nails of a person, other crates, fork lift, hard and sharp stalks of fruits, etc.

Injuries caused can take many forms—for example, splitting due to impact when they are dropped, internal bruising not visible externally, caused by impact, superficial grazing or scratches affecting the skins and outer layers of the cells and crushing of leafy vegetable and soft produces.

Injuries cutting through or scraping away the outer skin of produce:

(a) provide entry points for moulds and bacteria causing decay,
(b) increase water loss from the damaged area, and
(c) cause an increase in respiration rate and thus heat production

Brushing injuries which leave the skin intact and may not be visible externally will cause:

- increased respiration rate and heat production
- internal discoloration because of damaged tissues, and
- off-flavours because of abnormal physiological reaction in damaged parts.

In addition to mechanical injuries, there may be injuries from the temperature effects also as all fresh produce is subjected to damage when exposed to extremes of temperature, though commodities vary considerably in their temperature tolerance. Their tolerance levels to low temperature are of great importance when cold storage is concerned. These injuries are chilling injuries, freezing injuries and high temperature injuries as described below:

Chilling Injuries

Some types of fresh produces are susceptible to injury at low but non-freezing temperatures. Such horticultural crops/produces are mostly of tropical origin though a few temperate crops are also affected.

Sensitivity varies with the commodity but with each there is a specific temperature, the lowest safe temperature (LST), below which injury occurs. With a single commodity type, the LST may vary between varieties. Fruits are generally less sensitive when ripe. Symptoms of chilling injury (CI) may not develop until the produce is removed from the cold storage to normal ambient temperatures. When susceptible produce is to be held for sometimes in storage, it must be kept at a temperature just above its LST. This means that such crops will have a shorter marketing life than non-sensitive crops because respiration may continue at relatively faster rate during storage at higher than normal cold storage temperatures.

Freezing Injury

All produces are subjected to freezing at temperatures between 0 and –2 °C. Frozen produce has a water soaked or glassy appearance. Although a few commodities are tolerant of slight freezing, it is advisable to avoid such temperatures because subsequent storage life is short. Produce which has been recovered from freezing is highly susceptible to decay.

High Temperature Injury

If fresh produce is exposed to high temperature caused by solar radiation, it will deteriorate rapidly. Produce left in the sun after harvest may reach temperature as high as 50 °C. It will achieve a high rate of respiration and if packed and transported without cooling or adequate ventilation, it will become unstable. Long exposure to sun will cause severe water loss from thin-skinned vegetables, viz. carrots, turnips, leafy vegetables, etc.

In addition to mechanical injuries, there are post-harvest losses due to diseases and pests as described below:

(b) **Losses due to diseases and pests**

Diseases caused by fungi and bacteria commonly result in loss of fresh produce. Virus diseases, which can cause severe losses in growing crops, are not a serious post-harvest problem. Insects-pests that are mainly responsible for wastage in cereals and grain legumes are rarely a cause of post-harvest loss in fresh horticulture produces. Where they do appear, they are often locally serious, viz. the potato tuber moth.

Losses from post-harvest disease in fresh produce fall in to two main categories:

- **Losses in quality**: This type of more serious losses occurs where deep penetration of decay makes the infected produce unstable. This is often the result of infection of produce in field before harvest.
- **Losses in quality**: Such losses occur when the disease affects only the surface of the produce. It may cause skin blemishes that can lower the value of a commercial crop. In crops grown for local consumption, the result is less serious since the affected skin can often be removed and the undamaged interior can be used. Fungal and bacterial diseases are spread for most part by microscopic spores which are widely distributed in the air and the soil and on dead and decaying plant material. Produce can become infected:
  - through injuries caused by careless handling, insect or other animal damage or through growth cracks.
  - through natural pores in the above and below-ground parts of the plants which allow the movement of the air, carbon-di-oxide and water vapour in and out of the plant.
  - by direct penetration of the intact skin of the plant. The time of infection varies with the crop and with different diseases it can occur in the field before harvest or at any time afterwards.

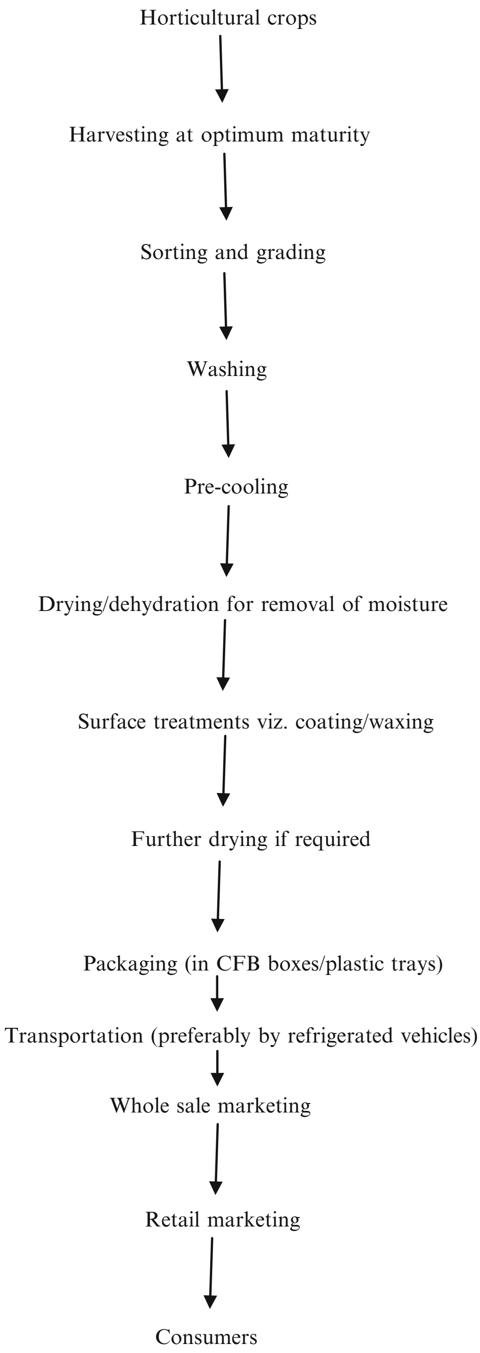
Although relatively few post-harvest losses of fresh produce are caused by attacks of insects or other animals, localized attacks by these pests may be serious. Insect damage is usually caused by insect larvae burrowing through the produce, e.g. fruit fly, sweet potato weevil, potato tuber moth, etc. Infestation is usually before harvest. Post-harvest spread is a problem where produce is held in store or is exposed to lengthy period of transport.

