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Best Practices for Efficient Postharvest Management of Fruits and Vegetables for Higher Value Addition and Profitability

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Introduction

The post-harvest or post-production operations of agricultural and horticultural products include a wide range of functions between production and consumption. These functions have to be carried out efficiently by different agencies/ individuals in the post-harvest chain in order to supply food of good quality to keep transaction costs low and to deliver high quality and safe raw material for further processing and value addition. Post-harvest operations deserve high priority since they contribute in several ways to the overall goal of sustainable development in agriculture and impact on its profitability. A substantial part of the consumer price for agricultural products, depending on the commodity, the type of post-harvest operation and the organizational structure, is attributable to processing, marketing, transport, storage and handling of the raw product. A considerable part of post-production activities is actually or may be potentially fulfilled on-farm by members of farm households. This adds to the value of the farm product and therefore the income of the household. Women and weaker sections with little access to resources can find income opportunities in handling, processing and trading agricultural products. Especially in rural areas, post-harvest operations contribute to employment, income generation and alleviation of poverty for these groups. Minimal processing has opened new avenues for handsome returns in the production catchments.

There is a pressing need to establish efficient, time-cost-energy saving post-harvest technology systems, which reduce losses and optimize produce suitability and quality for market requirements. Among the critical areas that urgently require attention are: loss minimization, handling production surpluses, safe transport, transit or longer time storage, market access and creating favourable conditions for higher acceptance of high quality and competitively priced processed food. Post-harvest losses remain unacceptably high ranging from 10 to 35 per cent of the perishable commodities produced. As per recent estimate, post-harvest losses in fruits and vegetables are $ 5 billion annually. The Green Revolution was followed by Golden Revolution which led to the large scale production of fruits and vegetables which need to be consumed, stored or exported, requiring additional technological input and infrastructure support. Export markets have become more competitive and discriminating, leading to increased emphasis on quality assurance and food safety. There is increasing shift in the consumption of fruits and vegetables in

Indian diet besides dairy products, fish and meat as sources of vitamin, mineral and protein, requiring newer and effective post-harvest technologies. This can create a win-win situation for producers, processors and consumers.

The global consumer demand for high-quality foods that are fresh, tasty and nutritious has created considerable interest and investment in the development of new or improved post-harvest handling and storage and food-processing technologies and practices. The competitive struggle for markets, which has resulted from more liberalised trade regimes, requires a much greater emphasis on efficient and effective post-harvest handling, processing and distribution to access domestic and global markets. Traditional post-harvest food-processing technologies such as freezing and canning etc are no longer at the forefront of consumer demand.

Indian Scenario on Fruits and Vegetables

India is the fruit and vegetable basket of the world. Being a home of wide variety of fruits and vegetables, it holds a unique position in production figures among other countries. Over 90% of India's exports in fresh products goes to West Asia and East European markets. However, the current level of processing being very low (around 5 per cent as against 70-80 per cent in some East Asian countries), India needs to quickly augment its food and processing at a mega scale.

The covered area under the fresh fruits in India was 5,510,000 ha with the production of 58,740,000 MT in 2005-06. The major fruits grown in India are: mango, grape, apple, apricots, orange, banana , avocados, guava, litchi, papaya, sapota and melons. This is due to its potential in different agro climatic zones. India's export of fresh fruits has increased from US$ million 50.98 in 2005-06 to US$ million 56.88 in 2006-07.

Total vegetable production in India before independence was 15 million tonnes and since Independence for decades the growth rate was stabilized around 0.5%. The impetus on vegetable research and policy intervention to promote vegetable crops witnessed a sudden spurt in growth rate of 2.5%, a hike of five times during the last decade. Major vegetables grown in India are: potato, onion, tomato, cauliflower, cabbage, bean, brinjal, cucumber and gherkin, field and frozen peas, garlic and okra.

The potential technological interventions with improved gene pool and precise management can take growth rate to nearly 6% per annum. The area under vegetables increased from 5.59 million ha in 1991–92 to 6.76 million ha during 2004–05. The production in this period increased from 58.53 million tonnes to 101.43 million tonnes. During the period, productivity of vegetables increased from 10.5 tonne/ha to 15.0 tonne/ha. While West Bengal continues to be the leading State in area and production, the productivity is higher in Tamil Nadu, followed by Uttar Pradesh and Bihar.

India's exports of fresh fruit and vegetable has increased from US$ 374.68 million in 2005-06 to US$ 534.97 million in 2006-07.

India ranks fifth in the world in cropped area under cultivation and production of potatoes. India produces 41% of world's mangoes, 23% bananas, 24% cashew nuts, 36% green peas and 10% onion. The total export value of the main exporting fruit crop from India is mango. Exports of mangoes, grapes, and mushrooms have started going to the United Kingdom, Middle East, Singapore and Hong Kong. Among vegetable, onion occupies first position, potatoes and green vegetables like okra, bitter gourd, green chillies have good export potential (Table 1).

India is the 2nd largest onion growing country in the world. Indian onions are famous worldwide for their pungency. The Gulf countries are the main importers of the onion bulb, and neighbouring Pakistan and China are India's main competitors in the global market. India's export of onion has increased from USD million 159.96 in 2005-06 to USD million 258.05 in 2006-07. Bangladesh, Malaysia, Sri Lanka, U.A.E, Pakistan and Nepal are the major markets of Indian Onion.

Mango, called the king of fruits in India, accounts for 40 percent of the national fruit production of 22.168 million tonnes a year. It occupies 42 percent of the country's 24.87 million hectares land under fruit cultivation. India exported 79,060.88 MT of fresh mangoes with the value of USD million 31.48 in 2006-07. The major markets for Indian mangoes are U.A.E, Bangladesh, U.K, Saudi Arabia and Nepal. India is estimated to account for about 60 percent (9.5 million tonnes) of the world's mango production of 15.7 million tonnes.

Table 1. Area and production of major horticultural crops (2008-09).

Crops	Area '000 ha	Production '000 tonnes
I. Fruits		
Mango	2309	12831
Apple	271	1985
Banana	708	27119
Citrus	926	8526
Guava	207	2330
Grapes	69	1764
Papaya	98	3641
Pineapple	84	1354
Total	**66106**	**69453**
II. Vegetables		
Potato	1824	36284
Onion	836	13792
Tomato	608	11328
Brinjal	602	10420
Cabbage	308	6805
Cauliflower	358	6566
Peas	349	2914
Okra	436	4524
Total	**8204**	**133071**

(Source: Horticulture Division, Ministry of Agriculture, Govt. of India, 2008)

The horticulture and allied sector is an integral element for food and nutritional security in the country. Horticulture is the main segment, while its various sub-segments are fruits, vegetables, aromatic and herbal plants, flowers, spices and plantation crops. All these are regarded as the essential ingredients of economic security. The wide range of agro-climatic conditions of India is conducive for growing a large variety of horticultural crops, including root and tuber crops, mushroom, ornamental crops, and plantation crops like coconut, areca nut, cashew and cocoa.

