Lecture schedule – 1

Importance of Post Harvest Technology in Horticultural Crops

Fresh fruits and vegetables (F&V) have been part of human diet since the dawn of the history. The systematic nutritional value of the some F & V was recognized in the early 17th century in England. One example is the ability of the citrus fruit to cure scurvy, a diseases wide spread among naval personnel.

An example of the importance of the field to post-harvest handling is the discovery that ripening of fruit can be delayed, and thus their storage prolonged, by preventing fruit tissue respiration. The knowledge of the fundamental principles and mechanisms of respiration, leading to post-harvest storage techniques such as cold storage, gaseous storage, and waxy skin coatings. Another well known example is the finding that ripening may be brought on by treatment with ethylene.

Fruits and vegetables are being rich in vitamins and minerals, known as protective foods. Due to their high nutritive valve, ready availability, and being inexpensive they make significantly contributes to human well-being. Realizing the worth of fruits and vegetables in human health ICMR recommend consumption of 120g of fruits and 280g of vegetables per capita per day.

- ✓ F&V are rich in ascorbic acid which have beneficial effects of wound healing and antioxidant. Dietary source of Vit.C is essential, since human beings lack the ability to synthesize it.
- ✓ Some F&V are excellent source of beta -carotene (provitamin A) which is essential for the maintenance of eyes health; and folic acid which prevents anemia.
- ✓ These also prevent degenerative diseases which are prevalent in people with sedentary lifestyle. Concern about obesity and coronary heart diseases have led to reduced levels of fat intake. Antioxidants, phenolic compounds and dietary fiber are considered to be beneficial in reducing risk of various cancers.
- ✓ Many F&V have neutraceuticals properties.

F & V provide variety in the diet through difference in colour, shape, taste, aroma and texture that distinguish from the other major food groups of grains, meats and dairy products. Sensory appeal of F&V is not confined to consumption but also has market value. Diversity in their colour and shape is used by traders in arranging product displays to attract potential purchasers; and chefs have traditionally used F & V to enhance the attractiveness of the prepared dishes or table presentations; to adorn meat displays and F & V carvings have becomes an art.

The ornamental provide sensory pleasure and serenity, derived from the colors, shape and aroma of individual species. Garden plants, cut flowers, foliage and flowering plants are increasingly used in exterior and interior decoration. Considerable commercial opportunities arise from their role in social, religious and economic ceremonies and special greeting occasion such as festivals, Valentine’s day and others occasion.

In India > 90 types of individual F&V are being produced by utilizing its varied agro climatic condition. India has now emerged as the largest producer of fruits relegating Brazil and 2nd largest producer of vegetables next to China.

The Indian total production during the year 2008-09 was of the order of 68.46 mill. ton fruits and 129.00 mill. ton vegetables and total horticultural produce was 214.71 mill. ton (Agri. Ministry, GOI, 2010). India accounts for about 8.40% and 9.10% of global production of Fruits and Vegetable respectively (except potato and onion where it accounts for 7.60% and 9.70% respectively). Crop wise consideration shows that it has largest producer of mango, accounting to 66% of world production; holding record highest productivity in grapes; contributing to 11% of world banana and; 3rd largest producer of coconut; largest exporter of cashew nut(production + import of raw nut and than export) and 1st in spice trade.

India's Exports of Horticultural Products (₹ in cores)

Items	*2007- 08*	*2008- 09*	*2009-10 (Provision)*
Fresh Fruits	1447	1946	2269
Fresh Vegetables	1473	2454	2904
Processed Vegetables	605	711	752
Processed Fruit Juices	769	1099	1156
Miscellaneous Processed Items	1362	2077	2137

(Source-Ministry of Agri. GOI-2010)

India share in global trade of horticultural produce is miniscule and it is < 1% and only 2.2% of the total horticultural produce is being processed. Due to inadequate post harvest handling 20-30% of horticultural produce are lost annually and such loss in terms of monitory values goes to about Rs.7000/- per annum. This loss of great magnitude not only robs labour and recourses of the farmer and the nation but also dwindle away a big profit of the farmer. Managing the post harvest losses is very much important. Preservation of the produce is one of the ways to manage post harvest losses.

Fruits and vegetables used for processing in different countries

Sl.No.	Countries	%
1	**Malaysia**	83
2	**Saudi Arabia**	80
3	**Philippine**	78
4	**Brazil**	70
5	**Australia**	60
6	**USA**	40
7	**UK**	50
8	India	2.20

Though India produces large quantity of horticultural produce in the world, per capita consumption is very low for our over a billion population. Major portion is being wasted at various stages of from production till it reaches end-user and its mainly due to inadequate facilities for processing. Delay in the use of harvested produce will affect its – fresh ness, palatability, appeal and nutritive value.

Need for Post harvest technology

F, V and ornamentals are ideally harvested based on optimum eating or visual quality. However, since they are living biological entities, they will deteriorate after harvest. The rate of deterioration varies greatly among products depending on their overall rate of metabolism, but for many it can be rapid. For example marketing chains where produce is transported from farm to end user with in a short time period, the rate of PH deterioration is of little consequences. However, with the increasing remoteness of production areas from population centers, the time lag from farm to market is considerable. The deliberate storage of certain produce to capture better return adds to this time delay between farm and end user, by extending the marketing periods into times of shorter supply. Thus a modern marketing chain puts increasing demands on produce and creates the need for the PH techniques that allows retention of quality over an increasingly longer period.

Harvest: is a specific and single deliberate action to separates the food stuff with or with out non edible portion from its growth medium.

Eg - Plucking of F &V - Reaping of cereals

- Lifting of fish from water - lifting of tuber or roots from soil *etc*.

Postharvest – all the succeeding action after harvest are defined as post-harvest technique. From this period of time all action is enters the process of preparation for final consumption.

Eg - pre cooling - waxing

- cleaning/washing - chemical treatments
- trimming/sorting - packaging
- curing, - transportation
- grading - storage, ripening and distribution

'The extending the PH life of horticultural produce requires knowledge of all the factors that can lead to loss of quality or generation of unsalable material. The field of study that adds to and uses this knowledge in order to develop affordable and effective technologies that minimizes the rate of deterioration is known as **postharvest technology**.'

Post harvest technology is inter-disciplinary "science and technique" applied to horticultural/agri produce after harvest for its protection, conservation, processing, packaging, distribution, marketing, and utilization to meet the food and nutritional requirements of the people in relation to their needs.

Hence thorough understanding of the structure, composition, biochemistry and physiology of horticultural produce is essential for PH technologist.

Post harvest Shelf Life - Once harvested, produce are subject to the active process of senescence. Numerous biochemical processes continuously change the original composition of the produce until it becomes unmarketable. The period during which consumption is considered acceptable is defined as the time of "post harvest shelf life".

Post harvest shelf life is typically determined by objective methods like

- Overall appearance
- Taste, flavor, and texture of the commodity. These methods usually include a combination of sensory, biochemical, mechanical, and colorimetric(optical) measurements.

Post Harvest Physiology - is the scientific study of the physiology of living plant tissues after they have been denied further nutrition by picking/harvest. It has direct applications to post harvest handling in establishing the storage and transport conditions that prolong shelf life.

Preservation - "the techniques of extending the storage life of the produce without deteriorating its edible quality for further use".
Horticultural produce is biological entity with various physiological activities like transpiration and respiration continuing even after harvesting. This process leads to the bio-chemical breakdown and cause spoilage of the produce. Spoilage is initiated by enzymes present inside the produce, involvement of micro organism, infestation of insect-pest and invasion of pathogens. By taking care of these factors, food products can be stored for longer period.

Processing - the application of techniques to prevent losses through preservation, processing, packaging, storage and distribution.

The processed foods have now become more of a necessity than a luxury. It has an important role in the conservation and better utilization of fruits and vegetables. It is necessary in order to avoid glut and utilize the surplus during the peak seasons. It is employs modern methods to extend storage life for better distribution and also processing technique to preserve them for utilization in the off season.

Problems faced in establishment of processing unit are identified as follows.

- insufficient demand
- weak infrastructure
- poor transportation
- perishable nature of crops and
- grower sustains substantial losses

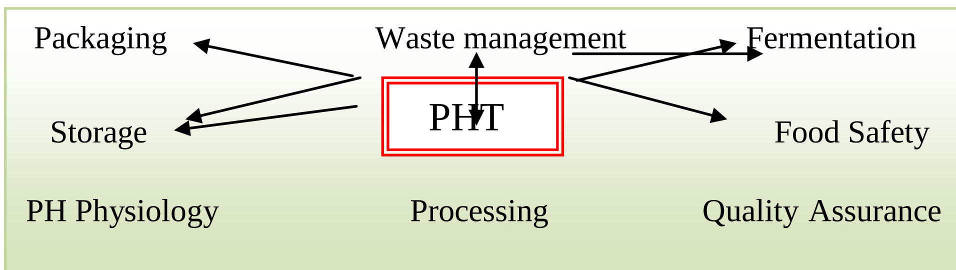
The market for many 'exotic' crops has increased many folds over traditional ones. Every year new crops are being offered for sale in the markets and it demands innovation in the handling methods and study of their quality factors.
The process which deals with handling of parts of the plants, such as fruits, vegetables, root crops, spices, foliage and flowers which are often collectively referred to as perishable crops, is called postharvest management. Perishables are botanically and physiologically very diverse and therefore behave in very different ways and require a variety of different treatments and conditions.
Post harvest handling is the stage of crop production immediately following harvest, including cooling, cleaning, sorting and packing. The instant a crop is removed from the ground, or separated from its parent plant, it begins to deteriorate. Post-harvest treatment largely determines final quality, whether a crop is sold for fresh consumption, or used as an ingredient in a processed food product. Effective handling decreases post harvest losses.
The most important goals of post-harvest handling are

1. Keeping the product cool, to avoid moisture loss and slow down undesirable chemical changes
2. Avoiding physical damage such as bruising, delay spoilage.

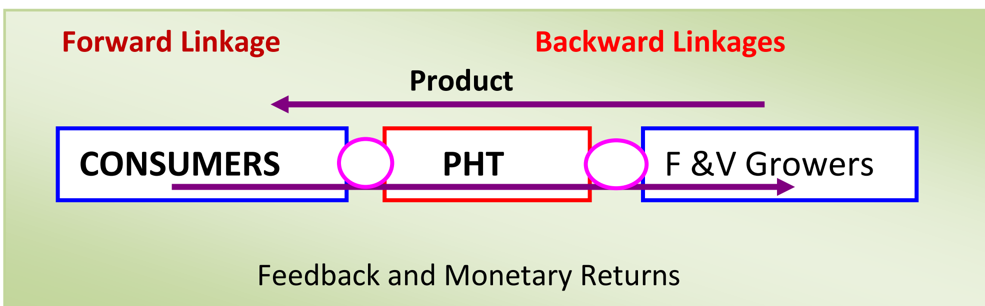
After the harvest, post-harvest processing is usually continued in a packing house. This can be a simple shed, providing shade and running water, or a large-scale, sophisticated, mechanized facility, with conveyor belts, automated sorting and packing stations, walk-in coolers. In mechanized harvesting, processing may also begin as part of the actual harvest process, with initial cleaning and sorting performed by the harvesting machinery.

Implementing Good Agricultural Practices (GAP) in production and harvest; Good Manufacturing Practices (GMP) especially during post-harvest and Quality and Safety Assurance Systems, such as HACCP (Hazard Analysis Critical Control Point), throughout the food chain to avoid and to control hazards are of the key factors for the flourishing nature of the post harvest industries.

Post harvest technology and its sub - disciplines



Post harvest technology functioning chain



Effective management during the postharvest period, rather than the level of sophistication of any given technology, is the key in reaching the desired objectives. Many simple practices have successfully been used to reduce losses and maintain produce quality of horticultural crops in various parts of the world for many years.

There are many interacting steps involved in any post harvest system. Produce is often handled by many different people, transported and stored repeatedly between harvest and consumption. While particular practices and the sequence of operations will vary for each crop, there is a general series of steps in post harvest handling systems that are often followed.

- ✓ Harvesting and preparation for market
- ✓ Curing root, tuber and bulb crops
- ✓ Packinghouse operations
- ✓ Packing and packaging materials
- ✓ Decay and insect control
- ✓ Temperature and relative humidity control
- ✓ Storage of horticultural crops
- ✓ Transportation of horticultural crops
- ✓ Handling at destination

- ✓ Packing and Packaging Practices

PHT – Importance and Role

1. PH Loss reduction
2. Value addition
3. Contribution to the Economy
4. Making availability of fruits and vegetables during off seasons
5. Tools for export earnings
6. Employment generation
7. Adding variety in taste and nutrition
8. Waste utilization
9. Home scale preservation
10. Supply of food to the defense forces
11. Special canned fruits for infants & children's
12. Food supplier to the Astronauts

Role of PH Technologist

1. To provide quality, nutritious and safe food
2. To develop new product & technologies - Discoveries - The best example for the highest post harvest life in the nature is the Swiss Apple - *Uttwiler Spatlauber*, is well known for its excellent storability; it can stay fresh looking for up to four months after being harvested. However, it has not been widely cultivated because of its sour taste. . Innovation –biotechnology has been used to extend the storage life in tomato and developed variety called FLAVR SAVR ™,- using technology to reduce the activity of the enzyme endopolygalcturonase, which involved in the cell wall breakdown during ripening and fruit will remain firmer during ripening on and off the plant.
3. To develop new equipment and determine their efficiency.

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Sl.No.	Title	Authors	Years	Publishers
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Lecture schedule - 2

Structure and Composition of Fruits, Vegetables and Flowers

Structure of fruits, vegetable and flowers

The fruits commercially comprise various combinations of tissues that may include an expanded ovary, the seed and other tissue.

Definition of Fruit: 'The edible product of a plant or tree, consisting of the seed and its envelope, especially the latter (envelope) when juicy and pulpy'.

Consumer definition of Fruit: 'Plant product with aromatic flavors, which are either naturally sweet or normally sweetened before eating'

Vegetables: do not represent any specific botanical groupings and exhibits wide verity of plant structure. (Edible seeds / roots / stems / leaves / bulbs / tubers / non sweet fruits of herbaceous plants).
Vegetables are grouped into 3 main categories

1) Seeds and pods – contain natural wax coating. Eg. Many legumes
2) Bulbs, roots and tuber – no coating, but tuber has suberisation
3) Flowers, buds, stems and leaves – low shelf life

Flowers: are variations of inflorescence. Basic structure of inflorescence is stem, including pedicel and peduncles, bracts and flowers. Inflorescence is low in carbohydrates compared to fruits. Hence sucrose solution is provided to enhance the vase life of the flowers.

Most of the fruits, vegetables and flowers are made up of paranchymatous tissues containing typical plant cell. Almost all the cell components of a plant cell are present in these cells too. All fruits and many vegetables being storage organs or sink of the plant are abundant in photosynthates.

Difference between fruit and vegetables

Sl.No	Fruits	Vegetables
1	Generally consumed as raw, not during meals. (Dessert purpose)	Consumed as cooked during meals
2	More sweet	Less/nil sweet
3	Juicy, pulpy and luscious	Hard and mostly not juicy
4	Fruits are developed from flower / flower part/inflorescences	It can be leaf/stem/root/flower *etc.*
5	Mostly woody perennial	Mostly non woody annuals or biennials
6	Mostly propagated asexually	Mostly by Seed
7	Fruits are acidic and are commonly called 'high acid' foods. (pH < 4.5)	Vegetables are less acidic than fruits and hence classified as 'low acid' foods.(pH >4.5)
8	Acidity naturally controls growth of micro-organisms	Micro-organisms are able to grow in moist low-acid products, which may lead to spoilage and the possibility of food poisoning.

9	The spoilage microorganisms are moulds and yeasts, which if consumed, rarely cause illness.	To prevent/minimise microbes like bacteria various methods are employed like processing
10	Processing may be achieved by using preservatives such as sugar, salt and vinegar and by drying, concentration or fermentation.	Processing by means of heating to destroy bacteria or by pickling, salting, or drying to inhibit bacterial growth. (Possibility of transmitting food poisoning bacteria to consumers).

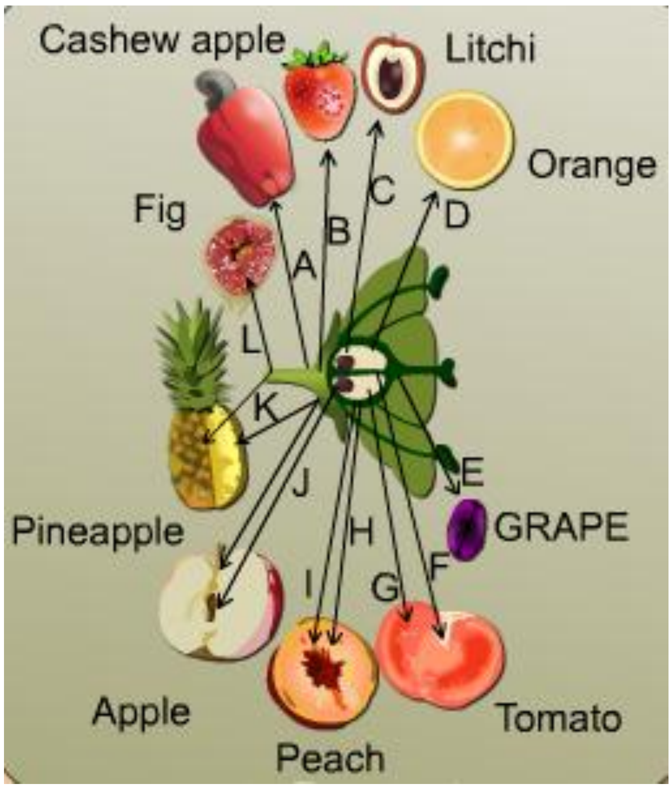


Figure 1. Derivation of some fruits from plant tissue.
The letters indicate the tissues that comprise a significant portion of the fruit illustrated: (A) pedicel, (B) receptacle, (C) aril, (D) endodermal intralocular tissue, (E) pericarp, (F) septum, (G) placental intralocular tissue, (H) mesocarp, (I) endocarp, (J) carpels, (K) accessory tissue,(L) peduncle

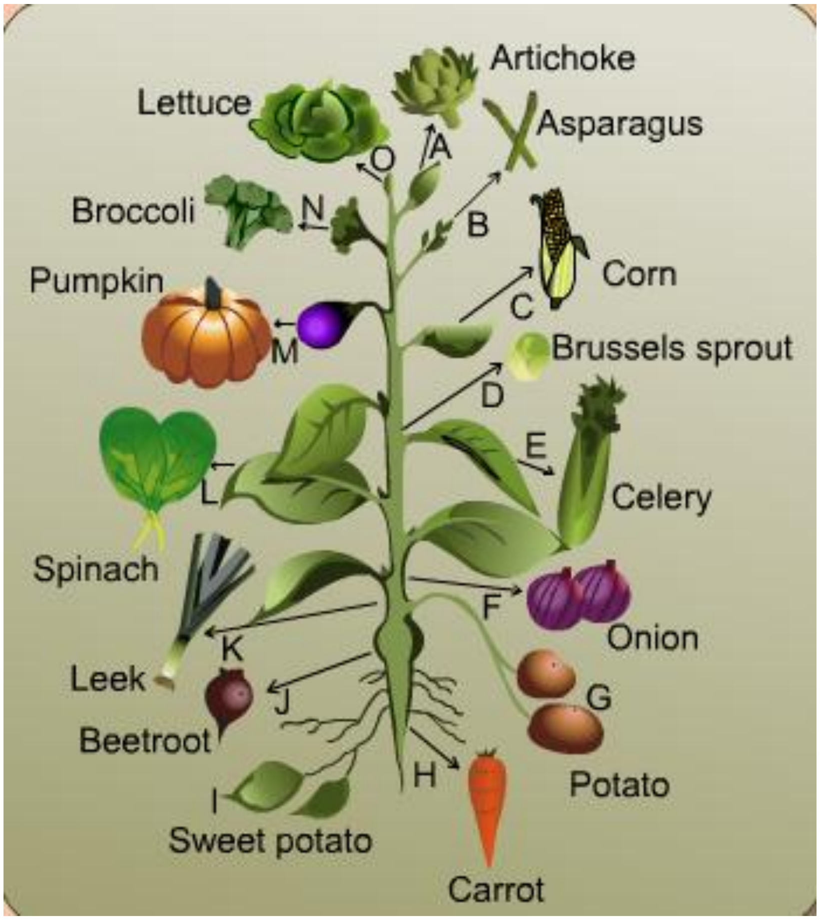


Figure 2. Derivation of some vegetables from plant tissue.

The letters indicate the principal origins of representative vegetables as follows: (A) flower bud, (B) stem sprout, (C) seeds, (D) axillary bud, (E) petiole, (F) bulb (underground bud), (G) stem tuber, (H) swollen root, (I) swollen root tuber,(J) swollen hypocotyls, (K) swollen leaf base, (L) leaf blade, (M) fruit, (N) swollen inflorescence, (0) main bud.

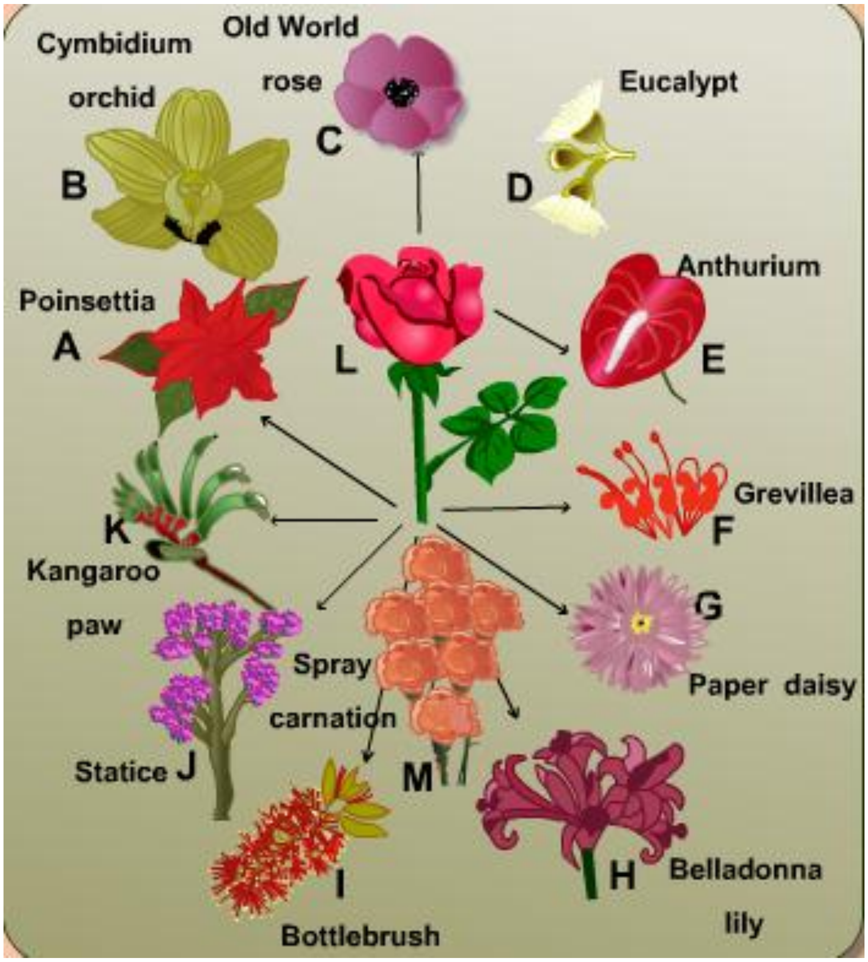
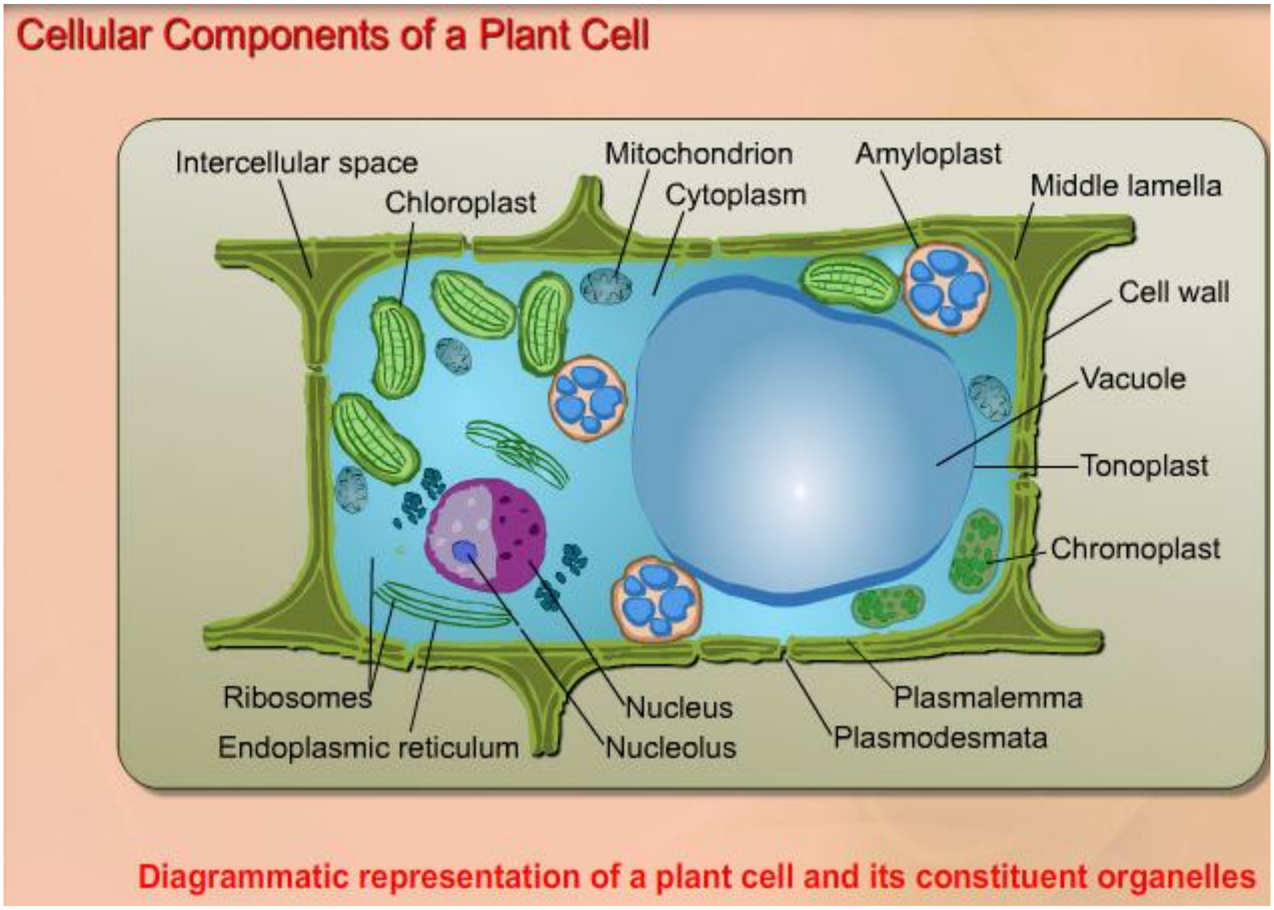


Figure 3. Examples of variations in the structure of flowers. (A) bract, (B) modifications and fusions, in which the labellum is a median modified petal and the column is comprised of fused stamens and pistils, (C) complete, single whorl of petals, (D) prominent feature (stamens), (E) spadix plus spathe, (F) raceme, (G) head, (H) umbel, (I) spike, (J) panicle, (K) cyme, (L) solitary, (M) corymb

Composition of Fruits, Vegetables and Flowers

Cellular Components of a Plant Cell



Cell components their function relevant to postharvest managemnt

	Components	Functions
I	Cell wall	
A.	Primary wall	Includes cellulose (9-25%) hemicelluloses (25-50%) pectin substances and protein (10%). It stretches plastically during cell growth & allows the free passage of water minerals dissolves in water
B.	Sec. wall	Cellulose (45%), hemicelluloses (30%) and lignin (22-28%). Provide structural support to the plants
C.	Middle lamella	A layer of pectin substances forms the middle lamella and acts to bind adjacent cell together
II	Protoplast (Content of cell with out cell wall)	
A	Cytoplasm : (Cytoplasm + nucleolus =Protoplasm)	
	PLASTIDS	
i	Chloroplast	Chloroplast contains 50% protein and 50-55% lipids and small amount of nucleic acids. These are found in green cells.
ii	Chromoplast	These are developed from mature chloroplasts after degradation of chlorophyll ands responsible for yellow – red pigmentation in the fruits.
iii	Leucoplasts &	Leucoplasts are colour less plastids and contain protein. In the later

	Amyloplasts	stages leucoplasts are known as amyloplasts
B.	Vacuoles	These are reservoir of cell and occupies about 80-90% of the cell volume. It contains various inorganic ions, sugars, amino acids, organics acids, gums, mucilages, tannins, flavonoids, phenolics, pigments and others nitrogenous compounds
C.	Nucleus	
D.	Ergastic substances	Crystal like calcium oxalate, tannins, fats. CHO and proteins are stored in various components of the cell.

Bio chemical constituents which plays an important role in determining the composition and quality of F & V are as follows.

1. Water – Most of the fruits and vegetables contain 70-80% moisture while some vegetables like leafy vegetables and melons contain almost 92-95% moisture. The tubers crops like cassava, yam and corms contain less moisture (around 50%) and are more starchy. Moisture plays an important role in fruits and vegetables because many of the nutrients exist in soluble state in them. The higher moisture content makes the fruits, vegetables and flowers perishable as it is easily vulnerable to attack by microorganisms. Further moisture is lost during the biological activity of these commodities which deteriorates its quality in terms of freshness. Therefore, retention of the moisture or prevention of loss of moisture is one of the important considerations in planning a storage technique or strategy for extension of shelf life. The actual water content is dependent on the availability of water to the tissue at the time of harvest. Water content of produce will vary during the day if there are fluctuations in temperature. For most produce, it is desirable to harvest when the maximum possible water content is present as these results in a crisp texture.