Rats, mice and other animal pests again are sometimes a problem when the produce is stored on the farms.

4 Post-harvest Management for Supply of Wholesome Fruits and Vegetables

Because of poor and faulty operations during harvesting and post-harvest management, processing and value addition, post-harvest losses in horticultural crops are very high, which range between 20 and 40 % or more in certain developing countries. These losses vary from fruits to fruits and vegetables to vegetables and their varieties and depend upon various other factors. They can be minimized through adoption of scientific post-harvest management practices. These practices have been standardized and can be presented with the following flow diagram:

The benefits of scientific post-harvest management and value addition can be realized in terms of minimal harvest and post-harvest losses, better shelf-life, improved nutritional and sensory qualities and higher marketability with enhanced profit.



Quality in further processing can be achieved through primary, secondary and tertiary processing operations for production of a variety of value added diversified products, while the by-products/co-products and residues obtained during post-harvest processing could be utilized with higher economic returns. Even the remaining biomass could be finally converted to useful products like manure/vermin compost or as fuel and fibre.

5 Injury Free Harvesting–Handling–Packaging of Fruits and Vegetables: Strategies

The strategy of decreasing losses is more economical because it requires smaller inputs per unit of the final product than a strategy of increasing production extensively, especially in the short term. The inputs that would be used for losses reduction are usually accessible and in most cases do not require expensive inputs. There are several simple and advanced technologies to minimize or avoid post-harvest losses. In this reference it may be noted that post-harvest losses increase proportionately as the time between harvest and consumption increases; hence the knowledge of the post-harvest management and on-farm value addition technologies become pertinent. Some important technological strategies are described below:

5.1 Harvesting and Harvest Handling

Quality of produce cannot be improved after harvest but only maintained. Therefore it is important to harvest fruits and vegetables at the proper stage/at peak quality. Immature or over mature produce may not last as long in storage as that picked at proper maturity. Harvesting should be completed during the coolest time of the day, which is usually in the early morning and produce should be kept shaded in the field. Appropriate maturity indices should be used and produce handled gently. Produce destined for the storage should be as free as possible from skin breaks, bruises, spots, rots, decay and other deteriorations. Bruises and other mechanical damage not only affect appearance, but provide entrance to decay organism as well.

Post-harvest rots are more prevalent in fruits and vegetables that are bruised or otherwise damaged. Mechanical damage also increases moisture loss. The rate of moisture loss may be increased by as much as 400 % by a single bad bruise on an apple and skinned potatoes may lose three to four times as much weight as non-skinned potatoes. Damage can be prevented by harvesting at proper maturity, harvesting dry whenever possible, handling each fruit/vegetable no more than necessary, installing padding inside bulk bins and avoiding over or packaging of containers.

5.2 Pre-cooling

Pre-cooling is the first step in good temperature management. The field heat of a freshly harvested crop, the heat the produce holds from the sun and ambient temperature, is usually high and should be removed as quickly as possible, before shipping, processing or storage. Refrigerated trucks are not designed to cool fresh commodities but only maintain the temperature of pre-cooled produce. Likewise most refrigerated rooms have neither the refrigeration capacity nor the air movement needed for rapid cooling. Therefore, pre-cooling is generally a separate operation requiring special equipment and/or rooms. Rapid pre-cooling to the products lowest safe temperature is most critical for crops with inherently high respiration rates. These include artichokes, Brussels sprouts, cut flowers, green onions, snap beans, asparagus, broccoli, mushroom, peas and sweet corn. Crops with low respiration rates include nuts, apples, grapes, garlic, onion, potatoes and sweet potatoes.

- **Different types of pre-cooling devices are described below:Hydro-cooling**: Hydro-cooling removes the heat and cleans the product at the same time. In addition it also reduces water loss and wilting. It is done by dipping/drenching/rinsing/immersing/spraying cold water over the fruits and vegetables.
- **Forced air pre-cooling**: Forced air pre-cooling has been reported to be most efficient and suitable method for certain fruits like Nagpur Mandarin as compared to hydro-cooling and room cooling. Temperature range of 6–7 °C with 90–95 % relative humidity during pre-cooling and storage is reported to be optimum. For export, Nagpur Mandarins are usually wax treated, packed in CFB boxes and then forced air pre-cooled before shipment.
- **Vacuum cleaning:** This system works best for leafy vegetables/crops having high surface to volume ratio.
- **Top or Liquid Icing:** These methods work well with high respiration commodities, viz. asparagus, beets, broccoli, carrots, cauliflower, radish, spinach, etc. Commodities sensitive to icing are strawberries, raspberries, tomatoes, green beans, cucumber, garlic, onions, okra, etc.

The choice of cooling methods is influenced by nature of the products, viz. sensitivity to chilling and moisture, product packaging requirement, etc. It may be noted that chemical treatment of the fruits and vegetables in combination with precooling, viz. hydro-cooling, is very effective. For example calcium compounds in general and calcium nitrate in particular have been reported to extend the shelf-life of many fruits by maintaining their freshness and minimizing their respiration rate, proteolysis and tissue breakdown (Gupta et al. 1980). It also acts as antisenescent agent by preventing cellular disorganization by maintaining protein and nucleic acid synthesis. Here hydro-cooling is used to remove field heat. A study on the effect of calcium nitrate and hydro-cooling on cold storage life of peach Cv. Shan-e-Punjab may be considered (Brar et al. 1998) as reference. Calcium nitrate spray (2.5 %) thrice at weekly intervals before anticipated date of harvest on peach and post-harvest hydro-cooling to 15–20 °C by dipping the fruits in ice cold water followed by packaging in corrugated fibre board (CFB) boxes and storage at 3.3 °C was examined. Pre-harvest spray of calcium nitrate improved the colour of fruits during storage. Hydro-cooling reduced the spoilage and physiological loss in weight. It was reported that 2 % calcium nitrate spray combined with hydro-cooling at 15 °C retained in highest fruit firmness. Evaporative cooling is an inexpensive and simple way to help reduce temperature. The simplest way is to wet a porous material that will hold water and move air through the wilted material (working a desert cooler). Air may be moved by fans or by using prevailing winds. Since cool air is heavier than hot air, it is also effective to place the wetted matter over the top of the container.