The Government of India has recognized horticulture crops as a means of diversification in agriculture in an eco-friendly manner through efficient use of land and optimum utilization of natural resources. Horticulture seeks to create ample opportunities for employment, particularly for unemployed youths and women folk. India has maintained leadership in the production of many commodities like mango, banana, acid lime, coconut, areca nut, cashew, ginger, turmeric and black pepper. Presently, it is the second largest producer of fruits and vegetables in the world.

India is next only to China in area and production of vegetables and occupies prime position in the production of cauliflower, second in onions and third in cabbage in the world. India has also made noticeable advancement in the production of flowers. Further, it is the largest producer, consumer and exporter of spices. India is home to a wide variety of spices like black pepper, cardamom (small and large), ginger, garlic, turmeric, chilli and a large variety of tree and seed spices. Almost all the States in the country grow one or more spices. The major spice producing States are Andhra Pradesh, Tamil Nadu, Orissa and Madhya Pradesh. North Eastern region and Andaman and Nicobar Islands also have potential areas cultivated for spices, particularly organically.

Post-harvest Management Procedures that are Critical to Maintaining the Quality and Safety of Horticultural Crops

Liberalization of trade in agriculture has provided newer opportunities to the farm sector to access markets of agricultural commodities worldwide. To benefit small and marginal farmers, who predominate country's economy, there is a need to strengthen post-harvest management system, encompassing all areas from production to final sale-quality standards, processing, storage, transport, and warehousing.

1. Production Practices

Production practices have a tremendous effect on the quality of fruits and vegetables at harvest and on postharvest quality and shelf life. To start with, it is well known that some cultivars ship better and have a longer shelf life than others. In addition, environmental factors such as soil type, temperature, frost, and rainy weather at harvest can have an adverse effect on storage life and quality. For example, carrots grown on muck soils do not hold up as well in storage as carrots grown on lighter, upland soils. Lettuce harvested during a period of rain does not ship well and product losses are increased.

Management practices can also affect post-harvest quality. Produce that has been stressed by too much or too little water, high rates of nitrogen, or mechanical injury (e.g., scrapes, bruises, abrasions) is particularly susceptible to post-harvest diseases. Mould and decay on winter squash, caused by the fungus, result from the fruits lying on the ground, and can be alleviated by using mulch. Broccoli heads are susceptible to postharvest rot caused by the bacteria Erwinia if nitrogen is applied as foliar feed, a grower should feed the soil, not the leaves. Beets and radishes are susceptible to soil-borne diseases when the soil temperature reaches 25-26℃; symptoms are black spots on these root crops.

Food safety also begins in the field, and should be of special concern, since a number of outbreaks of food-borne illnesses have been traced to contamination of produce in the field. Common-sense prevention measure include a number of don'ts:

- Don't apply raw dairy or chicken manure or slurries to a field where a vegetable crop such as leafy lettuce is growing;
- Don't apply manure to an area immediately adjacent to a field nearing harvest maturity;
- Don't forget to clean equipment that has been used to apply manure to one field before moving it to another field in production;
- Don't irrigate with water from a farm pond used by livestock;
- Don't harvest fruit from the orchard floor for human consumption as whole fruit or non-pasteurised juices, especially if manure has been spread or animals allowed to graze;
- Don't accumulate harvested product in areas where birds roost.

A grower *should* constantly evaluate water used for irrigation, and compost all animal manures before applying them to fields. There are many good sources of information on growing conditions and production practices that promote post-harvest quality. Consult textbooks, extension publications, and trade journals, and become involved with grower organizations to find our more.

2. Harvest Handling

Quality cannot be improved after harvest, only maintained; therefore it is important to harvest fruits and vegetables at the proper stages and size and at peak quality. Immature or over -mature produce may not last as long in storage as that picked at proper maturity. Horticulture Institutes of Indian Council of Agricultural Research (ICAR), Directorates of Extension of Agricultural Universities and State Departments of Agriculture publications, websites and call centres are excellent source of information on harvest maturity indicators for vegetables and fruits.

Harvest 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. Handle produce gently. Crops destined for storage should be free as possible from skin breaks, bruises, spots, rots, decay, and other deterioration. Bruises and other mechanical damage not only affect appearance, but provide entrance to decay organisms 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 as weight as non-skinned potatoes. Damage can be prevented by training harvest labour to handle the crop gently; harvesting at proper maturity; harvesting dry whenever possible; handling each fruit or vegetable no more than necessary (field pack if possible); installing padding inside bulk bins; and avoiding over or under-packing of containers.

3. Packing and Packaging of Fruits and Vegetables

Preparation of produce for market may be done either in the field or at the packing house. This involves cleaning, sanitizing, and sorting according to quality and size, waxing and where appropriate, treatment with an approved fungicide prior to packing into shipping containers, Packaging protects the produce from mechanical injury, and contamination during marketing.

Corrugated fibreboard containers are commonly used for the packaging of produce, although reusable plastic containers can be used for that purpose. Packaging accessories such as trays, cups, wraps, liners, and pads may be used to help immobilize the produce within the packaging container while serving the purpose of facilitating moisture retention, chemical treatment and ethylene absorption. Either hand-packing or mechanical packing systems may be used. Packing and packaging methods can greatly influence air flow rates around the commodity, thereby affecting temperature and relative humidity management of produce while in storage or in transit.

