Post-harvest Management of Horticultural Crops

Post harvest Management of Horticultural Crops

Importance of post-harvest technology in horticultural crops. Maturity indices, harvesting, handling, grading of fruits, vegetables, cut flowers, plantation crops, medicinal and aromatic plants. Pre-harvest factors affecting quality, factors responsible for deterioration of horticultural produce, physiological and bio-chemical changes, hardening and delaying ripening process. Post-harvest treatments of horticultural crops. Quality parameters and specification. Structure of fruits, vegetables and cut flowers related to physiological changes after harvest. Methods of storage for local market and export. Pre-harvest treatment and precooling, pre-storage treatments. Different systems of storage, packaging methods and types of packages, recent advances in packaging. Types of containers and cushioning materials, vacuum packaging, cold storage, poly shrink packaging, grape guard packing treatments. Modes of transport.

***Practical**: Practice in judging the maturity of various horticultural produce, determination of physiological loss in weight and quality. Grading of horticultural produce, post-harvest treatment of horticultural crops, physical and chemical methods. Packaging studies in fruits, vegetables, plantation crops and cut flowers by using different packaging materials, methods of storage, post-harvest disorders in horticultural produce. Identification of storage pests and diseases in spices. Visit to markets, packaging houses and cold storage units.*

Lecture - 21

Part -10

PULSING – Flowers

Pulsing is 'supplying a solution through transpiration stream'. Term pulsing means placing freshly harvested flowers for a relatively short time from few seconds to hours in a solution specially formulated to extend their vase life. This process is also called as hydration and it can be facilitated by addition of wetting agent to water.

Methods of Pulsing

Cut flowers are pulsed with sugars, such as sucrose. Sucrose pulsing involves concentration of 5 -20% treated for overnight at 2^0C or at warm temperature of 21^0C for 10 minutes.

Cut flowers such as carnation and delphiniums are pulsed with anti ethylene agents like silver thio sulfate (STS) or aminooxyacetic acids(AOA). AOA is toxic to most flowers except carnation. Pulsing is also done through applying 2-4 mM silver ions for 15-45 minutes at ambient temperature or 0.5mM silver overnight at 1^0C.

Cut flowers are also pulsed with dyes, such as the food grades blue used on white carnation to give interesting visual effects like blue coloured petal veins and margins.

Drying - Cut flowers and foliages reserved for desiccation/drying can be pulsed for one to a few days with humectants, such as 20-30% glycerol. This process is known as uptake preservation. This retains suppleness (flexible), associated with the humectants chemical attracting water vapour from the atmosphere in to the tissue. During pulsing with humectants, often brown, red, green, blue and others dyes are frequently supplied along with the humectants.

TINTING

Artificial colouration of flowers is called tinting. It is applied through

a. stem (carnation)
b. dipping the flowers heads (daisies)

a. Tinting via stem - is done with adding food grade dye solution with appropriate chemicals in a bucket of warm water of 41^0C. The carnation flowers to be tinted (usually white coloured) are allowed to stress overnight in packing house at 18^0C to increase the rate of solution uptake. Dying is stopped before the flowers reach the desired colour, because dye still in the stem is flushed into the flowers by vase solution.

b. Dipping – is carried through tinting solution containing aniline dyes dissolved in isopropanol. The head of the flowers are dipped in a dye solution and shaken to remove surplus solution and placed on a rack to dry before storage or packing.

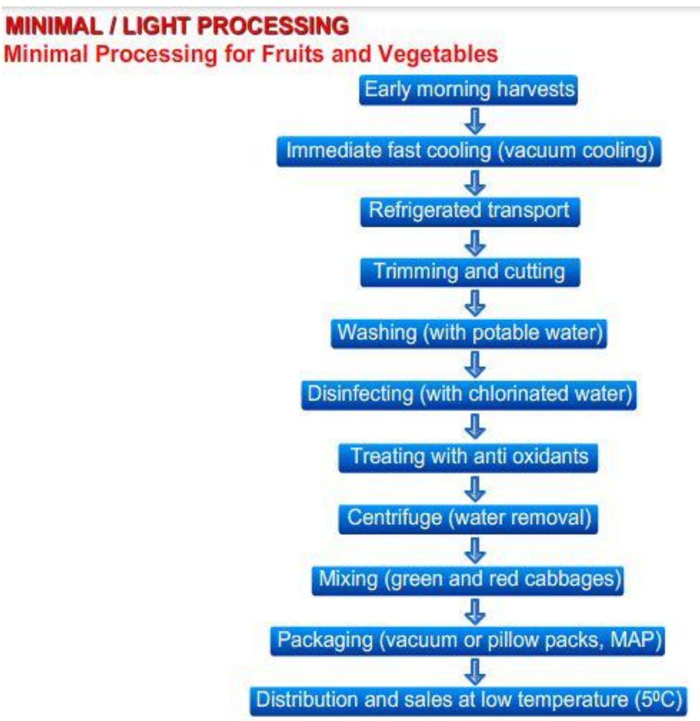
Fig. Artificial coloration in flower carnation

MINIMAL PROCESSING

Operations such as peeling, slicing, grating or shredding of fruits and vegetables is called minimally processing. It is also called partial/fresh/light processing or pre prepared products. Purpose of light processing is to serve the customers with fruits and vegetables that are convenient to prepare and yet maintain fresh like quality while containing only natural ingredient.

Consumers are demanding convenient, ready-to-serve and ready-to-eat fruits and vegetables with a fresh quality and appearance. However, these living products require special attention during the whole handling process, from harvest to consumption, to mantain quality.





Examples

1. Shredding of cabbage/ lettuce
2. Shelling of peas
3. Snapping of beans
4. Grating of carrot
5. Cauliflower and broccoli florets
6. Sticks of carrot and celery
7. Trimmed spinach
8. Peeled and sliced potatoes
9. Diced onion

10. Slices of mango cheeks/ melons/papaya/apple/others
11. Pieces of pomelo segments and other citrus fruits
12. Peeled and cored pineapple
13. Chilled peach
14. Pomegranate arils dressing
15. Drying of onion, mango lather, grapes, sun dried tomato
16. Microwaveable fresh vegetable trays


Minimal processing generally increases the rates of metabolic processes that cause deterioration of fresh products. Hence, modified gas atmosphere with low O_2 and high CO_2 minimise the oxidative browning on cut surface.
Good hygiene **+** low temperature handling is required to prevent the potential toxic pathogens like *Listeria* spp., E-coli, salmonella *etc*.

Important process variable which determines the degree of tissue wounding are:
- ✓ Methods of cutting (knives, lasers)
- ✓ Equipment maintenance (knife sharpening/cleaning)
- ✓ Angle of cut

Various non thermal methods have been used to maintain the freshness of the minimally processed products such as
- ✓ MAP
- ✓ Moderate vacuum packaging
- ✓ Irradiation
- ✓ Use of edible film and coatings (essential oils and waxing)
- ✓ Naval and new preservatives (eg. bacteriocins, polycationic polymers, anti microbial enzymes)
- ✓ High intensity pulsed electric fields
- ✓ Oscillating magnetic fields
- ✓ Intense light pulse
- ✓ Ultrasonics
- ✓ High hydrostatic presser

Minimum processing is generally without thermal treatments, excepting French beans which requires very short blanching. Permissible additives and preservatives with restricted levels is used so that it will not alter the sensory attributes helps in retaining the freshness of the produce to a longer period.

Lecture – 22

Part - 1

STORAGE OF HORTICULTURAL CROPS

Many horticultural crops are seasonal in nature and have a relatively short harvesting season. As discussed earlier they are also highly perishable. Hence, proper storage of these produce using appropriate methods would prolong their availability. Storage of fresh produce will also be helpful in checking market glut, providing wide selection of fruits, vegetables and flowers to the consumer through most part of the year i.e. especially during the off season. Storage helps in orderly marketing and increases profit to the producers/farmers. Storage of fresh produce is done to maintain freshness, quality, reduce the spoilage and extend their usefulness. One of the reasons for the huge post harvest losses of horticultural produce is lack of proper storage facilities. The basic principle of storage is to reduce the rate of physiological processes like respiration, transpiration, ripening and other biochemical changes. Proper storage also aims at controlling disease infection and preserving the commodity in its best quality for consumers.

What are the goals of storage?
- ✓ Slow down biological activity
- ✓ Reduce product drying and moisture loss
- ✓ Reduce pathogenic infection
- ✓ Avoid physiological disorders
- ✓ Reduce physical damage

Factors affecting storage:
Storage life of fresh horticultural produce is affected by many factors like

- **i)** Pre harvest factors
- **ii)** Maturity at harvest
- **iii)** Harvesting and handling practices
- **iv)** Pre-storage treatments
- **v)** Temperature and humidity in storage room
- **vi)** Overall hygiene

Temperature and relative humidity are the most important among the above factors. Fresh horticultural produce continue to respire after harvest and temperature is able to regulate this physiological activity. Higher the temperature, faster the, these physiological and biochemical processes leading to early senescence. Senescence is the final stage in the development of the plant organ during which changes take place that ultimately lead to break down and death of plant cells and termination of storage life of fresh produce.

Storage life of horticultural produce may be extended by temperature control, chemical treatments, atmosphere modification, mainly by regulating the physiological processes and controlling the post harvest diseases and pests. However, till date, low temperature storage is the only known economical method for long term storage and quality maintenance of horticultural produce. All other methods will only useful in supplementing the low temperature storage.

Principles of storage

1. Control of respiration:

Respiration is a breakdown process; hence storage method should provide a means to minimize this metabolic process**.** Cold storage, atmospheric modification, low pressure storage are the methods used based on this principle. The heat generated during respiration, usually know as respiratory heat /heat of respiration, accumulates in the centre of the storage. The rate of respiration of stored produce increases if this heat is not removed from the storage room. So, proper ventilation will help in removing this heat thereby reducing the respiration rate. Reducing respiration rate will also help in delaying the ripening process in some fruits and vegetables thereby extending the storage life

2. Control of transpiration:

Fresh produce continues to lose water even after harvest resulting in wilting or shriveling of produce. A 5% loss of moisture is enough to make the produce shrivel making it unattractive for marketing. Relative humidity and temperature are the important factors that influence the loss of moisture from fresh produce. Water loss will also be high with increase in storage temperature. Fresh produce transpire more at high temperatures and low humidity. Hence, this process can be controlled by storing the produce at low temperatures and high relative humidity.

3. Prolonging the Dormancy period/Control of sprouting and rooting: Some root and tuber type vegetables after harvest enter into a resting phenomenon know as Dormancy. During this period, sprouting and rooting of these crops does not occur. However, under favourable conditions these crops re-grow resulting in sprouting and rooting. Consumers do not prefer the sprouted or rooted vegetables for buying. Sprouting also makes the produce to lose moisture quickly, shrivel and become prone to microbial infection. Hence, prolonging the dormant period by creating unfavorable conditions is the principle for extending the storage life of this type of produce.

4. Control of spoilage

Fresh produce have high moisture and readily available nutrient and therefore readily attacked by microorganisms. Favourable conditions like warm temperature and high humid condition in the storage room enhance the growth of these micro-organisms and increase the spoilage. Hence, storage methods should aim at retarding or control of the growth of these spoilage causing micro-organisms.

A. TRADITIONAL / LOW COST STORAGE TECHNOLOGIES

1. In situ/ On site/ Natural or field storage

In Situ means delaying the harvest until the crop is required and is employed for the root, tuber and rhizomes crops. Crops should be left in the soil until preparation for the market. The land where crop is grown remains occupied and new crop cannot be planted there. This is similar to how citrus and some other fruits are left on the tree.

Eg.: Roots (carrots, sweet potato, and cassava) tubers (potato) and rhizomes (Ginger).

Disadvantages: In case of cassava, delayed harvest results in reduced acceptability and starch content and pre harvest losses. The crops should be protected from pest and disease attack, chilling and freezing injuries.

2. Sand and Coir

In India, potatoes are traditionally stored longer periods of time, which involves covering the commodity underground with sand.

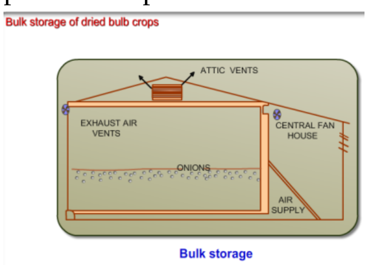
3. Bulk storage of dried bulb crops

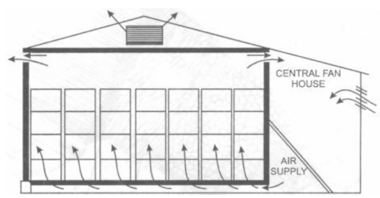
Onions, garlic and dried produce are best suited to low humidity in storage. Onions and garlic will sprout if stored at intermediate temperatures. Pungent types of onions have high soluble solids and will store longer than mild or sweet onions, which are rarely stored for more than one month.

Storage conditions for onion, garlic *etc.*

Commodity	Temp. °C	RH	Potential storage duration
Onions	0-5	65-70	6-8 months
	28-30	65-70	1 month
Garlic	0	70	6-7 months
	28-30	70	1 month
Dried fruits and vegetables	<10	55-60	6-12 months

For bulk storage of onions or garlic, ventilation systems should be designed to provide air into the store from the bottom of the room at a rate of 2 cubic feet /minute /cubic feet of produce. If produce is in cartons or bins, stacks must allow free movement of air.





Storage in cartons or bins

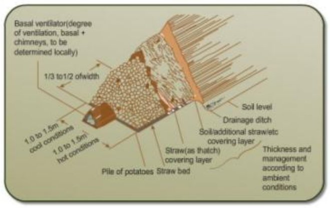

Field storage of onions in heaps

4. Clamp storage of root and tuber crops

Potatoes for processing are best kept at intermediate temperatures to limit the production of sugars which darken when heated during processing. Potatoes meant for consumption must also be stored in the dark, since the tubers will produce chlorophyll (turning green) and develop the toxic alkaloid solanine if kept in the light. Potatoes stored for use as seed are best stored in diffused light. The chlorophyll and solanine that accumulate will aid to protect the seed potatoes from insect pests and decay organisms.