Examples of moisture content of some of fruits and vegetables

95% - cucumber, lettuce, melons

>80% - many F&V

50% - starch tubers and seeds like –yam, cassava and corn

2. Carbohydrates –

Carbohyrates are the major constituent after water, which account for 2-40% in tissues with lowest found in cucurbits and highest found in cassava. They occur mainly as starches and structural polysaccharides like pectins, celluloses, hemicelluloses. In many of the fruits and some vegetables the starches and few other polysaccharides undergo conversion into simple sugars like sucrose, glucose and fructose during ripening. These are responsible for sweetness. Small quantities of carbohydrates also occur as organic acids which are responsible for sourness or acidity. The major organic acids found in fruits and vegetable are citric, malic, tartaric, oxalic and pyruvic. Small quantities of bi- and tri- carboxylic acids also are present. In fruits and vegetables carbohydrates contribute mainly for its calorific value.

Examples of carbohydrates content in some of fruits and vegetables

- ✓ Most abundant group after water, accounts for 2 - 40 g 100^{-1} g
- ✓ Low in cucumber and high in cassava (20g 100^{-1} g)
- ✓ In fruits and vegetables carbohydrates contribute mainly for its calorific value.

Sugars constitutes major carbohydrates in fruits particularly after ripining

a).SUGARS – Many tropical and sub-tropical fruits contain highest level of sugars. Glucose and fructose are the major sugars in all fruits and often present in similar level, while sucrose is only present in about 2/3rd of the produce. It helps in imparting colour, flavour, appearance and texture to the fruits. Flavour is fundamentally the balance between sugar and acids ratios. Sugar is the primary substrate for respiration and energy.

The glycaemic index (GI) of F & V varies from 22(cherries) -97(parsnip).

Potato and sweet potato – 55 - 60

Bread- 70

b).**FIBER** – cellulose, hemicelluloses, lignin and pectic substances

3. Protein – Fruits and vegetables are not an important source of proteins. Though some vegetables like brassica group contains 3-5% of proteins and legumes (5g), majority of fruits and vegetables contain not more than 1-2%. These proteins are present mainly as enzymes.

4. Lipids – Lipids are not more than 1% in majority of fruits and vegetables except some like avocado(20%) and olive(15%). In most of them it is present as protective cuticle layer on surface. However, nuts contain considerable amount of fats. Generally low fat levels seen in fruits and vegetables make it more healthy foods to combat heart related diseases and disorders like hyperlipidaemia.

5. Minerals - Fruits and vegetables are good sources of minerals. Minerals are essential for growth and development of body right from birth to old age. Calcium is present in several fruits as calcium pectate in cell walls. Calcium appears to be linked to control of enzyme activities, respiration and ethylene production. Some fruits like bananas are rich in potassium.

6. Vitamins – Generally F&V are rich vitamins but their quantity is varied among them. Fat-soluble vitamins A, D, E and K and water-soluble vitamins C and B group are found in F&V. These are needed for growth, normal function of the body.

Vitamins and their sources

Vitamin A	Leafy vegetables, radish tops, mango, papaya, carrots *etc*.
Thiamine (B_1)	Fresh peas & beans, cabbage, bael, pomegranate, jamum, *etc*.
Riboflavin(B_2)	Banana, litchi, papaya, radish top, pineapple, cowpea *etc*.
Niacin(B_3)	Banana, strawberry, peach, cherry, green vegetables *etc*.
Vitamin C	Anola, guava, citrus fruits, cashew apple, leafy vegetables, green chilli, drumstick *etc*.
Vitamin D	Cabbage, carrot
Pyridoxine (B_6)	Vegetables
Folic acid (B_9)	Fresh GLV, lady's finger, cluster beans
Cyanocobalamin(B_{12})	Yeast, fermented foods.

7. Pigments - The attractive colour of the many fruit is due to sugar derivates of anthocynidins. At the time of ripening, loss of chlorophyll and accompanied by synthesis of anthocyanins or carotenoids which present in vacuole and chloroplast respectively.

- anthocyanins – gives colour from red to blue
- carotenoids - are synthesized in green tissue eg. beta-carotene and lycopene

8. Phenolics and antioxidants – major class of plant compounds, it comprising of anthocyanins, leucoanthocyanins, anthoxanthins, hydroxybenzoic acids, glycosides, sugar esters of quinic and shikimic acids, esters of hydroxycinnamic acids and coumarin derivatives

The phenols are impotent in determining the colour and flavour of the fruit. Phenols are by products of the metabolism of the amino acids and contribute the sensory qualities of the fruits (colour, astringency, bitterness and aroma) and play the vital role in the resistance to attack of pathogen and stress. It is known for its antioxidant activities.

9. Organic acids – imparts taste and flavour.

The major acids are malic (apple), citric(citrus), tartaric(grape), quinic, succinic and shikimic acids

Organic acids plays important role in
- photosynthesis and respiration
- synthesis of phenolic compounds, lipids and volatiles aroma

10. Volatiles (Flavour) compounds –

Important in producing characteristic flavor and aroma (mol.wt <250 possess volatile nature)

Concentration – 10 mg 100^{-1}g

Compounds are – esters, alcohols, acids, aldehydes and ketones.

Ethanol is common to all F&V, where as others are specific.

Esters present in ripe fruits

Sulphur in Brassica sp. and tomato

11. Texture - Texture is governed by structural polysaccharides.

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Lecture Schedule – 3

Physiology and Biochemistry of Horticultural Produce

Part - 1

FRUIT AND VEGETABLES ARE ALIVE AFTER HARVEST

Horticultural Produce respire by taking up O_2, giving off CO_2 and heat and also transpire. While attached to plants, losses due to transpiration and respiration are replaced by flow of sap, which contain water, photosynthates and minerals. These functions continue even after harvest, and since the produce is now removed from the its normal source of H_2O, photosynthates and minerals, the produce entirely depend on their own food reserves and moisture content. Therefore, losses of repairable substrates and moisture are not made up and deterioration has commenced hence, produce are perishable.

PHYSIOLOGY OF FRUIT AND VEGETABLES

Fruits and Vegetables are living entities and diverse in structure, composition and physiology. They have the typical plant cell system.

The life of fruit and vegetables can be conveniently divided into three major physiological stages following germination.

These are: Growth → Maturation → Senescence

- **Growth** - involves cell division and subsequent cell enlargement, which accounts for the final size of the produce.
- **Maturation** - usually commences before growth ceases and includes different activities in different commodities. Growth and maturation are often collectively referred to as the development phase.
- **Senescence** - is defined as the period when synthetic (anabolic) biochemical process gives way to degradative (catabolic) process, leading to ageing and finally death of the tissue.
- **Ripening** - is a phase of qualitative change which occurs in fruits particularly, after completion of maturation, during which the fruit becomes acceptable for consumption in terms of taste and flavour. Ripening occur during the later stages of maturation and is the first stage of senescence.

Normally development and maturation processes are completed before harvest. The completion of this stage is referred to as 'maturity'. But depending upon the nature of produce and the desired characteristics in a particular fruit or vegetable, the stage of maturity differs. Sometimes in fruits like mango, it has to attain the full stage of maturation to develop the characteristic flavour and taste, while in vegetables like Okra/beans/drumstick it should not mature fully where it becomes fibrous and unpalatable. Similar terminology may be applied to the vegetables, ornamental and flowers, except that ripening stages does not occur. As consequence it is very difficult to delineate the changes from maturation to senescence in vegetables and ornamentals. Vegetables are harvested over a wide range of physiological ages, that is, from a time well before the commencement of maturation through to the commencement of senescence.Based on this requirement terms like 'physiological maturity' and 'harvest maturity' are used.

Fruit Respiration

One of the major physiological and biochemical change which occur in fruits and vegetables is a change in the pattern of respiration. The respiration rate of produce is an excellent indicator of the metabolic activity of the tissue and thus is a useful guide to the potential storage life of the produce. If the respiration rate of a fruit or vegetable is measured as their O_2 consumed or CO_2 evolved during the course of the development, maturation, ripening and senescent period, a characteristic respiratory pattern is observed. The respiratory pattern also impacts the pattern of evolution of ethylene. Based on this pattern, fruits can be classified into 'climacteric' and 'non-climacteric'. Few fruits exhibit the pronounced <u>increase in the respiration (increase in </u>CO_2 and C_2H_4<u>) coincident with the ripening</u>, such increase in the respiration is known as respiratory climacteric, and this group of fruits is called <u>climacteric</u>.

Difference between climacteric and non-climacteric fruits

	Climacteric Fruit (CF)	Non-climacteric Fruit(NCF)
1	Normally they ripen after harvest	Fruit that does not ripen after harvest. Ripen on the plant itself.
2	The quality of fruit changes drastically after harvest characterized by softening, change in colour and sweetness. (except in avocado, which will ripen only after detached from the plant)	The quality do not change significantly after harvest except little softening. Do not change to improve their eating characteristics
3	Exhibits a peak in respiration	Does not exhibit a peak
4	More ethylene is produced during ripening	Little / No ethylene production
5	Significant increase in CO_2 production	No significant increase in CO_2 production
6	Significant increase in CO_2 production	Slowly
7	Decrease in internal oxygen concentration	More
8	Low concentration of ethylene 0.1-1.0 µ L/L/day is sufficient to hasten ripening	Not much response is seen to exogenous application of ethylene.
9	Eg - Many except in the apposite column	Eg- Bell pepper, Blackberry, Blueberry, Cacao, Cashew apple, Cherry, Citrus sp.,Carambola, Cucumber, Eggplant, Grape, Litchi, Loquat, Okra, Olives, Pea, Pineapple, Pomegranate, Pumpkin, Raspberry, Strawberry, Summer squash, Tart cherries, Tree tomato and *rin* & *nor* tomato, Watermelon
		

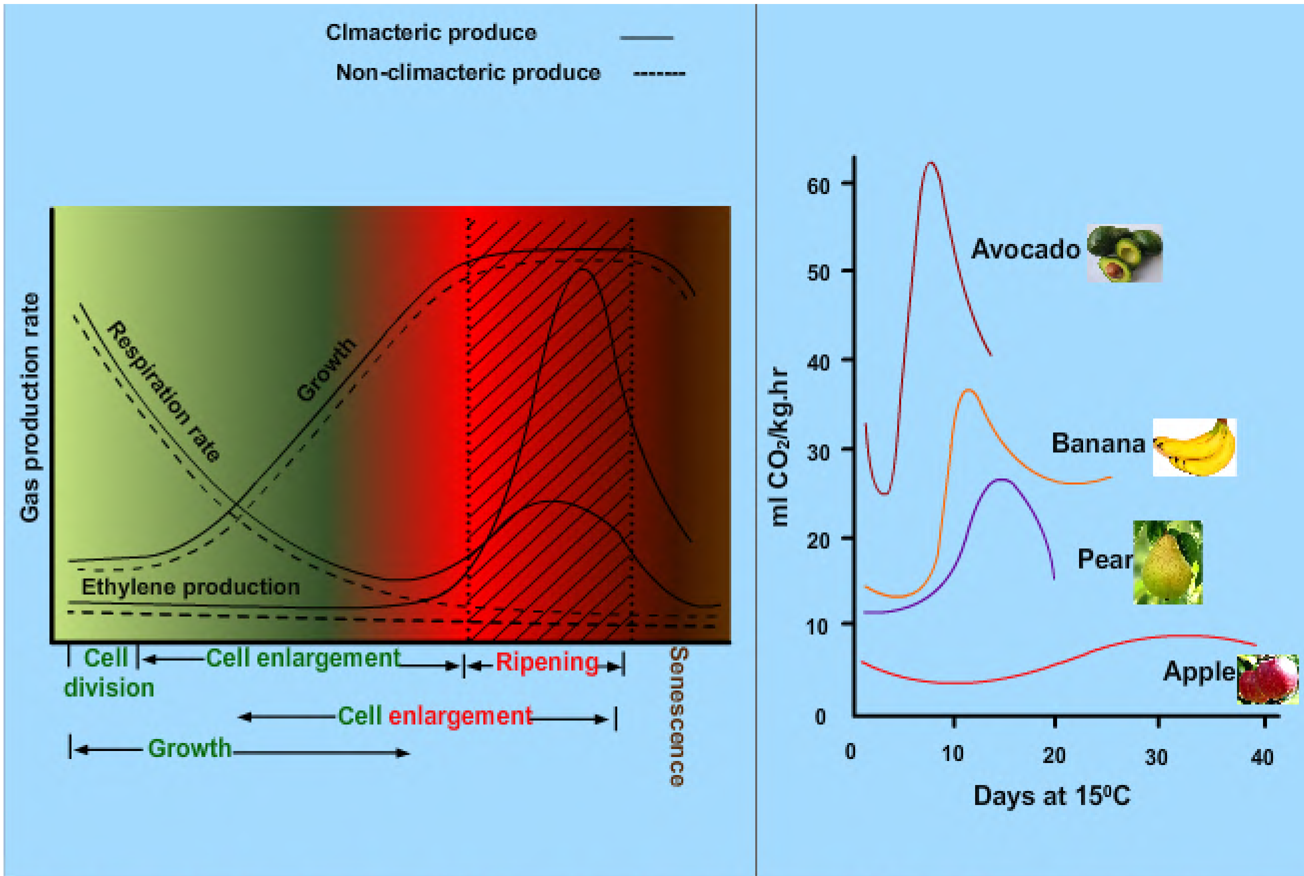


Fig.3.1 Growth, respiration and ethylene production patterns of climacteric and non-climacteric plant organs

Fig.3.2 Respiratory patteren of harvested climacteric fruits

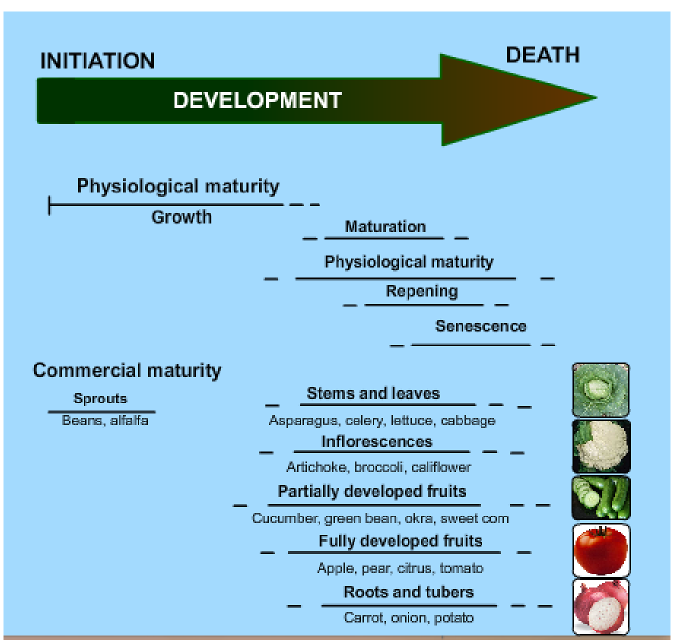


Fig. Maturity in relation to developmental stages of the plant

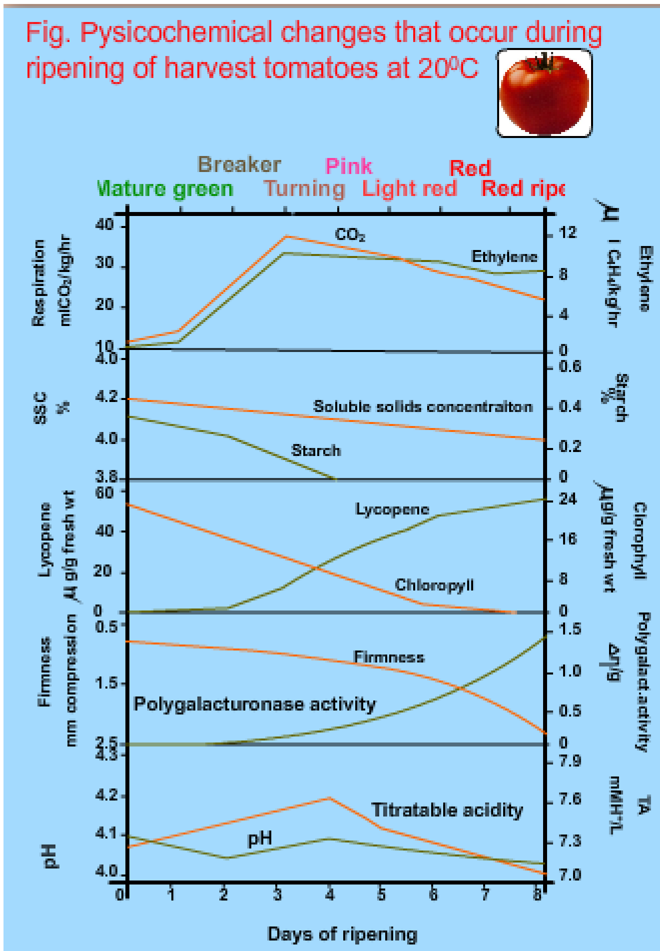


Fig. Pysicochemical changes that occur during ripening of harvest tomatoes at 20⁰C

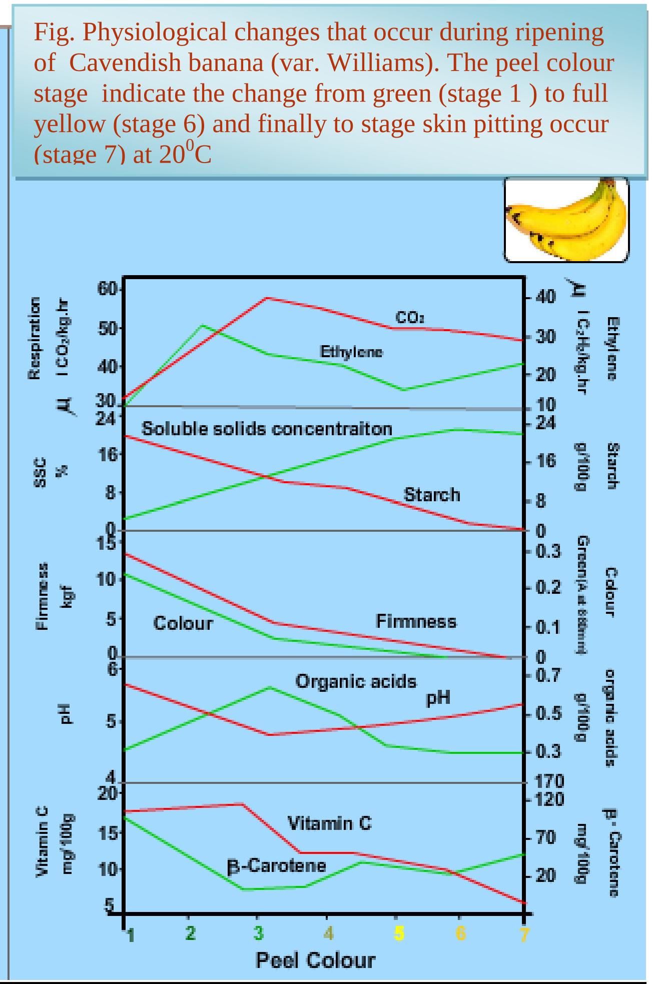


Fig. Physiological changes that occur during ripening of Cavendish banana (var. Williams). The peel colour stage indicate the change from green (stage 1) to full yellow (stage 6) and finally to stage skin pitting occur (stage 7) at 20⁰C

Respiration

Respiration is a process in which stored organic materials (carbohydrates, protein, and fat) are broken down into simple end products with release of energy. Oxygen is used in this process and carbon dioxide is produced.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy (686 k.cal)}$$

Oxidation of glucose generates an equal amount of CO_2 for the O_2 consumed, whereas oxidation of malate generate more CO_2 then the O_2 consumed. This ratio between the oxygen consumed and carbondioxide produced is called respiratory quotient. This relationship is important in measuring respiration by gas exchange.

The O_2 concentration at which anaerobic respiration commences varies between tissues and is usually below 1 % V/V and off falvour may results from fermentation.

<u>Respiration influences the product in following manner</u>

- Reduced food value (energy value) for the consumer
- Reduced flavor due to loss of volatiles
- Reduced sweetness

- Reduce weight
- Important for the commodities desire dehydration

The rate of deterioration of horticultural commodities is directly proportion to the respiration rate On the basis of their respiration rate we can classify different fruit and vegetables in following way:

Classification of horticultural commodities according to their respiration rate

CLASS	Range at 5° C ($mgCO_2Kg^{-1} hr^{-1}$)	COMMODITIES
Very low	**< 5**	Dates, Dried fruit and vegetables, Nuts, *etc*.
Low	**5 - 10**	Apple, Beet, Celery, Citrus Fruits, Garlic, Grapes, Kiwi Fruit, Onion, Papaya, Pineapple, Potato (Mature), Sweet Potato, Watermelon *etc*.
Moderate	**10 - 20**	Apricot, Banana, Cabbage, Carrot (Topped), Cherry, Fig, Lettuce (Head), Mango, Peach, Pear, Plum, Potato (Immature), Radish (Topped), Tomato, Summer squash
High	**20 - 40**	Avocado. Carrot (with tops), Cauliflower, Leeks, Lettuce (Leaf), Radish (with tops), Raspberry
Very high	**40 - 60**	Artichoke, Bean Sprouts, Broccoli, Brussels sprouts, Cut flowers, Green Onion, Okra
Extremely high	**> 60**	Asparagus, Mushroom, Parsley, Peas, Spinach, Sweet corn

Factors responsible for the respiration (external and internal)

1. Temperature
2. RH
3. Gas composition in the ambient and with in the cell
4. Moisture content of the tissue
5. Wounding or injury
6. Type of the plant parts
7. Stage of development of tissue
8. Surface area to volume of the produce
9. Pre-harvest treatments and PH methods employed
10. Chemical composition of tissue
11. Size of the produce
12. Presence of natural coating on the surface

Lecture schedule - 4

Physiology and Biochemistry of Horticultural Produce

Part - 2

Ethylene – its role, biosynthesis and effects

Ethylene is a natural plant hormone released by all plant tissues and microorganisms. It is also called 'Ripening hormone', as it plays an important role in ripening process. Low concentration of 0.1-1.0 microlitres is sufficient to trigger the ripening process in climacteric fruits. It has autocatalytic activity because of which such small quantities can trigger further release of large quantities of ethylene by the fruit tissue. Very little response is only seen to exogenous application of ethylene in case of non-climacteric fruits.

Production of ethylene results in premature ripening of certain horticultural produce.
All fruits produce minute quantity of ethylene during development, however, coincident with ripening, climacteric fruits produce much larger amount of ethylene than non climacteric fruits

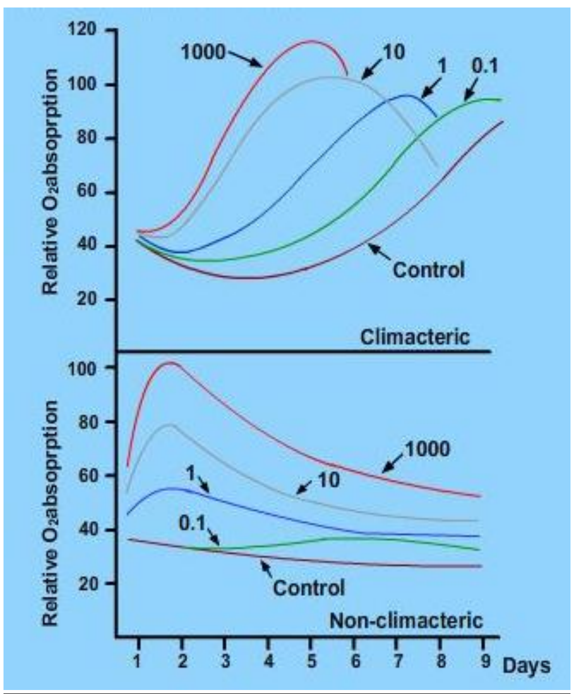
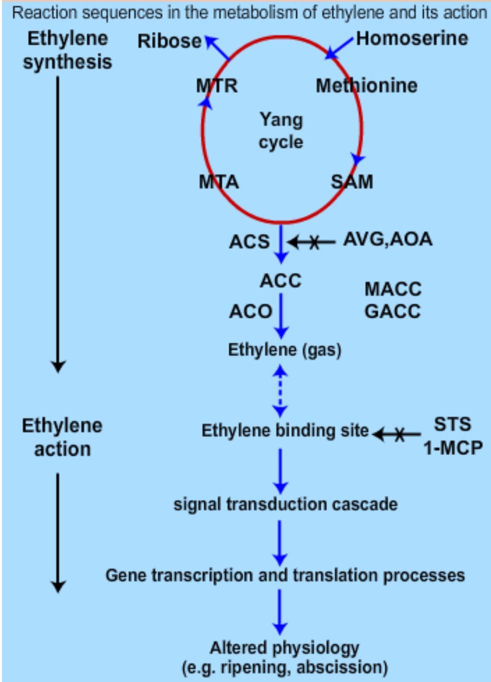


Fig. Effects of applied ethylene on respiration of climacteric and non-climacteric fruits

Ethylene Biosynthesis

Reaction sequences in the metabolism of ethylene and its action



Ethylene has been shown to be produced from methionine via a intermediates S-adenosyl-methionine (SAM) and 1-aminocyclopropane-1-carboxylic acid (ACC). The conversion of SAM to ACC by the enzymes ACC Synthase(ACS). In higher plants, ACC can be removed by conjugation to form malonyl ACC (MACC) or glutamyl ACC (GACC). Ethylene forming enzyme (EFE) or ACC oxidase (ACO) is required to convert ACC to ethylene. ACO is a liable enzyme and sensitive to oxygen and attached to outer layer of the plasmalemma. Factor that effect the activity of the ACS includes fruit ripening, senescence, auxin, physical injuries and chilling injury. This enzyme (ACS) is strongly inhibited by aminooxyacetic acid(AOA), rhizobitoxine and amino ethoxy vinayl glycine (AVG). ACO is inhibited by anaerobiosis, temperature above 35^0C and cobalt ions.

Among various chemical used for extension of shelf life fruits 1-MCP has been found to be very effective. The 1-methyl cyclo propene (1-MCP) has been shown to be highly effective inhibitors of C_2H_4 action. 1–MCP binds irreversibly to the C_2H_4 receptors in sensitive plants tissues and a single treatment with low concentration for a few hours at ambient temperatures confers protection against C_2H_4 for several days. Many fruits respond to 1-MCP in extension of storage life by retarding the process of ripening.

The pattern of C_2H_4 production in tomato is it rises before the onset of ripening, where as in, apple and mango it does not rise before increase in reparation. Immature tomato fruit has high rate of C_2H_4 production and it extremely tolerance to C_2H_4 but banana and melons can readily ripened with C_2H_4 even when immature.

On the basis of ethylene production rate horticultural commodities are classified into following way:

Class	Range at 20^0 C (µ C_2H_4 release $kg^{-1}hr^{-1}$)	Commodities
VERY LOW	< 0.1	Artichoke, Asparagus, Cauliflower, Cherry, Citrus fruits, Grape, Cut Flowers, Leafy Vegetables, Pomegranate, Potato, Root Vegetables, Strawberry
LOW	0.1-1.0	Brinjal, Chilli, Cucumber, Green Capsicum, Okra, Pine apple, Pumpkin, Water melon
MODERATE	1.0 -10	Banana, Guava, Fig, Litchi, Melon, Mango, Tomato
HIGH	10-100	Apple, Apricot, Avocado, Kiwi Fruit (ripe), Papaya, Peach, Plum, Pear
VERY HIGH	> 100	Sapota, Passion Fruit

Ripening is a catabolic process wherein the fruit undergoes a chain of biochemical reactions involving changes in colour, texture and taste.

Bio chemical changes that occur during the ripening of fruit

	Events	Quality Parameters
1	Seed maturation	
2	**Change in pigmentation**	Colour
	Degradation of chlorophyll	
	Unmasking of existing pigments	
	Synthesis carotenoid	
	Synthesis anthocyanin	
3	**Softening**	Texture
	Change in pectin composition	
	Changes in other cell wall composition	
	Hydrolysis of storage materials	
4	**Change in carbohydrates composition**	Flavour
	Starch conversion to sugars	
	Sugar conversion to starch	
5	Production of aromatic volatiles	
6	Changes in organic acids	
7	Fruit abscission	Dropping
8	Change in repatriation rate	
9	Change in rate of C_2H_4 synthesis	Ripening
10	Change in tissue permeability	Softening
11	Change in proteins	
	Quantitative	
	Qualitative – enzymes synthesis	
12	Development of surface waxes	Shining

Colour Development in fruit

The change in colour is either due to synthesis of plant pigments are due to unmasking of already existing colour. Change in colour is due to chlorophyll, which is magnesium organic complex. The loss of green colour is due to degradation of chlorophyll structure. Change in colour development is common except avocado, kiwi fruit and Granny Smith Apple. Chlorophyll degradation leads to development of yellow/orange/red/purple pigments.

The principle agents responsible for the degradation are

- ✓ change in pH,
- ✓ oxidation systems or
- ✓ enzymes chlorophyllases.

Carotenoids are stable pigments and remain there till senescence. They are either synthesized during developmental process or they are masked by the presence of chlorophyll. This kind of change is seen in case of banana. While in tomato, the colour pigment lycopene is developed simultaneously with degradation of chlorophyll. Other pigments found in fruits and vegetables are anthocyanins. They are red-purple or blue water soluble phenolic glucosides that are found in vacuoles like in beet root and epidermal cell of apple and grape. They produce strong colour, which often mask carotenoids and chlorophyll.. In acidic pH levels the anthocyanins are red in colour and in alkaline pH they tend to become blue. This gives rise to a phenomena in roses known as 'blueing', where as shift from red to blue coloration occur with aging. This is due to depletion of CHO and release of free amino acids resulting in more alkaline pH in the cell sap.