4. Temperature and Relative Humidity Management

Temperature is the most important environmental factor that influences the deterioration of harvested commodities. Most perishable horticultural commodities have an optimal shelf-life at temperatures of approximately 0℃. The rate of deterioration of perishables however increases two to three fold with every 10°C increase in temperature. Temperature has a significant effect on how other internal and external factors influence the commodity, and dramatically affects spore germination and the growth of pathogens.

i) Effect of temperature on the deterioration rate of a non-chilling sensitive commodity

Temperature (°C)	Assumed Q_{10}*	Relative rate of deterioration	Relative post-harvest life	Loss per day (%)
0	-	1.0	100	1
10	3.0	3.0	33	3
20	2.5	7.5	13	8
30	2.0	15.0	7	14
40	1.5	22.5	4	25

$$*Q_{10} = \frac{\text{Rate of deterioration at temperature T} + 10℃}{\text{Rate of deterioration at temperature T}}$$

ii) Effect of temperature on the deterioration rate of a chilling sensitive commodity

Temperatures either above or below the optimal range for fresh produce can cause rapid deterioration due to the following disorders:

Freezing: Perishable commodities are generally high in water content, and possess large, highly vacuolated cells. The freezing point of their tissues is relatively high (ranging from -3°C to -0.5°C), and disruption caused by freezing generally results in immediate collapse of their tissues and a total loss of cellular integrity. Freezing occurs in cold storage systems either due to inadequate refrigerator design, or to thermostat failure. Freezing can also occur upon exposure to inclement weather conditions as occurs when produce is allowed to remain for even short periods of time on unprotected transportation docks during winter.

Chilling injury: Some commodities (chiefly those native to the tropics and subtropics) respond unfavourably to storage at low temperatures which are well above their freezing points, but below a critical temperature termed their chilling threshold temperature or lowest safe temperature. Chilling injury is manifested in a variety of symptoms including surface and internal discoloration, pitting, water soaking, failure to ripen, uneven ripening, development of off flavours and heightened susceptibility of pathogen attack.

Lowest safe temperature (℃)	Commodity
3	Asparagus, cranberry, jujube
4	Cantaloupe, certain apple cultivars (such as McIntosh and Yellow Newton), certain avocado cultivars, litchi, potato
5	Cactus pear, cowpeas, guava, lima bean, mandarin, orange,
7	Certain avocado cultivars, okra, olive, pepper, pineapple, pomegranate, snap bean
10	Carambola, cucumber, brinjal, grapefruit, lime, mango (ripe), melons, papaya, passion fruit, plantain, rambutan, squash(soft rind), taro, tomato (ripe), watermelon
13	Banana, breadfruit, ginger, jackfruits, lemon, mango(mature-green), mangosteen, pumpkin and hard rind squash, sapota, sweet potato, tomato(mature-green), yam

5. Classification of Heating/Chilling-Sensitive Fruits and Vegetables According to Their Lowest Safe Temperature for Transport and Storage

Heat injury: High temperature conditions are also injurious to perishable crops. Transpiration is vital to maintaining optimal growth temperatures in growing plants. Organs removed from the plant, however, lack the protective effects of transpiration, and direct sources of

heat, such as sunlight, can rapidly elevate the temperature of tissues to above the thermal death point of their cells, leading to localized bleaching, necrosis (sunburn or sunscald) or general collapse.

Relative humidity (RH) Relative humidity is defined as the moisture content (as water vapour) of the atmosphere, expressed as a percentage of the amount of moisture that can be retained by the atmosphere (moisture holding capacity) at a given temperature and pressure without condensation. The moisture holding capacity of air increases with temperature. Water loss is directly proportional to the vapour pressure difference (VPD) between the commodity and its environment. VPD is inversely related to the RH of the air surrounding the commodity.

RH can influence water loss, decay development, the incidence of some physiological disorders, and uniformity of fruit ripening. Condensation of moisture on the commodity (sweating) over long periods of time is probably more important in enhancing decay than is the RH of ambient air. An appropriate RH range for storage of fruits is 85 to 95 percent while that for most vegetables varies between 90 and 98 percent. The optimal RH range for dry onions and pumpkins is 70 to 75 percent. Some root vegetables, such as carrot, parsnip, and radish, can best be held at 95 to 100 percent RH.

RH can be controlled by one or more of the following procedures:

1. adding moisture (water mist or spray, steam) to air with the use of humidifiers;
2. regulating air movement and ventilation in relation to the produce load in the cold storage room;
3. maintaining the temperature of the refrigeration coils in the storage rooms or transit vehicle to within about 1°C of the air temperature;
4. providing moisture barriers that insulate walls of storage rooms and transit vehicles;
5. adding polyethylene liners in packing containers and using perforated polymeric films for packaging;
6. wetting floors in storage rooms;
7. adding crushed ice in shipping containers or in retail displays for commodities that are not injured by the practice; and
8. sprinkling produce with sanitized, clean water during retail marketing of commodities that benefit from misting, such as leafy vegetables, cool season root vegetables, and immature fruit vegetables (such as snap beans, peas, sweet corn, and summer squash).

Post-harvest Treatments Designed to Minimize Produce Contamination and to Maximize Quality

1. Pre-cooling

Pre-cooling is the first step in good temperature management. The *field heat* of a freshly harvested crop-heat the product 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 storage 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-cooing to the product's 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, mushrooms, peas and sweet corn. Crops with low respiration rates include nuts, apples, grapes,garlic, onions, potatoes(mature), and sweet potatoes.

Appropriate pre-cooling methods as well as appropriate storage temperature and humidity for a number of fruits and vegetables. The following methods are the most commonly used:

Room cooling: Produce is placed in an insulated room equipped with refrigeration units. This method can be used with most commodities, but is slow compared with other options. A room used only to store previously cooled produce requires a relatively small refrigeration unit. However, if it is used to cool produce, a larger unit is needed. Containers should be stacked so that cold air can move around them, and constructed so that it can move through them. Used refrigerated truck bodies make excellent small cooling rooms.

Forced-air cooling: Fans are used in conjunction with a cooling room to pull cool air through packages of produce. Although the cooling rate depends on the air temperature and the rate of air flow, this method is usually 75-90% faster than room cooling. Fans should be equipped with a thermostat that automatically shuts them off as soon as the desired product temperature is reached.

Hydro-cooling: Dumping produce into cold water, or running cold water over produce, is an efficient way to remove heat, and can serve as a means of cleaning at the same time. In addition, hydro-cooling reduces water loss and wilting. Use of a disinfectant in the water is recommended to reduce the spread of diseases. Hydro-cooling is not appropriate for berries, potatoes to be stored, sweet potatoes, bulb onions, garlic, or other commodities that cannot tolerate wetting.

Water removes heat about five times faster than air, but is less energy efficient. Well water is a good option, as it usually comes out of the ground with temperatures in the 10-15°C range. Mechanical refrigeration is the most efficient method for cooling water. A thermal storage immersion hydro-cooler system can be fabricated economically to suit various volume requirements. Used stainless-steel bulk farm milk coolers may be an option. If hydro-cooling water is recirculated, it should be chlorinated to minimize disease problems.