Tropical root and tuber crops must be stored at temperatures that will protect the crops from chilling, since chilling injury can cause internal browning, surface pitting and increased susceptibility to decay.

Commodity	Temperature °C	RH (%)	Potential storage duration
Potatoes (Fresh market)	4-7	95-98	10 months
Seed potatoes	0-2	95-98	10 months
Cassava	5-8	80-90	2-4 weeks
	0-5	85-95	6 months
Sweet potato	12-14	85-90	6 months
Ginger	12-14	65-75	6 months



Field storage clamp

Simple storage house

Store room with plenty of ventilation

5. Storage using evaporative coolers/ Evaporative cooling

The principle of evaporation can be used to cool stores by first passing the air into the store through a pad of water. The degree of cooling depends on the original humidity of the air and the efficiency of evaporating surface. Both active and passive evaporative cooling systems are used. In a passive system, the cooling pads are placed over the entrance of the store and kept moist. In active system, air is drawn into the store by a fan through a pad, kept moist by constantly pumping water over it. The latter type is more efficient in cooling but requires an electricity supply.

Zero Energy Cool Chambers (ZECC)

It is based on the principle of direct evaporative cooling. It does not require any electricity or power to operate. The materials required to make this chamber are cheap and available easily.

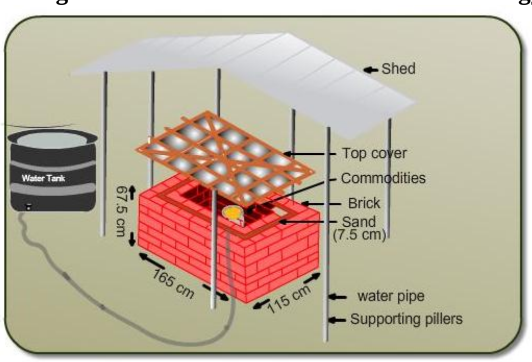
Design and Construction

The floor of the storage space is made with a single layer of bricks over which a doubled wall rectangular structure is erected with approximately 7.5 cm space between the inner and the outer brick walls. The outer dimensions of the chamber should be about 165x115x67.5 cm. The cavity between the two walls is filled with river sand. The top of storage space is covered with gunny cloth in a bamboo frame structure. The chamber should be constructed under a shed with a lot of aeration and should be closer to water source.

Operation: After construction, the whole structure is made wet by sprinkling water once in evening till it is saturated to maintain a lower temperature and higher humidity in it. Direct contact of water with fruits and vegetables should be avoided. Fruits and vegetables should be placed in crates or in suitable baskets and then in the chamber. Maximum and minimum thermometer and a wet and dry thermometer are placed in the chamber to note temperature and relative humidity in the cool chamber.

Storage life-Storage life of different commodities can be increased by 2 to 3 times as compared to ambient conditions especially during summer.

Storage life of different commodities in zero energy cool chambers



Vegetables	Months	Storage life (days)	
		Ambient	ZECC
Bitter gourd	May-June	2	6
Carrot	Feb-Mar	5	12
Cauliflower	Feb-Mar	7	12
Cucumber	May- June	3	8
Green chillies	May- June	3	6
Ladies finger	May- June	1	6
Peas	Feb-Mar	5	10
Spinach	Feb-Mar	3	8

6. Natural ventilation

Amongst the wide range of storage systems, this is the most simple. It takes advantage of the natural airflow around the product to remove heat and humidity generated by respiration. Buildings providing some form of protection from the external environment and with gaps for ventilation can be used. Produce can be placed in bulk, bags, boxes, bins, pallets *etc*. Eg. Onion, garlic and shallot

Fig.: Storing garlic in shelters with natural ventilation

Lecture schedule – 23

Part - 2

HIGH COST STORAGE TECHNOLOGY / IMPROVED STORAGE METHODS

1. Cold storage - Refrigeration, Chilling and Freezing
2. Controlled Atmosphere Storage (CA Storage)
3. Modified Atmosphere Storage (MA Storage)
4. Solar driven cold stores
5. Low Pressure Storage / Hypobaric Storage
6. Jacketed storages

Low temperature storage (Refrigeration/cold storage)

Low temperature storage is the best known, effective and most widely used method for extending the storage life and long terms storage of fruits, vegetables and flowers. In post harvest technology, "temperature management is the most important aspect to be looked after to maintain quality, reduce losses and extend the storage life of these perishable commodities. Cold storage is a system with thermal insulation and refrigeration in which perishables commodities can be stored for a set period of time under controlled conditions of temperature and humidity.

Why cold storage is necessary?

- For preservation
- For maintaining nutritional quality
- To increase storage life
- To ensure availability of the produce throughout the year for direct consumption as well as processing
- To reduce losses due to wastage
- To preserve the seasonal produce and selling during off season to fetch higher returns

Factors involved for effective cold storage of the produce:

- ✓ **Product quality**: Fresh horticultural produce intended for storage should be free from physical damage, of optimum maturity and free from infections.
- ✓ **Temperature**: Low temperature storage is recommended for perishables as it retards respiration and metabolic activity, aging due to ripening, softening and textural and colour changes, moisture loss, spoilage due to diseases and undesirable growth (sprouting/ cooling). Maintenance of uniform temperature constantly, continuously and also adoption of optimum low temperature for each specific produce are very essential.
- ✓ **Relative Humidity**: The relative humidity of the air in storage rooms directly affects the keeping quality of the produce held in them. If it is too low, wilting or shrivelling is likely to occur, if it is too high, it may favour the development of decay. An RH of 85-90% is recommended for most perishables.
- ✓ **Air circulation and package spacing**: Air must be circulated to keep a cold storage room at an even temperature throughout the storage. This is required to remove respiratory heat. Entry of outside air and proper spacing of containers on pellets are also important.
- ✓ **Respiration rates, heat evolution and refrigeration**: When the storage of fresh produce is considered, it should be remembered that these commodities are alive and carry on all activities of living tissues, the most important being respiration. During this process, energy is released in the form of heat which varies with the commodity and the temperature. This `vital heat' expressed in BTU (British thermal units) is of paramount importance in calculating the refrigeration load of the commodity.

- ✓ **Weight loss in storage**: Loss of water from harvested horticultural crops is a major cause of deterioration in storage. Some loss can be tolerated but losses great enough to cause wilting or shrivelling must be avoided. Under good handling conditions with recommended humidity and temperature, moisture loss can be held under control.
- ✓ **Sanitation and Air purification:** Good air circulation alone is of considerable value in minimizing surface moulds. Accumulation of odours and volatiles may contribute to off flavours and hasten deterioration.
- ✓ **Temperature management:** Refrigeration (Low temperature and humidity) requirements vary with different kinds of fresh produce and the maturity stages. For most of the fresh fruits and vegetables (except onion, garlic) the relative humidity in cold storage should be kept in the range of 85 to 95%. Temperature Management involving storage at optimum temperature requirement of each produce (as shown in the tables) is very essential to maintain quality and extend storage life. Chilling injury, to which the tropical fruits and vegetables are susceptible/sensitive, is a major problem, if they are stored at lower than optimum temperature.

Key words

Refrigeration – is the process of removing heat from an enclosed space or commodity. Main function is to lowering the temperature and maintaining the lower temperature.

Cooling - it refers to any natural or artificial process by which heat is dissipated.

Cryogenics – process of artificially producing extremely cold temperature by using cryogenic refrigerants such as liquid nitrogen.

Cold – it is absence of heat. To decrease the temperature, heat must be removed rather than adding cold.

Refrigeration ton/tonne – is the unit used to quantify the refrigeration load.

One tonne of refrigeration - is defined as the energy removed from the one metric tonne (1000kg) of water to freeze within 24hr at 0^0C.

One tonne of refrigeration =13898kj/hr = 3.861kw

One tonne of refrigeration is about 10% larger than 1 ton of refrigeration (3.517 kW).

Capacity requirement - 1 Ton(3.5 kw) of refrigeration required to cool 18 T produce.

Variation in whole cold storage should not exceed ± 1^0C, whereas it should not exceed ± 0.5^0C in one position

1kg of melting ice absorbs 325kj of heat

The refrigeration cycle - Principle of refrigeration

The refrigeration cycle (shown in Diagram 1 below) begins with the refrigerant in the evaporator. At this stage the refrigerant in the evaporator is in liquid form and is used to absorb heat from the product. When leaving the evaporator,the refrigerant has absorbed a quantity of heat from the product and is a low-pressure, low-temperature vapour.

This low-pressure, low-temperature vapour is then drawn from the evaporator by the compressor. When vapour is compressed it rises in temperature. Therefore, the compressor transforms the vapour from a low-temperature vapour to a high-temperature vapour, in turn increasing the pressure. This high-temperature, high-pressure vapour is pumped from the compressor to the condenser; where it is cooled by the surrounding air, or in some cases by fan assistance. The vapour within the condenser is cooled only to the point where it becomes a liquid once more. The heat, which has been absorbed, is then conducted to the outside air.

At this stage the liquid refrigerant is passed through the expansion valve. The expansion valve reduces the pressure of the liquid refrigerant and therefore reduces the temperature. The cycle is complete when the refrigerant flows into the evaporator, from the expansion valve, as a low-pressure, low-temperature liquid.

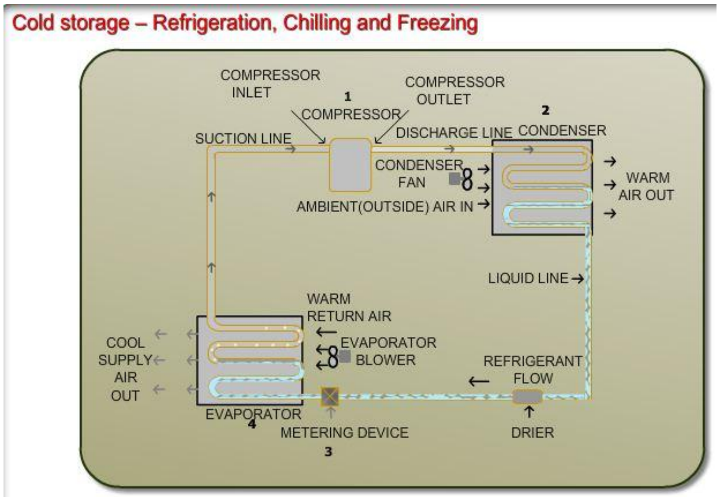


Illustration of a refrigeration cycle

For determination of refrigeration load, the following factors should be quantified (heat inputs)

- ✓ Field heat
- ✓ Heat of respiration of the produce
- ✓ Conductive heat gain – building floor, wall, roof ceiling *etc*.
- ✓ Convective heat gain – air mixing during opening of door
- ✓ Equipment load – fans, lights, forklifts and personnel *etc*.
- ✓ Service and defrost factors of the facility – hot weathers

Refrigeration system components

There are five basic components of a refrigeration system, these are:

- ✓ Evaporator
- ✓ Compressor
- ✓ Condenser
- ✓ Expansion Valve
- ✓ Refrigerant; to conduct the heat from the product

The Evaporator: The purpose of the evaporator is to remove unwanted heat from the product, via the liquid refrigerant. The liquid refrigerant contained within the evaporator is boiling at a low-pressure.

To enable the transfer of heat, the temperature of the liquid refrigerant must be lower than the temperature of the product being cooled. Once transferred, the liquid refrigerant is drawn from the evaporator by the compressor via the suction line. When leaving the evaporator coil the liquid refrigerant is in vapour form.

The Compressor: The purpose of the compressor is to draw the low-temperature, low-pressure vapour from the evaporator via the suction line. Once drawn, the vapour is compressed. When vapour is compressed it rises in temperature. Therefore, the compressor transforms the vapour from a low-temperature vapour to a high-temperature vapour, in turn increasing the pressure. The vapour is then released from the compressor in to the discharge line.

The Condenser: The purpose of the condenser is to extract heat from the refrigerant to the outside air. The condenser is usually installed on the reinforced roof of the building, which enables the transfer of heat. Fans mounted above the condenser unit are used to draw air through the condenser coils. The temperature of the high-pressure vapour determines the temperature at which the condensation begins. As heat has to flow from the condenser to the air, the condensation temperature must be higher than that of the air; usually between -12°C and -1°C. The high-pressure vapour within the condenser is then cooled to the point where it becomes a liquid refrigerant once more, whilst retaining some heat. The liquid refrigerant then flows from the condenser in to the refrigerant line.

The Expansion Valve: Within the refrigeration system, the expansion valve is located at the end of the refrigeran line, before the evaporator. The high-pressure refrigeran reaches the expansion valve, having come from the condenser. The valve then reduces the pressure of the refrigerant as it passes through the orifice, which is located inside the valve. On reducing the pressure, the temperature of the refrigerant also decreases to a level below the surrounding air. This low-pressure, low-temperature refrigeran is then pumped in to the evaporator.

Low temperature injuries: Majority of tropical horticultural produce are injured when stored at very low temperatures due to chilling injury. However, the optimum low temperature for storage should be above freezing temperature and also not to cause chilling injury.

Chilling injury occurs when commodities of tropical and subtropical origin, such as mango, banana and tomato are held at temperatures above their freezing point and below 5 to 15°C depending on the commodities. Chilling injury is manifested in a variety of symptoms, which are listed below.

Chilling injury symptoms:

1. Surface of pitting
2. Discolouration – browning, blackening, etc of the external or/and internal tissues.
3. Appearance of water soaked areas
4. Development of necrotic areas
5. Failure of mature fruits to ripen
6. Increased susceptibility to decay
7. Reduction in storage life
8. Loss of characteristic flavour
9. Increase in certain physiological activities like increase in respiration rate, ethylene production, etc.

The symptoms of chilling injury occurs while the produce is stored at lower temperature for comparatively longer time, but sometimes will only appear when the commodity is removed from the chilling temperature to a high temperature.

Reduction / alleviation of chilling injury

Storing at optimum temperature or above the critical temperature for particular commodity is the safest method to avoid chilling injury. Several treatments have been shown to alleviate or at least reduce the chilling injury on some commodities, if they are to be stored at lower temperature.