5.3 Post-harvest Hauling

Farm roads should be kept in good condition because great damage can be inflicted on produce carried over rough roads in unsuitable vehicles. Containers must be loaded on vehicles carefully and stacked in such a way that they should shift or collapse damaging their contents. Vehicles need good shock absorbers and low-pressure tyres and must move with care. Jolting of laden containers can aggravate damage to produce on rough roads, even at low vehicle speed.

Produce carried by trucks may be in palletized field containers, in bulk bins or in hand-loaded sacks or wooden or plastic boxes. Where vehicles wait in sun or rain for long periods before unloading, only top part of the load should be protected by a covering. Grasses or leaves are not recommended for this purpose because they restrict ventilation and may be a source of disease. Complete enclosing of the load with tarpaulin is disastrous because it restricts ventilation and the temperature of the produce rises rapidly.

During on-farm handling and transport of the fruits and vegetables, suitable packaging and handling techniques can reduce the amount of the damage to which fresh produce is exposed during transport and marketing. Following issues are to be taken care:

- to avoid the package itself damaging produce during handling and transport, wooden boxes or cardboard cartons must be properly assembled. Nails, staples and splinters are always a danger in wooden boxes.
- individual items of the produce should be packaged to avoid rubbing against each other during handling and transport. Loose fill packs are particularly susceptible to vibration damage.
- bruising results from overfilling containers or from the collapse of boxes. Collapse may be caused by weak walls of the boxes, by softening of the cardboard walls because of moisture or by the failure to stack boxes in such a manner that the sides and walls support those above. Stacks of the boxes should never exceed height that has been recommended by the vehicle maker. Produce in woven jute sacks or nets is especially susceptible to shock damage. Sacks of 25

Table 1 Journey hazards during transportation and handling of horticultural crops

Sl. No.	Hazards	Samples
1.	Biological	Insects, rodents, moulds and microorganism
2.	Compression, static	Stacks in warehouse or vehicles
3.	Human	Pilferage, inspection
4.	Impact, vertical	Package dropped when unloading trucks/wagons
5.	Impact, horizontal vibration	Shunting, rail track
6.	Puncturing, snagging	Projection on vehicles
7.	Racking or deformation	Uneven support due to poor floor or uneven lifting
8.	Temperature, high	Sun, ships, boilers
9.	Temperature, cold	Cold store
10.	Water, liquid	Rain, spray, condensation
11.	Water vapour	Humidity of atmosphere, natural or artificial

or 50 kg capacity are normally used for relatively low value produce, viz. root or tuber crops and are often roughly handled on account of their weight, so wherever possible, handling of bagged produce should be minimized by stacking sacks in unit loads on pallets or in pallet boxes.

Fruits and vegetables and their products may be scientifically transported for marketing and distribution by using different modes of transport, viz. road, rail, sea and air. However, care needs to be taken to minimize physical and mechanical losses during various journey hazards. These hazards are listed in Table 1. In transportation proper attention needs to be given to palletization and containerization as desired below:

(a) ***Palletization***: Loading and unloading of fruits and vegetables are very important steps in post-harvest handling which are quite often neglected. The individual handling of packaged produce in many cases leads to mishandling and to high post-harvest losses. With the introduction of CFB boxes, serious consideration should be given to palletization and mechanical handling of the produce with the use of fork lift trucks in order to minimize produce mishandling.

(b) ***Containerization***: The use of containers for the transport of horticultural produce is relatively new in countries like India. Containerization provides an excellent system for the shipment of the goods from one place to another. Refrigerated containers are used in transportation of fruits/vegetables. Very large numbers of containers are shipped through cargo under refrigerated condition. Containers are transported by refrigerated trucks without interfering the movement of the vehicle. Handling of the produce package is generally done by break bulk, unit loading or through load as described below:

- ***Break bulk*****:** It is the traditional system in which packages are handled individually; handling is essentially manual and no special requirements are imposed on vehicle.

- ***Unit loading*****:** In this system, packages are assembled into larger unit and it requires mechanical handling, viz. fork lift truck as 0.5–1.0 tonnes load is placed on a pallet and transported throughout the journey as one unit.
- ***Through load*****:** In this system consignment is usually over 5.0 tonnes and move together to ultimate destination in a container which is loaded at point of origin. In practice a combination of system is adapted that consists of break bulk used first followed by the unit load on pellet and ultimately shipped containers.

6 Improved/Advanced Post-harvest Technologies

6.1 Harvesting at Optimum Maturity and Controlled Ripening

Maturity indices help judging the appropriate stage for harvesting of fruits and vegetables from the point of view of the market value, shelf-life, nutritional and sensory qualities. The harvesting maturity is judged by:

- Visual colour change in the fruit
- Total soluble solids
- Size of the fruits

Maturity indices of the certain fruits produced in India are given in Table 2.

Controlled ripening is practised in climacteric fruits and vegetables, viz. tomatoes, banana, mango, guava, etc. These fruits are capable of generating ethylene, the hormone required for ripening even when detached from the mother plants.

Climacteric fruits and vegetables are harvested at slight immature stage and treated with ripening agents like ethylene gas or ethepton (2-chloro ethyl phosphoric acid) before shipment so that the product reaches the consumers at the right stage of maturity. Ripening agents are generally used to speed up the ripening process with uniform ripening; examples may be given of mangoes as well as papaya.

In case of mangoes, both premature and mature fruits are uniformly ripened with the help of ethrel (Ethepton). The period of ripening is also reduced by this treatment. Papaya ripens satisfactorily between 20 and 25 °C, but temperature above 32.2 °C causes uneven colour development, rubbery pulp texture and browning of fruit surface. Exposure of mature green to 1/4th yellow colour papayas to 100 ppm ethylene at 20–25 °C and 90–95 relative humidity for 24–48 h results in faster and uniform ripening.