A study compared sweet corn quality after hydro-cooling with ice water, well water cooling and refrigerated air cooling, and subsequent refrigerated storage. Hydro-cooling with ice water

lowered the temperature of the ears most quickly. Well water cooling followed by refrigerated storage appeared to offer no advantage over refrigerated storage immediately after harvest.

Top or liquid icing: Icing is particularly effective on dense products and palletized packages that are difficult to cool with forced air. In top icing, crushed ice is added to the container over the top of the produce by hand or machine. For liquid icing, a slurry of water and ice is injected into produce packages through vents or handholds without removing the packages from pallets and opening their tops. Icing methods work well with high-respiration commodities such as sweet corn and broccoli. One pound of ice will cool about three pounds of produce from 85 °F to 40 °F.

Vacuum cooling: Produce is enclosed in a chamber in which a vacuum is created. As the vacuum pressure increases, water within the plant evaporates and removes heat from the tissues. This system works best for leafy crops, such as lettuce, which have a high surface-to volume ratio. To reduce water loss, water is sometimes sprayed on the produce prior to placing it in the chamber. This process is called hydrovac cooling. The primary drawback to this method is the cost of the vacuum chamber system.

Temperature management is the most effective tool for extending the shelf life of fresh horticultural commodities. It begins with the rapid removal of field heat by using one of the cooling methods.

Variable	Cooling method				
	Ice	Hydro	Vacuum	Forced-air	Room
Cooling time (h)	0.1-0.3	0.1-1.0	0.3-2.0	1.0-10.0	20-100
Water contact with the product	Yes	Yes	No	No	No
Product moisture loss (%)	0-0.5	0-0.5	2.0-4.0	0.1-2.0	0.1-2.0
Capital cost	High	low	medium	low	low
Energy efficiency	low	High	High	low	low

2. Comparison of Methods Used for Cooling

Packing fresh produce with crushed or flaked ice provides rapid cooling, and can provide a source of cooling and high RH during subsequent handling. The use of crushed ice is, however, limited to produce that is tolerant to direct contact with ice and packaged in moisture-resistant containers.

Clean, sanitized water is used as the cooling medium for the hydro-cooling (shower or immersion systems) of commodities that tolerate water contact and are packaged in moisture-resistant containers. Vacuum cooling is generally applied to leafy vegetables that release water vapour quickly, thereby allowing them to be rapidly cooled. During forced-air cooling on the other hand, refrigerated air is forced through produce packed in boxes or pallet bins. Forced-air cooling is applicable to most horticultural perishables.

Precise temperature and RH management are required to provide the optimum environment for fresh fruits and vegetables during cooling and storage. Precision temperature management (PTM) tools, including time-temperature monitors, are increasingly being employed in cooling and storage facilities.

3. Refrigerated Transport and Storage

It retards the following elements of deterioration in perishable crops:

- Aging due to ripening, softening, and textural and colour changes;
- Undesirable metabolic changes and respiratory heat production;
- Moisture loss and the wilting that results;
- Spoilage due to invasion by bacteria, fungi, and yeasts; and
- Undesirable growth, such as sprouting of potatoes.

One of the most important functions of refrigeration is to control the crop's respiration rate. Respiration generates heat as sugars, fats and proteins in the cells of the crop are oxidized. The loss of these stored food reserves through respiration means decreased food value, loss of flavour, loss of saleable weight, and more rapid deterioration. The respiration rate of a product strongly determines its transit and postharvest life. The higher the storage temperature, the higher the respiration rate will be

For refrigeration to be effective in postponing deterioration, it is important that the temperature in cold storage rooms be kept as constant as possible. The optimum temperature ranges for various crops. Exposure to alternating cold and warm temperatures may result in moisture accumulation on the surface of produce (sweating), which may hasten decay. Storage rooms should be well insulated and adequately refrigerated, and should allow for air circulation to prevent temperature variation. Be sure that thermometers, thermostats, and manual temperature controls are of high quality, and check them periodically for accuracy.

On-farm cooling facilities are a valuable asset for any produce operation. A grower who can cool and store produce has greater market flexibility because the need to market immediately after harvest is eliminated. The challenge, especially for small-scale producers, is the set-up cost. Innovative farmers and researchers have created a number of designs for low-cost structures.

Cold storage facilities should be appropriately designed, of good construction, and be adequately equipped. Their insulation should include a complete vapour barrier on the warm side of the insulation; sturdy floors; adequate and well-positioned doors for loading and unloading; effective distribution of refrigerated air; sensitive and properly located controls; refrigerated coil surfaces designed to adequately minimize differences between the coil and air temperatures; and adequate capacity for expected needs. Commodities should be stacked in the cold room or the

refrigerated vehicle with air spaces between pallets and room walls so as to ensure proper air circulation. Storage rooms should not be loaded beyond their capacity limit if proper cooling is to be achieved. Commodity temperature rather than air temperature should be measured in these facilities.

Temperature management during transportation of fresh fruits and vegetables over long distances is critical. Loads must be stacked so as to enable proper air circulation, in order to facilitate removal of heat from the produce as well as to dissipate incoming heat from the atmosphere and off the road. Stacking of loads must also incorporate consideration for minimizing mechanical damage. Transit vehicles must be cooled prior to loading the fresh produce. Delays between cooling after harvest and loading into transit vehicles should also be avoided. Proper temperature maintenance should be ensured throughout the handling system.

As far as possible, environmental conditions (temperature; relative humidity; concentrations of oxygen, carbon dioxide and ethylene) should be optimized in transport vehicles. Treatment with ethylene to initiate ripening during transportation is feasible, and is commercially used to a limited extent on mature green bananas and tomatoes. Produce should be cooled prior to loading and should be loaded with an air space between the palletized product and the walls of the transport vehicles in order to facilitate temperature control. Vibration during transportation should be minimized, so as to avoid damage due to bruising. Controlled-atmosphere and precision temperature management should, where possible, be observed so as to allow non-chemical insect control for markets which possess quarantine restrictions against pests endemic to exporting countries and for markets that do not want their produce exposed to chemical fumigants.

Mixing several produce items in one load is common and often compromises have to be made in selecting an optimal temperature and atmospheric composition when transporting chilling-sensitive with non-chilling sensitive commodities. In the latter case, ethylene scrubbers can be used to remove ethylene from the circulating air within the vehicle. Several types of insulating pallet covers are available for protecting chilling-sensitive commodities when transported with non-chilling-sensitive commodities at temperatures below their threshold chilling temperatures.