Changes in texture and taste - on ripening of fruits, breakdown of starch to sugars, which affects taste and texture of the produce.

a. Textural Changes -

The texture of the fruit softens with ripening. This is because of the action of enzymes like hydrolases (poly galacturonase, pectin methyl esterase and cellulases) which breakdown the pectins, cellulose and hemicellulose.

Propectin is insoluble form of pectic substances binds to calcium and sugars in the cell wall. On maturation and ripening, propectin gradually broken-down to lower molecular weight fraction which are more soluble in water. The rate of degradation of pectic substances is directly correlated with rate of softening of the fruit.

b. Change in Taste -

The primary change in taste is the development of sweetness in fruits after ripening. During ripening the starch break down into simple sugars like glucose, fructose and sucrose which are responsible for sweetness. This change is also mediated through the action of various enzymes like amylase, invertase, phosphorylase, *etc*.

Changes in Vegetables

Seeds are consumed as fresh vegetables, for eg. Sweet corn (baby corn), have high levels of metabolic activity, because they are harvested at immature stage. Eating quality is determined by falvor and texture, not by physiological age. Generally seeds are sweeter and tender at an immature stage. With advancing maturity, the sugars are converted to starch, with a result of loss of sweetness: water content also decreases and amount of fiber material increases.

In edible flower/buds/stems/leaves textures is an often dominant character that determines the both harvest date and quality, as loss of turgor through water loss causes a loss of texture. The natural falvour is often less important than texture, as many of these vegetables are cooked and seasoned with salt and spices.

Bulbs/roots/tuber - in these crops using appropriate storage condition their storage shelf life can be prolonged.

Events of changes during maturation/ripening of Horticultural produce

Increase	Decrease
CO_2	Starch
C_2H_4	Chlorophyll
Colour pigments	Firmness
Polygalcturonase activity	Vit.C at the end
Acidity (marginal)	Texture
pH (marginal)	Water
Sugars	
Organic acids	
Aroma	
Sweetness	
Fibre at the end	

References

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 Physiology of Perishable Plant Products	Stanley J. Kays	1998	CBS, New Delhi
4	Post Harvest Technology of Fruits and Vegetables	A.K. Thomposon	1996	Blackwell Science ISBN 1-4051-0619-0

Lecture schedule - 5

Deterioration of horticultural produce or Causes of Postharvest loss

It is well known fact that fruits, vegetables and flowers are living commodities even after harvest and continue to respire, transpire and carryout other biochemical activities. Therefore they are more perishable when compared to other agricultural commodities. The deterioration in harvested fresh produce occurs both quantitatively and qualitatively.

The losses that occur from the time of harvesting of fresh produce till they reach the consumer are referred as post harvest losses.

Post harvest losses occur in terms of
1) <u>Quantitative loss</u> - referring to the reduction in weight due to moisture loss and loss of dry matter by respiration
2) <u>Qualitative loss</u> - referring to freshness deterioration leading to loss of consumer appeal and nutritional loss including loss in vitamins, minerals, sugars, etc.

Cost of preventing losses after harvest in general is less than cost of producing a similar additional amount of produce and reduction in these losses is a complimentary means for increasing production. These losses could be minimized to a large extent by following proper pre-harvest treatments, harvesting at right maturity stage and adopting proper harvesting, handling, packing, transportation and storage techniques.

The factors that are responsible for the deterioration of Horticultural produce are:

I. Biological factors
II. Environmental factors

I. Biological factors

Following biological factors are responsible for deterioration of Horticultural Produce:

1. Respiration rate
2. Ethylene production
3. Compositional changes
4. Growth and development
5. Transpiration
6. Physiological breakdown
7. Physical damage
8. Pathological breakdown
9. Surface area to volume
10. Membrane permeability

1. Respiration rate - being living entities fruits , vegetables, flowers respire actively after harvest. Detailed quantities an qualitative occurring due
life of horticultural to this factors is detailed in lecture - 3 (Physiology and Biochemistry of Horticultural Produce)

2. Ethylene production - ethylene plays a vital role in postharvest produce. Its detailed physiological changes are described in lecture - 4

3. Compositional changes -

Many pigment changes also takes place even after harvest in some commodities.
These changes are:

a. Loss of chlorophyll (green color) – In vegetables
b. Loss of carotenoids (yellow and orange color) – In apricot, peaches, citrus fruits and tomato
c. Loss of anthocyanins (red and blue color) – In apples, cherries and strawberries
d. Change in carbohydrates
    i. Starch to sugar conversion – potato
    ii. Sugar to starch conversion – peas, sweet corn
e. Breakdown of pectin and other polysaccharides – causes softening of fruit
f. Change in organic acids, proteins, amino acids and lipids. – can influence flavor
g. Loss in vitamins – effects nutritional quality

4. Growth and development

In some commodity growth and development continue even after harvest which accelerates deterioration. For example

- ✓ Sprouting of potato, onion and garlic
- ✓ Fresh rooting of onions
- ✓ Harvested corps continues to grows even after harvest but is very much evident in Asparagus
- ✓ Increase of volume in lettuce

5. Transpiration

Most fresh produce contain 80-90 % of water when harvested. Transpiration is a physical process in which high amount of water is lost from the produce, which is the main cause of deterioration. This exchange of water vapour in produce is carried through the cuticle, epidermis cells, stomata and hairs of the produce. Produce stored at high temperature will have high transpiration rate.

When the harvested produce loses 5 % or more of its fresh weight, it begins to wilt and soon becomes unusable. Water loss also causes loss in quality, such as reduced crispness and other undesirable changes in colour, palatability and loss of nutritional quality.

Factors influence the transpiration rate in various commodities:

- ✓ Surface of the commodity - commodities having greater surface area in relation to their weight will lose water more rapidly. It is clearly visible in leafy vegetables where the water loss is much faster than a fruit as they have more surface area to volume ratio.
- ✓ Surface injuries - Mechanical damages accelerate the rate of water loss from the harvested produce. Bruising and abrasion injuries will damage the protective surface layer and directly expose the underlying tissues to the atmosphere allowing greater transpiration.
- ✓ Maturity stage - less matured fruits lose more moisture then matured fruits/vegetables
- ✓ Skin texture - Fresh produce having thin skin with many more spores lose water quickly than those having thick skin with fewer spores.
- ✓ Temperature - Water loss is high with increase in storage temperature. The loss will be further enhanced when high temperature is combined with low relative humidity

- ✓ Relative humidity - The rate at which water is lost from fresh produce also depends on the water vapour pressure difference between the produce and the surrounding air. So water loss from fresh produce will be low when the relative humidity i.e. moisture content of the air is high. Further, the faster the surrounding air moves over fresh produce the quicker will be the water loss.

Transpiration results in following type of deterioration:

- ✓ Loss in weight
- ✓ Loss in appearance (wilting and shriveling)
- ✓ Textural quality (softening, loss of crispiness and juiciness)

6. Physiological breakdown

When produce is exposed to an undesirable temperature physiological breakdown takes place. Following physiological breakdowns are common in various commodities:

- ✓ Freezing injury - when commodity stored at below their freezing temperature
- ✓ Chilling injury - when commodity stored at below their desired storage temperature
- ✓ Heat injury - when commodity exposed to direct sunlight or at excessively high temperature. It causes defects like sunburn, bleaching, scalding, uneven ripening and excessive softening.
- ✓ Very low O_2 (<1%) and high CO_2 (>20%) atmosphere during storage can cause physiological problems
- ✓ Loss of texture, structure and microbial damage

7. Physical damage

Various types of physical damages responsible for deterioration are

- ✓ Mechanical injury/cut - during harvesting, handling, storage, transportation *etc*.
- ✓ Bruising due to vibration (during transportation),
  impact (dropping) and
  compression (overfilling)

8. Pathological breakdown

This is the most common symptom of deterioration where it is mainly caused by the activities of bacteria and fungi (yeast and mould). Succulent nature of fruits and vegetables make them easily invaded by these organisms. The common pathogens causing rots in fruits and vegetables are fungi such as *Alternaria, Btrytis, Diplodia, Phomopsis, Rhizopus, Pencillium* and *Fusarium* and among bacteria, *Ervina* and *Pseudomonas* cause extensive damage

Microorganisms usually directly consume small amounts of the food but they damage the produce to the point that it becomes unacceptable because of rotting or other defects. Losses from post-harvest disease in fresh produce can be both quantitative and qualitative. Loss in quantity occurs where deep penetration of decay makes the infected produce unusable. Loss in quality occurs when the disease affects only the surface of produce causing skin blemishes that can lower the value of a commercial crop.

9. Surface area to volume - grater surface leads to greater weight and respiratory loss

10. **Membrane permeability** - fluctuation in storage temperature and physiological injuries like chilling injury leads to membrane damage resulting in electrolyte leakage.

II. Environmental factors

Following environmental factors are responsible for deterioration

1. Temperature
2. Relative humidity
3. Atmospheric gas compositions
4. Ethylene
5. Light
6. Other factors

1. Temperature

Environmental temperature plays very major role in deterioration of produce.

- ✓ Every increase of 10^0C temperature above optimum increases the deterioration by two times
- ✓ Exposure to undesirable temperature results in many physiological disorders like; freezing injury, chilling injury and heat injury *etc*.
- ✓ Temperature influence growth rate of fungal spores and other pathogens.
- ✓ It affects the respiration and transpiration rate of produce.

2. Relative humidity

The rate of loss of water from fruit, vegetables and flowers depends upon the vapor pressure deficit between the surrounding ambient air, which is influenced by temperature and relative humidity. The rate of deterioration is a combined factor of temperature and relative humidity and affects the produce in following manner:

- ✓ Low Temp. & High Relative Humidity -- Low deterioration
- ✓ Low Temp. & Low Relative Humidity -- Moderate deterioration
- ✓ High Temperature & High Relative Humidity -- High deterioration
- ✓ High Temperature & Low Humidity -- Very high deterioration

3. Atmospheric gas composition

Build up of undesirably high carbon dioxide and very low levels of oxygen in the storage facility can lead to many physiological disorders leading to spoilage. Eg. Hollow heart disease in potato is due to faulty oxygen balance in storage or during transportation. Exposure of fresh fruits and vegetable to O_2 levels below the tolerance limits or to CO_2 levels above their tolerance limits in storage rooms may increase anaerobic respiration and the consequent accumulation of ethanol and acetaldehyde, causing off-flavours. The other bad effects of unfavourable gas composition include irregular ripening of certain fruits, soft texture, lack of characteristic aroma, poor skin color development, etc.

Example: CA storage of Apples(0-1^0C with 1-2%CO_2 and 2-3%O_2, RH 90-95%) for 6-12 month.

4. Ethylene

Effect of ethylene on harvested horticulture commodities may be desirable or undesirable. On one hand ethylene can be used to promote faster and more uniform ripening of fruits. On other hand exposure to ethylene can deteriorate the quality of certain vegetables such as destruction of green colour in leafy and other vegetables, early senescence of flowers, bitterness in carrots, increased toughness, accelerated softening, discoloration and off-flavor, etc.

5. Light

Exposure of potatoes to light results in greening of the tuber due to formation of chlorophyll and solanine which is toxic to human on consumption.

6. Other factors

Various kinds of chemicals (eg. pesticides, growth regulators) applied to the commodities also contribute to deterioration. Many of the chemical constituents present in stored commodities spontaneously react causing loss of color, flavor, texture and nutritional value. Further there can also be accidental or deliberate contamination of food with harmful chemicals such as pesticides or lubricating oils.

MAJOR PRE AND POST HARVEST DEFECTS

During crop growth and subsequently after harvest many imperfection and blemishes occur due various means.

Causes of defects in various Horticultural produce are categories as follows:

- ✓ Insect pests
- ✓ Microorganisms
- ✓ Nutritional deficiencies
- ✓ Birds / animals
- ✓ Mis-handling
- ✓ Environment
- ✓ Mechanical means
- ✓ Delayed harvesting
- ✓ Improper cultural practices
- ✓ Improper trimming and pruning
- ✓ Improper cold storage
- ✓ Physiological disorder

Sl No	Defects	Damage
1.	Insect pests	Holes and mis-shapen
2.	Microorganisms	Black scurf, canker, Scab, Blight, Blisters, Sooty blotch, Rotten/decay
3.	Nutritional deficiency	Dry circular crevices
4.	Improper cultural practices	Green spot(potato)
5.	Environmental factors	Russeting, water core, discoloration, staining, dried leaves, hail damage, dull/ pale look, shriveling / wrinkling, sunburn, sun scald, superficial sunscald, lanky, torn leaves, black/brown calyx, water core, fresh rooting, splitting, cracks, natural growth cracks, water berry, scales on surface

6.	Birds / animals	Bird damage
7.	Delayed harvesting	Mature/over mature, fibrous, over ripe, seed stem
8.	Handling	Black edges, handling damage, packing damage, pressure damage, shatter or loose berry, damage, soft, bruises and broken
9.	Mechanical means	Healed dark brown marks, chipped, hole, punctured skin, , cuts, mechanical damage
10.	Improper washing, cleaning, trimming and pruning	Long stalk, dirty outer leaves, secondary roots, wrapper/extra covered leaves, unclean
11.	Physiological disorders	Bitter pit, puffiness, cracking
12.	Improper cold storage	Dried berries, sprouting, hollow heart
13.	Genetic abnormalities	Misshape and double

Above mentioned defects can be broadly categorized into three main groups. Like one which occur before harvesting and other which develops after harvesting.

Some defects however are common to both the categories.

Pre- harvest	**Post- harvest**	**Both**
Misshaped	Black edges	Damage
Bird damage	Black/brown calyx	Dull look/Pale look
Bitter pit	Broken	Fungal infection
Black scurf	Bruising	Hole
Blight	Chipped	Rotten/ Decay
Blister	Cuts	Black/ brown spots on surface
Bottle neck	Dirty outer leaves	Dried berries
Canker	Dried leaves	Over ripe
Cracks	Dull look	Punctured/ damaged skin
Dark/healed brown marks	Fresh rooting	
Discoloration	Handling damage	
Double	Long stalk	
Dry circular crevices	Mechanical damage	
Fly speck	Packing damage	
Green spot	Pressure damage	
Hail damage	Shattered or loose berry	
Healed brown marks	Shriveling / wrinkling	
Hollow heart (potato)	Slanky	
Insect damage and presence of insects like scales, mealy bugs *etc*. on the surface of the produce	Soft	
Mature	Sprouting	
Natural growth cracks	Unclean	

Pale look	Wilted	
Puffy	Wrapper/Extra covered leave	
Riciness		
Russeting		
Scab		
Scar		
Secondary roots		
Seed stem		
Sooty blotch		
Splitting		
Staining		
Sun burn		
Sun scald		
Superficial scald		
Torn leaves		
Water core		
Yellow tip		

Lecture schedule – 6

Factors affecting the quality of horticultural produce

Part – 1

Quality of the fruits, vegetables, flowers and others depend on the various factors on and off the field of production site such as

I. Pre-Harvest Factors
II. Harvest Factors
III. Post-Harvest Factors

I. Pre Harvest Factors

1. Genetic / variety
2. Light
3. Temperature
4. Humidity
5. Mineral nutrition
6. Water relation/ Irrigation
7. Canopy manipulation
8. Rainfall
9. Seasons / Day and day length
10. Carbon dioxide
11. Use of agrochemicals
12. Planting density
13. Root stock, pruning and crop rotation
14. Pest and diseases

II. Harvest Factors

1. Stage of harvest
2. Time of harvest
3. Methods of harvest

III. Post – Harvest Factors

1. Temperature
2. Light
3. Humidity
4. Water quality
5. Ethylene
6. Ventilation, spacing & packaging
7. Preservatives
8. Growth regulators

I. PRE – HARVEST FACTORS

1. Genetic / variety – Varieties with shorter shelf-lives are generally prone to higher post harvest losses. Varieties with thick peel, high firmness, low respiration rate and low ethylene production rates would usually have longer storage life. The cultivars that have ability to withstand the rigors of marketing and distribution will have lesser losses after harvest. Varieties with resistance to low temperature disorders and/or decay-causing pathogens can be stored well for longer duration with minimum storage losses. Hence, while growing horticultural crops, one must choose such varieties that inherently have got good quality and storage potential in addition to the high yield and pest resistance potential.

2. Light – light regulates several physiological processes like chlorophyll synthesis, phototropisum, respiration and stomatal opening. The duration, intensity and quality of light affect the quality of fruits and vegetables at harvest. Most of the produce needs high light intensity (3000-8000 f.c.). Absorption of red light (625-700 nm) through pigments, phytochrome, is essential for carbohydrates synthesis which determines the shelf life of the produce. The vase life of the carnation and chrysanthemums is longer under high light intensity than low.
Citrus and mango fruits produced in full sun generally had a thinner skin, a lower weight, low juice content and lower acidity but a higher TSS. And citrus fruits grown in the shade may be less susceptible to chilling injury when subsequently stored in cold storage.
In tomatoes, leaf shading of fruits produced a deeper red colour during the ripening than in the case of those exposed to light. The side of the fruit that have been exposed to sun will generally firmer than the non exposed side. In general, the lower the light intensity the lower the ascorbic acid content of plant tissues. In leafy vegetables, leaves are larger and thinner under condition of low light intensity.

3. Temperature – all type of physiological and biochemical process related to plant growth and yield are influenced by the temperature. The higher temperature during field conditions decreases life and quality of the produce. At high temperature, stored carbohydrates of fruits, vegetables and flowers are quickly depleted during respiration and plant respires at the faster rate. The produce which is having higher amount of stored carbohydrates show longer storage/vase life. For example- high temperature during fruiting season of tomato leads to quick ripening of fruits on and off the plant.
Orange grown in the tropics tend to have higher sugars and TSS than those grown sub tropics. However, tropical grown oranges tend to be green in colour and peel less easily and it is due to the lower diurnal temperature that occurs in the tropics.

4. Humidity – High humidity during growing season results in thin rind and increased size in some horticultural produce and this produce is more prone to high incidence of disease during post harvest period. Humid atmosphere may cause the development of fungal and bacterial diseases, which damages produce during storage and transport. Damaged produce remove water very quickly and emit a larger concentration of ethylene than healthy ones. Low humidity may cause browning of leaf edge on plants with thin leaves or leaflets. High humidity can maintain the water – borne pollutants in a condition so that they can be more easily absorbed through the cuticles or stomata's. Reduced transpiration leads to calcium and other elemental deficiency.

5. Rainfall - Rainfall affects water supply to the plant and influences the composition of the harvested plant part. This affects its susceptibility to mechanical damage and decay during subsequent harvesting and handling operations. On the other hand, excess water supply to plants results in cracking of fruits such as cherries, plums, and tomatoes. If root and bulb crops are harvested during heavy rainfall, the storage losses will be higher.

6. <u>Wind</u> - Wind damages the produce by causing abrasions due to rubbing against twigs or thorns. These mechanically damaged produce are more prone to spoilage during post harvest period and have shorter post harvest life.

7. <u>Mineral nutrition</u> – balanced application of all nutrient elements is necessary for the maintaining growth and development of the plants. The application of fertilizers to crops influences their post harvest respiration rate. Excess or deficiency of certain elements can affect crop quality and its post harvest life. Numerous physiological disorders are also associated with mineral deficiencies which ultimately lead to post harvest losses.

<u>Nitrogen</u> - High N fertilization reduces while moderate to high K improves PH life and quality of anthurium, cut flowers and many horticultural produce. Application of K in water melon tend to decrease the PH respiration. High levels on N tend to decrease flavor, TSS, firmness and color of the fruit and in stone fruits it increases physiological disorders and decrease fruit colour.

Generally, crops that have high levels of nitrogen typically have poorer keeping qualities than those with lower levels as. High nitrogen increases fruit respiration, faster tissue deterioration thereby reducing their storage life.

<u>Phosphorous</u> - Application of phosphorous minimizes weight loss, sprouting and rotting in bulb crops compared with lesser application. Phosphorous nutrition can alter the post harvest physiology of some produce by affecting membrane lipid chemistry, membrane integrity and respiratory metabolism. The respiration rate of low-phosphorous fruits will be higher than that of high phosphorous fruits during storage.

<u>Potassium</u> - potassic fertilizers improves keeping quality, its deficiency can bring about abnormal ripening of fruits and vegetables. Potassium helps in reducing some physiological storage disorders, e.g. superficial rind pitting in oranges.

Calcium- the storage potential of the fruits is largely dependent on the level of Ca and it is associated with produce texture. The higher level of N, P and Mg and low levels of K and Bo lead to the Ca deficiency in fruits and reduce its storage life. Reduction in calcium uptake causes lateral stem breakage of poinsettia. Calcium treatment delays ripening, senescence, reduces susceptibility to chilling injury, increase firmness and reduces decay subsequent to storage in avocados and improves the quality.

Physiological disorders of storage organs related to low Ca content of the tissue are
- ✓ Bitter pit in apples
- ✓ Cork spot in pears
- ✓ Blossom end rot in tomato
- ✓ Tip burn in lettuce and hallow heart in potato *etc.*
- ✓ Red blotch of lemons

Zn is known to act as vehicle for carrying ions across tissue and increase Ca content of the fruit. Adequate supply of Bo improves the mobility of Ca in the leaves and the fruits and subsequently increases fruit firmness, TSS, organic acids and reduce the incidence of the drought spot, bitter pit and cracking disorders. And impart diseases resistance.

The incorporation of 4% Ca into proto pectin of middle lamella form bond with the cellulose of the cell wall and thus delayed softening in fruits.
Infused Ca inhibits the internal browning, retarded respiration, and reduced the metabolism of endogenous substrates. Post climacteric respiration of apple decreased as peel Ca level increased from 400 to 1300 ppm. Ca may reduce the endogenous substrate catabolism by limiting the diffusion of substrate from vacuole to the respiratory enzymes in the cytoplasm (limited membrane permeability).

Table: Storage disorder and storage characteristic of Cox's Orange Pippin apple in relation to their mineral content

Disorder	**Composition (mg 100 g^{-1})**				
	N	**P**	**Ca**	**Mg**	**K/Ca**
Bitter pit			< 4.5	>5	>30
Break down		<11	< 5		>30
Lenticel blotch pit			<3.1		
Loss of firm ness	>80	<11	< 5		
Loss of texture		<12			

Application of $CaCl_2$ delayed the accumulation of free sugars, decreased inorganic contents, mold development, softening and development of red colour in strawberry. In pears reduced cork spot, increased flesh firmness, total acidity and juiciness and in apple even after 90 day of storage at ambient condition shown acceptable quality.

5. Water relation and Irrigation – stress due to excessive or inadequate water in the medium reduce the longevity of the produce. Crop like carnation require 850 to 1200 g of water to produce one gram of dry matter. In general, <5 % of water absorbed in the plant system is utilized for the development of different plant components. Moisture stress increases the rate of transpiration over the rate of absorption and irregular irrigation/ moisture regime leads fruits/vegetable cracking (potato and pomegranate cracking). Higher level of moisture stress affects both yield and quality by decreasing cell enlargement.
Crops which have higher moisture content generally have poorer storage characteristics. An example of this is the hybrid onions, which tend to give high yield of bulbs with low dry matter content but which have only a very short storage life. If fully matured banana harvested soon after rainfall or irrigation the fruit can easily split during handling operations, allowing micro organism infection and PH rotting.
If orange is too turgid at harvest (early morning) the flavdeo/oil gland in the skin can be ruptured during harvesting , releasing phenolic compounds and causes Oleocellosis or oil spotting (green spot on the yellow / orange coloured citrus fruit after degreening).

Quailing – 'harvested produce is kept in the basket for few hours in the field before being transported to pack house, this will allow the produce to loose little moisture'. Some growers have practice of harvesting lettuce in the late in the morning/ early afternoon because when they are too turgid the leaves are soft and more susceptible to bruising.
In green leafy vegetables, too much rain or irrigation can results in the leaves becoming harder and brittle, which can make them more susceptible to damage and decay during handling and transport.

Mango hot water treatment is better if there is delay of 48 hr. between harvest and treatment and resulted better efficiency of hot water in disease control.

Generally, crops that have higher moisture content or low dry matter content have poorer storage characteristics. Keeping quality of bulb crops like onion and garlic will be poor if irrigation is not stopped before three weeks of harvesting.

6. Canopy Manipulation –

A. Fruit thinning – increases fruit size but reduces total yield. It helps in obtaining better quality produce
B. Fruit position in the tree – Fruits which are exposed to high light environment possesses higher TSS, acidity, fruit size, aroma, and shelf life compared to which lies inside the canopy. Hence better training system should be practiced to circulate optimum light and air. Eg.: Grapes, Mango, peaches, kiwifruits
C. Girdling - increases the fruit size and advance and synchronized fruit maturity in peach and nectarines. Increases fruitfulness in many fruit tree species.

7. Season / Day – seasonal fluctuation and time of the day at harvest will greatly affects the postharvest quality of the produce. Synthesis of higher amount of carbohydrates during the day time and its utilization through translocation and respiration in the night is responsible for the variation in the longevity of the cut flowers. Roses and tuberose have been found to show longer keeping quality in the winter season under ambient condition than in the summer seasons.
Generally produce harvested early in the morning or in the evening hours exhibits longer PH life than produce harvested during hot time of the day.
Day length - If long days Onion (temperate) grown during short day (tropics) condition it leads to very poor storage quality.

8. Carbon dioxide – quality planting material, early flowering, more flowering, increased yield and rapid crop growth and development at higher level of CO_2. Production of chrysanthemum under green house at 1000 – 2000 ppm of CO_2 showed an increase in stem length, fresh weight, leaf no. and longevity of cut flowers.

9. Use of Agro chemicals – Pre-harvest application of chemicals such as BA, IAA, GA_3, growth retardants like B-9, CCC, A-Rest and Phosphon-D have bee reported to improve quality and longevity of flowers crops. Application of GA_3 @ 50-100 ppm improves PH quality of roses by anthocyanin development. And it stimulate the accumulation of N, K, Mg and S. Pre-harvest spray with Alar(1500ppm), MH(500ppm), and Cycocel(500ppm) increased vase life of Aster. Beneficial effect of leaf manure, K and GA_3 is found to enhance the longevity of tuberose flowers.
Use of chemicals on the plants to prevent the pathogen will have direct impact on extending the postharvest life. Generally, if produce has suffered an infection during development its storage or marketable life may be adversely affected. Banana which suffers a severe infection with diseases such as leaf spot may ripen pre maturely or abnormally after harvest and in mango it is rapid postharvest loss. Pre harvest application chemicals like MH on onion filed prevent them sprouting during storage.

10. <u>Pest and Diseases</u> – infection by fungi, bacteria, mites and insects reduces the longevity as well as consumer acceptability. Tissue damage caused by them show wilting and produce ethylene leads to early senescence. Vascular diseases/stem rot /root rot of floral corps hinder the transport, affects the post harvest life and quality. The potato tuber moth may infest tubers during growth if they are exposed above the soil and subsequently in the storage.

Note : Refer lecture schedule - 7 for study questions and references

Lecture 7

Factors affecting postharvest quality

Part -2

II. HARVEST FACTORS

Maturity at harvest stage is one of the main factors determining compositional quality and storage life of fruit, vegetables and flowers. All fruits, with a few exceptions, reach peak eating quality when fully ripened on the tree. However, since they cannot survive the post harvest handling system, they are usually picked/plucked mature but not ripe.

1. Stage of Harvest – Harvesting can also affect final quality. For instance, when fruits and vegetables are harvested too late or too early in the season, overall taste, texture, and color may be compromised. Maturity at harvest is therefore an important factor that determines the final quality of the produce. Harvesting of fruits and vegetables at immature stage leads to both qualitative and quantitative losses. Immature fruits fail to ripen normally with low nutritive values and have inferior flavor quality when ripe. On the other hand over mature fruits are likely to become soft and mealy with insipid flavor soon after harvest.

Many vegetables, in particular leafy vegetables, and immature fruit-vegetables (such as cucumbers, green beans, peas, and okras), attain optimum eating-quality prior to reaching full maturity. This often results in delayed harvest, and consequently in produce of low quality.

Most of the cut flowers are harvested at the immature stage. Roses are harvested at tight bud stage/cracked bud stage than the half open or full open stage

2. Time of Harvest - It is advisable to harvest produce when temperature is mild as high temperature causes rapid respiration rate and excessive water loss. The recommended time for harvest of fresh horticultural produce is early morning hours or late evening hours.

The amount of time between harvesting and delivery to a market also can damage the quality of the fruit, vegetable or flower. If fresh produce isn't processed quickly, it may also lose nutritional value.

3. Methods of Harvest – The method of harvesting (hand vs mechanical) can also have significant impact on the composition and post-harvest quality of fruits and vegetables. Sharp tools/ secateur /harvester/hand gloves/digger/vibrater/ trimmer/ any such items should always be used to detach the fruits/vegetable/flowers from the mother plant. Mechanical injuries (such as bruising, surface abrasions and cuts) can accelerate loss of water and vitamin C resulting in increased susceptibility to decay-causing pathogens.

Cut flowers with long stem have higher post harvest life than short stem because shorter stem have less carbohydrate reserves. While cutting cut flowers care should be taken to give slant cut and not to crush. Slant cut helps in facilitating the maximum surface area to absorb water at rapid rate during vase life.

Management of harvesting operations, whether manual or mechanical, can have a major impact on the quality of harvested fruits and vegetables. Proper management procedures include selection of optimum time to harvest in relation to produce maturity and climatic conditions, training and supervision of workers, and proper implementation of effective quality control.

Expedited and careful handling, immediate cooling after harvest, maintenance of optimum temperatures during transit and storage, and effective decay-control procedures are important factors in the successful post-harvest handling of fruits and vegetables. Attention must be paid to all of these factors, regardless of the method of harvesting used. These factors are nevertheless more critical in the case of mechanically harvested commodities.