6.2 Fumigation

In case of certain fruits, fumigation is practised during storage which helps in extension of their shelf-life. For example, Litchi (*Litchi chinensis sonn*) fruits are fumigated with sulphur dioxide following a dip in dilute hydrochloric acid (HCL)

Table 2 Maturity indices of selected fruits and vegetables produced in India

Sl. No.	Crop wise indices	Values
1.	**Khasi mandarin**	
	Colour of the rind	Yellow–orange, orange
	Days from flowering to harvesting	230–250
	Juice yield, %	>49.0
	TSS, oBrix	9.5–10
	Titrable acidity, % of citric acid	0.75–0.81
	TSS: acid ratio	12.30–12.97
2.	**Pineapple (Kew variety)**	
	Average fruit weight	>1.0 kg
	Specific gravity	>0.93
	Days from flowering to harvesting	141–150 days after flowering when the colour changes from green to yellow in ¼ to ½ portion of the fruits from its base
	TSS (^{o}Brix)	>12
	TSS: acid ration	>20
Note In case of such pineapples it is recommended that the stem end of the fruits should be trimmed to 2.0 cm along with 1/3rd of the crown.		
3.	**Jack fruit**	
	Appearance	Dull
	Sound on tapping	Dull
	Colour	Changes from green to yellow and brown
4.	**Papaya**	
	Latex colour	Changes from white to watery
	Skin colour	Changes from dark green to light green with some yellowness at the blossom end (colour break)
Note Papayas are usually harvested at colour break to 1/4th yellowness for export or ½ to 3/4th yellowness for local markets		
5.	**Passion fruits**	
	Fruit surface colour	Amount of yellow or purple colour
Note Development of complete yellow/orange or purple colour is a better indicative of full maturity		

solution. This practice controls browning which is mainly due to the degradation of red anthocyanin pigments as well as oxidation of phenolics caused by poly-phenol oxidase. As an alternative, use of red phosphorous which has characteristics similar to sulphur and can be burnt easily without toxicity has been recommended. Litchi fruit can be fumigated with red phosphorous at 25 g/m^2 for 60 min and stored under ambient air temperature of 28–33 °C and 95–100 % relative humidity conditions. This treatment delays the increase in polyphenol oxidase (PPO) activity and pH value and decrease of colour and eating quality and maintains the level of anthocyanin and total phenolics. The treatment particularly inhibits the decay of the fruits during storage. Red phosphorous fumigation together with other post-harvest technologies viz. proper packaging and air-conditioning has shown promising results in extending the shelf-life of Litchi fruits.

6.3 Disinfectant Treatment

Following methods are used for disinfectant treatment of the fruits and vegetables:

(a) ***Sanitization*:** Sensitization not only protects the produce against post-harvest disease but also protects consumer from food-borne disease. Use of a disinfectant in wash water helps to prevent both post-harvest diseases and food-borne illness. For most of the vegetables, chlorine (75–150 ppm) or hydrogen peroxide (0.5 %) in wash water can be used effectively.
(b) ***Ozonisation*:** Ozone not only kills food-borne pathogens, but it also destroys microbes responsible for food spoilage. In fact, ozone is the most effective natural bactericide of all disinfecting agents. Ozone is now being used in food processing and storage of perishables as an antimicrobial agent and as a food processing aid. It is safe and natural purifier and disinfecting agent which is strong and ideal sanitizer, germicide, sterilizer and vermicide, antimicrobial, bactericide–fungicide, deodorizer, and detoxifying agent. Ozone oxidizes metabolic products and neutralizes the odour generated during the ripening stage in storage of fruits. This helps to preserve and almost double the shelf-life of fresh produce. It also enhances the taste by retaining the original flavour of the products. Ozone enhances the taste of most of the perishables by oxidizing pesticides and neutralizing ammonia and ethylene gases produced by ripening or decay. The reduction of ethylene gas increases the shelf-life and reduces shrinkages. It changes the chemical's complex molecular structure back to its safe and original basic elements. Its use does not leave any toxic by-products or residues, does not affect healthy cells or alter its chemistry and is non-carcinogenic. Factors like age, crispness, quality, humidity, temperature, the condition on receiving and the reduction of the pathogens during ozonisation will determine the shelf-life of each different type. Positive effects will show at low and constant levels between 0.05 and 0.1 ppm and it allows workers to enter storage area and carry out their works comfortably (Perez et al. 1993).

Ozone should be constantly consumed and absorbed during the oxidation process. The effectiveness is influenced (lowered) due to the presence of the steam or 100 % humidity levels. The microorganisms have to be in a certain condition of swelling in order to be affected when the humidity level is below 50 %. The efficiency of it slows down as a bacterial medium (Castillo et al. 2006).

Growers and processors can use ozonized water to wash the fruits replacing chlorine. Application of it can be safely done as process water in hydro-cooling system, bin, dump and dip tanks, flumes, spray wash, wastewater, processing and storage at an affordable cost.

6.4 Hot Water Treatment/Blanching

This process is also known as scalding, parboiling or pre-cooking. It is usually done in case of vegetables by exposing them to boiling water or steam for 2–5 min, followed by cooling. Fruits on the other hand are generally not blanched. Blanching inactivates most of the plant enzymes which cause toughness, discoloration (polyphenoloxidase), mustiness, off-flavour (peroxidase), softening and loss of nutritive value.

The other advantages of blanching are given below:

- it reduces the area of leafy vegetables such as spinach by shrinkage or wilting, making their packaging easier.
- it removes tissue gases which reduce sulphides.
- it also reduces the number of microorganism by as much as 90 %.
- it enhances the green colour of vegetables such as peas, broccoli, spinach, etc.
- it removes saponins in peas.
- it removes undesirable acids and astringent taste of the peel and thus improves the flavour.
- it also removes the skin of the vegetables such as beetroot and tomatoes which help in their peeling.

6.5 Pretreatment with Chemicals

Certain examples of pretreatment of fruits and vegetables are given below:

- Minimum spoilage and loss in weight of peach (Cv. Shan-e-Punjab) is reported for fruits which are pretreated with 2.5 % calcium nitrate. 2 % calcium nitrate spray combined with hydro-cooling at 15 °C retains significantly high fruit freshness (Brar et al. 1998).
- Treatment of cauliflower curds with 1 % Potassium meta-bisulphite, onion rings with 0.5 % NaHCO3 and potato slices with 0.5 % Sodium benzoate and 0.5 % Potassium meta-bisulphite solution, respectively, followed by solar dehydration and packaging in laminated foils enhance the shelf-life of these products up to 6 months. At the time of use, the rehydration values are reported to be high, viz. 6.5–7.0 in cauliflower, and 8.6 in onion.
- The combination of bavistin (0.1 %) dip for 5 min followed by packaging in polyethylene pouches/bags reduces the physiological weight loss of citrus fruits and improves the quality under cold and evaporative cooled structures (Kaushal and Thakur 1996).
- Kinnow fruits given a post-harvest dip in 0.1 % bavistin solution for 5 min and packed in 150 gauge LDPE bags could be stored under ambient conditions as well as in evaporative cooled chambers or cold storage conditions. Fruits stored under ambient conditions remain in marketable condition up to 8 weeks whereas in other conditions up to 10 weeks. Bavistin treatment followed by packaging of fruits in

LDPE bags is effective in retaining fruit quality during storage. Best results are obtained when four fruits are packed in a single unit (Thakur et al. 2002).