3.1 Maintaining the cold chain for perishables

Harvest	- Minimize delays before cooling
	- Cool the product thoroughly as soon as possible
Cooling	- Store the product at optimum temperature
Temporary storage	- Practice first in first out rotation
	- Ship to market as soon as possible
Transport to market	- Use refrigerated loading area
	- Cool truck before loading

	- Load pallets towards the centre of the truck
	- Put insulating plastic strips inside door of reefer if truck makes multiple stops
	- Avoid delays during transport
	- Monitor product temperature during transport
Handling at destination	- Use a refrigerated unloading area
	- Measure product temperature
	- Move product quickly to the proper storage area
	- Transport to retail markets or food service operations in refrigerated trucks
	- Display at proper temperature range
Handling at home or food service outlet	- Store product at proper temperature
	- Consume the product as soon as possible

4. Return on Investment in Temperature and Relative Humidity Management

Deficiencies in cold chain management whether due to limitations in refrigeration, improper handling and storage, or inadequate humidity control, can lead to losses in profits as well as in horticultural crops. Overcoming such deficiencies necessitates improvements in methodologies, operations and handling along the chain. Often the level of investment required in overcoming such deficiencies is minimal in comparison to the level of losses sustained over time.

Researches have established that a one-hour delay in cooling strawberries after harvest resulted in a 10 percent loss due to decay during marketing. The resulting economic loss exceeded the increased cost of expedited handling of the strawberries by more frequent deliveries of harvested fruit to the cooling facility and initiation of forced-air cooling. Similarly, another study showed that poor temperature management of lettuce resulted in a net income loss of US$172.50 per truck-load of 900 cartons.

Chilling injury

Many vegetables and fruits store best at temperatures just above freezing, while others are injured by low temperatures and will store best at 45 to 55 degrees F. Both time and temperature are involved in chilling injury. Damage may occur in a short time if temperatures are considerably below the danger threshold, but some crops can withstand temperatures a few degrees into the danger zone for a longer time. The effects of chilling injury are cumulative in some crops. Low temperatures in transit, or even in the field shortly before harvest, add to the total effects of chilling that might occur in storage.

Crops such as basil, cucumbers, eggplants, pumpkins, summer squash, okra, and sweet potatoes are highly sensitive to chilling injury. Moderately sensitive crops are snap beans, muskmelons, peppers, winter squash, tomatoes, and watermelons. These crops may look sound when removed from low temperature storage, but after a few days of warmer temperatures, chilling symptoms become evident: pitting or other skin blemishes, internal discoloration, or failure to ripen. Tomatoes, squash, and peppers that have been over-chilled may be particularly susceptible to decay such as *Alternaria rot.*

Preventing moisture loss

While temperature is the primary concern in the storage of fruits and vegetables, relative humidity is also important. The relative humidity of the storage unit directly influences water loss can severely degrade quality-for instance, wilted greens may require excessive trimming, and grapes may shatter loose from clusters if their stems dry out. Water loss means saleable weight loss and reduced profit.

Most fruit and vegetable crops retain better quality at high relative humidity (80to 95%) but at this humidity, disease growth is encourages. The cool temperatures in storage rooms help to reduce disease growth, but sanitation and other preventative methods are also required. Maintaining high relative humidity in storage is complicated by the fact that refrigeration removes moisture. Humidification devices such as spinning disc aspirators may be used. Even buckets of water will increase humidity as the fans blow air across the water's surface and increase evaporation. Keeping the floor wet is helpful, though messy and potentially hazardous to two-legged creatures; frequent cleansing with a weak chlorine solution will be needed to prevent harbouring of disease organisms in water and produce scraps on the floor. Crops that can tolerate direct contact with water may be sprinkled to promote high relative humidity.

Treatments

1. Treatments to Reduce Microbial Contamination

Over the past few years, food safety has become and continues to be the number one concern of the fresh produce industry. A "Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables," was published by the U.S. Food and Drug Administration in October 1998. This Guide is based on the following principles:

1) Prevention of microbial contamination of fresh produce is favoured over reliance on corrective actions once contamination has occurred;
2) In order to minimize microbial food safety hazards in fresh produce, growers, packers, or shippers should use good agricultural and management practices in those areas over which they have control;

3) Fresh produce can become microbiologically contaminated at any point along the farm-to-table food chain. Human and /or animal faeces are the source of microbial contamination of fresh produce;
4) Whenever water comes in contact with produce, its quality dictates the potential for contamination. The potential of microbial contamination from water used with fresh fruits and vegetables must be minimized;
5) The use of animal manure or municipal bio-solid wastes as fertilizers should be closely managed in order to minimize the potential for microbial contamination of fresh produce; and
6) Worker hygiene and sanitation practices during production, harvest, sorting, packing, and transport play a critical role in minimizing the potential for microbial contamination of fresh produce.

Clean water containing an appropriate concentration of sanitizers is required in order to minimize the potential transmission of pathogens from water to produce, from healthy to infected produce within a single lot, and from one lot of produce to another, over time (Table 2). Waterborne microorganisms, including post-harvest plant pathogens and agents of human illness, can be rapidly acquired and taken up on plant surfaces. Natural plant surface contours, natural openings, harvest and trimming wounds and scuffing can provide points of entry as well as safe harbour for microbes. When located in these protected sites, microbes are largely unaffected by common or permitted doses of post-harvest water sanitizing treatments. It is therefore essential that the sanitizer concentration is sufficient to kill microbes before they attach or become internalized in produce. The concentration of sanitizer is important in some pre-harvest water uses(such as spraying pesticides or growth regulators) and in all post-harvest procedures involving water, including washing, cooling, water-mediated transport (flumes), and post-harvest drenching with calcium chloride or other chemicals.

2. Treatments to Minimize Water Loss

Transpiration, or evaporation of water from the plant tissues, is one of the major causes of deterioration in fresh horticultural crops after harvest. Water loss through transpiration not only results in direct quantitative losses (loss of saleable weight), but also causes losses in appearance (wilting, shrivelling), textural quality (softening, flaccidity, limpness, loss of crispness and juiciness), and nutritional quality. Transpiration can be controlled either through the direct application of post-harvest treatments to the produce (surface coatings and other moisture barriers) or through manipulation of the environment (maintenance of high relative humidity).