Treatments to reduce/alleviate chilling injury

A. Treatments before storage

1. Temperature conditioning – gradual lowering of storage temperatures
2. Ethylene treatment of fruits
3. Exposure to elevated CO_2

4. Modified atmosphere packaging

B. <u>Treatments during storage</u>

1. Intermittent exposure to higher temperatures
2. Holding under modified atmosphere/controlled atmosphere
3. Holding under low pressure(Hypobaric storage)
4. Maintenance of high RH

Chilling sensitive (susceptible to chilling injury) commodities

Avocado	Cucumber	Passion fruit	Sapota
Banana	Guava	Pineapple	Squash
Beans(Snap)	Mango	Potato	Sweet Potato
Brinjal	Muskmelon	Pumpkin	Watermelon
Citrus	Okra(bhendi)	Tomato	Yam
Capsicum	Papaya		

Non-Chilling sensitive (not susceptible to chilling injury) commodities

Apple	Pears	Beets	Lettuce
Apricot	Plum	Broccoli	Onion
Carrot	Prunes	Brussels sprouts	Peas
Cherries	Strawberry	Cabbage	Radish
Figs	Artichokes	Cauliflower	Spinach
Grapes	Asparagus	Celery	Turnips
Peaches	Beans, Lima	Garlic	

Effect of cold storage on subsequent behaviour of horticultural produce: At refrigerated temperatures, aging and decay are retarded, resulting in longer life. As the potential life is used up in storage, the stored produce cannot stay for longer period after removal as freshly harvested produce. In some cases in post storage period, the produce has to be ripened properly. Removal of refrigerated stored produce to higher temperature should be done by a gradual warming to `avoid sweating' resulting in loss of quality.

Mixed commodities: Not all the produce can be stored together because of difference in their temperature requirements. But at times, it may be necessary to store different produce together provided the optimum low temperatures do not differ much. Cross transfers of odours, ethylene, and strongly scented produce should be avoided in mixed storage. Based on the compatibility of produce, without any deleterious effect it can be stored.

Cold chain: This involves the "chain" which starts from the field and ends on the consumer's table, involving Precooling, refrigerated transport, low temperature (refrigerated) storage and distribution i.e. transport to the wholesalers, retailers to the consumers, under refrigerator condition and storage in home refrigeration until consumed.

The harvested produce has to be graded either for export or local trade in nearby packing houses, packed in containers to be precooled to the storage temperature and then transported in refrigerated trucks to the cold storage for long term storage or to the wholesale market in reefer containers. The wholesale market should have the facility for the cold storage.

Once the produce is precooled after harvest, it should not be exposed to undesirable temperatures at any stage of storage and handling to maintain its harvest fresh quality till consumption. Cold stores form the most important element in the cold chain system though all steps in handling are equally important.

Cold chain linkage from farm to market: To preserve the freshness of the horticultural produce, it is essential to have refrigerated transport from farm to central cold storage, then to wholesale markets and distant markets, exports etc. This has to be disposed to retailers or the supermarkets with cold storage facilities. Wholesale canters must have cold storage facilities either individually or collectively. This type of cold chain linkage helps in introducing a systematic approach and result in reducing the wastage at farm level transport and storage. These cold storage centres can be put up in rural areas benefiting the rural sector. By ensuring proper cold chain linkages, the quality and freshness of the horticultural produce are maintained till the produce reaches the consumer.

Optimum cold storage conditions & approximate storage life of fruits and vegetables

	Temp (°C)	RH (%)	Approx. storage life(weeks)
Fruits			
Apple	0-2	85-90	20-30
Avocado Chilling tolerant varieties Chilling sensitive varieties	 4.4 12.5	 85-90 85-90	 4 2
Banana Cavendish green Cavnedish ripe Ney Poovan green Ney poovan ripe	 13 12 12 8	 85-90 85-90 85-90 85-90	 3-4 1-5 2-3 1
Ber	5-6	85-90	4
Citrus Coorg mandarin (main crop) Coorg mandarin (rainy season) Sathgudi orange (Moosambi) Lime yellow Lime green Grape fruit	 8 8 8 12-13 12-13 13-14	 85-90 85-90 85-90 85-90 85-90 85-90	 8 6 16 8 7 12
Custard apple	15	85-90	1.5
Date	6-7	85-90	2
Fig	1-2	85-90	6
Guava	10	85-90	2-5
Jackfruit	11-12	85-90	6
Litchi	2	85-90	8-10
Mango mature green Alphonso Banganapalli	 12-13 12	 85-90 85-90	 4 5-6
Papaya green	10	85-90	3-4
Papaya turning	9	85-90	2-3
Passion fruit	6-7	85-90	3
Pineapple all green	9-10	85-90	4-6
Pineapple 25% Yellow	6-7	85-90	1-2
Pomegranate	7-8	85-90	10-12
Sapota mature	20	85-90	2

Strawberry	0	85-90	1
Vegetables			
Asparagus	0-2	95	3-4
Beans Snap beans Winged beans	 8-10 10	 85-90 85-90	 3-4 8-10
Beetroot	0-1	90-95	8-10
Brinjal	10	90-95	2
Cabbage(wet season)	0-2	90-95	4-6
Cabbage(dry season)	0-2	90-95	12
Capsicum(green)	7-8	85-90	3-5
Carrot topped	0-2	90-95	20-24
Cauliflower	0-2	90-95	7
Celery	0-2	90-95	8
Coriander leaves	0-2	90-95	4-5
Chow chow	12-13	90-95	3
Cucumber	10-11	90-95	2
Garlic(bulbs) dry	0	65	28-36
Ginger	8-10	75	16-20
Gourd, bottle	8-9	85-90	4-6
Gourd, snake	18-20	85-90	2
Lettuce, leaf	0	95	1
Mushroom	0	95	1.5
Muskmelon, Honey dew	7-8	85	4-5
Okra	10	90	1.5
Onion, Red	0	65-70	20-24
Onion, white	0	65-70	16-20
Pea, green	0	90-95	2-3
Poato	4	85	30-34
Pumpkin	12-15	70-75	24-36
Radish, topped	0	90-95	3-5
Squash	12-15	70-75	8-24
Sweet Potato	10-12	80-90	13-20
Spinach	0	90-95	10-14
Tomato Mature green Red ripe	 12-13 5-6	 85-90 85-90	 4-5 2
Turnip	0	90-95	8-16
Watermelon	12-15	80-90	2
Yam	16-20	60-70	3-5

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Part - 3

Solar driven cold stores

In tropical countries, solar energy is utilized in refrigeration cycle. In Sudan, such stores have been developed having single stage ammonia/water absorption refrigerator with 13 kw peak cooling power and were designed to keep 10 tonnes of agricultural products (volume 50 m^2) at a minimum temperature of 5°C, as tested on bananas. This system is however costly when compared to conventional cold stores operated by electricity.

Jacketed storages

These are double walled storages where heat conducted through the floor, walls and ceiling is intercepted and removed by the refrigeration system before it reaches the storage space. The walls, ceiling and floor act as cooling surfaces. Humidity close to 100% is maintained. These jacketed storages built in Canada are 10% more costly than conventional storages.

Low Pressure Storage / Hypobaric Storage

Fruits can be stored under low pressure of 0.2 – 0.5 atmospheric pressure and temperature of 15 - 24^0C under airtight chamber. Pressure is reduced by sucking air and creating vacuum.

Mechanism :

- ✓ Reduced O_2 supply slows down the respiration. When presser reduced from the 1 atm to 0.1atm the effective O_2 concentration reduced from 21 to 2.1%.
  Eg. in apples, low pressure reduces level of ethylene to 0.01ppm which does not stimulate ripening.
- ✓ Released ethylene is removed out of storage.
- ✓ Volatiles such as CO_2, acetaldehyde, acetic acid, ester *etc*. are removed/reduced.

Comparative storage life (in days) of produce stored in refrigeration and under hypobaric conditions

Commodity	Cold storage	Hypobaric storage
Fruits (fully ripe)		
Pine apple (ripe)	9-12	40
Grapefruit	30-40	90-120
Strawberry	5-7	21-28
Sweet cherry	14	60-90
Fruits (unripe)		
Banana	10-14	90-150
Avocado	23-30	90-100
Apple	60-90	300
Pear	45-60	300
Vegetables		
Green pepper	16-18	50
Cucumber	10-14	41
Beans	10-13	30
Onion (green)	2-3	15
Lettuce	14	40-50
Tomato(mature green)	14-21	60-100
Tomato(breaker stage)	10-12	28-42

Controlled Atmosphere Storage (CA Storage)

The storage of fruits and vegetables in CA Storage is one of the most advanced methods of storage. It was first suggested by W.R. Philips of Canada.

From the construction point of view, controlled atmosphere facilities are similar to refrigeration facilities. However, they should be airtight to allow creation of an atmosphere different from normal. The Oxygen consumption and its replacement by carbon dioxide by respiration, create the atmosphere. When the appropriate combination has been reached, a limited intake of oxygen is required to satisfy the reduced rate of respiration. Accumulation of carbon dioxide is removed by means of different methods.

Physiological basis of CA Storage

Air contains about 20.9% O_2 78.1 % N_2, 0.003 % CO_2 and trace amount of other gases including Ne, He, CH_4 and water vapour. In CA storage, **oxygen is reduced and CO_2 is increased** and ripening and respiration rates are slowed down.

Essential features of CA Storage

1. Mechanical refrigeration is used to maintain temperature of -1 to 3°C.
2. The CA storage room is constructed gas tight.
3. Reduction on O_2 - Nitrogen gas is introduced into the storage by cylinder to reduce the oxygen level after room is filled and sealed. CO_2 is added into storage from CO_2 gas cylinder.
4. Excess CO_2 is removed by dry hydrated lime, Ethanolamine, Aluminium calcium silicate, Activated carbon, Magnesium oxide, activated carbon are other CO_2 scrubbers.
5. Atmospheric composition is crop specific. However, as a general rule the most common combinations are 2-5% oxygen and 3-10% carbon dioxide
6. The storage room atmosphere samples are taken daily for CO_2 and O_2 monitoring.

Benefits of CA storage

1. Retardation of senescence and associated biochemical and physiological changes
2. Reduction of produce sensitivity to ethylene action at O_2 levels below 8% and/ or CO_2 levels above 1 %.
3. Useful tool for insect control in some commodities.

Limitation of CA storage

1. Causes certain physiological disorders such as black heart in potatoes, brown stain of lettuce.
2. Irregular ripening of produce such as banana, pear, tomato *etc*.
3. Development of off flavours and off odours at very low O_2 concentrations.
4. Timely non availability of gas
5. Costly and technical knowhow is required

Fig: Blackening due to tissue asphyxia (suffocation) of an artichoke head caused by storing in an inadequate atmosphere

Modified Atmosphere storage (MAS)

MA storage implies a lower degree of control of gas concentration in atmosphere surrounding the commodity. The MA and CA differ only in degree of control, CA is more exact.
Advances in the manufacture of polymeric films with wide range of gas permeability have stimulated interest in creating and maintaining modified atmospheres within flexible film packages.

Biochemical and Physiological Basis of MA

The rate of respiration and metabolism doubles for every 10°C rise in temperature. Respiration can be therefore reduced by decreasing the temperature, O_2 level and/or increasing the CO_2 level in the storage atmosphere. Both O_2 and CO_2 levels exert independent effects on respiration. The net effect may be additive or synergistic. When O_2 concentration is reduced below 10%, respiration rate is decreased. However, when O_2 concentration falls below 2%, anaerobic respiration may set in, thereby leading to the accumulation of ethanol and acetaldehyde.
The desirable effect of MA on plant tissues is also attributed to lower pH, due to dissolution of CO_2 in tissues. Ethylene action and biosynthesis are also effected besides water loss and chilling injury

Summary of recommended MA conditions during transport and storage of selected vegetables

Commodity	Temperature range (°C)	Modified Atmosphere	
		% O_2	% CO_2
Asparagus	0-5	Air	5-10
Broccoli	0-5	1-2	5-10
Cabbage	0-5	3-5	5-7
Cauliflower	0-5	2-5	2-5
Sweet corn	0-5	2-4	10-20
Cucumber	8-12	3-5	0
Leek	0-5	1-2	3-5
Lettuce	0-5	2-5	0
Okra	8-12	3-5	0
Onion (green)	0-5	1-2	10-20
Pepper	8-12	3-5	0
Potato	4-12	None	None
Spinach	0-5	Air	10-20
Tomato(partially ripe)	8-12	3-5	0

<u>Environmental factors affecting MA storage</u>

a. Temperature and relative humidity

Ambient temperatures of the surrounding atmosphere affect the commodity temperature. Temperature changes also affect the permeability of the film, which increases with increase in temperature. CO_2 permeability responds more than O_2 permeability. Relative humidity has little effect on permeability of most film packages. Most common films are good barriers to moisture and vapour because they maintain high internal humidity even in dry, ambient conditions.

b. Light

Green vegetables consume large amount of CO_2 and reduce O_2 through photosynthesis and would antagonize the process of respiration which aids in maintenance of specified MA within the package. Greening of potatoes can cause loss in quality unless light is excluded. Hence, opaque packages should be used for such commodities.

c. Sanitation Factors

The high humidity maintained within MA packages may enhance the growth of plant pathogens. So care must be taken to ensure proper sanitation and to avoid conditions favourable to growth and reproduction of such micro organisms. Fungicidal treatment of packaged vegetables is thus very important.

Differences between CA and MA Storage

	CA Storage	MA Storage
1	High degree of control over gas conc.	Low degree
2	Longer storage life	Less
3	More expensive technology	Less
4	Atmosphere is modified by adding gas	It is created by either actively(addition or removal of gas) or passively(produce generated)
5	Specific temperature should maintain	May or may not be maintained

General Storage Recommendation

The University of California (Thompson,*etal*.,1999) recommends three combinations of temperature and relative humidity

	Temperature °C	RH %	Crops
1	0 – 2	90 – 98	leafy vegetables, crucifers, temperate fruits and berries
2	7 – 10	85 - 95	citrus, subtropical fruits and fruit vegetables
3	13 - 18	85 – 95	tropical fruits, melons, pumpkins and root vegetables

Note : ethylene level should kept below 1 ppm during storage

Tan (1996) recommends 5 different storage conditions

a. 0 °C and 90-100% RH
b. 7-10 °C and 90-100% RH
c. 13 °C and 85-90% RH
d. 20 °C and
e. ambient conditions

Lecture schedule – 25

Part - 1

PACKAGING OF HORTICULTURAL CROPS

The main function of packaging fruits, vegetables and flowers is to assemble the produce into convenient units for better handling and to protect them. A good package should aim at protection of produce from physical, physiological and pathological deterioration throughout storage, transport and marketing. In recent times, packaging is becoming an essential part of supply chain of horticultural crops because of the consumer's choice for convenience, appeal, information and branding.