- Papaya fruits (Cv. CO-2) may be treated with gibberellic acid. Gibberellic acid at 150 pm is most effective in reducing physiological loss in weight, TSS and total sugar content by maintaining fruit firmness. Ripening parameters like colour and total carotenoid content are delayed, thereby increasing the shelf-life of papaya fruits.

6.6 Surface Coating and Treatment with Wax

Surface coating using wax is one of the traditional methods of the fruits and vegetables' preservation practised since the twelfth/thirteenth century, when it was applied to citrus fruits in China. Surface coating is considered to be an easy to use and one of the most economical methods for prolonging shelf-life of variety of fruits and vegetables. Application of wax as surface coating material slows down the permeability of water vapour and other gases, retards the ripening and checks the microbial interaction. Nowadays carnauba wax, sugar cane wax, bees wax, shellac wax, resins and certain thermoplastics are most commonly used coating/waxing substances.

As people have become more health conscious and concerned with safety, there is now greater demand of food grade coating materials which should not be synthetic or chemical based.

Surface coating of fruits and vegetables has been found suitable for preservation of fruits and vegetables due to the following advantages:

- **Improved appearance**: Coating provides fruits and vegetables a gloss/shine which improves their appearance.
- **Lesser moisture loss**: Coating blocks the pores in the cuticle which results in significant reduction of water loss from fruits and vegetables.
- **Reduced post-harvest decay**: Surface coating establishes a barrier against the entrance of fungal and bacterial pathogens into the product. Post-harvest pathogens typically require a film of free moisture on the products skin to grow. A hydrophobic (non-water compatible) surface on the fruits/vegetables surface is not conducive to pathogen growth and development.
- **Longer shelf-life**: Fruits and vegetables are living organisms that continue to respire even after harvest. Coating helps in delaying post-harvest decay in those farm products which remain physiologically active after harvest by creating a modified atmosphere around it. This results in reduction in the product's respiration rate and an increase in the post-harvest shelf-life. A prolonged shelf-life allows for an extension in the marketing period for the crop.
- **Lesser susceptibility to chilling injury**: Surface coating reduces the severity of the chilling injury (CI) and allows for the storage of CI-sensitive commodities at slightly lower temperatures without incurring damage. It may, however, be noted that waxing does not eliminate C I on the susceptible commodities.

- **Reduced economic losses**: Water is the principal component of all fresh fruits and vegetables. Growers/producers often sell their horticultural produces based on their weight. The less is the weight, lower is the price and lower is the economic return. Coating helps to limit this loss of water and thus reduces the loss of profit margin. The mechanism, by which the surface coating helps in preservation of fruits and vegetables, is by producing a modified atmosphere surrounding the product. This modified atmosphere serves several purposes including reduced oxygen availability and increased internal carbon-di-oxide concentration in produces. Modified atmosphere created by surface coating is produced by physical trapping of carbon-di-oxide gas within the horticultural products tissues during respiration. The edible surface coating materials which have been investigated include Methyl cellulose, Hydroxy propyl methyl cellulose (HPMC), Stearic acid, Palmatic acid/wax, high amylose starch, collagen, gellatin, Zein, gluten, soy protein isolate, casein, casein bees wax, whey protein isolate, bees wax, shellac, etc. (Raj 2007). Different commercial coatings recommended for fruits are given in Tables 3 and 4.

Carnauba and sugarcane wax, thermo-plastic terpene, resins, chitosan-based coatings and shellac are used commercially. However, waxes of plant origin are now being preferred. Development in wax emulsion for surface coating is not

Table 3 List of some commercially available edible coatings

Sl. No.	Coating materials	Fruits for which used
1.	Semper fresh	Banana, apple, guava
2.	Brilloshine	Apple, avocado, citrus fruits
3.	Citrashine, Nu-coatflo	Citrus fruits
4.	Tal prolong, apple wax	Apple
5.	Nutrisave	Golden delicious Apple
6.	Vapour guard	Mango
7.	Banseel	Banana, plantains
8.	Chitosan	Strawberry, raspberry

Table 4 List of specific applications of coating of different fruits

Sl. No.	Coating materials	Application on fruits
1.	Prolong	Banana
2.	Semperfresh	Banana, Granny, Smith apple, Guava
3.	Semperfresh with organic acid	Banana
4.	Ban seel	Banana, and Plantains
5.	Tal prolong semperfresh and apple wax	Apple
6.	Nutrisave	Golden delicious apples
7.	Brilloshine and citrashine, Nu.coatflo	Citrus fruits
8.	Palm oil	Guava
9.	Vapour guard	Mango
10.	Chitosan	Strawberry and raspberry
11.	N_2O—Carboxy methyl chitosan	Fruits

limited to the formulation of new types of wax, but also includes the addition of chemical fungicides. For example, benzalconic chloride in association with surface coating of wax successfully controls rot caused by *Colletotrichum gloeosporides* in mango fruits. The effect of hydro dispersion of malto-dextrin, carboxyl methyl cellulose, propylene, glycol and sorbitan esters as coating for mango on reduction or prevention of spoilage by cogloeo-sporides which produce anthracnose, has also been established. Polysaccharides-based coatings have also been investigated.

6.6.1 Problems Associated with Edible Coating

Even though some edible coatings have been successfully applied to fresh produce, other applications adversely affect quality. Modification of the internal atmosphere by the use of edible coatings can increase disorders associated with high carbon-dioxide or low oxygen concentration. Smock (1940) had earlier indicated that waxing apples and pears inhibit normal ripening rate; if sufficient wax is applied, respiration is greatly inhibited and alcoholic flavours are developed by anaerobic fermentation. Smith and Stow (1984) reported that apples (cv. Cox's orange Pippin) coated with sucrose fatty acid ester have fewer detrimental changes in terms of firmness, yellowing and weight loss with increased incidence of core flush. Smith et al. (1987) summarized the effects of physiological disorders associated with modification of internal atmosphere by use of coatings, as score flush, flesh breakdown and accumulation of ethanol and alcoholic off-flavours.