Treatments that can be applied to minimize water loss in fruits and vegetables include:

a) Curing of certain root vegetables, such as garlic, onion, potato, and sweet potato;
b) Waxing and the sue of other surface coatings on commodities, such as apple, citrus fruits, nectarine, peach, plum, pomegranate, and tomato;

c) Packaging in polymeric films that act as moisture barriers;
d) Careful handling to avoid physical injuries, which increase water loss from produce; and
e) Addition of water to those commodities that tolerate misting with water, such as leafy vegetables.

Table 2. Sanitizing chemicals used in produce handling.

Sanitizing chemicals	**Advantages**	**Disadvantages**
Chlorine compounds Calcium hypochlorite Sodium hypochlorite Chlorine gas Chlorine dioxide	Low cost	Corrosive, irritating, trihalomethanes are a by-product
Iodine compounds	Low cost, non irritating	Slightly corrosive, staining
Ozone	Faster action on microorganisms, fewer disinfection by-products than chlorine	Higher cost than chlorine
Peroxyacetic acid, Hydrogen peroxide	More effective in removing and controlling microbial bio films	Higher cost than chlorine

3. Treatments to Reduce Ethylene Damage

The promotion of senescence in harvested horticultural crops by ethylene (1ppm or higher) results in acceleration of deterioration and reduced post-harvest life. Ethylene accelerates chlorophyll degradation and induces yellowing of green tissues, thus reducing the quality of leafy, floral and immature fruit-vegetables and foliage ornamentals. Ethylene induces abscission of leaves and flowers, softening of fruits, and several physiological disorders. Ethylene may increase decay development of some fruits by accelerating their senescence and softening and by inhibiting the formation of antifungal compounds in the host tissue. In some cases, ethylene may stimulate the growth of fungi, such as *Botrytis cineria* on strawberries and *Penicillium italicum* on oranges.

The incidence and severity of ethylene-induced deterioration symptoms is dependent upon temperature, time of exposure, and ethylene concentration. The yellowing of cucumbers can, for example, result from exposure to either 1 ppm ethylene over 2 days or to 5 ppm ethylene over ½ day at 10°C. Ethylene effects are cumulative throughout the post-harvest life of the commodity.

Treatment of ornamental crops with 1-methylcylopropene (1-MCP), which is an ethylene action inhibitor, provides protection against ethylene damage. The commercial use of this product

at concentrations of up to 1 ppm on apples, apricots, avocados, kiwifruit, mangoes, nectarines, papayas, peaches, pears, persimmons, plums, and tomatoes was approved by the United States Environmental Protection Agency. The use of 1-MCP will no doubt be extended to several other fruits and vegetables, and to use in other regions.

4. Treatments for Decay Control

A major cause of losses in perishable crops is the action of a number of microorganisms on the commodity. Fungi and bacteria may infect the plant organ at any time. "Latent" infections, in which fungi invade fruit tissues shortly after flowering, become apparent only at the onset of ripening. Post-harvest rots frequently occur as a result of rough handling during the marketing process and are caused by a wide array of microorganisms. The grey mould *Botrytis cineria* is a very important cause of loss in many commodities (such as grapes, kiwifruit, pomegranates, raspberries, and strawberries), and is an aggressive pathogen, even at low temperatures. Virus infection frequently lowers the quality of perishable commodities, usually as a result of visual deterioration, although viruses may also affect flavour and composition.

Curing is a post-harvest treatment that facilitates certain anatomical and physiological changes that can prolong the storage life of some root crops (Table 3). It is one of the most effective and simple means of reducing water loss and decay during subsequent storage of root, tuber and bulb crops.

Sanitation practices include treatment to reduce populations of microorganisms on equipment, on the commodity, and in the wash water used to clean it. Water washes alone are effective in removing nutrients that allow microorganisms to grow on the surfaces of produce as well as in removing inoculums of post-harvest pathogens. The addition of sanitizers to water dumps and spray or dip washes, reduces inoculums levels for decay-causing organisms from fruit surfaces, inactivates spores brought into solution from fruit or soil and prevents the secondary spread of inoculums in water.

Treatments for decay control include:

- heat treatments, such as dipping mangoes in water at a temperatures of 50 °C, for 5 minutes in order to reduce subsequent development of anthracnose;
- use of post-harvest fungicides, such as imazalil and /or thiabendazole on citrus fruits;
- use of biological control agents alone or in combination with fungicides at lower concentrations on citrus fruits;
- use of growth regulators such as gibberellic acid or 2, 4-D to delay senescence of citrus fruits; and
- use of 15-20 percent CO_2 in air or 5 percent O_2 on strawberries, cane berries, figs, and pomegranates; and (6) use of SO2 fumigation(100 ppm for one hour) on grapes.

Table 3. Conditions for curing root, tuber and bulb crops.

Crop	Temperature (℃)	Relative humidity %	Duration (days)
Tapioca/Cassava root	30-40	90-95	2-5
Onion and garlic bulbs	30-45	60-75	1-4
Potato tubers	15-20	85-90	5-10
Sweet potato roots	30-32	85-90	4-7
Yam tubers	32-40	90-100	1-4

5. Treatment for Insect Control

Fresh fruits, vegetables and flowers may harbour a large number of insects during post-harvest handling. Many of these insect species, in particular fruit flies can seriously disrupt trade among countries. The identification and application of acceptable disinfestations treatments including irradiation will greatly facilitate globalization of trade in fresh produce. Criteria for the selection of the most appropriate disinfestations treatment for a specific commodity include cost, the efficacy of that treatment against insects of concern, safety of the treatment as well as the ability of that treatment to preserve and maintain produce quality.

Currently approved quarantine treatments, other than irradiation, include certification of insect-free areas, use of chemicals (e.g., methyl bromide, phosphine, hydrogen cyanide), cold treatments, heat treatments, and combinations of these treatments, such as methyl bromide fumigation in conjunction with cold treatment. The use of alternative treatments, such as fumigants (carbonyl sulphide, methyl iodide, sulphuryl fluoride) and insecticidal atmospheres (oxygen concentrations of less than 0.5 percent and/or carbon dioxide concentrations ranging between 40 and 60 percent) along or in combination with heat treatments, and ultraviolet radiation, are currently under investigation. These treatments are not, however, broad-spectrum treatments and are potentially phytotoxic when applied to some commodities.