Benefits of packaging

1. Packaging serves as an efficient handling unit
2. It serves as a convenient storage unit
3. Packaging protects quality and reduces waste
    - ✓ Protects from mechanical damages
    - ✓ Protects against moisture loss
    - ✓ may provide beneficial modified atmosphere
    - ✓ provides clean produce
    - ✓ may prevent pilferage
4. Provides service and sales motivation
5. Reduces cost of transport and marketing
6. Facilitates use of new modes of transportation

Function of the packaging are

1. To assemble the produce into convenient units for handling(called unitisation)
2. To protect the produce during distribution, storage and marketing.
3. Presentation
4. Preservation
5. Containment – package contains the product with in it and prevents leakage *etc*.

Requirement for an ideal package

1. Package should have sufficient mechanical strength to protect the content during handling, transportation and stacking
2. It should be unaffected by moisture content, when wet and high RH for its strength
3. Stabilise and secure product against movement within the package while handling
4. Free from chemicals that could transfer to the produce and taint it or be toxic to the produce or to humans
5. Meet handling & marketing requirement in terms of weight(light), size and shape (rectangle)
6. Allow rapid cooling of the contents, and/or offer degree of insulation from the external heat/cold
7. Utilises the gas barrier (eg. plastic films) with sufficient permeability to respiratory gases as to avoid any risk of anaerobiosis (ventillation) and any bad odour
8. It must be easy to assemble, fill and close either by hand or by use of a simple machine
9. Offer the security for the contents, and /or ease of opening and closing in some marketing situation (eg. promotional activity)
10. Facilitate easy disposal, reuse or recycling

11. It should be easily transported when empty and occupy less space than when full.

Eg. Plastic boxes which nest in each other when empty

Collapsible plastic crates, cardboard boxes, fibre or paper or plastic sacks and.

12. Package must be readily available.

Prevention of mechanical damage

How damage occur to the produce?

Four different causes of mechanical injury affect the produce are vibration (transportation- light rubbing), impact (dropping), compression (over stacking) and cut (sharp edges, punctures- nails *etc.*).

Compression resistant produce are water melon, pumpkin, onion, carrot and potato these vegetables are also called as 'hard vegetables'.

Important practical requirement for packaging are to avoid under filing (vibration injury) and overfilling (compression and impact bruising). Individual items should be held firmly, but not too tightly, within the package.

Cooling Produce in the Package

Containers designed for pressure cooling should have holes occupying about 5% of the surface area on each of the air entry and exit ends. Ideally respiratory heat should be able to escape readily from the packages. In case of small and /or tightly packed commodities such as green beans, small fruits, green leafy vegetables and cut flowers, the heat of respiration are removed largely by conduction to the surface of the package. Therefore, the mass of the contents (i.e. minimum dimension of packages from the centre to the surface) becomes important factor. The acceptable mass depends on the respiration rate of the commodity. If the mass of the produce is excessive, that near the centre of the package will heat up because respiratory heat cannot dissipate fast enough.

Under dry conditions, produce in containers like wooden boxes, plastic crates may be sprayed with water. Direct wetting is also possible to cool. Fresh cut flowers and foliage are often transported wet usually in plastic buckets (eg. rose, gerbera *etc*.) and sometimes individual stem in veil of solution (eg. Anthuriam, orchids *etc*.)

Wood and solid and expanded plastic packages are inherently strong are resistant to high humidity, condensation and rain compared to fibreboard packages. Rigid expanded polystyrene is lightweight yet strong but require much space (collapsible i.e. foldable crates require less space on return journey) and costly. In comparison, fibreboard is attractive and can be made stronger by using two or 3 thickness, such as the bottom and lid of fully telescopic cartons. The strength of the fibreboard lies in the fluting between the inner and outer liners. Fibreboard comprises of 2 layers of fluting sandwiched between three layers is stronger than the single layer of fluting. Normal fibreboard carton rapidly absorb moisture under storage can be protected if fully impregnated with wax but wax impregnation is expensive and not fit for recycle.

Need for ventilation in packages

Suitable packaging for any product will consider the need to keep the contents well ventilated to prevent the build-up of heat and carbon dioxide during postharvest stages of transport, storage and marketing. A tight stack pattern is acceptable only if packages are designed to allow air to circulate through each package and throughout the stack. The effectiveness of ventilation during transport also depends upon the air passing through the load via vehicle.

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Part - 2

Packing of Horticultural Produce

Tightly filled packs are desirable for most produce, but without under filling and overfilling to avoid vibration injury. The package, not the produce should, bear the stacking load. Some produce, such as potato, carrot and orange will withstand reasonable compressive loads. For non-rigid packages, such as mesh bags are satisfactory provided they are handled with care.

1. **Bundles -** Some vegetables (drumstick, lemon grass stem, onion tops and asparagus *etc.*) and cut flowers (roses, gladiolus, carnation and iris *etc.*).
2. **Volume or box packing** – fruits are poured into the carton, after filling pack is vibrated to tight packing within box (eg. Apple, orange, tomato *etc.*) on a standard weight.
3. **Package insert** –moulded pulp or plastic trays to isolate the individual fruits. These are costly but are used in delicate and costly fruits such as mango and ready for retail displays.
4. **Wrapping** – covering individual fruits with paper/various film (eg. Papaya, gourds)
5. **Bags** – like gunny bag, hessian bag in crops such as potato, onion, garlic, carrot *etc*.
6. **Punnet packing** – soft fruits such as strawberry, grapes, minimally processed products



Bundles –Asparagus Punnet pack – Baby corn & Bhendi Wrap - Gourds

To recommend packages for all fruits, vegetables, flowers and others is impracticable. The most suitable packages depend on many factors such as

- ✓ Region – tropical/temperate
- ✓ Environmental condition – cool/ warmer/ humid/ hot
- ✓ length and nature of market chain – local/ distant/ international market
- ✓ method of handling and transport – manual/ machinery and
- ✓ availablity and cost of materials – plenty(tomato) or scare(strawberry) of produce
- ✓ whether the produce is to be refrigerated – wax impregnated fibreboard for cold storage

Environment friendly packaging

Polyethylene and polypropylene bags of 100 gauge (25µ) are normally used for mushroom packaging. The containers (small basket) are made from environment friendly material *viz.,* Sal leaves (*Shorea robusta*) and Arecanut leaf sheath (*Areca catechu*). These containers are in turn wrapped with low density shrink wrap (50 gauge (12.5µ) commercially called as L-50 cling film.

Pre-packaging (consumer size packing)

Pre-packaging is generally defined as packaging the produce in consumer size units either at producing centre before transport or at terminal markets. Packaging of fresh produce in consumer unit packs protects the produce against the damage and excess moisture loss.
The packaging material used should have the following properties

1. Sufficient permeability to oxygen, carbon dioxide and water vapour
2. Good tensile strength, transparency, heat sealability and printability
3. Desired protective physical properties

Considering above characteristics LDPE film is most widely used for consumer pack. It has got wider temperature range (50-70^{0}C) and cheapest

The permeability requirement depends upon rate of respiration of the produce, the package bulk density and storage temperature.

Pre-packing of banana fruits is done in 100 gauge polythene bags under room temperature and cold storage

The gas permeability of package can be controlled by

- ✓ varying either the **density** of the film
- ✓ varying **thickness** of the film
- ✓ providing **perforation/ventilation** to the film

Advantages of pre-packaging of produce

1. Pre- packing in clear plastic bag helps restrict weight loss and acts as a MAP
2. Reduces transportation cost by eliminating unwanted/ inedible portion of produce
3. The space required for shipping and storage is less.
4. It has a better eye appeal as the produce is pre-packed in attractive film and the quality of the produce can be seen from outside without opening the pack.
5. Pre-packaging has quick turnover because of the recent development of automatic machines.
6. It saves labour costs, makes the produce easy to handle and sale.

Disadvantage

1. Consumer sometimes worried about the quality of the pre-packaged items and still opts to select items from an open display (eg. local market, shandy/*santhe*).
2. Pre packing is restricted to retail malls in cities and other important places of interest.

Palletization

Loading and unloading are done manually in India. Due to low unit load, there is a tendency to throw, drop or mishandle the package, damaging the commodity. This loss can be considerably reduced by using pallet system. However, this requires the standardization of box dimensions. For each commodity it should be worked out. Once this is accomplished, mechanical loading and unloading become very easy with the fork-lift system.

Cushioning materials

The cushioning material used for packaging fruits/vegetables are dry grass, paddy straw, leaves, saw dust, paper shreds, thermocol, foam nets(apple, pear, citrus), bud net(rose) *etc.*

For the cushioning material to be useful

- ✓ it should have resilient/flexible property
- ✓ it should dissipate the heat of respiration of the produce
- ✓ it should be free from infection
- ✓ should be physiologically inactive

The cushioning materials commonly used are

airbags	bubble films	rubberized fibre	Plastic foam	polystyrene

		cushioning	cushioning materials	
polyurethane	foam in place	polyethylene foam	loose fill packing	tissue paper
buffered tissue	acid free tissue	moulded pulp tray	honey comb portion	cell pack
Air cellular cushioning - sealed air bubble wrap, bags, jumbo bubble wrap, transit bubbles, and bubble wrap sheets				


Fig. Individual protection for fruits using foam net

Wrapping

Covering the fruits after harvest with any material in order to improve its post harvest life is known as wrapping. The materials commonly employed as wrappers are old news paper, tissue paper, waxed paper, shrink film, poly film, Pliofilm, Cellophane paper, aluminium foils and alkathene paper *etc*.

Wrapping has the following advantages

1. It minimizes shrivelling by the loss of moisture
2. It protects against the spread of diseases from one to the other
3. It reduces bruises
4. It reduces damage during transport or in storage
5. It makes the fruit more attractive/appearance

Care must be taken to see that wrap is not too impervious to the passage of oxygen and carbon dioxide.

Eg. Wrapping papaya, gourds with news paper/spongy plastic mesh


Fig. Wrapping individual fruits in old news paper

Vacuum packaging (VP)

The vacuum packaging referred to the removal of all air within the package without deliberate replacement with another gas. It widely used for nuts and grains.

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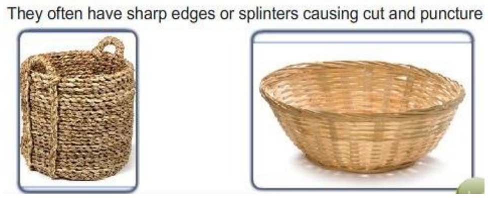
Part - 3

PACKAGING MATERIALS - CFB packing and others

1. Natural materials

Baskets and other traditional containers are made from bamboo, rattan, straw, palm leaves, etc. Both raw materials and labour costs are normally low and if the containers are well made, they can be reused.



Disadvantages

- ✓ They are difficult to clean when contaminated with decay organisms.
- ✓ They lack rigidity and bend out of shape when stacked for long-distance transport.
- ✓ They load badly because of their shape.
- ✓ They cause pressure damage when tightly filled.
- ✓ They often have sharp edges or splinters causing cut and puncture damage.

2. Natural and synthetic fibres- potato and Onion

Sacks or bags for fresh produce can be made from natural fibres like jute or sisal. "Bags" usually refers to small containers of up to about 5 kg capacity. They may be woven to a close texture or made in net form. Nets usually have a capacity of about 15 kg. Bags or sacks are mostly used for less easily damaged produce such as potatoes and onions, but even these crops should have careful handling to prevent injury.

Disadvantages

- ✓ They lack rigidity and handling can damage contents.
- ✓ They are often too large for careful handling; sacks dropped or thrown will result in severe damage to the contents.
- ✓ They impair ventilation when stacked if they are finely woven.
- ✓ They may be so smooth in texture that stacks are unstable and collapse, they are difficult to stack on pallets.

3. Wooden boxes – Apple, citrus and Tomato

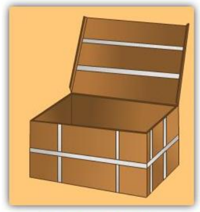
Wood is often used to make reusable boxes or crates, but less so recently because of cost. Wooden boxes are rigid and reusable and if made to a standard size, stack well on trucks.


Disadvantages

- They are difficult to clean adequately for multiple uses.
- They are heavy and costly to transport.
- They often have sharp edges, splinters and protruding nails, requiring some form of liner to protect the contents.

4. Wire-Bound Crates

Wooden wire-bound crates are used extensively for snap beans, peas, sweet corn and several other commodities that require hydro cooling. Wire-bound crates are sturdy, rigid and have very high stacking strength that is essentially unaffected by water. Wire-bound crates have a great deal of open space to facilitate cooling and ventilation. Although few are re-used, wire-bound crates may be dissembled after use and shipped back to the packer. In some areas, used containers may pose a significant disposal problem. They are not generally acceptable for consumer packaging because of the difficulty in affixing suitable labels.



Wire bound crates

Wooden baskets

5. Corrugated Fibreboard

Corrugated fibreboard is manufactured in many different styles and weights. Because of its relativity low cost and versatility, it is the dominant produce container material. Double-faced corrugated fibreboard is the predominant form used for produce containers. It is produced by sandwiching a layer of corrugated paperboard between an inner and outer liner (facing) of paper-board. The inner and outer liner may be identical or the outer layer may be pre-printed or coated to better accept printing. The inner layer may be given a special coating to resist moisture.

Both cold temperatures and high humidity reduce the strength of fibreboard containers. Unless the container is specially treated, moisture absorbed from the surrounding air and the contents can reduce the strength of the container by as much as 75 percent. New anti-moisture coatings (both wax and plastic) substantially reduce the effects of moisture. Waxed fibreboard cartons are used for many produce items that must be either hydro cooled or iced. The main objection to wax cartons is disposal after use as wax cartons cannot be recycled and are increasingly being refused at landfills.