It may be noted that wax and some other commercially available mixtures are not equally effective for all produce. Another problem is that consumers tend to be wary of the waxy coatings. Therefore, development of alternative edible coatings which do not impart a waxy taste is desirable. The effect of edible coating on internal gas composition and their interaction with quality parameters must be determined for coated fresh produce. For example, colour change and firmness are very important quality parameters in fruits. In this reference it has been suggested that colour change, loss of firmness, ethanol fermentation, decay ratio and weight loss of edible-film coated fruits are all important quality attributes for various products.

6.6.2 Edible Coating Materials

Following are some are edible coatings materials which have been studied by various researchers.

1. Sucrose polyester (SPE)
2. Cornz-ein
3. Methyl cellulose (MC)

4. Hydroxy propyl cellulose (HPC)
5. Chitosan
6. Wheat gluten

6.7 Treatment with Essential Oils as Coating Materials

Application of essential oils as coating materials to control post-harvest pathogens and maintenance of fruit quality as an alternate to chemical fungicides has been suggested. This process eliminates needs of synthetic fungicides and organic requirements and reduces environmental pollution. Essential oils are volatile, natural complex compounds characterized by a strong odour and are formed by aromatic plants as secondary metabolites. These are registered food grade materials and have the potential to be applied as an alternative treatment to control post-harvest decay of fruits. An important characteristic of essential oil and their components is their hydrophobicity, which enables them to partition the lipids of the bacterial cell membrane and mitochondria, disturbing the structures and rendering them more permeable. As a result, damage of the membrane proteins and depletion of proton motive forces takes place. Then leakage of ions and other cell contents can occur which after attaining extensive loss of cell contents or critical molecules and ions lead to death of the bacterial cells. A number of essential oil compounds have been identified as effective antibacterial, viz. eugenol, carvacrol, thymol, menthol, etc., in several fruits like apple, peach, sweet cherry, strawberry, grapes, citrus, mango, etc. Table 5 describes use of some essential oils for control of post-harvest diseases of fruits.

Table 5 Essential oils used for control of diseases of fruits

Sl. No.	Essential oils	Major components	Bacterial spp.	Fruit crop
1.	Clove oil	Eugenol	*P. expansum* *M. fructigena* *B. cinera* *P. vagabunda*	Apple, grape
2.	Mint oil	Menthol	*P. italicum* *B. cinerea* *R. stolonifer*	Orange, strawberry
3.	Thyme oil	Thymol, Carvacerol	*B. cinerea* *R. stolonifer* *M. fructicola*	Strawberry, grape, sweet cherry
4.	Cinnamon oil	Cinnamaldehyde	*Natural flora*	Kiwi fruit
5.	Lemon grass oil	Citral	*C. gloesporiodes* *P. expansum* *B. cinerea* *R. stolonifer*	Mango, peach

6.8 Treatment with Salicylic Acid

Salicylic acid (SA) or ortho-hydroxy benzoic acid is a ubiquitous simple phenolic compound involved in the regulation of many processes in plant growth and development. It is considered as plant hormone because of its role in regulating some aspect by disease resistance in plants. Recently the involvement of SA as a single molecule in systemic acquired resistance associated with the production of pathogenesis-related proteins has been extensively shown. Moreover, dietary salicylates from fruits and vegetables are described as bioactive compounds with health care potential and considered as generally safe (GRAS).

There are several reports on beneficial effects of SA treatment in fruits. For example during ripening of Kiwi fruits, the pattern of decrease in endogenous SA levels is to related to accelerated softening, while the application of acetylsalicylic acid (ASA), a derivative of salicylic acid, slows down the softening rate of Kiwi fruit by inhibiting ethylene production and maintaining higher endogenous SA levels. On the other hand, SA application, either pre-harvest or post-harvest reduces fungal decay in sweet cherry through induction of the defence resistance system and simulation of antioxidant enzymes (Xu and Tian 2008). In addition, in chilling injury-sensitive fruits, pretreatment with SA reduces chilling injury symptoms in peaches and pomegranate.

6.9 Treatment with Methyl Jasmonate

Jasmonates are a class of endogenous plant growth regulators that have unique and potential useful properties which affect plant growth and development in response to environmental stresses. Methyl Jasmonate (MeJA) is a sweet smelling compound in Jasminium gradiflorum flower extract. Its main effects in post-harvest management of fruits are to control post-harvest diseases and decay of fruit, alleviate chilling injury, regulate fruit ripening and senescence, maintain fruit quality, develop colour and aroma volatiles, etc. MeJA can be effectively used to control grey mould rot in strawberry caused by Botrytis cinerea (Zhang et al. 2006) and to enhance disease resistance in peaches. Loquat (Cao et al. 2000) and raspberries (Chanjirakul et al. 2006). MeJA has also been implicated in delaying the onset of fruit ripening on the tree. Jasmonate has been found to have close interaction with plant hormone ethylene in this regard. Jasmonate induced ripening delay is associated with upregulation of polyamine levels in peach fruit. The impact of Jasmonate application on volatile compounds production is dependent on fruit ripening stage. It increases the volatiles in preclimacteric fruits but decreases the volatiles in climacteric fruits (Kando 2009).

6.10 Treatment with Bio-control Agents

Bio-control strategy has picked up in last few decades for post-harvest management of fruits and vegetables. As a result several bio-control treatments have been approved for commercial applications. Now there is a focus on improving bio-efficiency of the antagonists. One of the approaches has been the selection of combination of antagonists, which may work more effectively. It is a very challenging work as microorganisms have differential growth habits, requirement for nutrition and cultural conditions.

Naturally occurring microorganisms, which are found to be adhered on the fruits and vegetables surfaces, have been shown to posses potential to protect the fresh produce against the postharvest disease causing pathogens. Of recent, several products viz. Serenade (*Bacillus subtilis* based), Messenger (*Erwinia amylovora* based). Biosave (*Pseudomonas syringae* strain 10 LP), Aspire (*Candida oleophila* strain I-18) AQ-10 Biofungicide (*Ampelomyces quisqualis),* etc., have been isolated and reported in the USA and Germany. Use of some safe bioactive compounds has been proved beneficial in bringing down the physiological activity of fruits during transportation, storage and minimizing the overall qualitative and quantitative losses (Asrey and Berman 2011).

6.11 Nitric Oxide Treatment

Nitric oxide is a gaseous free radical with relatively long shelf-life, lasting in biological systems up to 3–5 s. It is very reactive and forms other oxides, viz. NO_2, N_2O_3 and N_2O_4 in presence of atmospheric oxygen. Post-harvest treatment of fruits with a low concentration of NO can extend postharvest shelf-life, but the application of NO by release from a gas cylinder is practically difficult.