Most insects become sterile when subjected to irradiation doses ranging between 50 and 750 Gy. The actual dosage required to produce sterility in insects varies in accordance with the species concerned and its stage of development. An irradiation dose of 250 Gy was approved by the United States quarantine authorities for application to fresh commodities, such as leeches, mangoes and papayas in light of the efficacy of that dose in preventing the reproduction of tropical fruit flies. Irradiation doses of 250 GY can be tolerated by most fresh fruits and vegetables with minimal detrimental effects on quality. Doses ranging between 250 and 1000 Gy (the maximum irradiation dose allowed as of 2002), can, however, be damaging to some commodities. Fruits, in general, are more tolerant to the expected dose range (250 to 500 Gy absorbed by fruits on the inside vs. those on the outside of the pallet) than non-fruit vegetables and cut flowers.

Detrimental effects of irradiation on fresh produce may include loss of green colour (yellowing), abscission of leaves and petals, tissue discoloration, and uneven ripening. These detrimental effects may not become visible until after the commodity reaches the market. The effects of irradiation must therefore be tested on individual commodities, prior to large scale commercialization of the irradiation treatment.

Post-harvest Treatments Designed to Manipulate the Environment around Produce in Order to Enhance Quality

1. Controlled / Modified Atmosphere (CA/MA) Storage

When used as supplements to keeping fresh horticultural perishables within their optimum ranges of temperature and relative humidity, controlled atmospheres (CA) or modified atmospheres (MA) can serve to extend their post-harvest-life. Optimum oxygen and carbon dioxide concentrations lower respiration and ethylene production rates, reduce ethylene action, delay ripening and senescence, retard the growth of decay-causing pathogens, and control insects. CA conditions which are not suited to a given commodity can, however, induce physiological disorders and enhance susceptibility to decay.

Several refinements in CA storage technology have been made in recent years. These include: the creation of nitrogen-on-demand by separation of nitrogen from compressed air through the use of either molecular sieve beds or membrane systems; use of low (0.7 to 1.5 percent) oxygen concentrations that can be accurately monitored and controlled; rapid establishment of CA, ethylene-free CA, programmed (or sequential) CA (such as storage in 1 percent O_2 for 2 to 6 weeks followed by storage in 2-3 percent O_2 for remainder of the storage period), and dynamic CA where levels of O_2 and CO_2 are modified as needed based on monitoring specific attributes of produce quality, such as ethanol concentration and chlorophyll fluorescence.

The use of CA in refrigerated marine containers continues to benefit from technological and scientific developments. CA transport is used to continue the CA chain for commodities (such as apples, pears, and kiwifruits) that had been stored in CA immediately after harvest. CA transport of bananas permits their harvest at a more advanced stage of maturity, resulting in the attainment of higher yields at the field level. In the case of avocados, CA transport facilitates use of a lower shipping temperature (5 °C) than if shipped in air, since CA ameliorates chilling injury symptoms. CA in C) than if shipped in air, since CA ameliorates chilling injury symptoms.

At the commercial level, CA is most widely applied during the storage and transport of apples and pears. It is also applied to a lesser extent on kiwifruits, avocados, persimmons, pomegranates, nuts and dried fruits. Atmospheric modification during long-distance transport is used for apples, avocados, bananas, blueberries, cherries, figs, kiwi-fruits, mangoes, nectarines, peaches, pears, plums, raspberries and strawberries. Technological developments geared toward providing CA

during transport and storage at reasonable cost (positive benefit/cost ratio) are essential if the application of this technology to fresh fruits and vegetables is to be expanded.

Although MA and CA have both been shown to be effective in extending the post-harvest life of many commodities their commercial application has been limited by the relatively high cost of these technologies. There are however a few cases in which a positive on investment (cost/benefit ratio) can be demonstrated. In a comparison of losses due to decay during retail marketing of strawberries shipped in air and those shipped in an environment consisting of 15 percent CO_2-enriched air (modified atmosphere within pallet cover), the use of modified atmosphere was observed to reduce losses by 50 percent (an average of 20 percent losses was sustained in strawberries shipped in air vs. 10 percent losses in those shipped by MA). The economic loss of 10 percent value (US$50-75 per pallet) was much greater than the cost of using MA (US$15-25 per pallet).

Use of controlled atmosphere (CA) during marine transportation can extend the post-harvest-life of those fruits and vegetables that would normally have a short post-harvest-life potential, thereby allowing the use of marine transportation instead of air transport for the shipment of such produce. In terms of cost and benefit, savings, realized with the use of marine transportation are much greater than is the added cost of CA service.

2. Ethylene Exclusion and Removal

Many green vegetables and most horticultural produce are quite sensitive to ethylene damage. Their exposure to ethylene must therefore be minimised. Ethylene contamination in ripening rooms can be minimized by 1) using ethylene levels of 100 ppm instead of the higher levels often used in commercial ripening operations, 2) venting ripening rooms to the outside on completion of exposure to ethylene, 3) at least once per day ventilating the area around the ripening rooms and installing an ethylene scrubber, and 4) use of battery-powered forklifts instead of engine-driven units in ripening areas.

Ethylene-producing commodities should not be mixed with ethylene-sensitive commodities during storage and transport. Potassium permanganate, an effective oxidizer of ethylene, is commercially used as an ethylene scrubber. Scrubbing units based on the catalytic oxidation of ethylene are used to a limited extent in some commercial storage facilities.

Return on investment in reducing ethylene damage

A University of California study showed that the use of an ethylene scrubber in storage facilities used for lettuce significantly reduced russet spotting. The difference in value of lettuce that was protected from ethylene vs. that which was exposed to ethylene was estimated to be 20 to 25 percent, which was greater than the cost of the ethylene scrubber. Similar results were found with kiwi fruits, which soften very rapidly when exposed to ethylene levels as low as 50 ppb.

Treatments to enhance uniformity in fruit ripening

Ethylene treatment is commercially used to enhance the rate and uniformity of ripening of fruits such as bananas, avocados, mangoes, tomatoes, and kiwifruits. Optimal ripening conditions are as follows:

Temperature	18 °C to 22°C
Relative humidity	90 to 95 per cent
Ethylene Concentration:	10 to 100 ppm
Duration treatment	24 to 74 hours depending on fruit type and stage of maturity
Air circulation	Sufficient to ensure distribution of ethylene within the ripening room
Ventilation	Require adequate air exchange in order to prevent accumulation of O_2 which reduces the effectiveness of C_2H_4

Epilogue

It augers well that there is a better appreciation of effective and efficient post-harvest management (PHM) of food commodities especially of perishable kind as compared to situation in the past when production and productivity alone were the major criteria for achievement. This is especially true for India where the realisation has come only late and researches on PHM got a boost and the Government has also come out with policies and strategies to derive maximum benefit from the commodity by not only adopting Good Production Practices (GPP) but also reducing huge post-harvest losses by harvesting/plucking/picking at optimum maturity, improving the infrastructure for safe handling, transit or long term storage, packaging and transport under cool condition for boosting the shelf life. With the increasing growth of economy, a large middle class has (200-250 million) has emerged in India which has the capacity and willingness to buy quality goods at competitive price. Further, the intake of fruits and vegetables in the diet has also been increasing for meeting the requirement of vitamins, mineral and fibres etc. Also, there is increasing demand of processed (RTC, RTE, RTS) food due to convenience and its year round availability. There is an increasing demand for fresh and processed products amongst India Diaspora and other communities in the West Asia, Europe, etc.