III. POST – HARVEST FACTORS

1. Temperature - Optimal temperature is a major important factor in determining the PH life of the produce. Senescence accelerate at higher temperature, whereas at low temperature, respiration comes down and in F, V and flowers lesser amount of ethylene and the multiplication of microorganism does not take place at faster rate.
Harvested produce is ideally transported and stored under reduced temperature likely to maximize longevity. However, the effect of reducing temperature on maintaining produce quality is not uniform over the normal temperature range i.e. 0 - 30^{0}C for non chilling sensitive produce; 7.5 - 30^{0}C for moderately chilling sensitive produce; 13 - 30^{0}C for chilling sensitive plants. Normal ripening occur at temperature range of 10-30^{0}C, but best quality fruit develops ripening at 20-23^{0}C (Fig 1 & 2).

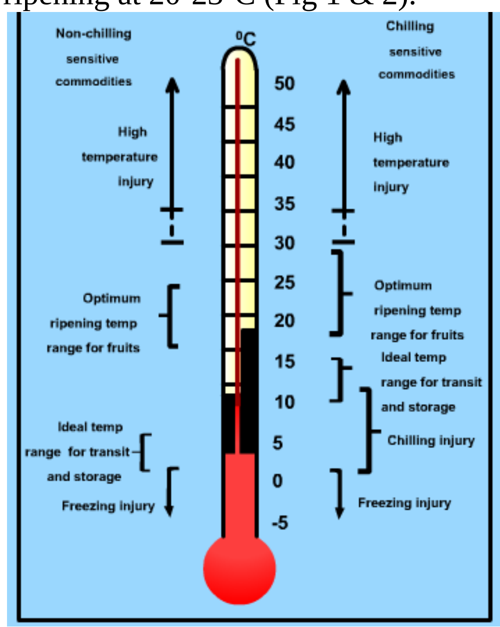


Fig. Response of non-chilling sensitive and chilling-sensitive produce to temperature

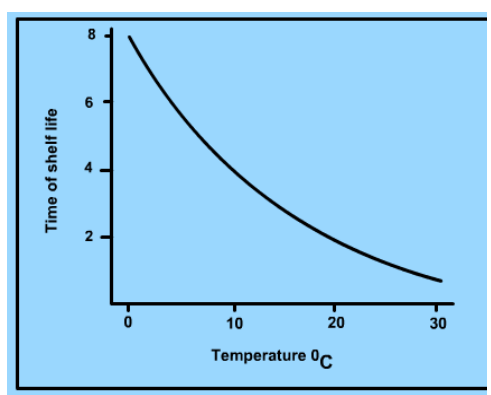


Fig. Effect on temperature on length of shelf life

2. Light – Potted flowering plants/cut flower, it is advisable to illuminate the plants with 2 - 3 k lux (200-300 f.c.) with fluorescent and incandescent to create illumination of red and blue light.

3. Humidity - Many horticultural produce should be kept at 80-95% RH for maintenance of freshness/turgidity. Produce start showing wilting symptoms when they have lost 10-15% of their fresh weight. The rate of transpiration from the produce is reduced with the increases of high RH. Care should to be taken not to maintain high RH coupled with high temperature results in faster infection by pathogen. Produce should not be stores in dry atmosphere because they become less turgid through quick transpiration.

4. Water Quality – water quality relates to pH, EC values, hardness contents of phytotoxic elements and microorganism causing vascular obstruction affecting longevity of the produce particularly cut flowers. Saline water decreases vase life flowers. Longevity of flowers reduced when salts concentrations reaches 200 ppm (roses, chrysanthemum and carnation) and 700 ppm (gladiolus). Basic ions like Ca^{++} and Mg^{++} present in hard water are less harmful than soft water containing sodium ions. Use of de-ionised water is better than ordinary tap water in enhancing vase life and even use of boiled water containing less air then tap water is readily absorbed by stem.

Use of Millipore filter water enhances flow rate of water through cut stem and reduction of air blockage from vessel. Acidification of alkaline water with H_2So_4 and HCL has been found to increase the vase life of cut flowers. At low pH, microbial population in stem of the flowers decreases. Acidification of water through citric acid is also helpful. The optimum pH for extending the vase life of flowers varies from 4.0 - 5.0.

Wetting agents/surfactants like Tween -20®/APSA® at 0.1 -0.01%(1.0 ml - 0.1 ml L^{-1}) decrease the surface tension of water , increase the lateral water flux which removes air bubbles and helps to maintain a continuous xylem water column in cut flowers.

5. Plant hormones – Use of Cytokinin(Kinetin, BA and B-9), auxin(IAA) and gibberellins (GA_3) are will delay senescence of the produce and are known to be ethylene inhibitors.

Abscisic acid – ABA accelerate the developmental process associated with aging and increase sensitivity of the tissue to the ethylene production. ABA is also involves in senescence to increase the permeability of the tonoplast leading to cell disorganization, resulting in decreased water uptake and development of water/ion stress effects.

6. Preservatives – in the form of tablet containing a mixture of chemicals such as sugars, germicides, salts, growth regulators, *etc*. is being used to extend the vase life of the flowers. Sugars, biocides, anti-ethylene compounds(1-MCP, Potassium permanganate) and hydrated compound are used for conditioning. All sugars used in holding solution make excellent media for the growth of micro-organism causing stem plugging. Therefore, sugars must be used in the combination with germicides in the vase solution. Metallic salts like silver nitrate, cobalt chloride, Al So_4 , Zn So_4, calcium nitrate and nickel chloride are used to extend the vase life of flowers. Growth regulators such as BA, IAA, NAA, 2.4.5.T, GA_3, B-Nine and CCC are also used.

7. Ventilation, Spacing & Packaging – provision for air circulation must be maintained to remove respiration heat. Sufficient commodity spacing should be provided so that at least one side remains exposed for air circulation to prevent heat generation. And only pre cooled products are allowed to be packed, but there should not be any direct contact between product and the containers (Refer chapter storage and packing).

8. Packing and packaging of fruits, vegetables and flowers: Preparation of produce for market may be done either in the field or at the packing house. This involves cleaning, sanitizing, and sorting according to quality and size, waxing and, where appropriate, treatment with an approved fungicide prior to packing into shipping containers. Packaging protects the produce from mechanical injury, and contamination during marketing. Corrugated fiberboard containers are commonly used for the packaging of produce, although reusable plastic containers can be used for that purpose. Packaging accessories such as trays, cups, wraps, liners, and pads may be used to help immobilize the produce within the packaging container while serving the purpose of facilitating moisture retention, chemical treatment and ethylene absorption. Either hand-packing or mechanical packing systems may be used. Packing and packaging methods can greatly influence air flow rates around the commodity, thereby affecting temperature and relative humidity management of produce while in storage or in transit.

9. Length of Storage: One of the most significant factors that affect the quality of fresh produce is storage. Making sure that fresh produce is stored at optimum conditions is a key to retain their quality. If it is stored in poor storage conditions such as high temperatures, it will lose its nutritional value or spoil quickly. Storing fresh produce beyond the recommended periods even at optimum temperature can still cause loss of nutritional value.

References

Sl.No.	Title	Authors	Years	Publishers
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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
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Lecture schedule – 8

Maturity Indices in Horticultural Produce

Part – 1

During growth and development of plants there are various stages through which series of events occur which are distinct in each stages. Maturity is viewed as natural phenomenon in plant biology, it is generally considered as stage of development, where plant is super imposed and capable of shifting from vegetative to reproductive stage.

Maturation is process by which fruit / vegetable develops from immature to mature state and this normally applied as

- ✓ Entire course of fruit development
- ✓ Only a period of development just preceding to senescence
- ✓ Time between final stage of fruit growth and to beginning of ripening

Harvesting of horticultural produce at right stage of maturity is very essential for optimum quality and to maintain further its intact intrinsic quality for maximum returns. Maturity is a stage of full development of the tissues of the fruit only after which it will ripen. Ripening stage comes only after maturity.

Maturation: is the stage of development leading the attainment of physiological or horticultural maturity.

Principles of harvest maturity

1. Harvested commodity should have its peak acceptable quality when it reaches the consumer.
2. Produce should develop an acceptable flavour or appearance.
3. Produce should have optimum size and shape required by the market.
4. It should not be toxic or un acceptable.
5. Harvest maturity should have adequate shelf life.

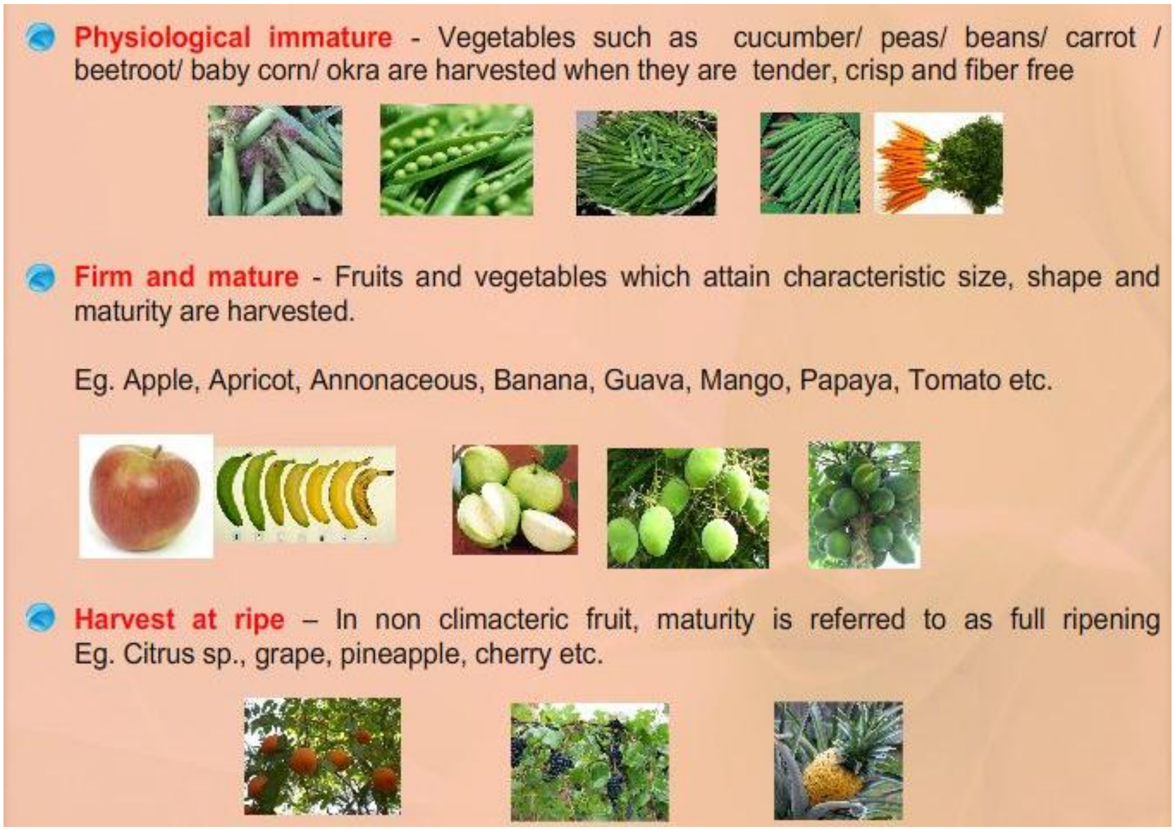
Type of Maturity

I. Physiological maturity: Attainment of full development of stage just prior to ripening or ripening in non climacteric fruits.
Eg.: Fruits and vegetables produced for seed production

II. Horticultural /Commercial maturity – stage at which growth and development is optimum for specific use(stage acceptable for consumers/market oriented).
Eg. Fresh vegetables for canning/ dehydration/ IQF – Individual Quick Frozen/ harvesting for local or distant market

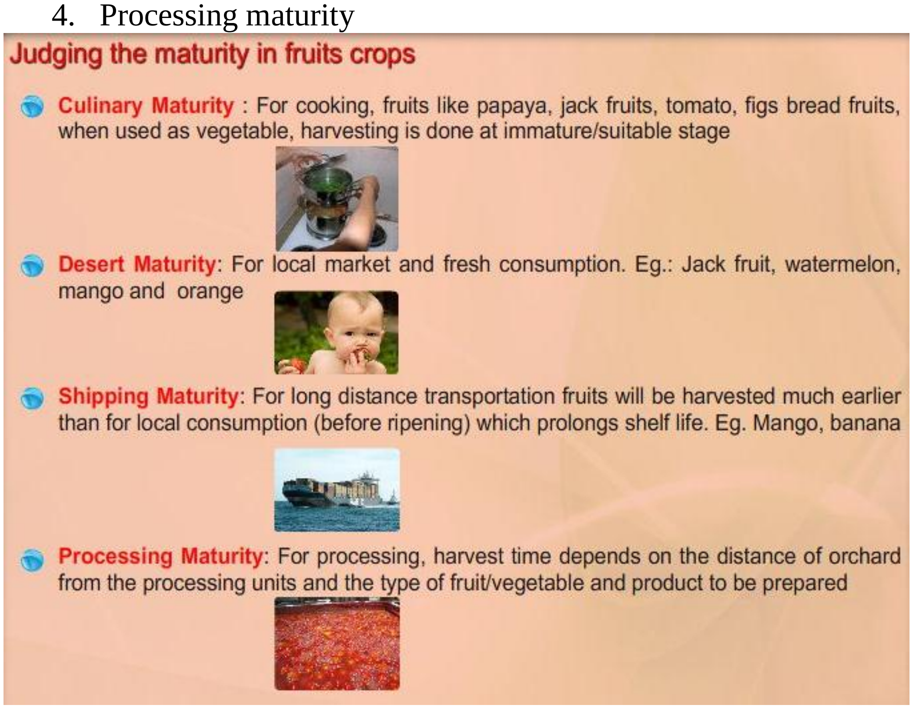
Horticulture maturity is classified into 3 different groups

1. Physiological immature
2. Firm and mature
3. Harvest ripe



Judging the maturity in fruits crops

1. Culinary maturity
2. Dessert maturity
3. Shipping maturity
4. Processing maturity

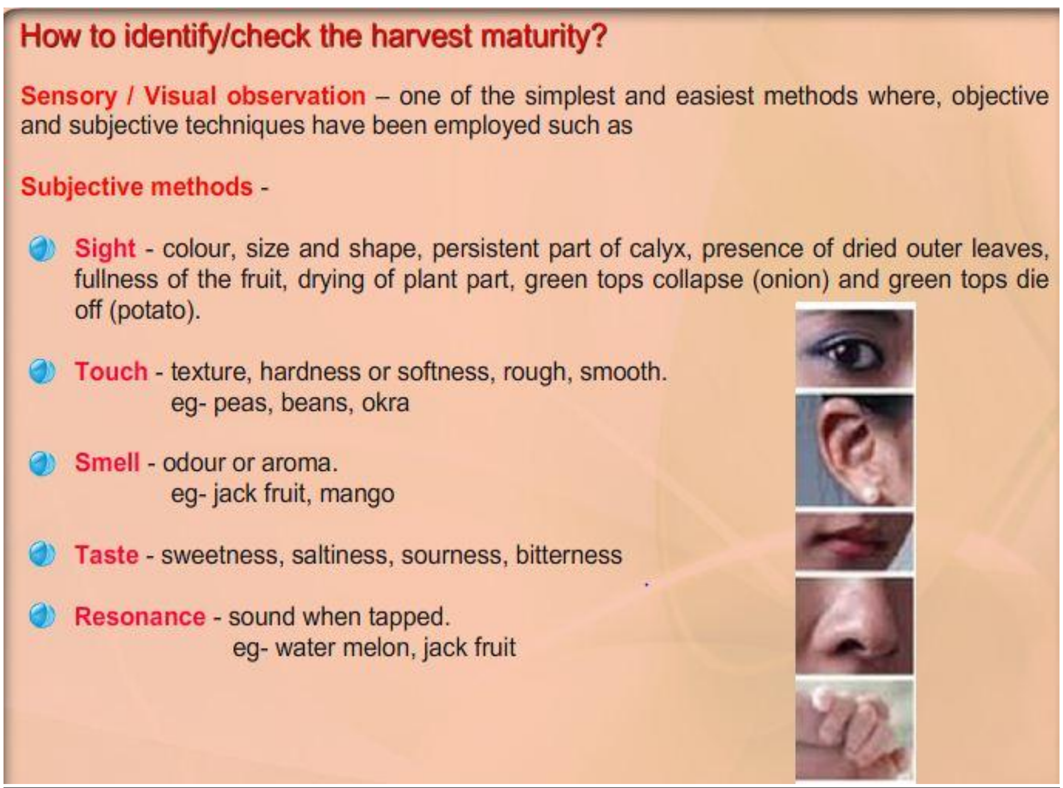


Advantage of Estimation of Maturity

1. To up keep the quality of product
2. To enhance freshness/appearance /elegance of the produce
3. Improvement in the storage life of the produce
4. Management of ripening and senescence (hasten /delay)
5. Extended utilization of the produce
6. Easy of handling
7. To maximize returns
8. To manage the environmental factors
9. To manage pest and diseases
10. For long distance transportation of the produce

DETERMINATION OF MATURITY INDICES

A great considerable variation occurs among the different types of verities, hybrids, cultivars, ecotypes/biotypes of some crop. These variations may be minimized by appropriate judging of maturity.



Disadvantage of sensory maturity

- ✓ When cultivated area is larger, these techniques are tedious.
- ✓ Colour of the each fruit/ bunch cannot be same due to variation in perception.
- ✓ Variation in weather will misleads the judging
- ✓ Variation in biotic and abiotic factors with in orchard (micro climate) influence the crop judgment(plants near pond/compost pit grows luxuriantly)

I. **Computational methods**
1. Calendar date
2. DFFB
3. Heat units
4. T- stage

II. **Physical methods**
1. Fruit retention strength
2. Fruit size and surface morphology
3. Weight
4. Specific gravity
5. Colour - skin, flesh and seed
6. Firmness
7. Ease of separation
8. Brittleness of the floral part
9. Juice content
10. Bulk density - Cole crops/lettuce structural properties – soft/rough
11. Development of abscission layer - melons

III. **Chemical methods**
1. Titratable acidity
2. TSS/acid ratio
3. Sugars
4. Sugar/ acid ratio
5. Bioelectrical conductance
6. Starch content - Iodine test
7. Tannin content - dates, persimmon and litchi
8. Oil content
9. Juice content

IV. **Physiological methods**
1. Rate of respiration
2. Rate of ethylene production
3. Transpiration
4. Production of volatiles

V. **Geo metrical methods**
1. Particles size and shape of the produce
2. Particle composition and orientation in a given tissue or food
3. Moisture content of produce

Many fruits and vegetables chewiness is being used to test the parameter like brittleness, elasticity and hardness

Partially developed fruits: Cucumber, green beans, okra, sweet corn
Fully developed fruits: Apples, peas, tomato, mango, banana
Roots and tubers: Carrot, potato, onion, cassava

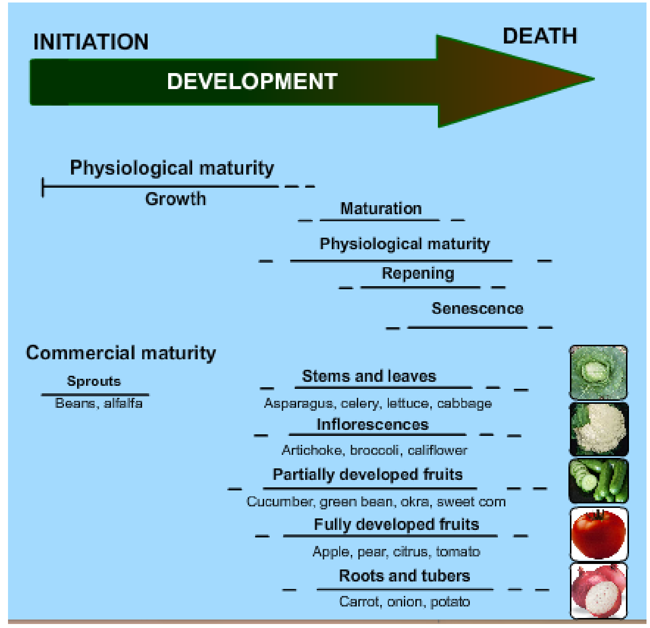


Fig. Developmental stages of the fruits and vegetables consider for harvesting

Methods of Maturity Indices

Sl.No	Maturity Indices	Fruits / Vegetables
EXTERNAL		
1.	Visual (OECD colour charts)	**All fruits and most vegetables**
2.	Calendar date	**All fruits**
3.	DFFB	**All fruits and radish**
4.	Heat unit	**Apple,pear,grape,mango, ber,litchi,sweetcorn *etc*.**
5.	T-Stage	**Apple**
6.	Size	**All fruits, beans, carrot, cucumber, cherry, asparagus and cauliflower, zucchini**
7.	Surface morphology	**Grape(cuticle formation), banana, mango, sapota, litchi, tomatoes, netting on some melons, glossy ness of some fruits (development of wax)**
8.	Specific gravity (Sinker/floater)	**Cherries, mango and ber**
9.	Fruit retention strength	**Apple**
10.	Colour –Surface Seed Flesh Instrument used colourimeter	**All fruits ,tomato, water melon** **Apple , Pears** **Mango, papaya, watermelon and muskmelon, tomato(jelly like material)**
11.	Leaf changes	**Potato, onion, melons(leaf axis on fruit dries)**
12.	**Textural Properties**	
13.	➢ Firmness (Penetrometer /Fruit presser tester)	**Pome and stone fruits, beans, lettuce and melons**

14.	➢ Tenderness (Tenderometer)	**Pea**
15.	➢ Touch/Finger Squeezing	**Beans, okra, peas**
16.	Shape	**Compactness in cabbage, cauliflower & broccoli Angularity of banana Full shoulder development in mango**
17.	Abscission layer	**Melons**
18.	**Solidity**-Bulk density/X/Gamma rays	**Lettuce, cabbage, brussels sprouts**
19.	Tight bud/ bud crack Flower opening	**Rose and many cut flowers Loose flower- crossandra, marigold *etc.***
INTERNAL		
20.	**Total solids :** Dry weight	**Potato, Avocado, Kiwi fruit *etc***
21.	TSS	**All fruits ,tomato, water melon**
22.	Starch content -Iodine test	**Apple, banana, pear *etc***
23.	Sugar content (Hand Refractrometer)	**All fruits**
24.	Acidity or Sugar/acid ratio	**Pomegranate, citrus, papaya, kiwi fruit and grape**
25.	Juice Content	**Citrus Sp.**
26.	Astringency (Tannin)	**Persimmon and dates**
27.	Oil content	**Avocado**
28.	**Physiological:** Respiration and C_2H_4 rate	**Apple and pears and many fruits**
29.	Optical methods(380-730 nm)	**Apricot, banana, orange, papaya**
30.	Aroma	**Many fruits**
31.	Fruit opening	**Nutmeg, chow chow (over mature), Ackee**
32.	Acoustic / Vibration	**Melons/ Apple, tomato(unripe 110- ripe 80 Hz)**
33.	Electrical Characteristics	**Peach (unripe 550,ripe150 Hertz)**
34.	Electormagnetic – Nuclear magnetic resonance (NMR)	**Apple, banana, avocado peach, pear, onion**
35.	Near-Infrared reflectance (400-2500 nm)	**Mango, pineapple**
36.	**Radiation (X-rays & gamma -rays)**	**Lettuce, potato**

The final decision on harvesting will take account of the current market value of the expected yield, and also the time during which the crop will remain in marketable condition. With seasonal crops, growers are often tempted to harvest too early or too late in order to benefit from higher prices at the beginning and end of the season.

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4	Small-Scale Postharvest Handling Practices:A Manual for Horticultural Crops (4th Edition) P ostharvest Horticulture Series No. 8E	Lisa Kitinoja Adel A. Kader	2002	University of California, Davis Postharvest Technology Research and Information Center

Lecture schedule – 9

Judging Maturity in Horticultural Produce

Part - 2

The principles dictating at which stage of maturity a fruit or vegetable should be harvested are crucial to its subsequent storage and marketable life and quality. Post-harvest physiologists distinguish three stages in the life span of fruits and vegetables: maturation, ripening, and senescence. Maturation is indicative of the fruit being ready for harvest. At this point, the edible part of the fruit or vegetable is fully developed in size, although it may not be ready for immediate consumption. Some typical maturity indexes are described in following sections

COMPUTATIONAL METHODS

1. Calendar date: is one of the commonly used indices of maturity and is reasonably accurate provided flowering and weather during growing season is normal. But standardization requires study for many seasons for given variety, location, rootstock *etc*.

Eg. Mango harvesting period – April to July

2. DFFB(Days From Full Bloom): is reliable but varies greatly from year – to - year and location –to- location. In such case the optimum date of harvest can be predicted by doing night temperature correction for 15 days fallowing full bloom. For every 1^0F variation from an average night temperature, a correction of one day is made in the standard figure from full bloom.

Eg. Mango 110 -125 day (Var. Alphonso and Pairi), Banana 99 - 107 days in dwarf Cavendish

3. Heat units/Day degree: Optimum maturity is computed by the sum of mean daily temperature, above base temperature ($10^oC/50^oF$ for apple)for a period concerned. The number of degree-days to maturity is determined over a period of several years. 10^oC /50^oF is the temperature at which growth occurs for apple and base temperature varies with crop.

The degree day is based on a growth-temperature relation. However this heat units work only within limited temperature. Heat units are not useful for photoperiod sensitive species.

A Heat unit is calculated by - (daily mean temp – base temp) **X** No. of Days (flowering to harvest)

Base temperature for tomato, spinach and pumpkin is 15^0, 2^0 and 13^0C respectively.

Table: Heat requirement for various crops

Crop	Cultivars	Base temp	Degree Days
Apple	Red delicious	18^oC	1659-1705
Grape	Thompson seedless	$10\,^oC$ /50^oF	1600-2000
	Bangalore Blue		3562
	Gulabi		3508
Mango	Banganapalli	18^oC	1426
Banana	-	9.8^oC	1930
Asparagus	-	$10\,^oC$ /50^oF	120-410
Peas	Early Wisconsin	$4.4\,^oC$ /40^oF	1319
	Alaska		**1200**

PHYSICAL METHODS

1**. Fruit retention strength**: is the force required to pull the fruit from the tree which indicates the maturity status of the fruit.

Eg. Immature fruit required more force to detach from mother plant compared to ripe fruits.

2**. Acoustic/sound tests:** the sound of a fruit as it is tapped sharply with a finger knuckle can change during maturation and ripening. This method of testing fruit is sometimes used by consumers when purchasing fruit.

Eg. - Water melon fruit may be tapped in the field to judge whether they are ready to be harvested, ripe fruit gives dull sound and also in jackfruit

3**. Skin colour** : This is the common method used in fruits to judge maturity, where, the skin colour changes as the fruit matures or ripens. Colour changes may vary from cultivars, seasons, site, light *etc*. In most of the fruits GREEN colour changes to LIGHT GREEN/YELLOW/ RED/ PURPLE /VIOLET during ripening after the optimum maturity. When it is still green it may be possible to develop the colour after harvest but not all the flavour characteristics. If the fruit is harvested just as the yellow colour begins to show in the shoulders / panicles of the fruits, fruit can eventually ripen to an acceptable flavour.

Fig. Objective colour measurement with a colourimeter

The assessment of harvest maturity by skin colour changes usually on the judgement of the harvester, but colour charts are used for some cultivars of apple, chilli, peach and tomato. The chlorophyll fluorescence spectrometer or colorimeter used to detect the loss of chlorophyll.

4. Shape: The shape referred to the design of the fruit. Shape of fruit can change during maturation.

- ✓ Eg. Banana - individual fingers become more rounded on maturity from angular shape(refer fig.).
- ✓ Mango - immature fruit shoulder shows slope away from the fruit stalk; on more mature fruit shoulders become more level with point of attachment (fullness of the checks adjacent to the pedicle) (refer fig.).

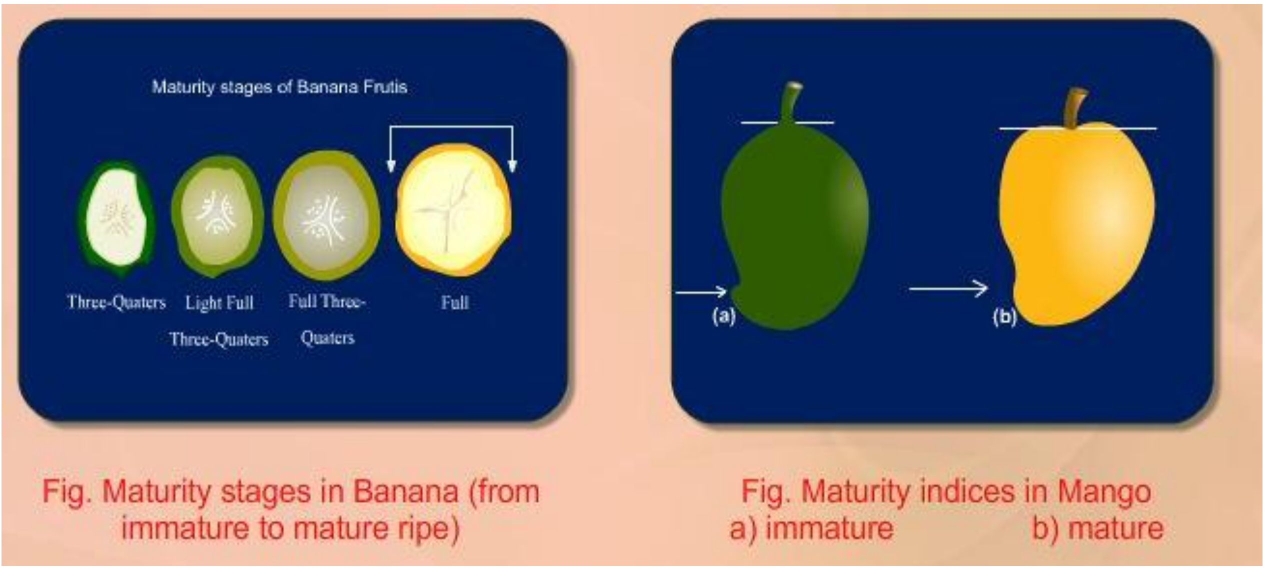

Fig. Maturity stages in Banana (from immature to mature ripe)

Fig. Maturity indices in Mango a) immature b) mature

5. **Size** : The change in size of crop as it is growing are frequently used to determine when it should be harvested. Eg.