In the above reference, the solid NO donor compound diethylenetriamine nitric oxide may be used in sachets for liberating nitric oxide in storage chambers. The use of nitric oxide can be made for delaying fruit ripening and improvement in retention of texture during storage (Zhu et al. 2010). Better retention of cellular components such as pigments, titrable acidity and antioxidants are retained well due to reduction in the degree of disintegration of cellular membranes with lesser electrolyte leakage. The chilling injury is reduced in the fruits kept in cold storage and symptoms like fresh browning and translucency are reduced. It is highly potent molecule for induction of resistance in produce against systemic infection. It also protects from microbial infections such as *Penicillium italicum, Rhizopus nigricans, Aspergillus niger* and *Monilinia fructicola*. This results in extension of shelf-life of the treated fruits. Due to maintenance of cellular compartmentation, the enzyme does not come into contact with the substrate, thus preventing the rate of reaction of enzymes such as polyphenol oxidase.

This new direction emanated from research on NO would allow more recent formulations for the use in enhancing shelf-life of the fruits in an eco-friendly manner (Asrey and Berman 2011).

6.12 Application of Ethanol

Ethanol is also known as ethyl alcohol, pure alcohol, and grain alcohol or drinking alcohol. It is a volatile, flammable and colourless liquid. It is a small molecule produced either by chemical synthesis or by microbial fermentation. The production of two anaerobic metabolites, acetaldehyde and ethanol in fruit while still attached on tree or during post-harvest storage, leads to dramatic changes in fruit ripening. Ethanol is a volatile compound naturally produced by plant tissues under anaerobic conditions. It is also accumulated in a short period of anaerobically stored fruits, without adversely affecting fruit quality.

Ethanol can be applied simply by dipping the fruits in an ethanol solution or as vapour. In some fruits, viz. grapes, ethanol can be applied as spray. It can be used in controlling decay of the fruits.

Ethanol also acts as a precursor of natural aroma compounds. It is converted to acetaldehyde by enzyme alcohol dehydrogenase. Acetaldehyde is the precursor for the acetate esters. Storage of red delicious apples for 24 h in an atmosphere containing ethanol vapours results in more than threefold increase in the ethyl ester formation.

The effect of ethylene on a range of climacteric fruits has been shown to enhance or inhibit ripening depending on the type of the fruit. Another application is to enhance anthocyanin content in fruit tissues as reported in baybery fruits when treated with 1,000 ml/lit ethanol (Zhang et al. 2007). The exogenous application of ethanol can be beneficially applied to many fruits for improving their aroma, controlling decay, delaying ripening and ethylene production and reduction of CI symptoms (Asrey and Berman 2011).

6.13 Treatment with Polyamines

Polyamines are low molecular weight small aliphatic amines that are ubiquitous in living organisms and have been implicated in a wide range of biological processes, including plant growth, development and response to stress. The polyamine treatment of the fruits inhibits biosynthesis of ethylene, increases fruit firmness, reduces chilling injury and respiration, induces resistance to mechanical damage and retards colour changes. Polyamines are applied by dipping the fruit in aqueous solution and vacuum/infiltration. Polyamines can be isolated commercially from plant as well as microbial sources which include leaves and stems of corn/maize, cucumber, oat, radish, etc.

6.14 Vapour Heat Treatment

Vapour heat treatment (VHT) is an effective non-chemical method of treatment to get rid of the oriental fruit-fly problem in fruits and vegetables. VHT is suitable for disinfestation of tropical and subtropical fruits, viz. mango, papaya, guava, citrus, etc. VHT treated mangoes are exported from India to Japan.

6.15 Degreening/Sweating/Curing

Degreening constitutes removal of chlorophyll from the peel when the night temperatures are not low enough (in case of citrus fruit) for the fruit peel to develop its characteristics colour. This process also called grassing, sweating or curing is accomplished by post-harvest treatment of fruits with dip in Ethephon (2,000–4,000 ppm) at 20–25 °C temperature and 92–95 % relative humidity. Pre-harvest spray with Ethephon (150–250 ppm) at colour break stage also improves the colour of mandarins, but calcium acetate 1 % should be added in the spray solution to check the leaf drop in this treatment. The fruits after degreening need to be washed by dipping fruits in disinfectant for 1 min in a tank filled with sanitized water at room temperature. Care should be taken that fruits are not washed before degreening. Depending upon the amount of the green colour, size of the fruits and some cultural practices, degreening time varies; e.g. excessive nitrogen fertilization promotes vigorous growth and intense green colour. For oranges maximum degreening time ranges between 48 and 50 h.

6.16 Enzymatic Hydrolysis

Enzymatic hydrolysis is a well-known pretreatment process which increases the juice yield from fruit and vegetables. In this process, enzymes of microbial origin are used for disintegration of fruit and vegetable pulp for more juice yield and clarification of juices (Birch et al. 1981).

Enzymatic degradation of biomaterials depends upon the type of enzyme, application temperature, incubation time, agitation, concentration, pH, and use of different enzymes combination (Baumenn 1981).

These parameters require optimization for maximum bio-conversion to get a quality product. In this reference the pure enzyme preparations that are highly specific and uncontaminated are very costly due to their extraordinarily and expansive downstream processing used for extraction and purification of enzymes from crude mass. Different enzymes with less purity and activity are derived from microbial sources and with minimum downstream processing may be a step towards cutting losts of enzymes.

The above approach may be understood in reference to enzymatic hydrolysis of carrot for increased juice recovery (Chadha et al. 2003). The effects of temperature, incubation time, concentration pectolytic and cellulolytic enzymes and their ratio on enzyme hydrolysis of carrot mash were studied using response surface methodology. The parameter ranges were 35–55 °C, 50–90 min, 0.2 = 0.4 mg enzyme protein/kg of carrot mash and the pectolytic and cellulolytic enzymes were mixed in the ratio 3.7–7.3. Results showed that all the parameters affected the juice yield, pectin content and crude fibre content significantly and enzyme concentrations were more pronounced than those of the incubation time and enzyme ratio. The juice yield increased by 5–10 %. Viscosity of juice decreased, while pH, colour index and total solids increased due to enzymatic hydrolysis.