The ability to print the brand, size and grade information directly on the container is one of the greatest benefits of corrugated fibreboard containers. There are basically two methods used to print corrugated fibreboard containers:

a. Post Printed

When the liner is printed after the corrugated fibreboard has been formed, the process is known as post printing. Post printing is the most widely used printing method for corrugated fibreboard containers because it is economical and may be used for small press runs. However, post printing produces 'graphics' with less detail and is usually limited to one or two colours.

b. Pre-printed

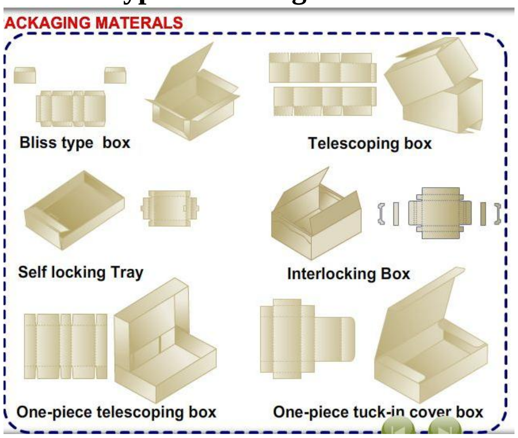
High quality, full-colour graphics may be obtained by pre-printing the linerboard before it is attached to the corrugated paperboard. Pre-printed cartons are usually reserved for the introduction of new products or new brands. Market research has shown that exporters may benefit from sophisticated graphics. The increased cost usually does not justify use for mature products in a stable market, but this may change as the cost of these containers becomes more competitive.

Advantages of CFB cartons over the conventional wooden boxes

1. Minimal bruising damage
2. Easy handling and stacking

3. More economical transport
4. Can be turned quickly into highly precise and accurate size
5. Can be appropriately punched, ventilated, printed low cost
6. Made pilfer-proof and reveal tampering at a glance
7. Offer the most acceptable packaging in the international markets
8. Collapsible and occupy less volume for storage of empty cartons
9. Cartons can be used for cold storage conditions giving water proof treatment
10. Can be made stronger by reinforcing with Hessian or nylon fibre.

Various types of corrugated fibreboard diagram are illustrated below.



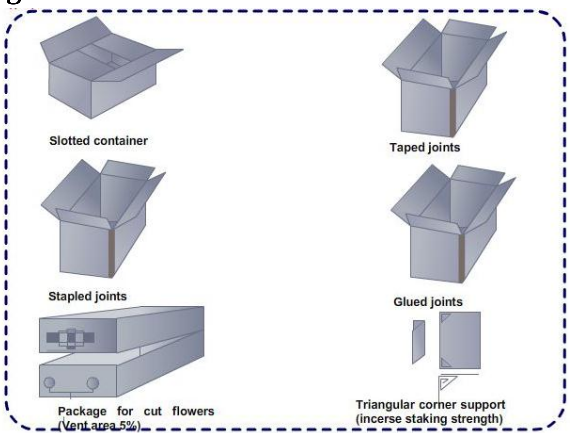


Fig. Fruits packed to avoid vibration + increase staking strength

Containers boxes of CFB, plastic and wood

Lecture schedule -29

Part – 5

MODERN PACKAGING SYSTEMS

Modern packaging systems are packages having both the function of a typical packaging material as well as serves as storage system by reducing the physiological activity of produce and preventing the proliferation of pathogens.

I. Modified atmosphere package - MAP

MAP does control of gas concentration (O_2 and CO_2) in atmosphere surrounding the commodity. Oxygen and CO_2 can be controlled by the chemical (eg. polymers type) or physical (thickness) characteristics of the film and holes in the film. Oxygen and CO_2 flux through the hole is propositionally greater in magnitude than water vapour and C_2H_4 flux because of their flux is driven by comparatively large concentration gradients. Oxygen diffuses faster than CO_2 through hole on account of its grater diffusion coefficient. In contrast, all plastic films are relatively more permeable to CO_2 than O_2. Both CO_2 than O_2 (reactive gas) can be chemically scrubbed from packages and filled with inert gas like N_2.

Methods of creating modified atmosphere conditions

1 Commodity generated or passive MA

First produce is packed in sealed plastic film. As result of respiration the produce and non/selective permeability of the package to oxygen, the concentration of the O_2 reduced and concentration CO_2 increased due to respiration thus generating MA.

Film must allow O_2 to enter the package at a rate offset by the consumption of O_2 by the commodity and CO_2 must be vented from the package to offset the production of CO_2 by the commodity. This atmosphere must be established rapidly and without danger of the creation of injurious or high levels of CO_2.

2. Active Packaging

This can be done by creating a slight vacuum and replacing the package atmosphere with the desired gas mixture. This mixture can be adjusted by the use of adsorbers or absorbers in the package to scavenge O_2, CO_2 or C_2H_4. Active modification ensures rapid establishment of the desired atmosphere. Ethylene absorbers can help to ensure the delay of the climacteric rise in respiration. CO_2 absorbers can prevent the building up of CO_2 to injurious levels.

Package that offer a level of control over in-package conditions and how they vary with produce (eg. ethylene production) and environmental (eg. temperature) factors. Eg. Polymer film that can increase or decrease in permeability to O_2 and CO_2 as temperature rise and fall, respectively.

Modified atmosphere conditions are created inside the packages by an active modification and also using O_2, CO_2 and ethylene scavengers within the package. These scavengers may be held in small sachets within the packages or impregnated in wrappers or into porous materials like vermiculate. The smart wrap, which contains a permeable membrane impregnated with an ethylene absorbent, an anti-fog material to avoid moisture condensation and a slow release fungicide to inhibit the mould growth.

Inadequate (high) temperature and differences in the gas diffusion across plastic films as compared to those of physiological process such as respiration increases the anaerobic condition may occur in sealed plastic film packages. This risk is minimised using safe foil (eg. low melting point polymer) or variable aperture devices (eg. bimetallic strips) to regulate formation and/or size of the holes. Advances in microelectronics, biosensor and polymer sciences may develops the film that actively sense and respond in a controlled way of stimuli, such increase in temperature.

3. Oxygen Absorbers
Most commonly available O_2 absorbers include Ferrous oxide (FeO): Iron is main active ingredient in powdered form becoming Fe_2O_3 and Fe_3O_4 and its hydroxides after absorption of O_2.
4. CO_2 Absorbers - They are hydrated lime, activated charcoal, magnesium oxide.
5. Ethylene Absorbers/scrubber
Compounds that can be used for ethylene absorption within polymeric film packages are potassium permanganate $KMnO_4$ absorbed on celite, vermiculite, silica gel or alumina pellets. They oxidize ethylene to CO_2 and H_2O. Squalene and phenyl methyl silicon can also be held in small sachets within the packages or impregnated in the wrappers or into porous materials like vermiculite.

Films available for MA Packaging
I. LD Polyethylene,
2. HD Polyethylene
3. Polyethylene - Cast and Oriented
5. Rigid PVC
6. Ethylene Vinyl Acetate

Moisture Management - Water condensation in packages can be reduced by use of micro (pin-hole size) or macro-perforated films. In heat shrink wrap film (eg. citrus), condensation is not a problem because the film is in intimate contact with the fruit and assumes the same temperature as the fruit. In case of loose wrapped produce (eg. cut flowers with in carton liner and fruit in a consumer pack), condensation can be reduced by using simple newspaper or slats in spun bonded polythene sachets. Anti fogging film and film with relatively high water permeability can be used (eg. cellophane and PVC).
Water absorbent is incorporated into packages to absorb and hold the free water
Eg. Silica gel in dry fruits packing.

II. Insulation and dry ice
In absence of refrigeration, a certain level of temperature control during postharvest handling can be achieved with insulation (eg. polystyrene boxes) and heat sinks provided inside the packaging (eg. loose ice or ice packs). Use of external reflective and/or insulative covers (eg. thermal blankets) and heat sinks (eg. dry ice) can assist or provide an alternative to, temperature control management.

Plastic impregnated with chemicals capable of absorbing ethylene gas are also being researched.

III. Individual seal /shrink packaging technique

Individual seal packaging, which may be considered as the MAP for an individual fruit, involves sealing of a fruit in a plastic film with or without heat shrinking to conform the shape of a fruit. Individual seal packaging would help to reduce the fruit decay by prevention of secondary infection during long term storage or shipment. Seal packaging has been found to extend the shelf life of several fruits like apple, pear, kiwifruit, citrus and pomegranate.

IV. GRAPE GUARD

Grape guards are chemically treated paper-sheets using active ingredient - Anhydrous Sodium Bisulfite ($Na_2S_2O_5$). Grape guard paper is a special chemically treated cellulosic antifungal paper that regulates the release of SO_2 concentration at around 80 ppm for over 12 weeks at a time in each individual carton of grapes. Their function is to preserve the quality of grapes in store and transit by control of decay. Grape guards improve quality by obtaining sturdy, bright un-shrivelled appearance of fruit.

They are available in two types.

a. Quick release grape guard
b. Dual release grape guard

Quick release grape guard retards decay development up to three weeks at 0^o C. It can help for a few days to control decay without refrigeration. Dual release grape guards can be used for decay retardation up to 12 weeks in storage or transit with refrigeration facilities. It is effective only at 0^0 C.

Fig. Grape guard in craft paper

Packing grapes in carton

Placing Grape gurd in packing

Corrugated fiber board boxes three ply with a capacity of 2 kg and 5 kg having a dimension of 25x20x12 cm is being used for packing. Use of fresh paper shavings as cushioning material to minimize transportation damages to the grape bunches is advocated. Different packaging materials like kraft paper, butter paper and soft tissue paper for preparation of grape guard is used.

Grape guard containing 6 and 9 gram of sodium bisulphite is good. Berry decay and berry drop was controlled by the use of grape guards with containing 9g sodium bisulphite.

Grape guards containing sodium bisulphite extended the shelf life of Thompson Seedless, Anab-e-Shashi, Dilkush and Sharad Seedless grapes upto 14, 8, 8 and 16 days respectively at ambient temperature and upto 75, 60, 75 and 85 days respectively under cold storage conditions.

Lecture schedule – 30

Part - 1

POSTHARVEST DISORDERS IN HORTICULTURAL PRODUCE

Postharvest disorders are common in many crops, where storage at low temperature for long periods is required. The most important non-pathological problem encountered in the market chain is physiological disorder. "Physiological disorders refer to breakdown of tissue in response to an adverse environment, particularly temperature and/or nutritional deficiency during growth and development".

Metabolic disturbance occurring at reduced temperature are generally divided into two main groups:

1. Chilling injury – results from the exposures of tissue to temperature below critical level. Injury is caused due to change in the physical state of membrane lipids, dissociation of enzymes and other proteins.
2. Physiological disorders – problems which arises other than the chilling injury.

Physiological disorders involve plant tissue breakdown that is not directly caused either by pests and diseases or by mechanical damage – which includes tissue disruption upon ice crystal formation associated with freezing injury. Physiological disorders may develop in response to various pre (nutrient accumulation or deficiency) and postharvest (low-temperature stress during storage) conditions.

Physiological disorders can be divided into five general categories:

1. Nutritional – Eg. bitter pit in apple, blossom end rot in water melon and tomato.
2. Temperature (low and high) – Eg. sunburn on the shoulders of tomato and mango,(high-temperature injury occurred prior to harvest).
3. Respiratory - low oxygen and or high carbon dioxide concentrations in and/or around harvested produce in CAS and MAP. Eg. black heart of potato (low-oxygen injury).
4. Senescent – Eg. mealiness in apples, are due to harvesting over-mature produce and/or overstoring produce.
5. Miscellaneous - disorders which are product-specific in terms of symptoms expressed.
   Eg. a) Bitterness (isocoumarin accumulation) in carrot.
   b) Greening of potatoes exposed to light
   c) Rooting of onions exposed to high humidity
   d) Russet spotting on the midrib of lettuce leaves (exposure to ethylene)

Nutritional and low-temperature disorders are more problematic than others.

The cellular, biochemical and biophysical mechanisms that give rise to physiological disorders in produce are extremely complex. Moreover, they often involve elusive interactions with the pre-and postharvest conditions.

Causes of physiological disorders: (Fig.1.)

1. Preharvest environment conditions
   - ✓ temperature
   - ✓ nutrition
   - ✓ water regimes
   - ✓ crop development factors (e.g. yield or crop load, position on the plant and carbohydrate, water and /or nutrient partitioning)
2. Postharvest environment conditions

- ✓ temperature regime
- ✓ gas atmosphere
- ✓ storage time

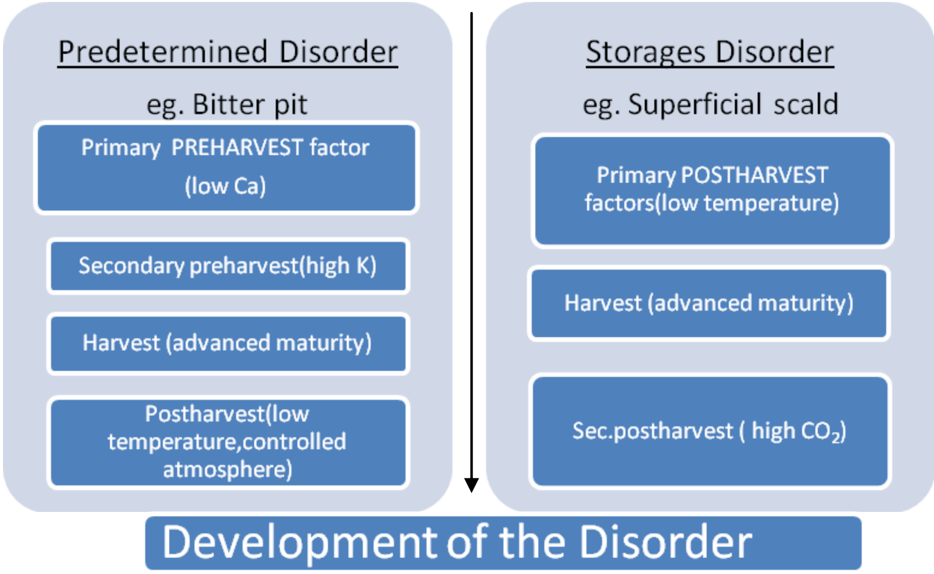


Fig.1 Model for the development of postharvest disorders

(**Source:** Ferguson, R. Volz and A.. Woolf, 1999, Prehatvest factors affecting physiological disorder of fruit. Postharvest Biology and technology 15, pp. 255-62)

I. Mineral Deficiency Disorders

Disorders associated with deficiencies of specific minerals, and whose symptoms are sometimes expressed only after harvest in fruits, may be prevented by providing the specific mineral element either during growth or after harvest.