Even though there has been tremendous spurt in the production of fruits and vegetables, the scenario at processing and value addition is not very impressive. Still, the levels of processing are low and most of processing is done in un-organized sector which has least concern / knowledge about quality and safety aspects so crucial for a better acceptance of processed produce at domestic and international level. Obviously, there is a great need for achieving quantum jump in organized. This can happen by developing/ strengthening backward and forward linkages, emphasis on high quality of raw materials, effective PHM including safe handling, transport and storage and

efficient marketing. In this value chain, the importance of producers/growers needs to be highlighted. They need to be sensitized/trained on the GPP, safety and quality and given access to latest technology, effective cold chain and strong market intelligence. ICT will play an increasing role in the PHM for empowering all stakeholders.

The future of fruits and vegetable, both in raw and processed form, is bright and beside providing quality, safe, healthy, nutritive food for huge domestic market in India but also capture a good slice of international market as well. The need is to devise suitable strategies for effecting necessary changes in the current practices which are ripe for such action.

Postharvest Handling of Fruits and Vegetables Horticulture Technical Note

Abstract

Appropriate production practices, careful harvesting, and proper packaging, storage, and transport all contribute to good produce quality. This publication covers postharvest practices suitable for small-scale operations, and points out the importance of production and harvesting techniques for improving quality and storability. Various methods for cooling fresh produce are discussed, and resources are listed for further information, equipment, and supplies.

Introduction

You have spent months working in the fields, and now have a bountiful harvest of beautiful fruis and vegetables. You want to ensure that your customers will also enjoy this healthy harvest. Howe can you best maintain the quality and safety of your produce as it travels from the field to the table ? How can produce be stored so that it does not need to be sold immediately? High-quality, disease-free produce with a good shelf life is a result of sound production practices, proper handling during harvest, and appropriate postharvest handling and storage.

Sanitation

Sanitation is of great concern to produce handlers, not only to protect product against postharvest diseases, but also to protect consumers from food borne illnesses. *Salmonella, Chryptosporidium, Hepatitis, and Cyclospera* are among the disease-causing organisms that have been transferred via fresh fruits and vegetables. Use of a disinfectant in wash water can help to revent both postharvest diseases and food borne illnesses.

The effectiveness of chlorine concentrations are reduced by temperature, light and interaction with soil and organic debris. The wash water should be tested periodically with a monitoring kit,

indicator strips, or a swimming pool-type indicator kit. Concentrations above 200 ppm can injure some vegetables (such as leafy greens and celery) or leave undesirable off-flavours.

Ozonation is another technology that can be used to sanitize produce. A naturally occurring molecule, ozone is a powerful disinfectant. Ozone has long been used to sanitize drinking water, swimming pools, and industrial wastewater. Fruit and vegetable growers have begun using it in dump tanks as well, where it can be thousands of times more effective than chlorine. Ozone not only kills whatever food borne pathogens might be present, it also destroys microbes responsible for spoilage. A basic system consists of an ozone generator, a monitor to gauge and adjust the levels of ozone being produced, and a device to dissolve the ozone gas into the water. Systems cost anywhere from US $10,000 to US $1,00,000 and should be installed by an ozone sanitation company experienced in produce industry applications.

Hydrogen peroxide can also be used as a disinfectant. Concentrations of 0.5% or less are effective for inhibiting development of post harvest decay caused by a number of fungi. Hydrogen peroxide has a low toxicity rating and is generally recognized as having little potential for environmental damage. The ATTRA publication ***sources for Organic Fertilizers and Amendments*** lists several sources of food-grade hydrogen peroxide.

Ethylene

Ethylene, a natural hormone produced by some fruits as they ripen, promotes additional ripening of produce exposed to it. The old adage that one bad apple spoils the whole bushel is true. Damaged or diseased apples produce high levels of ethylene and stimulate the other apples to ripen too quickly. As the fruits ripen, they become more susceptible to diseases.

Ethylene “producers” should not be stored with fruits, vegetables, or flowers that are sensitive to it. The result could be loss of quality, reduced shelf life, and specific symptoms of injury. Some examples of ethylene effects include:

- Russet spotting of lettuce along the midrib of the leaves;
- Loss of green colour in snap beans;\
- Increased toughness in turnips and asparagus spears;
- Bitterness in carrots and parsnips;
- Yellowing and abscission of leaves in broccoli, cabbage, Chinese cabbage, and cauliflower;
- Accelerated softening of cucumbers and summer squash;
- Softening and development of off-flavour in watermelons;
- Browning and discoloration in brinjal pulp and seed;
- Discoloration and off-flavour in sweet potatoes;
- Sprouting of potatoes;
- Increased ripening and softening of mature green tomatoes; and

- Shattering of raspberries and blackberries

Ethylene producers include apples, apricots, avocados, ripening bananas, cantaloupes, honeydew melons, ripe kiwifruit, nectarines, papayas, passionfruit, peaches, pears, persimmons, plantains, plums, prunes, quinces, and tomatoes.

Mixed Loads

When different commodities are stored or transported together it is important to combine only those produce products that are compatible with respect to their requirements for temperature, relative humidity, atmosphere (oxygen and carbon dioxide), protection from odours, and protection from ethylene.

In regard to cross-transfer of odours, combinations that should be avoided in storage rooms include : apples or pears with celery, cabbage, carrots, potatoes, or onion; celery with onions or carrots and citrus with any of the strongly scented vegetables. Odours from apples and citrus are readily absorbed by meat, eggs, and dairy products. Pears and apples acquire an unpleasant, earthy taste and odor when stored with potatoes. It is recommended that onions, nuts, citrus, and potatoes each be stored separately.