7 Storage

The storage of fruit and vegetables has assumed great significance all over the world because of their continued and increased demand at all times of the year as well as need to spread peaks of the production over long periods to maximize profit and reduce wastage. Certain crops like apples and potatoes can be stored for long period whereas in case of certain crops like tomato and peach, the storage period is very short. There are few important factors which need to be taken into account before storage of the produce. These are:

- Suitability of crop for storage
- Knowledge of appropriate storage conditions, and
- Compatibility with other crop for storage

Different methods of fruits and vegetables storage are described below:

7.1 Storage at Low Temperature

Low temperature is achieved by taking away heat from the storage area. Heat is transferred from the storage area by the principles of latent heat of vaporization. The low temperature methods can be classified in the following ways:

Refrigeration: In the refrigeration technique, the fruits and vegetables are stored at low temperature (4–5 °C) by means of refrigerants. Refrigerants commonly used are ammonia, freon, methyl chloride, ethyl chloride, sulphur dioxide and carbon-di-oxide. Ammonia is used in large commercial applications because of its economy and the amount of heat carried away per kg of ammonia evaporated is quite high. However, for small household system and installations for food, Freon is used because it is inert and operates at low pressure difference. Storage of polyethylene packed citrus fruits under refrigerated conditions is reported to enhance their storage life considerably (Ben-Yehoshua 1985; Cohen et al. 1990). Papaya fruits have a maximum storage life of up to 7 days under tropical ambient conditions. However, the mature green to 1/4th yellow papayas can be stored up to 2 weeks at 12–13 °C. The low temperature storage for particularly ripe fruits is recommended between 7 and 10 °C. The mature green papayas fruits are more susceptible to chilling injury than ripe fruits.

7.2 Freezing

Freezing is low temperature preservation technique where the product is frozen at −40 °C or more low temperature depending upon the type of freezing technique chosen and further stored at −20 °C. Freezing is cheaper than canning and frozen products are close to fresh products and of better quality. The metabolic activity and spoilage due to post-harvest chemical changes are retarded by freezing. Though the product preserved by freezing retains their quality appreciably, the major disadvantage of the process is that the low temperature has to be maintained during handling, transportation and storage before the product is finally consumed. Properly conducted freezing is effective for retaining the flavour, colour and nutritive value of food and is moderately effective for preservation of texture if quick freezing is practised. During freezing, there is a physical change within the food by conversion of water to ice crystals. This helps to capture the biological condition of the food at a point at which it is frozen and thereby upon defreezing the food, the some colour, flavour and taste is obtained.

The methods of food freezing include:

(a) **Slow freezing:** Technique involve freezing by air circulation either naturally or with forced circulation by fans. The temperature may vary from −15 to −29 °C and freezing may be accomplished in 3 to 72 h. The ice crystals formed are large and rupture the biological cells.
(b) **Quick freezing:** In this process the food attains the temperature of maximum ice crystal formation (0 to −40 °C) within 30 min or less. Quick freezing maintains the natural properties of the produce by reducing post-harvest changes and microbial deterioration to the barest minimum without any influence on the original qualities. The rate of freezing plays a great role in the quality of frozen fruits and vegetables. Faster freezing rate is required to obtain better quality. Liquid nitrogen is the most common cryogenic substance used in food freezing. Ultra quick freezing rate, minimum dehydration loss, freedom from oxidative changes, minimum freezing damage of the sensitive frozen products, maximum quality retention of texture, colour and flavour during freezing and the inert nature of refrigerant are the advantages of liquid nitrogen freezing. A systematic establishment of quick freezing can boost export trade. Methods have been standardized for the manufacture of cryogenically frozen, crack-free, peeled ripe mango slices having excellent retention of quality attributes, well comparable with those of fresh mangoes in ready to serve form with cent-percent

edible portion. Problems generally faced in the export of fresh mangoes, viz. short storage life, added bulk of stone, hidden disorders, live spongy tissue and weevils, etc., can be successfully overcome by producing the cryogenically frozen mango slices (Roy 2007).

The different methods of quick freezing are:

1. **Direct immersion freezing:** It is a very rapid method of freezing, in which the prepared fruits and vegetables are directly immersed in a refrigerated brine or sugar solution
2. **Indirect contact with refrigerants:** In this technique fruits and vegetables are frozen by placing them in contact with metal surface which is cooled by a refrigerant. This system can be batch type or continuous
3. **By freezing in air:** There are two types of air systems for fruit and vegetables freezing, namely still air and forced air. Still air freezing is accomplished by placing packaged or loose package in suitable freezing rooms. In the forced air method, refrigerated air at low temperature, −18 to −34 °C or below is blown across the material to be frozen.

(c) **Cryogenic freezing:** In this technique freezing is done at very low temperature (below −60 °C). The refrigerants used for cryogenic freezing are liquid nitrogen and liquid carbon-di-oxide. Cryogenic freezing is used for mushroom, sliced tomatoes, strawberry, etc.

(d) **Dehydro Freezing:** In this technique, freezing is preceded by partial dehydration. In case of some fruits and vegetables about 50 % moisture is removed by dehydration prior to freezing. This technique improves the quality of food.

7.3 Controlled Atmosphere Storage

The controlled atmosphere storage involves a system for holding fresh fruits and vegetables in an atmosphere that differs from normal air in respect to the proportion of nitrogen, oxygen and carbon-di-oxide. The composition of the atmosphere can be altered by restricted venting the storage room or the container, scrubbing the atmosphere of carbon-di-oxide and oxygen or by adding individual gases to the container. The controlled atmosphere storage, however, does not prevent deterioration but lengthens the storage life.

7.4 Modified Storage

Modified atmosphere storage refers to a storage system including a package in which air is removed and replaced with desired gases.

The main purpose of controlled and modified atmosphere storage is to reduce as much as possible the respiration rate of the stored produce.

7.5 Sub-atmosphere Storage

The produce in this storage system is stored under low atmospheric pressure at the required low temperature and optimal relative humidity conditions. It retains the fresh condition of the produce for much longer period than what is possible with conventional cold storage. The sub-atmosphere storage is suitable for a wide range of fruits, viz. apples, avocado, mango, papaya, pine apple, strawberry, etc.

8 Conclusion

Fruits and vegetables are an important nutritional requirement of human beings as these foods not only meet the quantitative needs to some extent but also supply vitamins and minerals which improve the qualities of diet and maintain the health. It is therefore necessary to make them available for consumption throughout the year in fresh or processed/preserved form. India is the second largest producer of fruits and vegetables after China. However it processes less than 2 % of the total production of the fruits and vegetables. Most of the processed products are consumed domestically. There is a need to develop for fresh preservation technologies to avoid the heavy post-harvest losses.

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