Calcium

Calcium is associated with more postharvest-related deficiency disorders than any other mineral. Ca deficiency disorders, such as blossom-end rot of tomatoes, can be eliminated by applying calcium salts as a preharvest spray. For others, such as bitter pit of apples, only partial control is obtained by preharvest sprays. Variability in the extent of control achieved is probably related to the amount of calcium taken up by the fruit. Postharvest dipping at sub-atmospheric pressures, which markedly increases the uptake of calcium, can result in total elimination of bitter pit. A substantial amount of the added calcium binds with pectic substances in the middle lamella and with cell membranes. Added calcium may possibly prevent some disorders by strengthening these structural components, without alleviating the original causes of the disorder. Strengthening cell components could prevent or delay the loss of sub-cellular compartmentation and the associated chemical and enzyme mediated reactions that cause browning symptoms.

Table: Calcium-related disorders of fruit and vegetables

Produce	Disorder
Apple	Bitter pit, lenticels blotch, cracking, internal breakdown, water core
Avocado	End spot
Bean	Hypocotyl necrosis

Brussels sprout	Internal browning
Chinese cabbage	Internal tipburn
Carrot	Cavity spot, cracking
Celery	Blackheart
Cherry	Cracking
Chicory	Brownheart, tipburn
Lettuce	Tipburn
Mango	Soft nose
Parship	Cavity spot
Pear	Cork spot
Peppers	Blossom-end rot
Potato	Sprout failure, tipburn
Tomato	Blossom-end rot, blackseed, cracking
Watermelon	Blossom-end rot

Adding calcium to intact fruit or fruit slices generally suppresses respiration, but the response is concentration-dependent. The activities of isolated pectic enzymes have shown differential responses to calcium concentration. For example, the activity of pectin methylesterase is initially increased by increasing concentrations of calcium but is inhibited at higher concentrations, while the large form of endo polygalacturonase is stimulated slightly by concentrations of calcium that inhibit the smaller forms of the same enzyme.

Fig. Apple bitter bit due to calcium deficiency

Boron

Bo deficiency in apple leads to a condition known as **internal cork**. This condition is marked by pitting of the flesh and is often indistinguishable from bitter pit.

<u>The differences between</u>

Internal cork	**Bitter pit**
Prevented by applying boron sprays	Responds to calcium treatment only
Develops only on the tree	Develop after the harvest

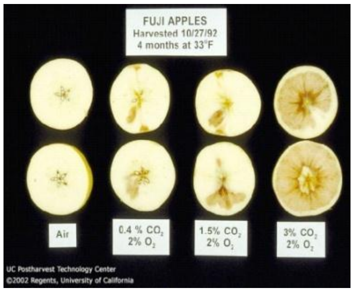
Potassium

The major mineral in plants is potassium, and both high and low levels of potassium have been associated with abnormal metabolism. High potassium (and also magnesium) and low calcium has been associated with the development of bitter pit in apple.

Low potassium delays the development of full red colour by inhibiting lycopene biosynthesis in tomato.

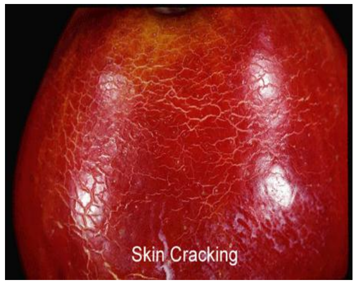
Heavy metals- Copper

Copper, act as catalysts for enzyme systems that lead to enzymatic browning, such as browning of cut or damaged tissues that are exposed to air. The levels of these metals are important in processed fruits and vegetables, whether they are derived from the produce or from metal impurities acquired during processing.



Apple high CO_2 injury

Apple skin Checking



Apple skin Cracking

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Sl.No.	Title	Authors	Years	Publishers
1	Post Harvest- An Introduction to the Physiology and Handling of Fruits, Vegetable s and ornamentals	Wills, McGlasson, Graham Joyce	2007	Cab International ISBN97818459322755
2	Post Harvest Technology of Fruits and Vegetables. Vol. I & II	L.R.Verma V.K.Joshi	2000	Indus Publishing Co. New Delhi ISBN 81-7387-108-6
3	Post Harvest Technology of Fruits and Vegetables	A.K. Thomposon	1996	Blackwell Science ISBN 1-4051-0619-0
4	www.postharvest.ucdavis.edu			

Lecture schedule – 31

Part - 2

LOW-TEMPERATURE DISORDERS

Storing produce at low temperature is generally beneficial because the overall rate of metabolism (e.g. respiration, ethylene production) is reduced. However, low storage temperatures do not suppress all cellular processes to the same extent. Some processes are especially sensitive to low temperature, and may cease completely below a critical temperature. Several cold-labile enzyme systems have been identified in plant tissues. Metabolic imbalance as a consequence of low temperature can lead to accumulation of reaction products and a shortage of reactants. If the imbalance becomes serious, essential substrates may not be produced and toxic products can accumulate. Consequently, cells will cease to operate properly and will lose their function and structure. Damaged cells often appear as discoloured areas (usually brown or black). Ethylene may be involved in low-temperature injury, since treatment with the ethylene binding site blocker 1-MCP can reduce discolouration symptoms associated with low-temperature disorders in some fruit (e.g. apple, pineapple).

Metabolic disturbances occurring at sub-ambient temperature are generally divided into:

1. Chilling injury- cellular process expressed in short (fast)time frames
2. Low temperature associated disorder- cellular process expressed in long (slow) time frames

1. Chilling Injury

Chilling injury typically results from "exposure of susceptible produce, especially that of tropical or sub-tropical origin, to temperatures below 10-15^{0}C".
However, the critical temperature at which chilling injury occurs varies among commodities. Chilling injury is completely different to freezing injury(which results when ice crystals form in plant tissues at temperatures below their freezing point). Both susceptibility and symptoms of chilling injury are product and even cultivar-specific. Moreover, the same commodity grown in different areas may behave differently in response to similar temperature conditions.

Symptoms of Chilling Injury

1. Skin pitting - is a common chilling injury symptom that is due to collapse of cells beneath the surface. The pits are often discoloured. High rates of water loss from damaged areas may occur, which accentuates the extent of pitting.
2. Browning or blackening of flesh tissues - is another common feature of chilling injury (e.g. avocado; Chilling-induced browning in fruit typically appears first around the vascular (transport) strands. Browning can result from the action of the polyphenoloxidase (PPO) enzyme on phenolic compounds released from the vacuole during chilling, but this mechanism has not been proven in all cases.
3. Water-soaking - in leafy vegetables and some fruits (e.g. papaya)
4. De-greening of citrus fruit is slowed by even mild chilling.
5. Fruit that has been picked immature may fail to ripen or ripen unevenly or slowly after chilling (e.g. tomato).
6. Development of off-flavour or odour (low O_2 levels)
7. Rotting - chilling injury causes the release of metabolities (e.g. amino acids, sugars) and mineral salts from cells. Leakage of metabolites and ions, together with degradation of cell membranes, provides substrates for growth of pathogenic organisms, especially

fungi. Such pathogens are often present as latent infections or may contaminate produce during harvesting and postharvest operation. Thus, rots is another common symptom of chilling injury, particularly upon removal from low-temperature storage.
Symptoms of chilling injury normally occur while the produce is at low temperature. However, they sometimes chilling injury appear when the produce is removed to a higher temperature and deterioration may then be quite rapid, often within a matter of hours.

Chilling injury symptoms of some fruits

Produce	Lowest safe storage temperature (^{0}C)	Symptoms
Avocado	5-12	Pitting, browning of pulp and vascular strands
Banana	12	Brown streaking on skin
Cucumber	7	Dark-coloured, water-soaked areas
Eggplant	7	Surface scald
Lemon	10	Pitting of flavedo, membrane staining, red blotches
Lime	7	Pitting
Mango	12-13	Dull skin, brown areas
Melon	7-10	Pitting, surface rots
Papaya	7-15	Pitting, water-soaked areas
Pineapple	6-15	Brown or black flesh
Tomato	10-12	Pitting, Alternaria rots

Management of Chilling Injury

1. **Maintaining critical temperature** - The safest way to manage chilling injury is to determine the critical temperature for its development in a particular produce and then not expose the commodity to temperatures below that critical temperature (Eg. Safe storage temperature for apple is 0-2^{0}C and care should to taken to not to store apple below this critical temperature to avoid chilling injury). However, it has been found that exposure for a short period to chilling temperatures with subsequent storage at higher temperatures may prevent the development of injury. This conditioning process has been effective in managing
   - ✓ black heart in pineapple
   - ✓ Woolliness in peach
   - ✓ Flesh browning in plum.
2. **MAS** - Modified atmosphere storage may also reduce chilling injury in some commodities.
3. **Maintaining high RH** - both in storage at low temperature and after storage can minimize expression of chilling injury symptoms, particularly pitting (e.g. film-wrapped cucumbers).

Mechanism of chilling injury

The critical temperature, below which chilling injury occurs is an integrated genotypic but expressed in phenotypic characteristic of the particular organ. Highly chilling-sensitive fruits, such as banana and pineapple, have relatively high critical temperatures such as 12^{0}C or higher. It has even been suggested that the critical temperature may be greater than 20^{0}C for some pineapple cultivars. Chilling-insensitive fruits, such as apple and pear, have much lower critical temperatures, around 0^{0}C. Of course, low-temperature storage at/ below 1^{0}C is not possible for fresh fruit, vegetables or flowers because of freezing damage.

The cellular events of chilling injury can be separated into primary and secondary events. Primary events are transiently reversible, but become irreversible, particularly with the onset of cell death and tissue necrosis.

The main primary events in chilling injury are:

- ✓ low temperature-induce changes in the properties of cell membranes due to changes in the physical state of membrane lipids (membrane phase change)
- ✓ production of reactive oxygen species (eg. hydrozen peroxide) that oxidize leading to altered enzymatic activities and structural proteins (e.g. tubulin) are disrupted(Fig.2).

Secondary events are:

The physical changes in membrane lipids alter the properties of their parent membranes. Consequently,

- ✓ ion and metabolites moves across affected membranes
- ✓ activities of membrane-bound enzymes are disrupted
- ✓ The overall consequence of membrane disturbance is breakdown of sub-cellular compartmentation, which is readily measured as increased ion leakage from chill-injured tissues.
- ✓ Changes in the relative activities of enzymes lead to imbalanced metabolism and can ultimately result in cell death.
- ✓ Accumulation of toxic compounds (e.g. acetaldehyde)
- ✓ Structural proteins of the cell cytoskeleton (eg. tubulin) dissociate in chilling-sensitive tissues at low temperatures.

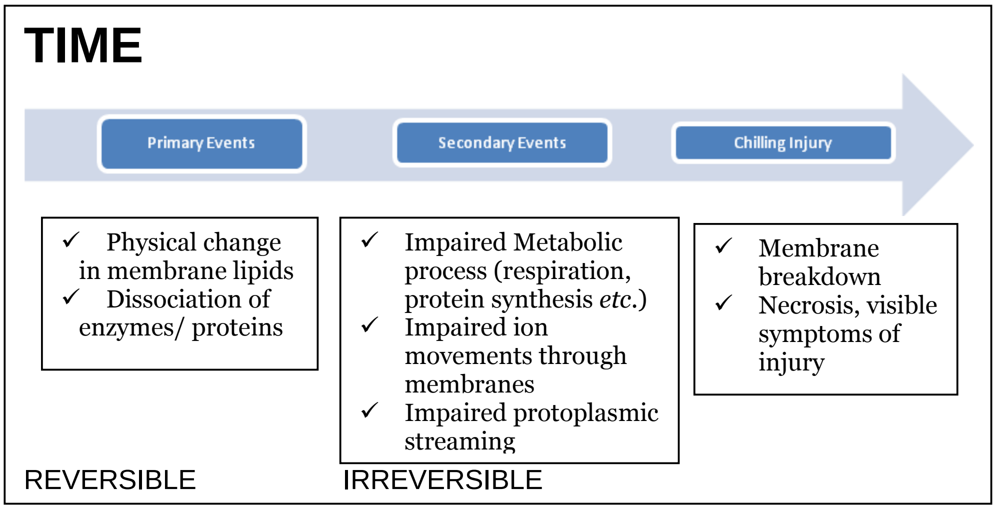


Fig. 2. Time Sequence of events leading to chilling injury

2. Low temperature – associated physiological disorders

Low temperature physiological disorders tend to be expressed in discrete areas of tissue. These disorders affect the skin of produce, but leave the underlying flesh intact. Others affect only certain areas of the flesh, or perhaps the core region. Low-temperature disorders may be considered to be chilling injuries that have developed slowly under low-temperature conditions.

These affects a range of fruit crops, but are particularly well described for deciduous tree (eg. pome and stone) and sub-tropical citrus fruit crops. Low-temperature disorders also affect a range of vegetable and ornamental crops

Physiological disorders fruits

Disorder	Symptoms
Apple	
Superficial scald	Slightly sunken skin discolouration, may affect whole fruit
Sunburn scald	Brown to black colour on areas damaged by sunlight during growth
Senescent breakdown	Brown, mealy flesh; occurs with over-mature, over-stored fruit
Low-temperature breakdown	Browning in cortex
Soft(or deep) scald	Soft, sunken, brown to black, sharply defined areas on the surface that extend a short distance into the flesh
Core flush (brown core)	Browning within core line
Water core	Translucent areas in flesh; may brown in storage
Brown heart	Sharply defined brown areas in flesh; may develop cavities
Pear	
Core breakdown	Brown, mushy core on over-stored fruit
Neck breakdown, vascular breakdown	Brown to black discolouration of vascular tissue connecting stem to core
Superficial scald	Grey to brown skin speckles; occurs early in storage
Over-storage scald	Brown areas on skin in over-stored fruit
Brown heart	Sharply defined brown areas in flesh; may develop cavities
Grape	
Storage scald	Brown skin discolouration of white grape varieties
Citrus	
Storage spot	Brown, sunken spots on surfaces
Cold scald	Superficial grey to brown patches
Flavocellosis	Bleaching of rind; susceptible to fungal attack
Stem-end browning	Browing of shriveled areas around stem-end
Peach	
Woolliness	Red to brown, dry areas in flesh
Plum	
Cold storage	Brown, gelatinous areas on skin; flesh breakdown

Studies on low temperature-associated physiological disorders revealed that, although a particular variety may be susceptible to a certain disorder, not all fruit will develop the disorder.