- ✓ Litchi, green beans, okra and asparagus and potato related to size at maturity.
- ✓ In banana width of individual fingers can be used for determining their harvest maturity.
- ✓ In baby corn more immature and smaller cob are marked for maturity.

6**. Aroma/ Orgnoleptic quality**: Fruits synthesize volatile chemicals as they may give its characteristic odour and can be used to determine whether it is ripe or not with indication of fruit flies. This method has limited scope in commercial application.

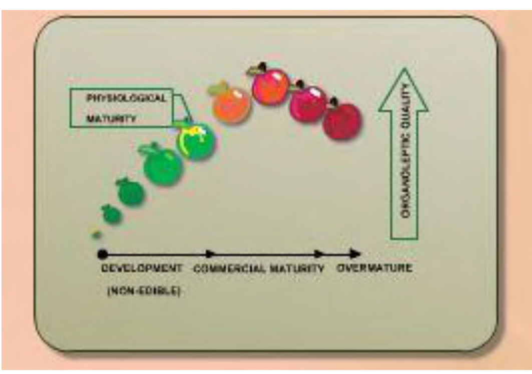

Figure : Organoleptic quality of a fruit in relationship to its ripening stage

7**. Fruit opening**: When the fruit is fully mature on the tree it splits.
Eg. - It is common in fruit of spice tree nutmeg, ackee tree. In vegetable like chow chow distal end of the fruit opens and large single seed emerges and germinates.

8**. Abscission** : Abscission layer is formed in the pedicel as the natural development in the fruit advanced. However, fruit harvested at this maturity will have only short marketable life.
Eg.: In cantaloupe, watermelons, harvesting before abscission layer is fully developed results inferior flavoured fruit compared with those left on the vine for the full period.

9**. Specific gravity**: is the relative gravity/weight of solids or liquids compared to pure distilled water at 16.7^{o}C (62^{o}F).
Eg. Cherries, watermelon, potato, ber and mango (at 1.015 immature and at 1.02 ready for harvest)

10. **Firmness/solidity**: Here harvester slightly presses vegetables such as cabbage and lettuce with his thumb and finger. Harvest maturity is assessed on the basis of how much the vegetable yield to this pressure. Normally the back of the hand is used for testing the firmness of lettuce in order to avoid damage. Fruit may change in texture during maturation and especially during ripening; excessive moisture loss may also affect the texture of crops.

The textural changes can be detected by following ways;

Destructive firmness test methods

a. **Penetrometer / Pressure testers**: Here a representative sample of fruits may be taken from the orchard and tested in a device (Magness Taylor or Effegi fruit presser tester) which will give a numerical value of texture; when that value reaches a pre determined critical level then the fruits in that orchard are harvested.

Eg. Firmness test in mango 1.75 -2 kg.

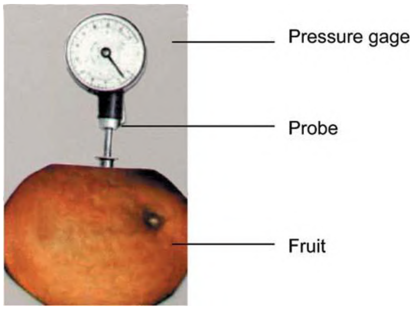

Fig. Objective firmness measurement using Penetrometer

b. **Tenderometer:** It is used in peas only. As pea matures in the pod it is sweet and tender. As maturation progress sugars are converted to starch which coincides with the peas becoming firmer. Therefore for processing sample peas are taken from the field and their texture is tested in a shear cell. The whole field of peas is harvested when a particular tenderometer value is reached.

Fig.Tenderometer to test the pea maturity by presser tester

c. Fingure squeeze/touch: Here peas/beans/okra *etc*. are squeezed between the fingers to determine their firmness. Only experience plays a role here whether to harvest or not.

CHEMICAL METHODS

1. Juice content: The juice content of fruit increases as they mature on the tree. By taking representative samples of the fruit, extracting the juice in a standard and specified way and then relating the juice volume to the original mass of the fruit it is possible to specify its maturity.

	Type of citrus fruit	Min. juice content(%)
1	Navel oranges	30%
2	Other oranges	35%
3	Grape fruit	35%
4	Lemons	25%
5	Mandarins	33%

2. Oil content: Oil content of the fruit may be used to determine the harvest maturity of avocados. At the time of picking and at all times there after shall contain not less than 8% of oil by weight of the avocado excluding the skin and seed. There is good correlation between taste and oil content and dry matter.

3. Dry matter: Rate of dry matter accumulation is used to predict optimum harvest time by using instrument hydrometer. Dry matter is also being used to as the maturity standard in processing varieties of potato. Potato dry matter content at the time harvesting should be in the range of 18 - 24.

4. Sugar: In climacteric fruit carbohydrates are accumulated during maturation in the form of starch. As the fruit ripens starch is broken down to sugars. In non-climacteric fruits sugars tend to be accumulated during maturation. In both cases it follows that measurement of sugars in the fruit can provide an indication of the stage of ripeness or maturity of that fruits. Sugar is measured in terms of soluble solids using Brix hydrometer or Refractometer.

Fruit	TSS (%)	Fruit	TSS (%)
Apple	11.50 -14.50	Papaya	11 - 12
Citrus	12 -14	Pineapple	13.00
Grapes	12-20	Mango	12 -18
Kiwi	8.00		
Pear	12.92-12.99		

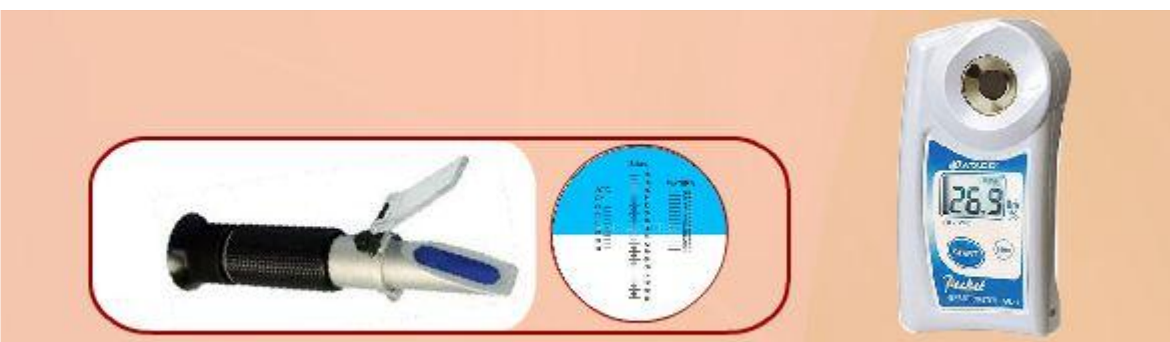

Fig. Hand and Digital Refractometrs

5. Acidity: in many citrus fruits and others acidity progressively reduces on maturation and ripening. Extract the juice from the sample and titrating it against a standard alkaline solution gives a measure which can be related to optimum time of harvest. It is important to measure acidity by titration and not the pH of the fruit because of the considerable buffery capacity in fruit juices. This measure gives the brix: acid ratio

Physiological maturity

This is the stage where plant attain full development of stage just prior to ripening

Eg. Fruits and vegetables produced for seed production

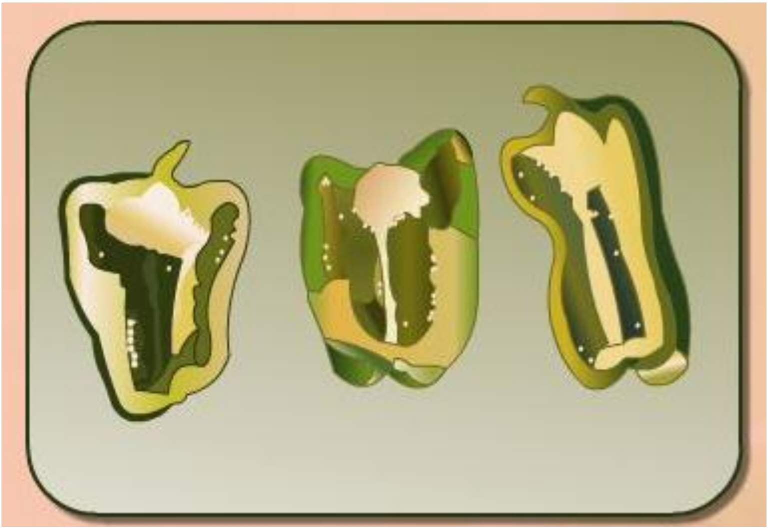

Fig. Physiological maturity in bell pepper is reached when seeds become hardened the internal cavity of fruit starts colouring.

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Lecture schedule- 10

HARVESTING HORTICULTURAL PRODUCE

Harvesting is the gathering of plant parts that are of commercial interest. Harvesting of fruits, vegetables and flowers generally involves separating them from the vital sources of water, nutrients and growth regulators. Harvesting also bring out wound responses like ethylene production and increased respiration in the tissue. Mature tissue generally shows only small responses to harvesting because it stored carbohydrates reserves and relatively low respiration and transpiration rates, and its destined for natural separation by abscission any way. Rapidly metabolizing tissue such as leafy vegetables/immature fruits & vegetables exhibits larger responses to harvesting.
Harvest the produce when the heat load is low, however around–the–clock harvesting is done when machinery are used to meet the cost of the machine and factory processing schedule.

Harvest: is a specific and singe deliberate action to separates the food stuff with or without non edible portion from its growth medium.
Eg - Plucking of F, V & Flowers - Reaping of cereals
- Lifting of fish from water - Lifting of tuber or roots from soil *etc*.

Important factors conceded while harvesting crops are:
- Delicacy of the crop (soft –grapes/strawberry: hard - melons)
- Importance of speed during/after harvest
- Economy of the harvest operation.

'Remember damage done to produce during harvest is irreparable'.
Improper harvesting leads to shortening of shelf life due to
- ✓ increased respiration and ethylene bio synthesis
- ✓ increased levels of micro organism infection through damaged areas
- ✓ possible increase in physiological disorder

Employing improper harvesting methods will results in damage to crop by
I. **Cuts** - where produce comes in contact with sharp object during harvesting/ handling
II. **Bruising** - is caused by
a. **Compression**–due to over filling of boxes, over load in transportations and bulky storing.
b. **Impact** – due to dropping or something hitting the produce
c. **Vibration** – occur due to lose packing in transportation

An important precaution at harvest is to
- ✓ Avoid contaminating produce with pathogens. Practice such as allowing the mango stem end down on the ground to allow the sap to drain should be discouraged.
- ✓ Harvested produce should be kept under shaded tree or using tarpaulins/shade nets.

Harvesting can be performed by hand or mechanically. However, for some crops - eg. onions, potatoes, carrots and others - it is possible to use a combination of both systems. In such cases, the mechanical loosening of soil facilitates hand harvesting. The choice of one or other harvest system depends on the type of crop, destination and acreage to be harvested.
Fruits and vegetables for the fresh market are hand harvested while vegetables for processing or other crops grown on a large scale are mainly harvested mechanically (peas, beans, potato *etc*.).

HARVESTING METHOD

I. Hand harvesting

It predominates for the fresh market and extended harvest period (due to climate, there is accelerated ripening and a need to harvest the crop quickly) particularly the produce which is more susceptible to physical injury and soft fruit like grapes/litchis/jamum and strawberry and others berries which are borne on low growing plants.

Benefits of hand harvesting

- ✓ hand harvesting is less expensive
- ✓ less damage and harvest rate (times) can be increased,

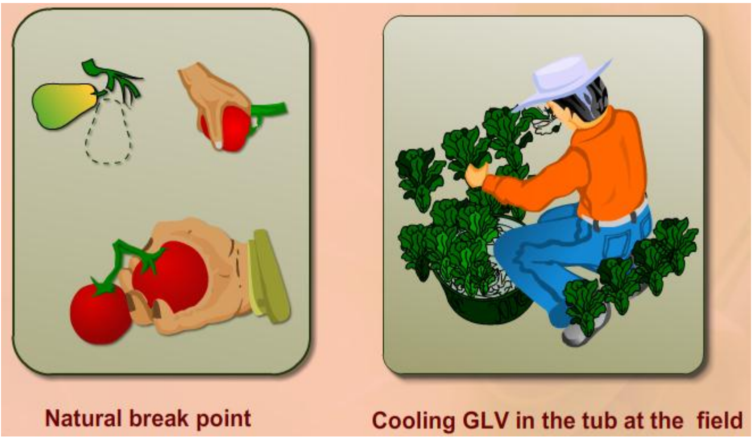
The main benefit of hand harvesting over mechanized harvesting is that humans are able to select the produce at its correct stage of ripening and handle it carefully. The result is a higher quality product with minimum damage. Examples,

- ✓ Breaking off – twisting off pineapple, papaya, tomato
- ✓ Cutting – snipping off mandarins and table grapes with secateurs and apple, roses *etc*

Harvesting methods is also use full reducing incidence of fungal infection in papaya/grapefruit.-When fruit are cut from the tree using clipper shows less infection then the harvesting by twisting and pulling (Fig.).

But harvesting small fruits and from thorny plants are major obstacle(disadvantage).

Different harvesting practices at filed



Natural break point

Cooling GLV in the tub at the field

Harvest containers

Harvesting from the sharp tools

Use of sack to break the fall

Use of plastic sheet for collecting fallen fruit

Tools and containers for harvesting

Tools - Depending on the type of fruit or vegetable, several devices are employed to harvest produce. Commonly used tools for fruit and vegetable harvesting are secateurs or knives, and hand held or pole mounted picking shears.

When fruits or vegetables are difficult to catch, such as mangoes or avocados, a cushioning material is placed around the tree to prevent damage to the fruit when dropping from high trees.

Containers - Harvesting containers must be easy to handle for workers for picking/cutting produce in the field. Many crops are harvested into bags.

Harvesting bags with shoulder or waist slings (as they are easy to carry and leave both hands free) can be used for fruits with firm skins, like mango, citrus, avocados *etc*. The contents of the bag are emptied through the bottom into a field container without tipping the bag.

These containers are made from a variety of materials such as paper, polyethylene film, sisal, hessian or woven polyethylene and are relatively cheap but give little protection to the crop against handling and transport damage. Sacks are commonly used for crops such as potatoes, onions, cassava, and pumpkins.

Plastic buckets - are suitable containers for harvesting fruits that are easily crushed, such as tomato. These containers should be smooth without any sharp edges that could damage the produce.

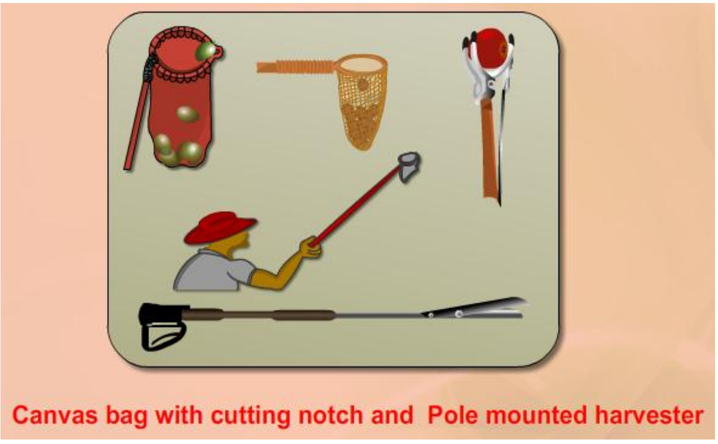
Use of bulk bins(commercial growers) - with a capacity of 250-500 kg, in which crops such as apples and cabbages are placed, and sent to large-scale packinghouses for selection, grading and packing.

Other types of field harvest containers include baskets, carts, and plastic crate.

For high risk products, woven baskets and sacks are not recommended because of the risk of contamination. Eg. Strawberry

Fig. Harvesting strawberry

Fig. Harvesting aid to remove soft fruit



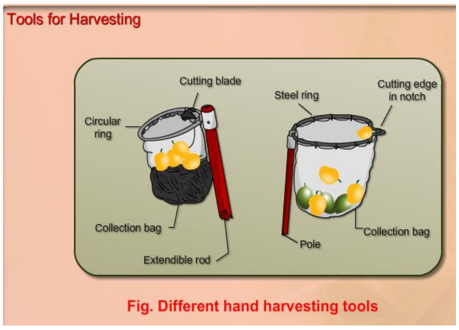


Fig. Different hand harvesting tools

II.Mechanical harvesting

In region where labour cost is high machine harvest is popular for processing crops because it could damage the produce and subsequent faster deterioration.
Eg.: Peas for freezing, peaches for canning and grapes for wine making.
Likewise machine harvest is used for robust, low-unit-value ground crop such as potatoes and onions. The main advantages of mechanized harvesting are speed and the reduced costs per ton harvested. However, because of the risk of mechanical damage, it can only be used on crops that require a single harvest.

i. Mechanical assistance – These are the simple machine used to provide assistance to hand pickers with ladder and positioners (tree towers and platforms).Combination of these process is possible by process by providing bins mounted on trailers moving along the plant rows.
'Flying foxes' (over head ropeways) are similar systems provided to convey heavy banana bunches into packing house.

ii.Harvesting machine – it employ direct harvest by contact methods such as

- Shaking machine
- Picking pole fitted with cutter device – For fruits high on trees like mango, avocados
- The 'shake and catch' machine used in apple and citrus to harvest and collect the fruit by shaking the trunk and collection the fallen fruit on the canvas which spread under the tree.
- Use of vibrating digger is used harvest under ground roots/tuber/rhizomes.
- Use of robotics to harvest mushroom by method of sucker end-effecter.


Positioners and ladder to harvest fruits from tall trees


Fig. Tree shaker and catcher


Fig. Harvesting lettuce at filed


Fig. Raspberry harvester


Fig. Potato harvester

FOLLOWING CARE IS REQUIRED WHILE HARVESTING THE PRODUCE

- ✓ Harvesting should be done in the cool hours of the day - produce exposed to sunlight soon become 4 – 6^{o}C warmer than air temperature.
- ✓ Harvested produce should not be kept on the soil.
- ✓ Hand gloves should be used for harvesting on spiny plants.
- ✓ Falling of produce on earth should be avoided while harvesting.
- ✓ Ladders should be used to harvest produce in case of tall trees.
- ✓ Produce selected for harvesting should be of right maturity.
- ✓ Harvesting should be done gently, without jerks to protect the produce from possible damage.
- ✓ While harvesting underground crops like potato, onion, radish, carrot and beet root *etc.* care should be taken that produce should not get damaged by digging implements.
- ✓ Trained labour should be deployed for harvesting.

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Lecture schedule - 11

HANDLING OF HORTICULTURAL PRODUCE (Supply Chain Management)

Moment produce is harvested, from that point on quality cannot be improved; only maintained. Remember the suitability of produce for sale begins at harvest. Damage done to produce during harvest is irreparable. No postharvest treatments or miracle chemicals exist which can improve inferior quality produce resulting from improper handling.

Fruit and vegetables are highly perishable and unless great care is taken in there harvesting, handling and transportation, they soon decay and become unfit for human consumption. The process of decay being accelerated if poorly harvested and handled produce is placed in storage for any length of time.

Growers should understand that although there is a place for added value approach to the sale of produce, it is however of no value to purchase expensive equipment and packaging for produce if the basic product is already spoilt by poor harvesting, handling and storage. Hence, production costs, harvesting, handling, packaging, transport and marketing costs are the same irrespective of whether produce makes a premium at point of sale or is acceptable for storage or not.

Where/ How to handle horticultural produce?

It has been observed that improper handling of fresh fruit and vegetables is a major cause of deterioration and post harvest losses. To minimize this produce should be handled carefully during entire supply chain. Handling at each stage plays an important role in protecting the quality and enhancing the shelf life of produce. Produce handling plays an important role in following stages of supply chain:

1. At the time of harvest
2. At the field
3. At the time of loading and unloading
4. At the time of transportation
5. At whole sale market
6. At retail market
7. At customer end

1. Handling at the time of harvest

The throwing of produce during hand harvesting or handling should not be allowed. When crops are harvested at some distance from the packinghouse, the produce must be transported quickly for packing.

Conveying banana from field to pack house through conveyor

- ✓ Containers - avoid the use of dirty containers, contaminated with soil/crop residues/ the remains of decayed produce. Containers should be cleaned and disinfected at the end of each storage period.
- ✓ Growers should make certain that harvesting labours are fully conversant with the quality control strategy employed on the farm.
- ✓ Mechanical damage during harvesting and subsequent handling operations can result in defects on the produce and expose to disease-causing microorganisms. The inclusion of dirt from the field further aggravates the process.
- ✓ Every effort should be made to harvest produce at its optimum maturity, as storage life is reduced proportionate to the immaturity and/or over maturity of a vegetable crop.

2**. Handling at the field**

As all fruit and vegetables are tender and have soft texture/skin should be handled gently to minimize bruising and breaking/rupturing of the skin. After harvesting, produce is handled at the field for three main activities before dispatch to the market for sale.

i. Washing, cleaning and dressing
ii. Sorting-grading
iii. Weighment and packaging

i. Washing, cleaning and dressing/trimming

After harvest all underground vegetables and most of the leafy vegetables require washing and cleaning before sorting-grading and packing. While washing and cleaning care should be taken that produce does not get damaged while rubbing to clean the outer surface and only clean water should be used for washing to protect the produce from contamination. Removal of extra water is a must before packing to avoid rotting. Eg.

- Washing with 100 ppm chlorine solution is better to control microbial growth.
- Vegetables like Cauliflower, Cabbage, Radish and other leafy items require to be dressed by removing unwanted leaves and stalk before sending them for marketing.

ii. Sorting-grading

All defective produce such as bruised, cut, decayed and insect infested pieces should be discarded while sorting-grading. This will help to control further deterioration of the produce while in transit. Care should be taken that produce is picked gently and should not be thrown.

iii. Weighment and packing

Packing material and package itself play a protective role against mechanical damage, dust and infection. They also diminish the rate of loss of water, or hinder gaseous exchange and thus modify the composition of the atmosphere around the produce. Type of packaging material and pack size for primary and secondary packaging is very important to enhance life of the produce after harvesting. Different types of packs are suitable for different type of produce depending upon the distance of location and transport mode used. Pack should not have inside sharp edges. Proper cushion in the pack helps the produce to sustain jerks/vibrations during transportation. As far as possible, uniformly graded produce should be packed in one type of pack.

Packing must withstand the following

- ✓ Rough handling during loading and unloading
- ✓ Compression from the overhead weight of other containers.
- ✓ Impact and vibration during transportation.
- ✓ High humidity during pre-cooling, transit and storage.

After packing, each pack has to be weighed before sending to the market for sale. Each pack should have some extra quantity to take care about the moisture loss during transit.

3. **Handling during loading-unloading**

During entire supply chain loading and unloading mainly takes place at following stages:

- ✓ At field
- ✓ At pack house
- ✓ At wholesale market
- ✓ At retail market

Following care is required while loading and unloading of produce:

- ✓ Care should be taken that all the packs should be gently placed on the transport vehicle.
- ✓ While loading and unloading packs should not be thrown.
- ✓ Hooks should be avoided for picking the bags and crates.
- ✓ Torn bags and broken crates should not be used.
- ✓ Different grade packages should be kept separately.

4. **Handling during transportation**

Post-harvest handling is the ultimate stage in the process of producing quality fresh fruits/vegetables/flowers for market or storage. Getting these unique packages of water (fresh produce) to the point of retail or safely into store with the minimum of damage and exposure to disease risk must be a priority for all growers. Much damage is done to fresh produce during transport and growers should take all necessary remedial measures to ensure that produce leaving the field/firm for markets / storage arrives in the same condition as it left the field or the firm.

All transport vehicles should be checked for following before loading the produce:

- ✓ Cleanliness - The vehicle should be well cleaned before loading.
- ✓ Damage - Walls, floors, doors, and ceilings should be in good condition.
  - No sharp object should be there inside the vehicle.
- ✓ Temperature and humidity control – For refrigerated transport temperature, humidity and air circulation should be checked before loading.

Following care should be taken during transportation of fruit and vegetables:

- ✓ Transport vehicle loaded with fresh produce should be driven safely as driving too fast on fields, rough farm tracks or the highway will cause compression damage to produce.
- ✓ Containers, bulk bins or sacks should be loaded onto transport carefully and in such a way as to avoid shifting or collapse of the load during transportation.
- ✓ Bulk loads or open top containers traveling long distances should be covered with Hessian/shade net/plastic to prevent excessive dehydration.
- ✓ Transport loaded with vegetables should not remain grounded (halted) for long periods, as this causes excessive heat build up and will accelerate the onset of breakdown, cause condensation and make produce more vulnerable to diseases. If fresh vegetable deliveries are delayed, vehicles should preferable be placed with covers removed/ in a covered open sided building or at least in the shade.
- ✓ In wet weather however loads of vegetables destined for storage should be covered to protect the produce from getting wet as the first priority.
- ✓ Supervision is needed at all stages of field transport to minimize the accumulation of physical injuries.
- ✓ Nobody should be allowed to sit on top of the loaded packs inside the vehicle.

Following type of damages takes place to the produce during transportation:
- ✓ Impact bruises occur when packs are dropped or bounced.
- ✓ Compression bruises results from stacking of overfilled field containers.
- ✓ Vibration bruises may occur when fruits move or vibrate against rough surfaces of other fruit during transport.

Machinery used during transportation at the filed

Machineries like Field fork lift system, Trailer system and gondola system are used in transportation of horticultural produce at the field level in Peach, citrus, apple, plum and prune orchard

5. **Handling at wholesale market**

At wholesale market produce may get damage at the following stages:
- ✓ Unloading – Handle gently
- ✓ Storage - store in cool, clean and shaded place
- ✓ Loading for retail dispatch

6. **Handling of produce at retail market**
- ✓ It should be ensured that produce is unloaded at the shop with proper care.
- ✓ After unloading only required quantity of produce should be displayed in the shop for sale. Display of large quantity produce not only reduce the shelf life of produce, it gives customer a opportunity to pick and choose from a large lot, which results in loss of freshness/luster and damage of the produce by customers touching and mis-handling. Normally the harvested produce stays at retail market for longer duration. Therefore special care is required to store and protect the produce from mishandling by the customers.
- ✓ Produce which is not kept on display should be stored only in polythene bags or in wet gunny sacs to maintain its freshness.
- ✓ Periodic water spray on leafy items helps in maintain the quality for longer period or centralized air conditioned shop.
- ✓ Customers should not be allowed to break/put pressure, squeeze or damage the produce during sale.

7. **Handling at customer end**

Last person to handle the produce in entire supply chain is consumer. When customer purchases the fruit, vegetables and flowers, lot of damage is already taken place, sometimes this damage is not visible at the time of purchase, but develop within few hours of purchase. Visibility of any damage to the produce itself is an indication that produce should be consumed as early as possible to avoid further deterioration. Users who have refrigeration facility may buy 3-4 days requirement at a time.

At low temperature if produce stored in following manner it can be kept fresh for a longer period:

- ✓ Green leafy vegetables - wrap in wet cloth and store.
- ✓ Beans, Brinjal, Cauliflower, Cabbage, Radish, Carrot, Chilli, Capsicum and rooty vegetables – keep in polythene bag and store. Before keeping in bag extra moisture should be removed.

- ✓ Apple, Guava, Onion and Garlic should be avoided along with other vegetables due to their typical flavor/aroma.

TIPS FOR HANDLING FRUIT AND VEGETABLES

- ✓ Pick all the fruits very gently with thumb and middle finger only
- ✓ Never press any fruit and vegetable (Any damage to produce due to bad handling is not visible but damage occurs; however it develops over a period of time.)
- ✓ Do not pick banana from the body; Pick them by stem only
- ✓ Do not pick leafy vegetables by the leaf end; Pick them from stem only
- ✓ Do not press citrus fruits; It damage oil cells present on skin and turn brown after some time
- ✓ Do not press ripe fruits like sapota, banana and mango *etc*. to check the ripening

Examples for checking ripeness

- ✓ Papaya – Punch the body with fine needle, if thick milk secretion comes it is unripe, if watery substance comes out it is ripe
- ✓ Sapota – Place in your full hand and feel the ripening with slight pressure
- ✓ Mango- Press the mango from its beak.; if it hard it is unripe, if it takes pressure/smooth, it is ripe

Growers should follow basic principles when handling fresh produce:

- ✓ All labour engaged in handling and transporting fresh produce should be trained
- ✓ All cut produce, such as cabbage/others should be kept away from being placed in contact with soil
- ✓ Remove or minimise the affect of all likely damage points from within the handling system
- ✓ Use methods of padding or cushioning when first filling containers or transport to minimise the risk of bruising or scuffing of produce
- ✓ Make certain that vegetables being transferred from one point to another during harvesting or grading and sorting, that they suffer the absolute minimum of drop
- ✓ Protect harvested produce from the debilitating effect of sun, wind and rain each of which cause problems especially to crops destined for long term storage.

References

Sl.No.	Title	Authors	Years	Publishers
1	Small-Scale Postharvest Handling Practices:A Manual for Horticultural Crops (4th Edition) P ostharvest Horticulture Series No. 8E	Lisa Kitinoja Adel A. Kader	2002	University of California, Davis Postharvest Technology Research and Information Center
2	Post Harvest Technology of Fruits and Vegetables	A.K. Thomposon	1996	Blackwell Science ISBN 1-4051-0619-0
3	Post Harvest- An Introduction to the Physiology and Handling of Fruits, Vegetable s and ornamentals	Wills, McGlasson, Graham Joyce	2007	Cab International ISBN97818459322755
4	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

Lecture schedule - 12

POST- HARVEST TREATMENTS ON HORTICULTURAL PRODUCE

Part - 1

Introduction

Many post harvest treatments are applied to horticultural crops, either to maintain the quality (taste, colour, flavour, texture) or improve the visual appeal. Most important of these treatments are temperature management including the cold chain where the temperature of the crop is reduced rapidly and stabilize temperature after harvesting. Exposing the crop to high or low temperature and application of chemicals after harvest helps in managing/prevent pest and diseases and sprouting occurrence respectively.