Susceptibility to disorder depends on various factors

1. Maturity at harvest (immature fruits are more susceptible)
2. Cultural practices- pruning, moderate thinning, preharvst Ca spray such as calcium chloride $CaCl_2$, calcium nitrate $Ca(NO_3)_2$
3. Climate
4. Position of fruit- fruit located on vigorous, leafy, upright growing branches have a greater potential to develop bitter pit than does fruit that develops from spurs or on horizontal wood near the tree's main frame
5. Age of the tree- older trees, which are less vigorous and produce larger crop loads, reduce their susceptibility to bitter pit
6. Fruit size (bigger size apple more prone to bitter pit)
7. Harvest practices- preharvest sampling and pre-cooling

The risk of a fruit developing a particular disorder can, therefore, be minimized by identifying susceptible fruit batches and not storing them for prolonged periods. However, the market often has a preference for types of fruit that are highly susceptible to a disorder.
For eg.: the consumer often prefers large apples with intense red colouration, even though such fruits are susceptible to low-temperature breakdown. Thus, methods needed to be developed to successfully store susceptible produce and meet consumer requirements.

Various temperature-management programs have been developed to minimize the development of specific low temperature-related storage disorders. For some produce (e.g. persimmons, nectarines), visible symptoms of chilling injury may develop later and be less severe at temperatures closer to 0^0C than at higher storage temperatures (e.g. 2-5^0C).

Susceptibility of harvested produce to low storage temperature stress may be improved by practicing fallowing methods:

- ✓ Lowering the temperature in steps from 3^oC down to 0^oC in the first month of storage (i.e. step-down low-temperature conditioning) can minimize the development of low-temperature breakdown and soft scald in apple.
- ✓ Low-temperature breakdown of apple and stone fruits can also be reduced by periodically raising the temperature to around 20^0C for a few days during the storage period called intermittent warming. This method is not been widely adopted in commercial practice because of the logistical problems of having a room full of uniform produce ready to treat at one time (different batches of fruit in a storage room) and the difficulty of rapidly changing the temperature of a room full of fruit. Another issue is that transient increase in the storage temperature will shorten the storage life of any produce held in the same room that is not susceptible to the particular disorder (e.g. other varieties).
- ✓ Relatively brief periods of pre-storage exposure to intermediate low temperature (i.e. low-temperature conditioning)
- ✓ High-temperature stress (e.g. hot air, hot water dipping, hot water brushing)
- ✓ Warm temperature and high RH condition (i.e. curing)
- ✓ Nitrogen atmosphere (i.e. anoxia) has also proven beneficial in terms of reducing produce susceptibility to various low-temperature injuries.
- ✓ The pre-harvest temperature regime (i.e. periods of high or low temperature up to harvest) significantly influences postharvest susceptibility to low-temperature injury and response to conditioning treatments.

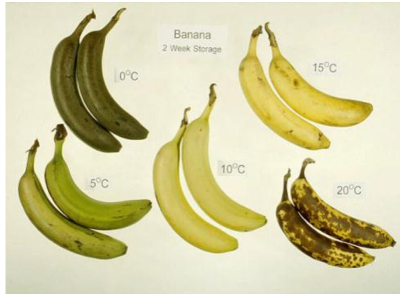
Illustration of some physiological disorders

Apple Scald (inside good)

Water Core

Low O_2 injury

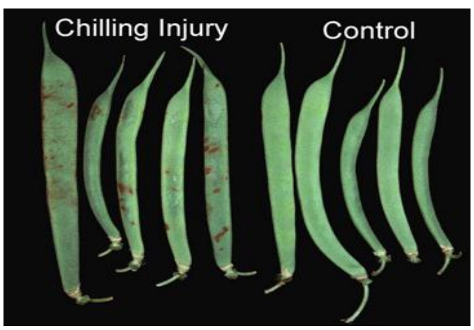
Freezing Injury



Banana Chilling Injury

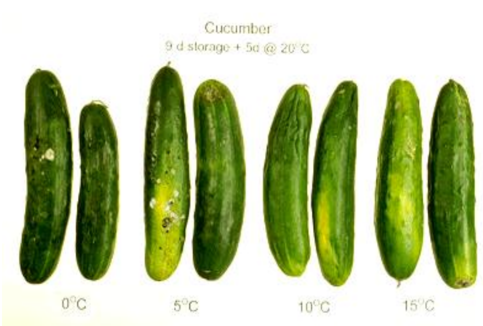
Mango Chilling Injury

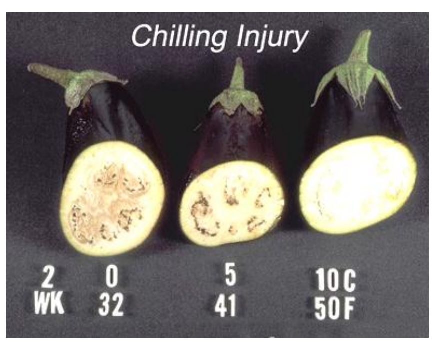
Pineapple Chilling Injury

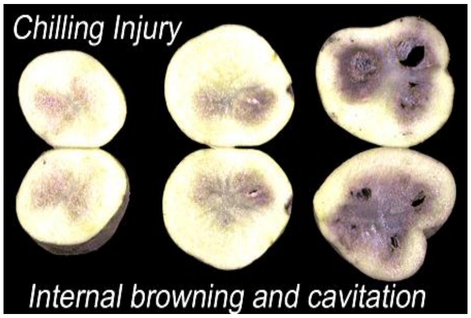


Beans chilling Injury

Capsicum chilling Injury







Potato Chilling Injury

Chilling injury of Tomatoes

Lecture schedule – 32

Part - 3

IMPORTANT PHYSIOLOGICAL DISORDERS OF VEGETABLE CROPS

Crop	Disorder	Symptoms
	Chilling Injury	Chilling sensitive at temperatures below 10°C. Consequences are failure to ripen and develop full colour and flavour, irregular/blotchy colour development, premature softening, surface pitting, browning of seeds and increased decay.
	Freezing Injury	Freezing injury will be initiated at -1°C. Symptoms of freezing injury include a water soaked appearance and excessive softening of fruits with dull colour.
	Blossom end rot	Lesions appear at blossom end of the green fruit. Water soaked spots appear at the point of attachment of the senescent petals. The affected portion of the fruit becomes sunken, leathery and dark coloured.
	Cat face	Fruits are characterized by the distortion of the blossom end. Affected fruits have ridges, furrows, indentations and blotches.
	Cracking	Three types – concentric, radial and cuticular. Common during rainy season when temperature is high, especially when rain follows long dry spell.
Capsicum	Blossom-end rot	Deficiency of calcium in fruit
Onion	Freezing Injury	Soft water-soaked scales rapidly decay due to subsequent microbial growth.
	Translucent Scales	Resembles freezing injury. 3-4 week delay in cold storage increases risk significantly.
Garlic	Sprouting of bulbs	Excessive moisture or winter rains and supply of nitrogen.
	Splitting	Delayed harvesting or irrigation after long spell of drought.
Bhendi	Chilling injury	Discoloration, pitting, water-soaked lesions and increased decay.
	Freezing injury	Occurs at temperatures lower than -1.8°C.
Cucumber	Freezing injury	Freezing injury will be initiated at - 0.5°C (31°F). Symptoms include a watersoaked pulp becoming brown and gelatinous in appearance over time.
Peas	Freezing injury	Freezing injury will be initiated at -0.6°C resulting in water soaking followed by rapid decay due to soft-rot bacteria.

Potato	Greening	Surface of the tuber turns green on exposure to light.
	Black heart	Sharply defined, purplish-grey to black area in center or cavities due to oxygen starvation.
	Chilling injury	Gray to red-brown areas or black heart.
	Freezing injury	Vascular tissue turns black and tubers leak when thawed.
	Blackspot	Internal black spots due to bruising.
	Internal Brown Spot	Brown Center / Hollow Heart and Translucent End Dry, corky reddish-brown or black spots appear on the tissue of the potato.
Brinjal	Chilling Injury	Chilling sensitive at temperatures below 10°C. Symptoms are *Alternaria* rot, pitting, surface scald and blackening of seeds.
	Freezing Injury	Freezing injuries are caused at - 1°C. Symptoms appear as water soaked pulp which finally turns brown.
Cabbage	Yellowing	Gradual loss of green chlorophyll pigment and yellowing of the outer leaves. Sensitive to ethylene, which causes both leaf yellowing and leaf shedding.
	Black Leaf Speck	Development of individual specks, randomly distributed over the leaf. Initially the specks are small in size, but they may develop further in storage and unite into spots as large as 2 mm (0.08 in) in diameter.
	Physical Injury	Damage to the midribs often occurs during field packing and causes increased browning and susceptibility to decay.
	Chilling injury	Occurs during storage at 0°C for 3 months or longer. Symptom is midrib discoloration, especially on outer leaves.

Cauliflower	Freezing Injury	Freezing injury will be initiated at -1°C. Symptoms of freezing injury include a water soaked and greyish curd and wilted crown of leaves. The curds finally become brown and gelatinous in appearance.
	Physical Injury	Due to improper practices of harvesting the curds get bruised leading to rapid browning and decay.
Broccoli	Browning	Boron deficiency. Water soaked areas appear on bud clusters which turn pinkish or rusty brown in advanced stages, leads to rotting.
	Bitterness	Caused by preharvest stress or exposure to ethylene.
	Splitting/Cracking	Split carrots had a larger top in relation to the size of the root than the smooth carrots. Early cultivars tend to split more readily than late cultivars.
	Cavity spot	Appears as a cavity in the cortex. Associated with an increased accumulation of K and decreased accumulation of Ca.
	Freezing injury	Freezing injury is caused at temperatures of -1.2°C. An outer ring of water-soaked tissue is developed in frozen carrots which further blacken.
Radish	Freezing Injury	Freezing injury will be initiated at -1°C. Shoots become water-soaked, wilted, and turn black. Roots appear water-soaked and glassy. Roots become soft quickly on warming and pigmented roots may "bleed" (lose pigment).
Beet root	Internal black spot/brown heart/heart rot	Boron deficiency. Within fleshy roots hard/corky spots are found scattered throughout the roots but more numerous on the light coloured zones or cambium layers.
Turnip	Whip tail	Deficiency of Mo. Young leaves become narrow, cupped, showing chlorotic mottling especially around the margin, develop deep patches which ultimately affect the root growth.
Lettuce	Tip burn	Burning or scorching of lateral margins of inner leaves of mature head.

Lecture schedule – 33

TRANSPORTATION OF HORTICULTURE PRODUCE

The basic requirements during transportation are better control of temperature, humidity and adequate ventilation. In addition, the produce should be immobilized by proper packaging and stacking, to avoid excessive movement or vibration. Vibration and impact during transportation may cause severe bruising or other mechanical injury. Refrigerated containers and trailers are more often used for long distance shipping, whether by sea, rail or truck. Shipping by refrigerated trucks is not only convenient, but also effective in preserving the quality of product. However, both the initial investment and the operating costs are very high. Another possibility is insulated or ventilated trailer trucks.

Factors to be considered for reducing or avoiding losses during transport

- ✓ to ensure that vehicle is in good condition
- ✓ drive the vehicles properly, smoothly
- ✓ minimize movement of containers inside the vehicle
- ✓ use horizontal dividers or racks inside the transport.
- ✓ protect commodities from rain, sun and wind
- ✓ while transporting without packaging, provide sufficient cushioning on the floor and all the four side walls.

A range of different handling and stacking methods are used for perishables within the transportation systems.

Bulk transport: Produce handled in bulk in general is either of low value or relatively resistant to bulk handling. The maximum depth to which produce is stacked depends on the commodity, for example citrus fruits may be loaded 1-1.5 m deep with some padding on the floor. Produce loaded loose and transported on poor roads or long distances should not be stacked more than 1 meter and should always be placed on some form of floor and wall padding such as leaf, grass or foam rubber.

Palletization: Handling produce as units of 24-60 containers on a pallet has greatly improved produce handling and efficiency in marketing. Pallets are made from a range of materials eg. wood, moulded plastics. Disposable pallets have also been developed using plastic and fiberboard. The main problems faced in the adoption of palletization have been:

- ✓ Variation in pallet sizes; 1200 x 1000 mm is the most common pallet size although many shippers use 1200 x 800 mm size. There are many other pallet sizes available but these are used to a lesser extent.
- ✓ Pallets do not always efficiently use the floor space of a vehicle.
- ✓ The variation in shape of the ships' hold means that a different stowed pallet does not always optimize on the space available
- ✓ Cost of pallet
- ✓ Space occupied by the pallet in the vehicle
- ✓ Return of the non-disposal pallet
- ✓ Do not trample or travel sitting on the commodities.

The different modes used for transport of horticultural produce are

1. Road transport
2. Rail transport
3. Marine transport
4. Air transport

Road Transport

Pre-cooled products can be transported through well-insulated non-refrigerated trucks for up to several hours without any significant rise in product temperature. There are considerable cost savings without any loss of quality if trucks are only insulated, rather than refrigerated, for short-distance shipping (eg. milk tanker).

If the product is not pre-cooled and shipping distance is long, a ventilated truck is a better choice than an insulated truck without ventilation and without refrigeration. Ventilation alone does not usually provide a uniform cool temperature, but it may help dissipate excessive field heat and respiration heat, and thus avoid high temperature injury.