Harvested produce must be handled with care at every stage to avoid the mechanical damage and subsequent fungal/bacterial infection. Adopting appropriate post harvest handling operation will minimize the all ill effects of post harvest (Fig.).

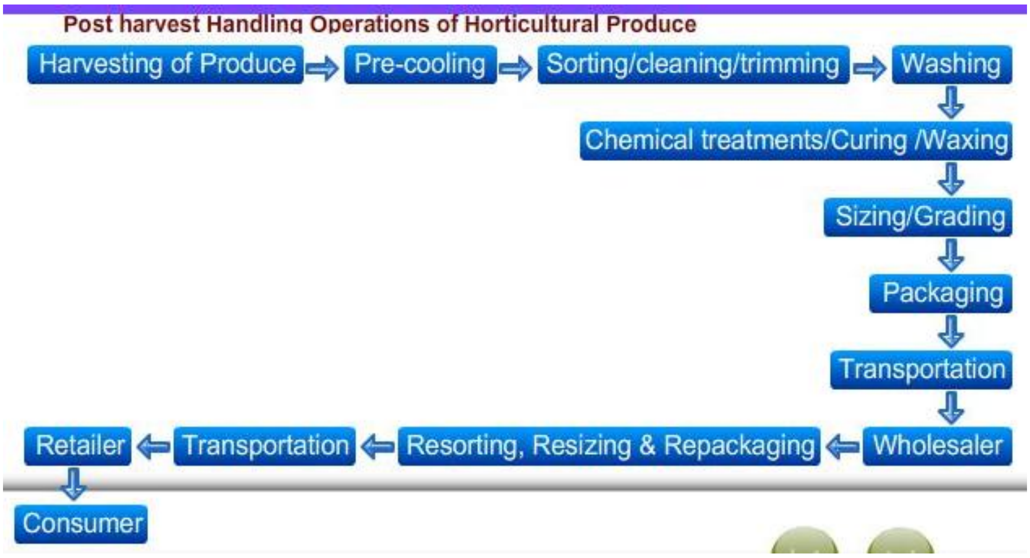
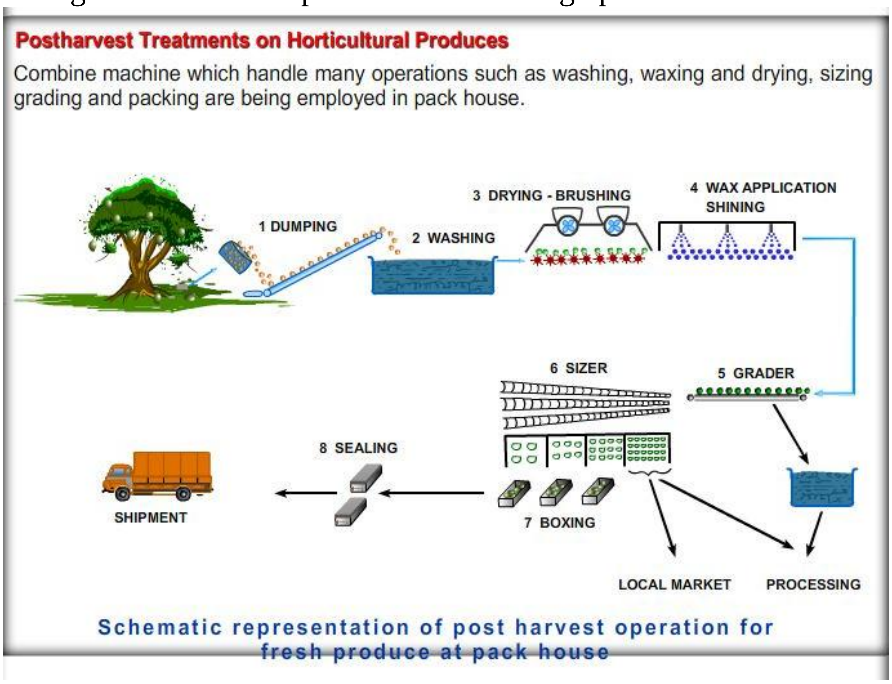


Fig. Flow chart for post harvest handling operations of horticultural produce



Schematic representation of post harvest operation for fresh produce at pack house

<u>Basic conditions for postharvest treatments are</u>

- ✓ Only fresh produce can be preserved
- ✓ Produce should be free from defects

A basic principle in shelf life enhancement process is to control or minimize the respiration rate and spoilage.

Following are post-harvest treatments in handling and storage of horticultural commodities

1. Pre-cooling (Low temperature)
2. Cleaning, washing and trimming
3. Sorting, grading and sizing
4. High temperature – Curing / Drying / Hot water treatments / Vapour heat treatment /Degreening
5. Chemical treatment - Disinfestations/ Sprout suppressants/Mineral application/ethylene inhibitors(1-MCP)
6. Fruit coating (waxing)
7. Astringency removal
8. Irradiation
9. Regulation of ripening -Control/ethylene scavenging/ Degreening
10. Pulsing and tinting
11. Minimal/ Light processing
12. Cold storage
13. Packing

References Part 1 – 10 (Lecture schedule 12 - 21)

Sl.No.	Title	Authors	Years	Publishers
1	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
2	Post Harvest- An Introduction to the Physiology and Handling of Fruits, Vegetable s and ornamentals	Wills, McGlasson, Graham Joyce	2007	Cab International ISBN97818459322755
3	Post Harvest Physiology of Perishable Plant Products	Stanley J. Kays	1998	CBS, New Delhi
5	Post Harvest Technology of Fruits and Vegetables	A.K. Thomposon	1996	Blackwell Science ISBN 1-4051-0619-0
6	Small-Scale Postharvest Handling Practices:A Manual for Horticultural Crops (4th Edition) P ostharvest Horticulture Series No. 8E	Lisa Kitinoja Adel A. Kader	2002	University of California, Davis Postharvest Technology Research and Information Center

Lecture schedule - 13

Part – 2

PRE - COOLING

Pre-cooling refers to removal of field heat (quick cooling) after harvest; if not, its deterioration is faster at higher temperature of 1 hour at 32^0C = 1day at 10^0C or 1 week 0^0C. The entire products must be pre-cooled as early as possible to the recommended storage temperature and relative humidity. Pre-cooling is done just above chilling and freezing temperature.

Advantages of pre-cooling:

- ✓ It removes the field heat
- ✓ Reduces the rate of respiration and ripening
- ✓ Reduces the loss of moisture
- ✓ Reduce bruise damage during transits
- ✓ Reduces the production of ethylene
- ✓ Reduces /inhibits the growth of spoilage organisms
- ✓ Eases the load on the cooling system (refrigeration) of transport or storage chamber
- ✓ Above factor helps in extends the product shelf life

Pre cooling depends on the following factors

- ✓ Air temperature during harvesting (during summer pre-cooling time is more)
- ✓ Time between harvest and precooling
- ✓ Nature of the crop (High perishable crop require immediate pre-cooling)
- ✓ Difference in temperature between the crop and cooling medium
- ✓ Nature/Velocity of the cooling medium
- ✓ Rate of transfer of heat from the crop to the cooling medium.
- ✓ Type of package material used – Use of water proof ventilated boxes for good air circulation in the room is helpful. Plastic boxes/ fiber board cartons which have been treated with wax will render them water proof.

Choice of pre-cooling method depends:

- on the nature of the produce
- economics of the process

Mechanism of pre-cooling - Conduction and convection are the two main heat-transfer mechanisms used for cooling of produce. With conduction, the heat is transferred within a produce to its coldest surface. This is direct movement of heat from one object to another by direct methods (from fresh produce to water or warmer to cooler).With convection, the heat is transferred away from the surface of the produce via a cooling medium such as moving water or air.

Potatoes/ apples/cauliflower/orange and other fruits (bigger mass and lesser surface area) and vegetables require more time to pre-cool than produce which is having smaller mass and large surface area like lettuce/green onion/ carrot tops/peas/corn/brussel sprouts. This is because of the heat from the inside of the crop has to move to the surface before it is transferred in bigger produce.

The rate of cooling depends on individual volume and the exposed surface of product. The difference in temperature between product and the refrigerating medium also needs to be taken into account.
For example: large exposed surfaces, leafy vegetables cool almost 5 times faster than large fruit such as melons (more volume, less surface).

Heat with in the crop comes in two ways:

i. Through the convection from the surrounding air mainly from the sun in the form of radiation

Eg.: Crop harvested in the early morning will be cooler, since the sun has not been able warm the surrounding air or crop and lower metabolic heat.

ii. From the metabolic heat from chemical reactions within the crop(respiration)

When the heat is removed by way of evaporative cooling then the fresh produce must not be sealed in moisture proof film like polyethylene bags.

Pre-sorting - Pre-sorting of produce is usually done to eliminate injured, decayed and other unwanted produce before cooling and handling. Pre-sorting will save energy in that culls will not be handled.

Types of pre-cooling methods

A. Cold air – i. Room cooling
ii. Forced air cooling (presser cooling)

B. Cold water / Hydro cooling

C. Top icing – direct contact with ice

D. Evaporation of water from produce – i. Evaporative cooling
ii. Vacuum cooling

E. Hydrovac cooling – combination of hydro and vacuum cooling

Commodity –wise cooling methods

Cooling methods	Commodities
Room cooling	All fruits and vegetables
Forced air cooling	Fruits and fruits type vegetables, tubers and cauliflowers
Hydro cooling	Stems, green leafy vegetables, fruits and fruit type vegetables
Package icing	Roots, stems, cauliflowers, green onion, brussel sprouts
Vacuum cooling	Stems, Leafy and flowers type vegetables
Transits cooling -Mechanical -Top iceing & channel icing	 All fruits and vegetables Roots, stems green leaf vegetables and cantaloupes

A. Room cooling

- ✓ In room cooling, heat is transferred slowly from the mass of the produce (by convection) to the cold air being circulated around the stacked containers.
- ✓ This is most common and widely used method. Here cold air is passed from the fan and cool by convection process.
- ✓ Its commonest use is for products with relatively long storage life and marketed soon after harvest.
- ✓ Advantages of this room air-cooling are that produce can be cooled and stored in the same room without the need of transfer and hence it is economical.

- ✓ Under this system, cold air from evaporator enters the room, moves horizontally and then passed through the produce containers and return to the evaporator.
- ✓ Disadvantage - It takes more time to cool the products- the removal of heat slowly makes this system unsuitable for highly perishable commodities. This is because the product needs at least 24 hours to reach the required storage temperature.
- ✓ Almost all crops are suitable for this type of cooling but it is mainly used in citrus fruits, potato, onions, garlic, citrus *etc*.

B. Hydro cooling

Principle **-** 'the transmission of heat from a solid to a liquid is faster than the transmission of heat from a solid to a gas'. i.e. water is better heat conductor than air.

In this method cold water is used for quick cooling of a wide range of fruit and vegetables. Hydro cooling avoids water loss and may even add water to the fruit. Under this method, water is usually cooled by mechanical refrigeration, but ice may be used to make process faster. Chlorine (150-200ppm)/Iodine/Nutrients/Growth regulators/ Fungicides can be added in water to sanitize/ improve nutrient status and prevent post harvest diseases of the produc.

For quick cooling of the produce, cold water must constantly be passed over the crop. This can be done by submersing the crop in cold water which is constantly being circulated through a heat exchanges.

Cooling time -

- ✓ 2 min for asparagus(long & narrow) & Leafy vegetables (more surface to volume ratio)
- ✓ 10 minutes for small produce like capsicum (large and globular)/ cherries/tomato
- ✓ up to 1 hour for large products such as melons.

Hydro-cooling has the advantage over the pre-cooling method where it helps in cleaning the produce, provides fast, uniform cooling for commodities. It is faster than forced air cooling. Hydrocooling can be achieved by immersion or through means of a chilled water shower. Not all crops can be hydrocooled, because they need to be able to tolerate wetting, chlorine, and water infiltration.

Disadvantage -Tank water can be contaminated with micro organisms which can result in increased levels of spoilage during subsequent storage or marketing so chlorine should be added to avoid the problems.

Two types of hydro coolers are generally used.

i. **Shower/batch type** - The water showers over the commodity, which may be in bins or boxes, or loosen a conveyer belt. A common design is to transport the crop on a perforated conveyer belt (the speed of the conveyer can be adjusted to the time required to cool the crop) and cold water is pumped from the tank and allowed to fall on the produce in sprinkled type and then falls through to the tank below then filtered, recycled and re cooled (Fig.3).

Efficient cooling depends upon adequate water flow over the product surface. For product in bins or boxes, water flows of 75-100 lt. /min./ft.(400-600 l/min/m^2) of surface area are generally used.

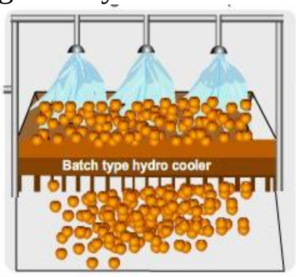


Fig.: Shower/Batch type hydro cooler

ii. **Immersion type** – It is simplest type of a hydro-cooler in which produce is dipped in cold water. Here product are normally in bulk, is in direct contact with the cold water as it moves through a long tank of cold. This method is best suited for products that do no float, because, slow cooling would result if the product simply moved out of the water. Immersion hydro coolers convey product against the direction of water and often have a system for agitating the water. Depth of the water tank should be >30 cm and water tends to penetrate inside fruits, particularly those that are hollow such as peppers. Water temperature also contributes to infiltration. It is recommended that fruit temperature is at least 5^0C lower than liquid.
Eg.: Radish, Asparagus, Artichoke, Green onion, capsicum and leafy vegetables.

Crops normally hydro cooled

Artichoke	Carrot	Kiwifruit	Potato(early)
Asparagus	Cassava	Kohlrabi	Pomegranate
Beet	Celery	Leek	Radish
Belgian endive	Chinese cabbage	Lima bean	Rhubarb
Broccoli	Cucumber	Orange	Snap beans
Brussels sprouts	Eggplant	Parsley	Spinach
Cantaloupe	Green onions	Parsnip	Summer squash
Cauliflower	J. artichoke	Peas	Sweet corn

C Forced air cooling or pressure cooling

- ✓ In this system 'cold air is passed by force from one side to other side using big fan'.
- ✓ Cold air movement is through the containers rather than around the containers.
- ✓ Cooling is 4 to 10 times more rapid than room cooling and its rate depends on airflow and the individual volume of produce
- ✓ Air is blown at a high velocity leading to desiccation of the crop. To minimize this effect, air is blown through cold water sprays.
- ✓ It is slow compared to hydro cooling but is a good alternative for crops requiring rapid heat removal which cannot tolerate wetting or chlorine of cooling water.
- ✓ Adequate airflow is necessary. This is because fruits in the center of packages tend to lose heat at a slower rate, compared to those on the exterior.
- ✓ This system is also called as high humidifier. High RH of 90 - 95% is to be maintained in the precooler to avoid dehydration during cooling.
- ✓ This system can be applied to all crops particularly berries, ripe tomatoes, bell peppers and many other fruits, cabbage, green peas, cucumber, brinjal, muskmelon, watermelon and mushroom.

Baby corn : 5 – 6 hr cooling at 2 - 4^0C,
Leafy vegetables : 1 – 2 hr cooling at 6 - 8^0C (too low temperature causes chilling injury)

Fig. Forced air cooling (High humidifier)

Difference between Forced air cooling and Vacuum cooling

Forced air cooling	Vacuum cooling
The air passes over the surface of the crop, cooling the outside while the inside is cooled by heat transfer from inside to the outside for the crop.	In cooling chamber, pressure (reduced) is exactly the same around the produce and in the centre of the produce. This means the cooling is very even and quick throughout the crop.

Crops usually pre-cooled by forced air

Anona	**Citrus**	**Litchi**	**Plantain**
Avocado	Coconut	Mango	Pomegranate
Banana	Cucumber	Mangosteen	Prickly pear
Barbados cherry	Eggplant	Melons	Pumpkin
Berries	Fig	Mushrooms	Rhubarb
Breadfruit	Ginger	Okra	Sapota
Brussels sprouts	Grape	Orange	Snap beans
Cactus leaves	Grapefruit	Papaya	Strawberry
Capsicum	Guava	Passion fruit	Summer squash
Carambola	Kiwifruit	Persimmon	Tomato
Cassava	Kumquat	Peas	Tree tomato
Cherimoya	Lima bean	Pineapple	Yam

D. Top icing

- ✓ This is one of the oldest ways to reduce field temperature.
- ✓ It is commonly applied to boxes of produce by placing a layer of crushed ice directly on top of the crop.
- ✓ It can also be applied as an 'ice slurry'made from 60% finely crushed ice, 40% water and 0.1% sodium chloride to lower the melting point of the ice.
- ✓ Ice slurry give greater contact between produce and ice compared only top icing, and therefore result in quicker cooling.
- ✓ The main use for top icing is for road transport and it can be applied shortly after harvest. Top-ice on loads should be applied in rows rather than a solid mass. It is important not to block air circulation inside the transport vehicle. Ratios of water to ice may vary from1:1 to 1: 4.
- ✓ Direct contact between the produce and the ice provides fast, initial conduction cooling. However, as the ice melts, an air space is created between the ice and the produce and the conduction cooling stops. Subsequent cooling is by radiation and convection, both of which are slower processes than conduction.

Package ice can be used only with

- ✓ during transport to maintain a high relative humidity for certain products
- ✓ water tolerant, non-chilling sensitive products
- ✓ with water tolerant packages such as waxed fiberboard, plastic or wood.

It also increases costs because of the heavier weight for transportation and the need for oversized packages. In addition to this, as water melts, storage areas, containers, and shelves become wet.

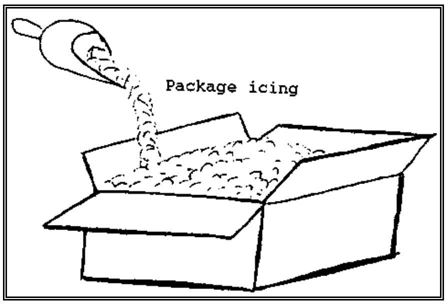


Fig. Package icing of vegetables

Crops suitable for ice cooling

Belgian endive	Chinese cabbage	Leek	Sweet corn
Broccoli	Carrot	Parsley	
Brussels sprouts	Green onions	Pea	
Cantaloupe	Kohlrabi	Spinach	

E. Vacuum cooling

- ✓ Vacuum cooling takes place by water evaporation from the product at very low air pressure (At a normal pressure of 760 mmHg, water evaporates at 100ºC, but it does at 1ºC if pressure is reduced to 5 mmHg.).
- ✓ Most rapid and uniform methods of cooling. Products that easily/rapidly release water may cool down rapidly.

  Eg.: Most suitable - Leafy vegetables, cabbage

  Not suitable - Tomato with low ratios between mass and surface area and effective water barrier like wax on surface is not suitable.
- ✓ Produce is placed in a strong, airtight, steel chamber. Moisture loss is achieved by pumping air out of the chamber containing the product and reducing the pressure of the atmosphere around the product. It causing the water in the produce to vapourize. Cooling occurs because the heat energy for vapourization comes from the produce.
- ✓ Vacuum cooling causes about 1% product weight loss for each 5^0 of cooling.
- ✓ This method is also used to cool the products like beans, carrots, capsicum, celery, corn, lettuce, mushrooms, spinach, sweet *etc*.
- ✓ High cost and sophistication operation needed.

Crops that can be vacuum cooled

Belgian endive	Celery	Mushrooms	Swiss chard
Brussels sprouts	Escarole	Snap beans	Watercress
Carrot	Leek	Peas	
Cauliflower	Lettuce	Spinach	
Chinese cabbage	Lima bean	Sweet corn	

Fig. View of room cooling Forced air cooling Vacuum cooling

Tips to increase pre cooling- efficiency

- ✓ Pre cooling should be done as soon as possible after harvest.
- ✓ Harvesting should be done in early morning hours to minimize field heat and the refrigeration load on pre cooling equipment.
- ✓ Harvested produce should be protected from the sun with a covering until they are placed in the pre cooling facility.

Precautions

- ✓ Since most tropical produce are sensitive to chilling injury, care must be taken not to precool or store the produce below the recommended temperature.
- ✓ All produce are sensitive to decay. Precooling equipment and water should be sanitized continuously with a hypochlorite solution to eliminate decay producing organisms.
- ✓ Care also must be taken not to allow produce to warm up after precooling. Condensation on pre cooled produce surfaces at higher air temperatures also spreads decay.

Lecture schedule - 14

Part - 3

CLEANING, WASHING, DRESSING AND WATER SPRAY

(What makes fruits & vegetables fresh?)

Simple postharvest operation such as cleaning, washing and trimming makes produce very fresh after harvest and make convenient for the produce to sales in the market.
Preparation for the fresh market starts with dumping onto packinghouse feeding lines. Dumping may be dry or in water (fig.1&2). In both cases it is important to have drop decelerators to minimize injury as well as control the flow of product. Water dipping of produces causes less bruising and can be used to move free-floating fruits. However, not all products tolerate wetting. A product with a specific density lower than water will float, but for the produce which sinks, salts (NaCl) are diluted in the water to improve floatation.

Fig.1 Dry dumping of lemons

Fig.2 Water dumping of apple

Cleaning

Most of the fruits and underground vegetables like beetroot, radish, carrot, ginger *etc*. when harvested are with soil/mud/latex/pesticides/dried/pest infested/diseases and look dirty. Cleaning and washing makes them marketable. After harvest they should be gently rubbed with wet cloth/dry air and then washed properly to remove all soil and secondary roots. Unclean produce may contain bacteria and fungus which can damage the produce during transit and storage.

- ✓ Very small produce is mechanically removed by mesh screens, pre-sizing belts or chains.
- ✓ Bruised, rotted,mis-shaped produce, wilted or yellow leaves are usually removed by hand.
- ✓ Garlic and onions are topped to remove the dry foliage attached to the bulbs (fig.3).
- ✓ In many crops soil and loose parts are removed by brushing (Fig.4, 5 and 6).

Fig.3: Topping onions before grading

Fig.4: Brushing and hand removal of damaged fruits before grading

For produce such as kiwifruits and avocadoes, dry brushing may be sufficient to clean the produce. Soft brush bristles are preferred in washing, the stiffness must be just enough to remove the dirt without injuring the fruits. The brush speed should not exceed 200 rpm.

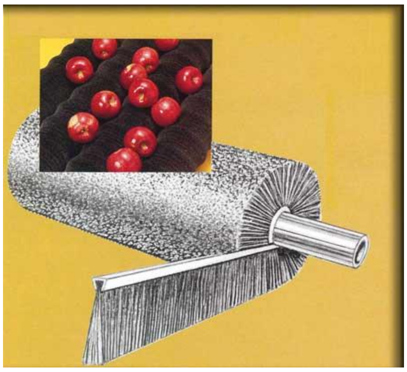


Fig.5 Spiral wound cylinder brushes.

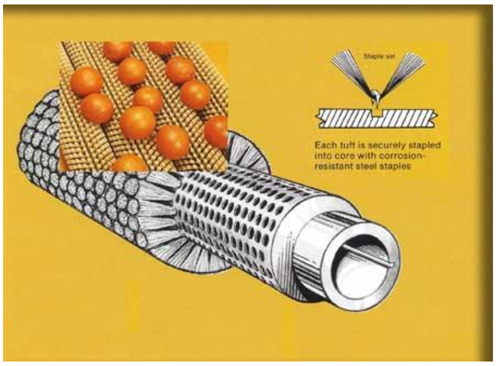


Fig.6 Staple set cylinder brushes (www.industrial-brush.com)

Washing

- ✓ Washing of fruits and vegetables is done to remove adhering dirt, stains, insects, molds and sometimes spray residues.
- ✓ Washing not only help in cleaning and making the vegetables/fruits fresh and also improves appearance, it also helps in extending the shelf life of the produce.
- ✓ Washing is done manually under tap water or in a wash tank using soft muslin cloth.
- ✓ Produce should be thoroughly washed with clean water (preferably with 100 – 150 ppm hypochlorite/chlorine) or soap or calcium hydroxide. Most efficient detergent used is sodium meta bisulphate.
- ✓ After washing they are then wiped with dry muslin cloth or air-dried to remove excess surface moisture. Under automated systems, the produce passes under a spray washer on a moving conveyor rollers.
- ✓ Thumb rule is to use 1 to 2 ml of chlorine bleach per liter of water gives 100-150 ppm of Cl. pH of the water must be around 6.5 to 7.5.
- ✓ Sanitation is essential, both to control the spread of disease from one item to another, and to limit spore buildup in wash water or in the packinghouse air. Fungicide may be used as post harvest dip to control diseases and disorder.
- ✓ Excess water should be removed from the produce to avoid rotting.
- ✓ In crops where water dipping is possible, differential floatation could be used to separate rejects.
- ✓ Root and tuber vegetables are often washed to remove adhering soil**.**

The choice of brushing and/or washing will depends on the type of commodity and contamination.

i. Wash before cooling and packing- Carrot(soil), cucumbers, leafy greens, tomatoes
ii. Wash to remove latex, reduce staining – mangoes(sap), bananas(debris/sap)
iii. Wash after storage - sweet potatoes, potatoes, carrots
iv. Dry brush after curing or storage - onions, garlic, kiwifruit
v. Brushing and wiping – Melons
vi. Do not wash -strawberry, beans, melons, cabbage, okra, peas, pepper,summer squash *etc.*

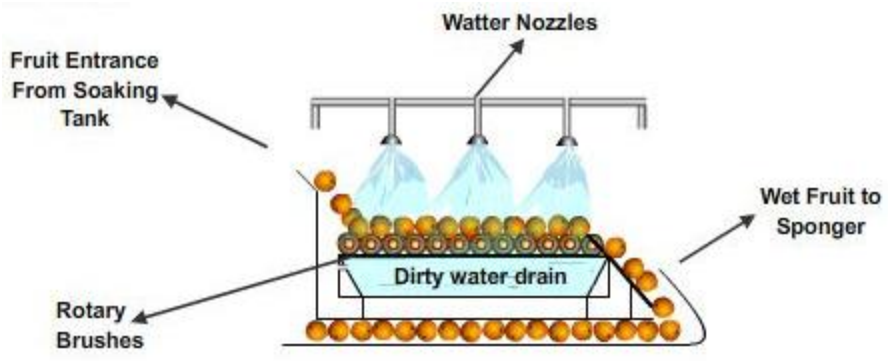


Fig.: A typical fresh produce washing machine

Dry cleaning

In some cases cleaning is done by dry brushing instead of washing.

Eg. Removal of white cottony mealy bugs attached in between the surface holes of custard apple fruits.

Some fruits and vegetables are just wiped with clean dry cloth.

Fruits and vegetables which are not suitable for washing are: onion, garlic, okra, grapes, strawberry, mushrooms, *etc*.

Dressing

Removal, trimming and cutting of all undesirable leaves/ stem/ stalks/ roots/ other non edible or unmarketable parts is called dressing. Dressing makes vegetables attractive and marketable.

Trimming is done especially in vegetables and flowers to remove unwanted, discoloured, rotting and insect damaged parts (e.g., cabbage, cauliflower, spinach, lettuce, rose, chyrysanthemum, gladiolus, tuberose *etc*.) or parts that may favour deterioration or damage during later handling. In case of grapes, trimming of bunches is done to remove the undersize, immature, dried, split and damaged berries. Trimming and removal of decaying parts are preferably done prior to washing. Trimming enhances visual quality, minimizes water loss and other deteriorative processes. Trimming reduces the likelihood of diseases or their spread, facilitates packaging and handling, and reduces damage for other produce.

Water spray

Produce starts loosing water as soon as it is detached from the plant. Water spray helps in compensating that water loss and maintaining the quality for longer period. Produce can also be covered with gunny sack soaked in cold water, if it has to store for longer period before sale.

Example: Green leafy vegetables

SORTING, SIZING AND GRADING

Sorting

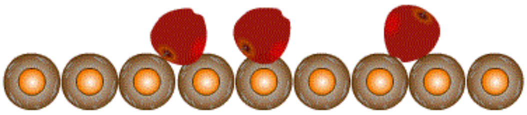
Sorting is done by hand to remove the fruits and vegetables which are unsuitable to market or storage due to damage by mechanical injuries, insects, diseases, immature, over-mature, misshapen *etc*. This is usually carried out manually and done before washing. By removing damaged produce from the healthy ones, it reduces losses by preventing secondary contamination. Sorting is done either at farm level or in the pack-houses. In sorting, only sensory quality parameters are taken into consideration.

The following illustrations represent three types of conveyors used to aid sorting of produce.

- The simplest is a belt conveyor, where the sorter must handle the produce manually in order to see all sides and inspect for damage.

- Push-bar conveyor causes the produce to rotate forward as it is pushed past the sorters.

- Roller conveyor rotates the product backwards as it moves past the sorter.



Sizing

Before or after sorting, sizing is done either by hand or machine. Machine sizers work on two basic principles; weight and diameter. Sizing on the basis of fruit shape and size are most effective for spherical (oranges, tomato, certain apple cultivars) and elongated (Delicious apples and European pears are of non-uniform shape) commodities, respectively.

Mechanisms/Types of sizing

A. Diverging belts/rope grader - the different speed of belts makes produce rotate besides moving forward to a point where produce diameter equals belt/rope separation. Eg. cucumbers, gherkins, pineapples and large root vegetables(fig.8).

B. Sizing rollers - with increased spaces between rollers (fig.9) Eg. Citrus

C. Hand held template-Sizing can be performed manually using rings of known diameter (fig.11).

D. Sizing by weight - sorting by weight is carried out in many crops with weight sensitive trays. These automatically move fruit into another belt aggregating all units of the same mass. Individual trays deposit fruit on the corresponding conveyor belt (fig.10). Eg. Citrus, apples and pear and irregular fruits

E. Mesh screens - eg, potato, onion, anola *etc*.

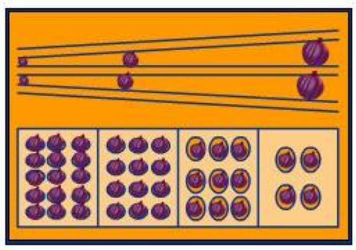


Fig. 8 Sizing onion bulbs by diverging belts/rope

Fig.:9 Sizing by rollers of increasing distance between them.

Fig.:10 Sizing by weight.

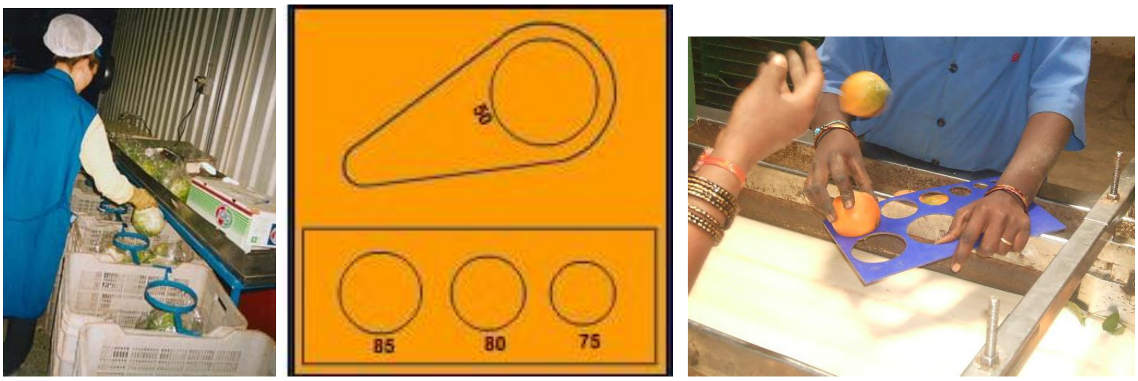


Fig.:11 Sizing with rings of known diameters

Grading

The produce is separated into two or more grades on the basis of the surface colour, shape, size, weight, soundness, firmness, cleanliness, maturity & free from foreign matter /diseases insect damage /mechanical injury.
For eg.: Apple I. Extra Fancy II. Fancy III. Standard IV. Cull (for processing).

Grading may be done manually or mechanically. It consists of sorting product in grades or categories based on weight/size.

Systems of grading : Static and Dynamic.

A. Static systems - are common in tender and/or high value crops. Here the product is placed on an inspection table where sorters remove units which do not meet the requirements for the grade or quality category (fig.12).

B. The dynamic system - here product moves along a belt in front of the sorters who remove units with defects (fig.13). Main flow is the highest quality grade. Often second and third grade quality units are removed and placed onto other belts. It is much more efficient in terms of volume sorted per unit of time. However, personnel should be well trained. This is because every unit remains only a few seconds in the worker's area of vision. Eg. Onion grading
There are two types of common mistakes: removing good quality units from the main flow and more frequently, not removing produce of doubtful quality

Fig.12 Static quality grading system

Fig. 13: Dynamic quality grading system

Fig. Grading of Gherkin through divergent rope after deflowering

New Innovation in grading systems

i. Computerized weight grader – operate on the basis of tipping buckets that drops to release the pre weighed item at a particular position. – Apples, citrus
ii. Video image capture &analysis–used for size, colour &external defect grading-coffee bean, apple
iii. NIR Spectrometers – to assess the TSS non – destructively in apple and stone fruits
iv. X-ray imaging and Computer aided tomography
v. MRI - Magnetic Resonances Imaging
vi. Spectroscopy
vii. Acoustic methods
viii. Volatile emission analysis

Lecture schedule – 15

Part - 4

HIGH TEMPERATURE – Curing / Drying / Hot water treatments / Vapour heat treatment / Degreening

Curing

When roots and tubers are to be stored for long periods, curing is necessary to extend the shelf life. It is an effective operation to reduce the water loss during storage from hardy root and tuber vegetables such as potato, sweet potato, yam and other tropical vegetables where cuticle are poorly developed. They are relatively susceptible to mechanical wounding during harvesting and handling. These problems can be minimized by the process of 'curing' at intermediate to high temperature and high relative humidity (RH). During curing it develops periderm over cut, broken or skinned surfaces and helps in wound restoration.

'Curing is accomplished by holding the produce at high temperature and RH for several days, while harvesting wounds heals and new protective layers of cell forms around wound'.

Advantages –

- ✓ It helps in wound healing of harvest and handling injuries through skin hardening
- ✓ Reduce water losses
- ✓ Prevent infection from pathogen

How curing happen?

- ✓ Curing is normally undertaken in the field, but in some case curing structure are employed.
- ✓ Produce can be cured in the field by piling them in a partially shaded area. Cut grass or straw can serve as insulating material, while, covering the pile with canvas, burlap, or woven grass matting. This covering will provide sufficient heat to reach high temperatures and high relative humidity. The stack can be left in this state for up to four days.
- ✓ Curing in potato starts with deposition of suberin in parenchymatous cell just below the damaged area of the tuber.
- ✓ Suberin (a waxy waterproof substance found in the cell walls of many plants, especially corky in nature) is a group of fatty acids which provides initial protection to the tuber against water loss and infection.
- ✓ Subsequently, below the suberized cells a meristematic layer of cells is formed which is the periderm, also called as cork cambium (Fig.19). This produces new cells which seal off the damaged area. But these processes are temperature and humidity dependent.
- ✓ Eg.Curing of potato takes place in 1 days at 21^0C ;2 days at 15^0C ;3 days at 10^0C;5-8 days 5^0C.

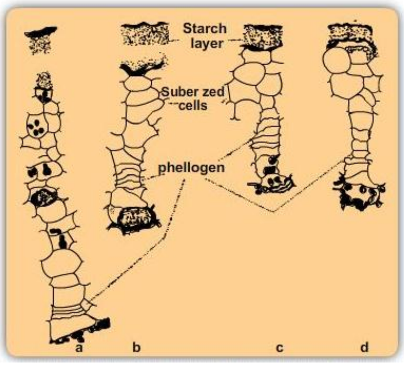
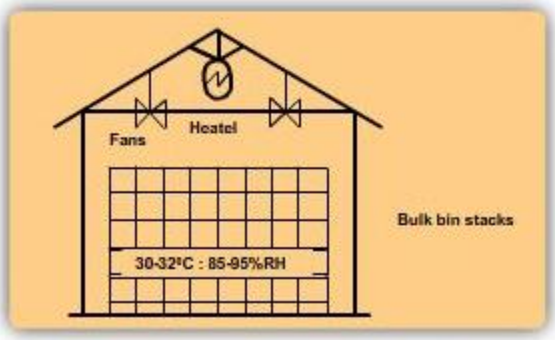


Fig.: . Histological sections through the cut surfaces of yam tubers (*D. cayenesis*) after 7 days curing and 8 days subsequent storage. Curing condition wear A: direct sunlight; B: 26^0C and 66% RH; C: 30^0C and 91%RH; D: 40^0C and 98% RH

Table: Optimum condition for curing of vegetables

Commodity	Temp(^{0}C)	RH (%)	Days for curing
Potato	13-17	>85	7- 15
Sweet potato	27-33	>90	5- 7
Yam	32-40	>90	1- 4
Cassava	30-35	>80	4- 7
Garlic and onion	**35-45**	**60-75**	**0.5-1 warm forced air**

When extreme conditions in the field exist, such as heavy rain or flooded terrain, and curing facilities are not available, a temporary tent must be constructed from large tarpaulins or plastic sheets to cure the produce and avoid heavy loss.



Typical curing houses for roots and tubers

Field curing of Yams

Curing citrus fruits – curing treatments facilitates

- ✓ the wound healing
- ✓ reduce decay through lignifications
- ✓ increase in the antifungal chemicals in the fruit peel in orange (30^{0}C), pomelo, lemons and grapefruit at 34^{0}C and 90-100 % RH for 2-3 days, not later than 48 hr after harvest.

In pumpkins and other cucurbits, curing is the hardening of the skin.

Drying

Drying is carried out to preserve the fruits and vegetables by reducing the water activities below that which support the growth of microorganisms and action of enzymes. This irreversibly changes the nature of the produce.

Eg.: Onion and garlic dying in the field

- ✓ Dying in onion and garlic does not involve the uniform and low moisture content as in case of dehydration but drying only the outer layer.
- ✓ Objective is to provide a surface barrier to water loss and microbial infection.
- ✓ Some times this process is referred to as curing, but since no cell regeneration or wound healing occur it is clear to refer to it as drying.
- ✓ Drying of onion has been carried out in the field and called 'windrowing'. This involves the pulling the bulb from the ground and laying them in ground in small heaps for 1-2 weeks. When ground is wet they can cured in pack house for 7-10 days with condition of 30^{0}C and 70% RH.
- ✓ Curing is judged to be complete when necks of bulbs have dried out and tight and the skin rustles when held in the hand.

Hot Water Treatments

'Dipping of fruits in hot water of specific temperature for specified periods for the purpose of disease control, insect disinfestations or uniform ripening' is known as hot water treatment.
Hot water was originally used for fungal control, but has been extended to disinfestations of insects. Hot water treatment is an approved quarantine treatment for export of many fruits and vegetables against pests. However, for insect disinfestations a longer treatment is necessary than for fungal control. The times of immersion can be 1 hour or more and temperatures are below 50°C. It also adds other additional advantages such as – removal of surface residues, removal of sap fallen on the fruit surface during harvesting and facilitates washing.

Many post harvest diseases can be controlled by immersing the fruits in hot water before storage or marketing. Hot water treatment along with fungicides is more effective at 51-55^{0}C for 5-30 min. depending upon the size of the fruit.

Crop	**Problem**	**Temp. (^{0}C)**	**Duration (min.)**
Mango	Anthracnose/ Stem end rot	55	5
Sweet potato		40	2
Blue berries		46-55	3

In mango, fruit should not be treated with hot water for 48 hr when the produce is drenched in rain at harvesting or immediately before harvesting to reduce the damage caused by brushing.

Vapour Heat Treatment

Vapor heat treatment is a method of heating fruit with air saturated with water vapor (humidified by injection of steam) at temperatures of 40–50°C to kill insect eggs and larvae as a quarantine treatment before fresh market shipment. Vapor heat was developed specifically for insect control. The temperature and exposure time are adjusted to kill all stages of fruit fly infected produce(mango). The treatment consists of a period of warming (approach time) which can be faster or slower depending on a commodity's sensitivity to high temperatures. Then there is a holding period when the interior temperature of the produce reaches the desired temperature for the length of time required to kill the insect. The last part is the cooling down period which can be air cooling (slow) or hydrocooling (fast).
Eg.: Treatment of citrus, mango, papaya and pineapples at 43^{0}C in saturated air for 8 hr and then holding the temperature for a further 6 hr.
For control of papaya fruit fly, fruit should be exposed to 43^{0}C and 40% RH for 11hr., followed by 43^{0}C and 100% for 8 hr.

Problems - Hot water and vapour heat treatment may causes both internal and external damage to produce if not properly done -

- ✓ injury to fruit such as increased weight loss
- ✓ acceleration of colour development

External damage - includes peel browning, pitting, or yellowing of green vegetables. Tissue damage caused by heat will also result in increased decay development.
Internal damage - causes poor pulp color development, abnormal softening, the lack of starch breakdown and the development of internal cavities as in case of mango and papaya. In addition, the fruit can soften quickly or show abnormal softening where some areas of the flesh remain hard while others soften.

Degreening

Post harvest treatment of citrus fruits with ethylene under controlled conditions hastens the loss of chlorophyll, a process known as 'degreening'. Degreening consists of chlorophyll degradation to allow the expression of natural pigments masked by the green colour. Eg. Yellowing of citrus fruits. Degreening process can be hastened by applying ethylene and done mainly in non-climacteric fruits like citrus. On a small scale dip treatment in ethrel solution also bring about degreening . The concentration of ethylene required and time of exposure is significantly high in case of degreening when compared to ripening.

The main causes for greening are climatic conditions before harvest. For example, citrus often reaches commercial maturity with traces of green colour on the epidermis (flavedo). Although not different from fruits with colour, consumers sense that they are not ripe enough and have not reached their full flavor. Exposure to low temperature during maturation is necessary for an orange-coloured peel to develop. Hence fruit grown in low altitude tropics fail to degreen completely.

Degreening is done by 2 methods

1. **Exposing to ethylene** - Degreening is done at 25-30^{0}C and 85-95% RH with ethylene gas trickled into room to achieve 20-30 PPM or 10 µL L^{-1} for 24-72 hr. with regular ventilation of the chamber to prevent CO_2 build up and injury. In batch process it is at 20-200 µL ethylene L^{-1}. Trickle process is faster than batch process; since degreening condition accelerate deterioration and decay of citrus fruits. This is most popular methods
Citrus fruits are exposed from 1-3 days (depending on degree of greening) to an atmosphere containing ethylene (5-10 ppm) under controlled ventilation, 20-26^{0}C and 90-95% RH. Conditions for degreening are specific to the production area.

2. **Artificial colouring** - When weather is not conducive for the development for colour in orange; legally permitted dye can be used to colour the peel of the fruits like orange, with Citrus Red No.2 (1-2(2,5-dimethoxy phenylazo)2-napththol) this process is called as 'Colour Add'. It is used on mature fruit which are not intended to processing. Dye is applied to fruit by dip at 49^{0}C for 4 min. for oranges. Rinsed enough to prevent bleeding and residue tolerance is 2ppm / 2 mg kg^{-1} of fruit.

Lecture schedule – 16

Part - 5

CHEMICAL TREATMENT- DISINFESTATION

Succulent nature of fruits and vegetables make them easily invaded by these organisms. The common pathogens causing rots in fruits and vegetables are fungi such as *Alternaria, Botrytis, Diplodia, Phomopsis, Rhizopus, Pencillium* and *Fusarium* and among bacteria, *Erwinia* and *Pseudomonas* cause extensive damage.
Losses from post-harvest disease in fresh produce can be both quantitative and qualitative. Loss in quantity occurs where deep penetration of decay makes the infected produce unusable. Loss in quality occurs when the disease affects only the surface of produce causing skin blemishes that can lower the commercial value of a crop.

DISINFESTATION

Post harvest diseases of fruits, vegetables and flowers are caused by fungi and bacteria but viruses are rare. These exist either as parasite (on living matter) or saprophytes (dead produce). Most fungi require acidic pH (2.5 – 6) condition in which they grow and develop, while bacteria thrive best at neutral and few can grow at levels below pH 4.5. Bacteria therefore don't usually infect fruits, normally but only vegetables and flowers.
Chlorine and sulfur dioxide are most widely used chemicals. Chlorine is probably the most widely used sanitizer. It is used in concentrations from 50 to 200 ppm in water to reduce the number of microorganisms present on the surface of the fruit. However, it does not stop the growth of a pathogen already established.

Mode of infection of micro organism

Fungal and bacterial infection can occur through mechanical injuries and cut surfaces of the crop, growth cracks and pest damage. They also infect through natural opening on the surface of the crop such as stomata, lenticels, cuticles and hydrathodes. Most fungi are able to penetrate the intact healthy skin of the fruits and vegetables. Many pathogens remain dormant on the surface of the produce for many weeks before visible symptoms of the infection occur.

Damage by micro organism

It mainly causes physical loss of the edible matter, which may be partial or total. Also affects marketability, particularly where mold growth is obvious on the produce surface. In some cases the superficial infection also make the produce either entirely unmarketable or at least reduce its economic value.
Example: Fungi *Aspergillus flavus* and *A. parasitica* which produce aflatoxin like mycotoxin on ground nut kernels, coconut, dry beans and some leafy foods. The apples juice is also affected by mycotoxin "patulin" produced by *Penicillium patulum* and *P. expansum, P.urticae, Aspergillus clavatus* when stored for too long before being processed. This mycotoxin is carcinogenic and has maximum permitted levels of 50 ppb in fruit juices.

Disinfestation process can be carried out by
Physical methods - low temperature, vapour heat and irradiation.

Disinfestation methods

A. Field management: Growing fruits and vegetable adopting scientific standard and recommended practices can reduce the field inoculum of disease causing pathogens. Adopting standard cultural practices in terms of sanitation, proper nutrition, irrigation and appropriate harvesting time and methods, etc. are known to reduce post harvest diseases. Use of wind breaks can reduce spread of field infection where wind is the carrier of pathogen. Other practices like cultivation of crops in regions free from diseases, cultivation of disease resistant cultivars, care in harvesting and handling to avoid wounding fruit, fruit bagging for reducing surface wetness and deposition of inoculum will all help in reducing post harvest diseases.

B. Pre-harvest spraying: Field sprays with fungicides are known to prevent spore germination and the formation of deep seated infections in the lenticels or in the floral remains of the fruits.

C. Post harvest chemical treatments: Post harvest treatments with fungicides like Thiobendazole and Benomyl have rendered good control of stem end rot in many citrus fruits, anthracnose of banana and mangoes despite the fact that infection occurred long before the treatment was applied.

Safer and less toxic chemicals grouped under the category of GRAS (generally regarded as safe) can be used for the control of post harvest diseases of fruit and vegetables. These compounds mostly include week organic acids, inorganic salts and neutralized compounds. It has been reported that extracts of *Eucalyptus globula*, *Punica granatum*, *Lawsonia inumis*, *Datura stramonium* and *Ocimum* sp. extracts are effective against various fruits rots. Some vegetable and other oils are also effective against fruit rots. Mustard, castor and paraffin oils have been found effective against *Rhizopus* rot of mango.

Disinfection of all handling equipment in pack-houses with 1-3% formaldehyde solution, hypochlorite or SOPP (Sodium ortho phenylphenate) will help in prevention of secondary infection. Washing with water alone reduces many disease of fruits and vegetables.

Methods of Chemical Application

1. **Dipping** – for effective control of diseases chemical may be used with hot water at 55^0C for about 10 min. The crop may be passed below shower of the diluted chemicals. This is called ‘cascade’ application. Use of chemical like citric acid to lower the pH of the solution along with fungicides seems more effective.

In pineapple, infection occur commonly through the cut fruit stalk, therefore dipping cut end was found sufficient to control the disease, save pesticides solution and lower residues on the fruits.

Eg. Citrus, apples, pineapple, root vegetables.

2. **Spraying** - Spraying is more effective than dipping, because fungicide effectiveness is reduced if the crop has been washed and is still wet and many pesticide chemicals are formulated so that they are not in a solution , but rather in a fine suspension. This results in a concentration gradient in the tank between top(less concentration) and bottom (more) of the tank unless suspension frequently agitated.

Eg. Citrus, apple

3. **Electrostatic Sprays / Thin film of Coating** – breaking up the pesticides solution into fine droplet and then giving them an electric charge to obtain uniformity of application. Principle is that the particle all have the same electrical charges hence, thus repel each other. These charges are attracted toward the crop and form uniform coating on the produce.

Eg.: Potato and crown rot of banana

4. **Dusting** – with wood ash and lime in case of yam. Fungicides along with talc on potato.

5. Fumigation / Vapour treatment – Fumigation is to eliminate insects, either adults, eggs, larvae or pupae and pathogen inoculum. Fumigant such as sulphur dioxide (SO_2) is used for controlling post harvest disease in grapes. This is achieved by placing the boxes of fruit in a gastight room and introducing the gas from the cylinder to the appropriate concentration. This treatment results in a residue of 5-18 ppm SO_2 in the grapes is sufficient to control decay. Its toxicity to *Botrytis cinerea* was found to be proportional to temperature over the range of 0-30^{0}C, where the toxicity of SO_2 increased about 1 ½ times for every 10^{0}C rise in temperature. In general treatment with 0.5- 1% SO_2 for 20 min is found to be effective fallowed by ventilation. During storage, periodic (every 7-10 days) fumigations are performed in concentrations of 0.25%.

Disadvantages-

a. SO_2 can be corrosive, especially to metals, because it combines with atmospheric moisture to form sulphurous acids. Hence, special sodium met bisulphate impregnated pads are available which can be packed into individual boxes of fruits to gives a slow releases of SO_2. Eg.: **Grape guard** used in grapes fruit packing.
b. At higher concentration it has bleaching effects on black grapes.
c. Some people are allergic to SO_2, particularly those who have chronic respiratory problems.

Litchi fruits - SO_2 fumigation at 1.2% for 10 min. is used to prevent discolouration of the skins of fresh litchi fruits caused by fungal infection, followed by 2 min. dip in 1 N HCL stabilizes the red colour and reduces the skin browning.
Snap beans - Exposing the beans to SO_2 at 0.7% for 30 seconds reduced the broken end dis-coloration due to mechanical injury.
Other chemicals -

- ✓ Acetaldehydes fumigation in Sultana grapes @500 ppm for 24hr. control postharvest diseases.
- ✓ Paper pad impregnated with diphenyl fungicides are commonly applied to citrus fruit.
- ✓ Tecnzane, 2-aminobutane(potato) and 2-AB (orange) are the chemicals used.

Fumigation with gaseous sterilants is the most effective techniques for disinfesting produce. However, these are becoming increasingly unpopular or banned because of high mammalian toxicity (hydrogen disulphide), flammability (carbon disulphide) and damage to the atmospheric ozone layer (methyl bromide).
Fumigation with methyl bromide has been replaced by temperature (high and low) treatments, controlled atmosphere, other fumigants or irradiation.

5. **Absorbent paper** – chemical may be absorbed into a pad made of suitable material like paper. This absorbent pad soaked in fungicides like thiabendazole and dried, is placed over cut surfaces, such as cut crown end to control the crown end rot of banana. Here pad absorbs latex from the cut surfaces, which also helps to keep the pad in the position and prevents staining the banana. Potassium aluminum sulphate may be added to the pads, which helps to coagulate the latex. This method is used when banana is dehanded in the field and packed directly into export cartoon, where no washing, spraying or dipping take place. Insecticides like dichlorovos has limited vapour phase activity, therefore dichlorovos based pest strip have been included in cartoon packed with flowers to effects ongoing disinfestations during export.

6. **Cold storage** – many insect pests do not tolerate prolonged exposure to low temperature.

Storing the produce at <1.6^{0}C for 16 days has been shown to be effective for disinfesting fruits against Mediterranean and Queensland fruit fly. But chilling susceptible fruits are not suitable for the this method

7. High temperature – Heat treatments like hot water dips or exposure to hot air or vapor is employed for insect control (and for fungi, in some cases). Using high temperature of about 40-55^{0}C for about 15 minutes can be easily disinfected. Generally, high temperatures can cause softening of tissues and promote bacterial diseases.

- ✓ Dipping temperature depends on commodity, insect to be controlled and its degree of development.
- ✓ Dipping in hot water also contributes to reduced microbial load in plums, peaches, papaya, cantaloupes, sweet potato and tomato but does not always guarantee good insect control.
- ✓ Heat treatments is reconsidered as quarantine treatments in fruits such as mango, papaya, citrus, bananas, carambola and vegetables like pepper, eggplant, tomato, cucumber and zucchinis.
- ✓ Temperature, exposure and application methods are commodity specific and must be carried out precisely in order to avoid heat injuries, particularly in highly perishable crops. On completion of treatment, it is important to reduce temperature to recommended levels for storage and/or transport.
- ✓ Many tropical crops are exposed to hot and humid air (40-50 °C up to 8 hours) or water vapor to reach a pulp temperature which is lethal to insects. Hot air is well tolerated by mango, grapefruit, Navel oranges, carambola, persimmon and papaya. Similarly, vapor treatments have been used for grapefruits, oranges, mango, pepper, eggplant, papaya, pineapple, tomatoes and zucchinis.
- ✓ A common mango fruits disease, anthracnose can be successfully controlled by dipping at 55^{0}C for about 5 min.

8. Biological control –

- ✓ The yeast *Candida guilliermondii* is used against *Penicillium spp.* incorporated into citrus waxes
- ✓ *Bacillus subtilis* is used against mango anthracnose and stem end rot

Table.: List of post harvest diseases of fruits

Fruit	Disease	Casual organism
Banana	Crown rot	*Acremonium sp, Curvularia sp, Colletotrichum musae, Fusarium semitectum, Verticillium sp*
Ber	Fruit rot	*Alternaria sp, Phomopsis sp, Colletotrichum sp.*
Citrus	Black rot	*Alternaria citri*
	Grey mold	*Botrytis cinerea*
	Green mold	*Penicillium digitatum*
	Stem-end rot	*Diaporthe citri, D. medusae, D. natalensis.*
Guava	Anthracnose	*Colletotrichum gloeosporioides*
Kiwifruit	Stem rot	*Botrytis cinerea*
	Ripe rots	*Botryosphaeria dithodea*
Litchi	Skin injuries	*Aspergillus sp., Penicillium sp., Rhizopus sp.*
Mango	Anthracnose	*Colletotrichum gloeosporioides*
	Stem-end rot	*Botryodiplodia theobromae*

	Alternaria rot	*Alternaria alternata*
	Black mold	*Aspergillus niger*
Papaya	Chocolate spot	*C. gloeosporioides*
	Dry rot	*Mycosphaerella sp.*
	Wet rot	*Phomopsis sp.*
	Alternaria spot	*Alternaria alternata*
	Fusarium rot	*Fusarium solani*
	Internal yellowing	*Enterobacter clocae*
	Anthracnose	*C. gloeosporioides, C. dematium, C. capsici, C. circinans, C. papayae*
Pear	Blossom-end rot	*Alternaria sp., Botrytis sp., Penicillium sp.*
Pineapple	Black rot	*Chalara paradoxa*
	Fruitlet core rot	*Penicillium funiculosum, Fusarium moniliforme, Candida guilliermondi.*
Pomegranate	Heart rot Penicillium rot	*Aspergillus niger, Alternaria sp.*
Stone fruits	Brown rot	*Monilinia fructicola*
Onion	Black mold Neck rot	*Aspergillus spp.* *Botrytis allii*

Table. Chemicals used to control spoilage and quality in fruit and vegetables

Item	Chemicals
Apple	Sodium-phenyl phenate
Banana	Thio bendazole, Benomyl
Citrus	Sodium carbonate, Borax, SOPP, Biphenyl, 2,4- D, N Cl_3 fumigation
Mango	Hot water, Benomyl
Grapes	SO_2 fumigation
Papaya	Hot water
Pomegranate	Ethyl oleate
Potato	Hypo chlorite
Carrot & cabbage	Thiobendazole , Benomyl
Onion	Benomyl
Sweet potato & tomato	2,6-dichloro-4-nitroaniline

Post harvest pests

Although relatively few post-harvest losses of fresh produce are caused by attacks of insects or other animals, localized attacks by these pests may be serious.

- ✓ Insect damage is usually caused by insect larvae burrowing through produce, e.g. fruit fly, stone weevil, sweet potato weevil, potato tuber moth and infestation usually occurs before harvest.
- ✓ Rats, mice and other animal pests again are sometimes a problem when produce is stored on the farm.

Almost all post harvest pests originate from field infestations. Wounds and punctures caused by insect pests not only adversely affect visual quality but also serve as entry points for pathogens, leading to secondary infection and spoilage.

Table.: List of insect pests affecting postharvest quality

Pests	Common name	Common host
Fruit flies		
Dacus ciliatus	Lesser pumpkin fly	Cucurbits
D. cucurbitae	Melon fly	Cucurbits and tomato
D.dorsalis	Oriental fruit fly	Most fleshy fruits and vegetables
Mites		
Halotydeus destructor	Red legged earth mite	Leafy vegetables
Panonchus ulmi	European red mite	Apple and other deciduous fruits
Phthorimaea operculella	Potato tuber moth	Potato, tomato, brinjal
Mealy bugs		
Planococcus citri	Citrus mealy bug	Citrus, grape
Dysmicoccus bevipes	Pineapple mealy bug	Pineapple
Moths		
Cydia pomonella	Codling moth	Apple,pear,peach,quince,prunus,walnut
Maruca testulalis	Beam pod borer	Legumes
Scale insects		
Aonidiella aurantii	Red scale	Citrus
Lepidosaphes beckii	Purple scale	Citrus
Quadraspidiotus preniciosus	San Jose scale	Deciduous fruits
weevils		
Cylas formicarius	Sweet potato weevils	Sweet potato
Sternochaetus mangiferae	Mango seed weevils	Mango

Study Questions

I. Choose the appropriate answer

1. Disinfectant gas released by grape guard in packing is
   a. ethylene **b. SO_2** c. CO_2 d) Acetaldehyde

2. Fungi grows luxuriously in the medium of
   a. acidic b. neutral c. alkaline d. sodic

3. Pathogens enters the fruits through
   a. cut surfaces b. pest damage surfaces c. growth cracks **d. all of these**

4. Chlorine used as
   a. colour additive b. sprout suppressant **c. sanitizer** d. odour enhancer

II. State true or false.

1. Chlorine prevents the growth of pathogens already established on produce.-**False**
2. Cold water and benomyl is used to pathogens on fruits **- False**
3. Grape guard is a source of SO_2. **- True**
4. The absorbent papers prevent the invasion of pathogens and absorption of latex. - **True**
5. *Bacillus subtilis* is used to control mango anthracnose. – **True**

III. Match the following.

1. Chlorine …… a. fungi
2. Mycotoxin ……. b. *pencilium*
3. Thiobendazole ……. c. lowers pH
4. Patulin ……. d. sanitizer
5. Citric acid ……. e. post harvest chemical

Answer keys : - 1 – d, 2- a, 3 –e, 4 –b, 5 - c

IV. Answer the fallowing

1. Write the mode of infection of microorganism on fruits and vegetables?
2. **How fumigation is helpful in controlling postharvest diseases of fruits?**
3. How absorbent papers control the postharvest problems in banana?
4. List important postharvest diseases, pest and chemicals

Lecture schedule – 17

Part - 6

SPROUT SUPPRESSANTS

Root and tuber type vegetables have dormant period after harvest and then re-grow under favourable conditions. In potatoes, garlic, onion and other crops, sprouting and root formation accelerate deterioration. This determines the marketability of these produce as consumers strongly reject sprouted or rooted produce.