The transportation of vegetables may be done by trucks, public vehicle, tractor-trolley, bullock-carts *etc*. depending on situations considering speed, timely, cheap and economics of operation. Highly perishable produce like tomato, mushroom, beans, radish, GLV *etc*., are transported by road to long distances, subjected to spoilage quickly in comparison to garlic, onion, potato, *etc*., and need special care while handling during transit. Road transport can be done either in unrefrigerated or refrigerated vehicles.

Unrefrigerated road transport - Closed or open sided vehicles are mostly used for transportation during short journeys, for example between a market or packing station and the retail outlet. Unless the vehicle is insulated and product pre-cooled, this type of vehicle is generally unsuitable for long distance transportation.

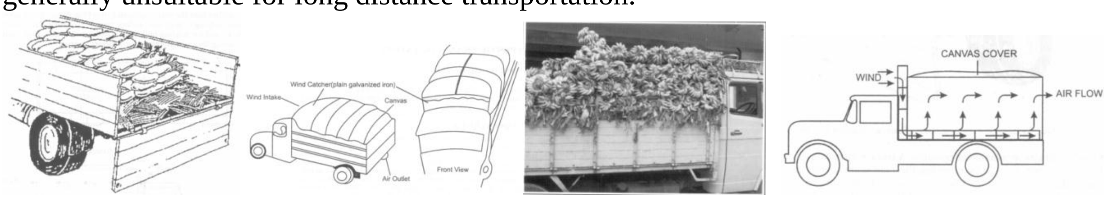


Fig. Unrefrigerated road transport vehicles

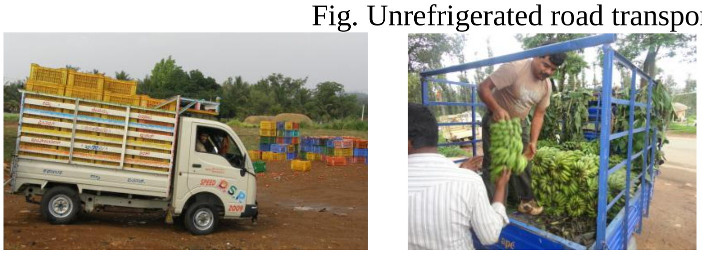


Fig. Transporting tomato and banana from farm to local market in plastic crates

Refrigerated road transport - Different types and capacities of refrigerated road vehicles are available for transportation of perishable goods. The cooling media may be ice, ice and salt, dry ice, cryogens and refrigerants. Today majority of refrigerated vehicles operate on a mechanical refrigeration system.

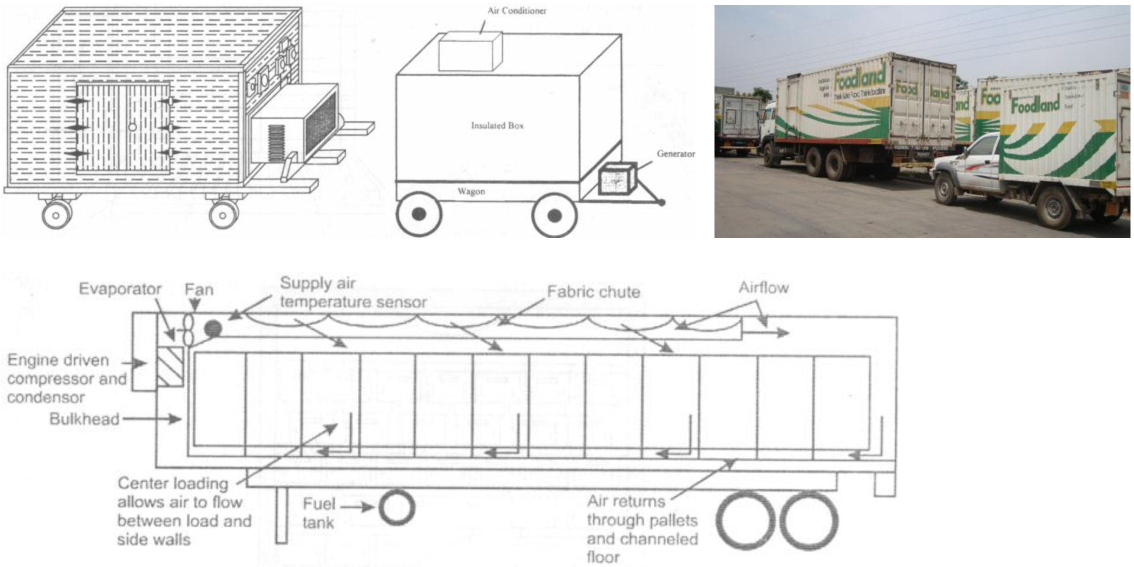


Fig. Refrigerated road transport vehicles

The vehicle should be as airtight as possible to prevent heat loss. It should also be well insulated to prevent heat loss through exchange, through floor, walls and roof.

Rail transport

Wherever possible, goods train are important means of transportation for most of the commodities However the time taken by rail is sometimes more than by roads but the cost of transportation is very cheap. Eg. onions, potato, root vegetables *etc*.,

Unrefrigerated rail transport - As with road transport of perishables, unrefrigerated rail transport can only be effective over relatively short distances, actual distance being influenced by prevailing weather conditions and time of transportation.

Refrigerated rail transport - A rail car with mechanical refrigeration equipment can be a larger unit than that transported by road, i.e. 15-20 m in length. A number of modifications can be made to rail cars. For example, a car may be modified to carry bulk produce e.g. potatoes, provided with heaters for winter transportation of chill-sensitive produce in cool climate.

Sea transportation

Major portion of the perishables in international trade is transported by sea. The various method of sea transport include: ambient sea transportation, refrigerated break bulk, refrigerated containers, modified atmosphere containers and hypobaric containers.

A critical factor in sea transportation is to prevent the collapse or dislodging of stacks. The best result is obtained from a uniform pattern of arrangement. Most fruits and vegetables are now packed in containers of fiberboard. However, fruits packed in wooden boxes generally have a fewer problems than fruits packed in fiberboard cases. Sea transportation is carried out in unrefrigerated and refrigerated holds.

Unrefrigerated sea transport - The commodities which have a relatively long storage life at ambient temperatures such as garlic, onion, potato, zinger, turmeric and others are transported in this method.

Refrigerated sea transport - In refrigerated ships, conditions of temperature and relative humidity are rarely held for periods over 3 weeks.

Refrigerated containers - There exist three basic types of containers namely insulated containers, insulated-ventilated containers and temperature-controlled containers (perishable goods).

Certain containers are also approved for fumigation of a cargo or modified to allow use of a controlled atmosphere system. The prepared atmosphere is placed in refrigerated container by displacing air with a specified mixture of N_2, O_2, CO_2 and some trace gases.

Shipping of mixed loads - In general, it is preferable to handle each commodity as a separate load. However, frequently this is not practical. When mixed load shipments are made up only commodities which have compatible requirement *viz*. temperature, modified atmosphere, relative humidity, protection from odours and ethylene should be placed in same hold.

Water ways

This method is used among growers whose fields are situated near on bank of river or lakes. In India, this transportation system is used only in Kashmir, Kerala, parts of Andhra Pradesh and West Bengal. It is yet to be developed for the quick and easy disposal of perishable vegetables from the fields which are situated far away from big markets but near or on the banks or river or lakes.

Air transportation

This method is followed only in case of high value crops such as flowers, rare fruits and vegetables, because of the very high cost of transportation. Costs are high and losses often heavy because of:

1. Poor, non-standard packages
2. Careless handling and exposure to the elements at airports
3. Consignments left behind in favour of passengers
4. Flight delays owing to bad weather or breakdowns
5. Intermittent refrigeration followed by exposure to high temperatures
6. Relatively small produce shipments

Causes of losses during non refrigerated transportation

The damage and loss incurred during non-refrigerated transport are caused primarily by mechanical damage and by overheating.

1. Mechanical damage

1. Careless handling of packed produce during loading and unloading
2. Vibration (shaking) of the vehicle, especially on bad roads
3. Fast driving and poor condition of the vehicle
4. Poor stowage, which allows packages in transit to sway; the stow may collapse
5. Packages stacked too high; the movement of produce within a package increases in relation to its height in the stack.

2. Overheating

This can occur not only from external sources but also from heat generated by the produce within the package itself. Overheating promotes natural breakdown and decay and increases the rate of water loss from produce. The causes of overheating include:

a. The use of closed vehicles without ventilation
b. Close-stow stacking patterns blocking the movement of air between and through packages and thus hindering the dispersal of heat
c. The lack of adequate ventilation among packages themselves
d. Exposure of the packages to the sun while awaiting transport or while trucks are queuing to unload at their destination.

Lecture schedule – 34

QUALITY AND GRADES SPECIFICATION OF HORTICULTURAL PRODUCE

Quality of fresh horticultural commodities is a combination of characteristics, attributes and properties that give the commodity value to humans for food (fruits and vegetables) and enjoyment (ornamentals). The term quality implies the degree of excellence of a produce or its suitability for a particular use. Quality is a human construct comprising many properties or characteristics. Quality of produce encompasses sensory properties (appearance, texture, taste and aroma), nutritive values, chemical constituents, mechanical properties, functional properties and defects. The word "quality" is used in various ways in reference to fresh horticultural produce. The quality of fresh fruits and vegetables may be explained in terms of the following:

1. Fresh market quality
2. Edible quality
3. Storage quality
4. Transport quality
5. Shipping quality
6. Table quality
7. Internal quality
8. Nutritional quality
9. Appearance quality
10. Processing quality

For producers of horticultural crops "good quality" produce (fruits, vegetables or flowers) should give high yield with good appearance, disease resistance, insect resistance, good transport quality and bring higher profit. To receivers and market distributors, appearance quality is most important and also the firmness and long storage quality. Consumers consider good quality fruits, vegetables or flowers to be those that have good fresh market quality i.e., good appearance, good colour, firm or tender (good and optimum texture), good flavour and nutritive value. Although, consumers buy on the basis of appearance and feel, their satisfaction and repeat purchase are dependent upon good edible quality in case of fruits and vegetables.

Quality components: The different components of quality are listed in the following table. These components are used to evaluate quality of the commodities in specifications for grade and standard, selection in breeding programme, and evaluation of responses to various environmental factors and post harvest treatments.

Quality components of fresh fruits and vegetables

S.No	Main factors	Components
1.	Appearance(visual)	Size, dimension, weight, volume, shape and form, smoothness, compactness, uniformity colour, uniformity and intensity Gloss, nature of surface wax Defects: external, internal (morphological, physical and mechanical, physiological, pathological and entomological)

2.	Texture	Firmness, hardness or softness, Crispness, succulence, juiciness, Mealiness, grittiness, fibrousness, Toughness
3.	Flavour (Taste and smell)	Sweetness, sourness(acidity), astringency, bitterness, aroma, off odour, off flavour
4.	Nutritive value	Contents of carbohydrates, proteins, Lipids, vitamins, minerals, fiber, water Antioxidants *etc*.
5.	Safety	Naturally occurring toxicants, Contaminants(chemical residues, heavy metals) Mycotoxins Microbial contamination

There is no universal set of quality standards for any given commodity. Each country has its own criteria depending on local circumstances. Different standards may apply for produce for home consumption and for export. Generally only the better/higher quality produce is exported, because of longer time it has to survive before consumption and to excel in the international market competition.

Quality systems

Management of quality in horticulture industries in whole distribution chain from farm gate to final point of sale requires holistic approach. To achieve this, it is necessary to monitor and prevent quality problems as early as possible in the production or initial post production process rather then relaying on end point.

Among quality assurance systems

1. **ISO 9000** series was used initially but it is a slow process.
2. **HACCP** (Hazard Analysis Critical Control Point) risk management approach systems - It enable to assess the risk and thus identify what go wrong, establish control to minimizes the likelihood of such an occurrence and take corrective action to manages those wrongs.

The 7 steps in HACCP are

- ✓ Identify and assess all hazards
- ✓ Identify the critical control points
- ✓ Identify the critical limits
- ✓ Establish the monitoring procedures
- ✓ Establish the corrective actions
- ✓ Establish a record-keeping systems
- ✓ Establish verification procedures

Based on HACCP, many systems has been established such as

- ✓ EurepGAP – European Good Agriculture Practices
- ✓ SQF 2000 ™ - Safe Quality Foods

Fruits and vegetables are graded into different categories based on sensory quality as well as physical attributes like weight and size. While formal grades and standards are specified codex almintorious for certain fruits and vegetables, many commodities are not covered under this.

Informal grading based on physical appearance and sizes are practiced in trade. Some of the standard used in export trade of important fruits and vegetable are listed below.

Weight grading standards of fruits for export purpose

Crop	A grade	B grade	C grade
Mango	200-350 g	351-550 g	551-800 g
Grape (Bunch)	300 (Extra class)	250 (Class I)	150 (Class II)
Pomegranate	350 g & above	250-350 g	<200 g
Figs	50 g above	40-50 g	30-40 g
Papaya	200-700 g	700-1300 g	1300-1700 g
Guava	>450 g	351-450 g	251-350 g
Pineapple (with crown)	2750 g	2300 g	1900 g
Litchi (diameter)	33 mm	20 mm	
Lime	Minimum wt: 75 g and minimum diameter: 4 cm		

Quality or grading standards for vegetables

Crop	Specific requirement
Okra	Green, tender, 6-9 cm long
Chilies	Green, 6-7 cm long
Cluster bean	Green, tender, 7-10 cm long
Bitter gourd	Green, 20-25 cm long having short neck
Bottle gourd	Light green, straight, cylindrical, 25-30cm long
Tomato	Round, medium size in middle east, cherry tomatoes in European countries
French bean	10-12 cm long, straight, round green pods in bush beans Flat beans with 12-13 cm & straight are also demand in European markets
Big onion	4-6 cm, light to dark red, round , strong pungency for gulf & SEA markets Yellow/brown colour, 7-10 cm, round or spindle shape for European & Japan markets
Small onions	2-3 cm dark red and round
Garlic	White, round, 5 cm & above, bigger cloves of 10-12 cm & above with 10-15 in number. For Bangladesh and Sri Lanka 4-5 cm size bulbs also acceptable
Potato	White, oval, 4.5 to 6 cm. Bangladesh demands red type and Iran & Iraq demands potatoes with yellow flesh

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