Disadvantage of Sprouting

- ✓ Sprouting makes the produce to lose moisture quickly, shrivel
- ✓ become prone to microbial infection
- ✓ the quality of sprouted tubers becomes poor due to high respiratory utilization of reserved food.
- ✓ Due to above factors because consumers strongly reject sprouting or rooting products.

Physiological basis for sprouting

- ✓ After development, bulbs, tubers and some root crops enter into a rest period.
- ✓ This is characterized by reduced physiological activity with non response to environmental conditions. In other words, they do not sprout even when they are placed under ideal conditions of temperature and humidity.
- ✓ During rest, endogenous sprout inhibitors like abscisic acid predominate over promoters like gibberellins, auxins and others. This balance changes with the length of storage to get into a dormant period. They will then sprout or form roots if placed under favorable environmental conditions. There are no clear-cut boundaries between these stages. Instead, there is a slow transition from one to the other as the balance between promoters and inhibitors change. With longer storage times, promoters predominate and sprouting takes place.




Methods of sprout suppression

A. Physicals method –

Refrigeration and controlled atmosphere reduces sprouting and rooting rates but because of their costs, chemical inhibition is preferred.

Sprouting of potatoes is suppressed at and below 5^0C and enhanced at higher temperature storage, and in yam no sprouting was observed during 5 month storage at 13^0C, but tubers sprouted during that period at 15^0C.

B. Chemicals methods –

Sprouting can be suppressed by application of growth regulators on the crop. In bulbs, such as onion, this is not possible because the meristamatic region where sprouting occurs is deep inside the bulb and difficult to treat with post harvest chemicals. Therefore, chemicals like Maleic Hydrazide (MH) is applied to the leaves of the crop at least 2 weeks before harvesting, so that chemical can be translocated deep into the middle of the bulb in the meristamatic tissue where sprouting is initiated.

Potatoes - commercially CIPC (3-chloro –iso-propyl-N phenylcarbamate is also called **chloropropham**) is applied prior to storage as dust, immersion, vapor or other forms of application as sprout suppressant. CIPC inhibits sprout development by interfering with spindle formation during cell division. However, cell division is extremely important during wound healing or curing period after potatoes have been placed onto storage. Wound healing requires production of 2-5 new cell layers by cell division. CIPC should be applied after wound healing process/suberisation is complete, but before periderm formation. Hence, it must be applied after curing is completed.

Care must be taken not treat seed potato with CIPC and also avoid storing same in place where, already CIPC treated potato has been stored. CIPC is mainly used for the potato stored for processing purpose.

C. Ionization methods

Sprout suppression can also be achieved by irradiating onion bulb, potato and yam tubers.

MINERAL APPLICATION

Deficiencies of certain minerals result in physiological disorders, loss of storage life or quality. Calcium is the nutrient most commonly associated with post harvest disorders and can be overcome by external application of fruits after harvest by spraying or dipping, vacuum infiltration and pressure infiltration.

Advantages of minerals application

- ✓ Reduce physiological disorder - internal break down/ pitter pit, storage scald *etc*
  Calcium chloride (4-6%) dips or sprays for bitter pit in apples.
- ✓ Reduced chilling injury
- ✓ Increase diseases résistance
- ✓ Delaying ripeness - tomatoes, avocados, pear and mango
- ✓ Reduces chilling injury and increase disease resistance in stored fruits
- ✓ Low concentrations of 2.4-D to waxes assists in keeping citrus peduncles green

Disadvantages

- ✓ Skin discoloration (at higher concentration)
- ✓ Rotting (at higher concentration)

The pre-harvest spray problem can be overcome by dipping the apple fruit in solution containing calcium salts. Uptake can be enhanced by pressure infiltration to force calcium solution into apple flesh. The best results are obtained with apples that have a closed calyx so that the calcium solution is forced through lenticels and thus spread around the peripheral tissue where the disorder occurs. With open –calyx fruit, the uptake of solution is difficult to control as it readily enter the fruit via the calyx and excess solution accumulates in the core area, often lading to injury or rotting.

Vacuum infiltration (250mmHg) of calcium chloride at concentration of 1- 4% is beneficial.

Guava - Fruit dipped in 1% solution of calcium nitrate reduces weight loss, respiration, disease occurrence and increased the shelf life for more than 6 days as compared to 3 days in the control at room temperature.

Table. : Chemical used to extend the shelf life and quality of produce

Commodities	Chemical	Concentration (%)	Commodities	Chemical	Concentration (%)
Apple	Ca	1- 4	Banana	GA_3	50 ppm
Mango	Ca nitrate	1.0		Kinetin	20 ppm
	Ca chloride	0.6	Guava	Ca nitrate	1.0
Ber	Ca	0.17			

GROWTH REGULATORS

Growth regulators like GA_3 are useful in extending the shelf life of some climacteric fruits for short duration and retention of green colour of non-climacteric fruits for longer periods. 2, 4-D is widely used herbicide and can be used to prevent stem end rot development in citrus. As a post-harvest treatment, 2, 4-D induces healing of injuries, retard senescence and control post harvest decay of fruits and vegetables.

Lecture schedule – 18

Part - 7

FRUIT COATING - WAXING

Fruits and vegetables have a natural waxy layer on the whole surface (excluding under-ground ones). This is partly removed by washing. Waxing is especially important if tiny injuries and scratches on the surface of the fruit or vegetable are present and these can be sealed by wax.

Waxes - are esters of higher fatty acid with monohydric alcohols and hydrocarbons and some free fatty acids.
Waxing generally reduces the respiration and transpiration rates, but other chemicals such as fungicides, growth regulators, preservative can also be incorporated specially for reducing microbial spoilage, sprout inhibition etc. However, it should be remembered that waxing does not improve the quality of any inferior horticulture product but it can be a beneficial in addition to good handling.

A protective edible coat on fruit and vegetable which protect them from transpiration losses and reduce the rate of respiration is called '**waxing**'.

Skin coating (Protective coating) - is defined as artificial application of a very thin film of wax or oil or other material to the surface of the fruits or vegetables as an addition to or replacement for the natural wax coating.

Advantages of wax application are:

- ✓ Improved appearance
- ✓ Reduced PLW - reduced moisture losses and retards wilting and shriveling during storage
- ✓ Reduced weight loss
- ✓ Prevents chilling injury and browning
- ✓ Protect produce from bruising
- ✓ Reducing respiration rate - by creating diffusion barrier between fruit and surrounding as a result of which it reduces the availability of O_2 to the tissues.
- ✓ Protects fruits from micro-biological infection
- ✓ Considered a cost effective substitute in the reduction of spoilage when refrigerated storage is unaffordable.
- ✓ Carrier agent - used as carrier for sprout inhibitors, growth regulators and preservatives.
- ✓ Increase in the shelf life

Mango fruits treated with wax emulsion containing 8 to 12% solids have one or two week's longer storage life than the untreated ones.

Disadvantage:

- ✓ Development of off-flavour if not applied properly. Adverse flavour changes have been attributed to inhibition of O_2 and CO_2 exchange thus, resulting in anaerobic respiration and elevated ethanol and acetaldehyde contents.

Specifications of a desirable wax

- ✓ The selected wax material should provide a lasting shine
- ✓ Must be manufactured from food grade materials

- ✓ It should not develop any off-flavour and resistant to chalking. This can be determined by cooling waxed fruit to 0°C and allowing moisture to condense on fruit on removal from cold room
- ✓ It should reduce weight loss of commodity by 30% to 50%
- ✓ Rapid drying, competitive price and easy clean up

How fruit coating works?

Fruit coating results in the restriction of the gas exchange between the fruit and surrounding atmosphere. This causes a builds up of CO_2 and a depletion of O_2 with in the fruit, thus causing an effect similar to CAS (controlled atmosphere storage).

If surface coatings and their concentration are not selected properly, the respiratory gas exchange through fruit skins is excessively impaired leading to development of off-odours and off-flavours. Over waxing also results in abnormal ripening and softening that affects the marketing of such fruits.

Fruit coatings can be formulated from different materials including lipid, resins, polysaccharides, proteins, and synthetic polymers. Most coatings are a composite of more than one film with the addition of low molecular weight molecules such as polyols, that serve as plastisizers (increase the plasticity or fluidity of the material). Otherwise, coatings can be too brittle and will flake or crack on the coated product. Surfactants, antifoaming agents, and emulsifiers are also often used in coatings.

Fruits suitable for waxing

Immature fruit vegetables - cucumbers and summer squash

Mature fruit vegetables - eggplant, peppers and tomato, potato, pumpkin, carrot, snake gourd, coccinia and capsicum

Fruits – apple, avocado, banana, citrus (orange, mandarin, lemon, grapefruit), guava, mangoes, melons, papaya, peaches, pine apple *etc*.

Food grade waxes are used to replace some of the natural waxes removed in washing and cleaning operations, and helps in reducing loss during handling and marketing. If produce is waxed, the wax coating must be allowed to dry thoroughly before further handling.

Types of Waxing

A. Natural waxing

On the plant when fruit attains desired stage of maturity, nature provides them with thin coat of whitish substance, which is called bloom or natural waxing. Natural coat is clearly visible on fruits and disappears after harvest due to repeated handling of fruit.

Ex: apple, pear, plum, mango and grapes.

B. Artificial waxing

To Prolong the shelf life of produce some of the fruit and vegetables are dipped in a wax emulsion and then dried for few minutes. This process provides thin layer (<1 µ) of artificial wax on skin of the produce by which the small pores present on the skin are fully covered and reduce the transpiration and respiration process resulting in increased shelf life. Artificial wax also provides good shining and luster to the produce, which increases its market value.

Artificial waxes like solvent waxes, water waxes and paste or oil waxes are used.

List of commercial waxes

	Waxes	
1	Shellac	
2	Carnauba wax	
3	Bee wax	
4	Polyethylene	12% used in Israel for Mango
5	Wood resins	
6	Paraffin wax	

Methods of wax application

Performance of waxing depends on method of application. Amount of wax applied and uniformity of application are extremely important. Fruits should be damp dry prior to wax application to prevent dilution. Waxes should never be diluted with water. The following methods are commonly used.

i. **Spray waxing:** This is most commonly used method. Fruits and vegetables which move on the roller conveyor are sprayed with water-wax emulsion. The waxed produce is dried in a current of air at 55°C. There are two types of spray waxing namely low pressure spraying and high pressure atomizing.

ii. **Dipping:** Here fruits are dipped in water wax emulsion of required concentration for 30 to 60 seconds. The fruits or vegetables could be waxed by keeping them in wire boxes holding about 100 fruits (30 kg) and dipping in 30 litre capacity tank containing wax emulsion. The fruits are then removed and allowed to dry under electric fan or in the open air or with warm air at 54 to 55°C. The produce should be turned periodically while drying.

iii. **Foam waxing:** Foaming is a satisfactory means of application because it leaves a very thin coating of wax on the fruit after the water has evaporated. A foam generator is mounted over a suitable brush head, and water is applied to the fruit or vegetable in the foam of foam. Spraying tends to waste wax, but it can be recovered in catch pans.

iv. **Flooding:** Flooding is similar to dipping and is a safe and convenient method of application.

Trade name of some extensively used waxes

- ✓ Citrashine@ from DECCO, India UPL
- ✓ Waxol -12 – Oil/ water-emulsion wax containing 12% solids
- ✓ Tal-Prolong
- ✓ Semper fresh
- ✓ Frutox - Emulsion of different waxes with 12 % solids.

Table.: Use of wax concentration on the fresh produce

Conc. of wax (%)	Commodity
12	Carrot, brinjal, snake gourd, potato, cucumber, coccinia, capsicum, ribbed gourd, pine apple, guava and papaya
09	Tomato, lime, orange
08	Apple
06	Mango and musk melon

Quantity of wax emulsion at 12% concentration required for one mt. of commodity

Item	Wax emulsion (12%) in L
Orange	3.6
Mosambi	5.4
Mango(300-350gm)	3.6
Potato	7.9
Apple	5.4
Guava	5.7
Tomato	5.0
Banana	3.0
Lime	9.0

Cost of wax treatment

Approximately it costs around 1 rupee for treating 100 apples/oranges, Rs. 2.0 for 100 mangoes and about Rs. 6.0 for 40 kg. of potato.

Colouring waxes - Dyes are sometimes added to waxes for greater consumer appeal, it is being used on red variety of Irish potatoes, sweet potatoes, and other vegetables. They enhance the colour to give the same shade or tint as when the roots were freshly dug.

In citrus fruits, dye has been approved for general use. Citrus Red No.2 is 1-2(2,5-dimethoxy phenylazo)2-napththol with an established tolerance of 2 ppm.

Study Questions

I. Fill in the blanks

1) Fruits and vegetable have a natural……… coating on their surface. **(wax)**
2) Waxing generally reduces the……..… & …..….. rates. **(respiration & transpiration)**

II . True or false

1) Waxing is done to seal the injuries and scratches on surface of fruits. - **True**
2) The selected wax material should provide a lasting shine. – **True**
3) Application of wax on fruits causes effect similar to modified atmosphere storage - **False**
4) Colour may be mixed with wax solution during its application on fruits - **True**

III. Multiple choice questions

1. Natural waxing on fruits and vegetables is partly removed during
   a) pre -cooling b) drying c) **washing** d) sorting
2. Fruits most suitable for waxing is
   a) custard apple b) grapes **c) orange** d) strawberry

II. Answer the fallowing

1) What is waxing?
2) Write the advantages and disadvantages of waxing?
3) Write the mechanism of waxing principle?
4) List the types of waxing with examples?
5) List the fruits and vegetables suitable for waxing.
6) List some commercial waxes.

Lecture schedule - 19

Part - 8

ASTRINGENCY REMOVAL

Astringency is the dry, puckering (to gather something around the lips) mouth feel caused by tannins found in many fruits such as red grapes, blackthorn, quince, persimmon fruits, and banana skin.

Why we feel astringent?

The tannins denature the salivary proteins, causing a rough sand papery sensation in the mouth. It coagulates the viscous protein on the surface of our tongues, we feel its astringency. Astringency tastes unpleasant to many which tend to avoid eating astringent fruits.
Astringent is Latin word meaning 'to bind fast'.

Astringency occurs in many fruits due to the presence of tannins. These can impart an unpleasant flavor and are associated with immature fruit. In banana, tannins polymerise as the fruit ripen and lose their astringency.

Varieties of fruits high in phenolics (phenols have no particular taste charterstics, except astringency of condensed flavor and bitterness in some of the citrus falvonoids) are more astringent than varieties with low in phenolics.
For eg. Red grapes (var. Cabernet Sauvignon) have high astringency than white grape.

During maturation, the condensation of phenolics continuously increases and at the same time the astringency decreases, perhaps because highly condensed flavans are less soluble and tightly bound to other cell components.

How to reduce astringency?

Treatment with high levels of CO_2 and spraying with alcohol (ethanol) is used to reduce the astringency.

Eg.

1. Storage of persimmon in 4% CO_2 at -1^{0}C for about 2 weeks before removal from the storage followed by 6-18 hours in 90% CO_2 at 17^{0}C removes the astringency.
2. Spraying persimmon fruit with 35 - 40% ethanol @ 150-200 ml per 15 kg of fruit is known to remove the astringency 10 days later in the ambient storage. This treatment takes much longer time than CO_2 treatment, but fruits quality is better.

Fig. Cut persimmon fruits (the upper left and right cut pieces are non astringent as for an unripe persimmon and a mellowed persimmon, and lower left and right are the astringent of an unripe persimmon and a mellowed persimmon).Source-http://en.wikipedia.org/wiki/Persimmon

IRRADIATION

Radiation can be applied to fresh fruits and vegetables to control micro organism/insects/parasites and inhibit or prevent cell reproduction and some chemical changes. It can be applied by exposing the crop to radioisotope in the form of gamma-rays but X-rays can also be used from the machine which produces a high energy electron beam.

Unit of measurement

Radiation doses are measured in Grays (Gy). One Gray = 100 rads.
One Gy dose of radiation is equal to 1 joule of energy absorbed per kg of food material.
In radiation processing of foods, the doses are generally measured in kGy (1,000 Gy).

Radiation helps in breaking the chemical bonds in the produce or micro organism. Ionizing radiation involves damage to DNA, the basic genetic information for life. Microorganisms can no longer proliferate and continue their harmfull or pathogenic activities. Insects do not survive, or become incapable of proliferation. Plants cannot continue the natural ripening or aging process.

Cobalt 60 is commonly used as a source of gamma-rays in food irradiation. Radioisotopes cannot be switched on or off so they are immersed in a pool of water to allow operators to enter the processing area. When food is to be irradiated the radioisotopes is raised out of the water and material to be irradiated is usually passed through radiation field on the conveyer belts. The whole processing area is surrounded by thick concrete to prevent the radiation out.

<u>Advantages of Irradiation</u>

- ✓ Reduce the spoilage
- ✓ Slowing down the rate of metabolism in the produce
- ✓ Delay ripening and senescence
- ✓ Controlling sprouting in potato, onion, garlic and yams – 0.05-0.3 kGy
- ✓ Extend shelf life of fresh produce
- ✓ <u>Insect and parasite disinfestations</u>- egg phase is most sensitive followed by larval, pupal and adult stages. Most insects are sterilized at doses of 0.1 -1.0kGy. And survived adults progeny are sterile.
  <u>Eg</u>. Irradiation is being is used in Australia to produce sterile male Queensland fruits flies and in Hawaii it is being used in papaya for papaya fruit fly

<u>Factors effecting Radiation of the produce</u>

Moisture content in foods and the surrounding environment during treatment influence the sensitivity of microorganisms to irradiation.
For eg. high RH and high water content in foods reduce the effectiveness of irradiation.
Ultraviolet lamps are sometimes used in refrigerated storage for the control of bacteria and moulds.

Dosage

In general, most vegetables can withstand irradiation dosages up to a maximum of 2.25 kGy; higher doses can, however, interfere with the organoleptic properties of food products.
Combining irradiation + temperature control + gaseous environment + adequate processing conditions is one of the most effective approaches to vegetable preservation.
The maximum absorbed dose delivered to a food should not exceed 10 kGy.

Fig. Logo used to show a food has been treated with ionizing radiation

Table.: Desirable effects and dose of irradiation on fresh produce

Commodities	Dosage (kGy)	Effect
Apple	1.5	Control scald and brown core
Apricot and peach	2.0	Inhibit brown rot
Asparagus	0.05 - 0.1	Inhibit growth
Avocado, banana, mango and papaya	0.025 - 0.75	Delay ripening
Avocado, banana, mango and papaya	1-3	Inhibit mould
Mushroom	2.0	Inhibit stem growth and cap opening
Papaya	0.25	Disinfect fruit fly
Potato, onion, yams	0.05 - 0.3	Controlling sprouting
Strawberries, mushrooms, onion etc.	2 - 3	Reducing the decays
Shredded carrots	2.0	Inhibited the growth of aerobic and lactic acid bacteria
Grapes	0.25-0.50	Inhibit grey mould
Tomato	3.0	Inhibit *Alternaria* rot
Mango, dried fruits and raisins	0.25 - 0.75	Insect disinfestation
Garlic, Ginger	0.03 - 0.15	Sprout inhibition

Lecture – 20

Part - 9

RIPENING REGULATION

During ripening an inedible mature fruit will turn into edible soft fruit with optimum taste and characteristic flavour. Fruits start ripening after reaching maturity by release of a ripening hormone known as ethylene from the fruit. All fruits especially climacteric fruits produce small amounts of ethylene during ripening that triggers ripening changes. During this ripening process fruits attain their desirable colour, flavour, quality and other textural properties. A series of metabolic activities like increase in respiration rate of fruits, conversion of starch to sugars, reduction in acidity, removal of astringency or tart taste, softening of the fruit, development of characteristic aroma, surface colour and pulp colour occur during ripening. However, in some fruits like grapes, litchi, pineapple, strawberry, plum, which are harvested at ready to eat stage, these changes are not significant.

Control/Delay of ripening

Manipulating the ripening is important in extending the shelf life and ensuring appropriate quality of fruit to the consumer. Unpredictable ripening during storage, transport and distribution can result in spoilage before consumption. The ripening hormone, ethylene is known to trigger ripening in climacteric fruit and senescence in non-climacteric. The risks of accidental exposure to ethylene can be minimized by reducing ethylene concentrations in the storage environment with practices such as oxidation by potassium permanganate, or ultraviolet light. However, these systems, while being effective for certain commodities, have limited commercial application. Recent development of new chemicals like 1-methylcyclopropene (1-MCP) provides a new approach for manipulation of ripening and senescence.

1-MCP (1-methylcyclopropene): The 1- methylcyclopropene (1-MCP or C_4H_6) is an ethylene action inhibitor. It binds with ethylene receptors and thereby prevents ethylene dependent responses in many horticultural commodities. 1-MCP has been formulated into a powder that releases its active ingredient when mixed with water. This nontoxic compound can be used at very low concentrations (nL L^{-1}). The beneficial effects of 1-MCP in fresh produce include the inhibition of respiration and ethylene production, delayed fruit softening, restricted skin color changes, prolonged cold storage life and alleviation of certain ethylene-induced post harvest physiological disorders. 1-MCP treatment is also useful in reducing chilling injury symptoms and decay in tropical fruit during cold storage

Enhancing ripening

The ripening process of fruits can start when the fruits are still on the tree if left un-harvested. However, once ripe, handling and marketing of fruit will become difficult. Hence, majority of fruits like mango, banana, papaya, sapota, guava and custard apple are harvested in a mature but unripe condition. They are subsequently allowed to ripen by natural release of ethylene from the fruit. But natural ripening is a slow process leading to high weight loss and desiccation of fruits and some times results in uneven ripening in some fruits. Hence, ethylene is externally applied to enhance the ripening process of fruits. Fruits ripened with ethylene will develop better colour, taste and have all the qualities almost near to naturally ripened fruits.

Artificial ripening of fruits

In the past, acetylene gas was used as a replacement to naturally released ethylene to enhance the ripening of fruits. Though the acetylene triggers ripening process in fruits, it is an inflammable gas involving risk of fire hazards. Calcium carbide is used as a source of acetylene gas which when comes in contact with water vapour present in the atmosphere releases acetylene gas. However, calcium carbide contains chemical impurities such as arsenic hydride and phosphorus hydride that are highly carcinogenic compounds. Improper use of calcium carbide can therefore cause chemical contamination of fresh produce. Further fruits ripened with calcium carbide though develop attractive surface colour, are inferior in taste, flavour and spoil faster. Government of India has banned the use of calcium carbide for ripening of fruits under PFA Act 8-44 AA, 1954.

Ethylene is recommended in place of acetylene for enhancing the ripening fruits. 2-chloroethane phosphonic acid (available with trade names of Ethrel or ethaphon) is a commercially available plant growth regulator that can be used is a source of ethylene. This ethylene is similar to that naturally released by fruits during ripening process.

Advantage of controlled ripening

- ✓ Improved uniformity of ripening among fruits
- ✓ Minimizes the development of rots
- ✓ product reaches consumers at the right stage of maturity

Majority of world banana is ripened under controlled condition. It can also be carried out on tomatoes, melons, avocados, mangoes and other fruits.

Ethylene is known as ripening gas, which is a low molecular weight hydrocarbon.

Non climacteric fruits will not respond to artificial ripening with little or no desirable changes in the composition after harvest and are not harvested until they fit are for consumption.

Optimum ripening condition for fruits

Temperature	18-25^{0}C (<18delay ripening, > 25 microbes)
RH	85-90%
Ethylene conc.	10-100 ppm
Duration	12 -72 hr
Air circulation	sufficient to maintain the air temperature
Ventilation	sufficient to prevent accumulation of CO_2

Ripening process –

Initial heating to reach the desired pulp temperature

⇩

Injection of ethylene at the desired concentration

⇩

Product is maintained for a certain period of time followed by ventilation in order to remove accumulated gases

⇩

On completion of the treatment, the temperature is reduced to the desired level for transportation and/or storage

Typical banana ripening process

a. Batch/shot process - in which the chamber is charged with ethylene gas at once to a concentration of 20-200 μL^{-1}. The chamber has to be ventilated after 24hours to prevent the accumulation of CO_2. CO_2 Concentration should not exceeds 5000 μL^{-1} (0.5%) to allow personal to enter the to inspect the fruits. If the chamber is poorly sealed, it may be necessary to recharge the chamber with C_2H_4 after 12 hours.

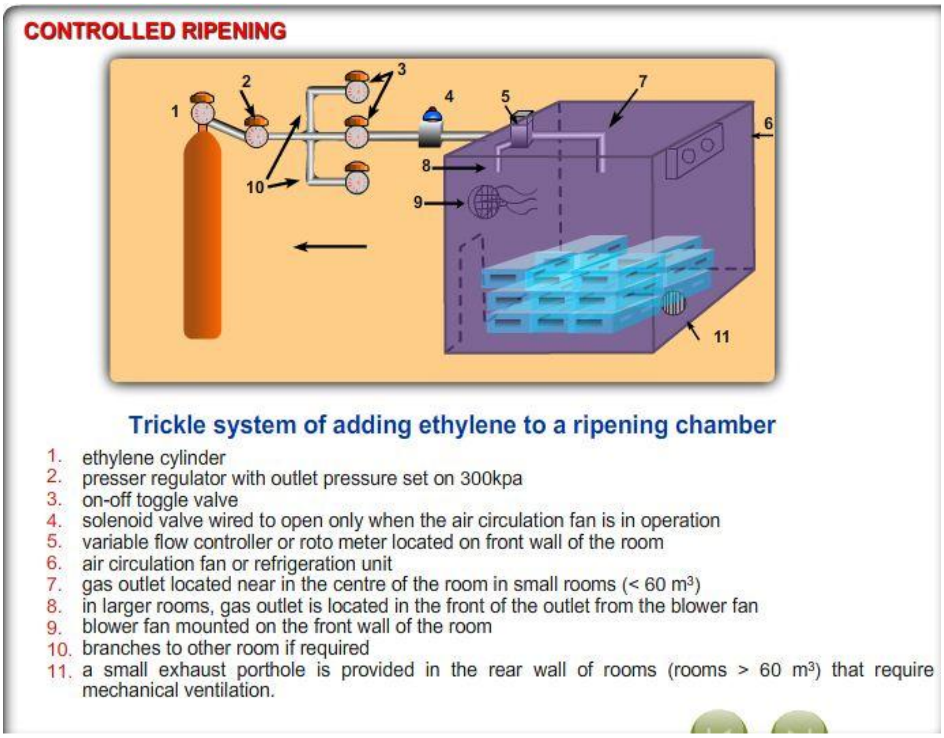
b. Trickle/flow process – ethylene is introduced into the room slowly in thin stream continuously. into the chamber at a rate just sufficient to maintain the required concentration. The ripening chambers should be ventilated at the rate of about one room volume each 6 hours, to prevent he accumulation of CO_2. In practice it not necessary to install a ventilation system in rooms < 60 m^3 because they have natural air leakage rates higher than the required minimum rates(Fig.).

When banana is placed in chamber so as to expose at least two faces to the circulating air, ensuring that fruits temperature are even. Or fruit is packed in vented cartoon, unitized on pallets, and fruit temperature is controlled by forced air temperature. A minimum air flow of about 0.34 L/sec.kg of banana is required. Regulating RH during the course of ripening is important for banana. A RH range of 85-90% has been recommended at stage 2(green, trace of yellow), but this should be reduced to 70-75% during the later colouring stages to avoid the skin splitting. If RH is high, fruits will become too soft and may split and if it is low it may cause weight loss, poorer colour and more blemishes on fruit. Regular cleaning with chlorine is require to avoid mould growth due to high RH during storage.

It is important to harvest at the correct stage of maturity otherwise quality will be inferior after ripening. At full maturity it is only necessary to hold fruit at desired temperature and RH and ethylene is not always necessary to ripen fruits, some fully developed fruits produce sufficient C_2H_4 to ripen itself and adjacent fruit(triggering effect).

Table 3: Conditions for controlled ripening of fruits at RH of 85-90%

Commodities	**C_2H_4 (ppm)**	**Temperature (°C)**	**Treatment time (hr.)**
Avocado	10-100	15-18	12-48
Banana	100-150	15-18	24
Honeydew melon	100-150	20-25	18-24
Kiwifruit	10-100	0-20	12-24
Mango	100-150	20-22	12-24
Stone fruits	10-100	13-25	12-72
Tomato	100-150	20-25	24-48



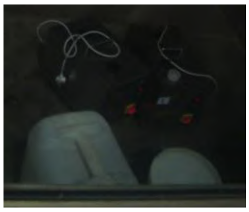


Fig.Controlled ripening of banana with automation.Fig.Ethylene gas in portable can Fig. Ethylene generator

Sources of ethylene

1. Ethylene gas – pure C_2H_4 gas enclosed in the can/cylinder is sprayed /injected into chamber. Ethylene portable can which contain 3 g sufficient to ripe 2-6 ton of produce is available commercially
2. Ethephon – Used as spray/ dip, acidic in water releases C_2H_4
3. Ethylene mixture - C_2H_4 + inert gas like CO_2. Inert gas because not enough O_2 remains in the chambers to provide an explosive mixture. Eg, Ripegas contain 6% C_2H_4
4. Ethylene generators - Widely used method where in liquid spirit produces C_2H_4 when heated in the presence of catalyst platinised asbestos.
5. Use of ripe fruits – cheap and simple, where in ripe fruit with high C_2H_4 producers such as apple, banana, mango, sapota and tomato is used at home to ripe / degreen

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.

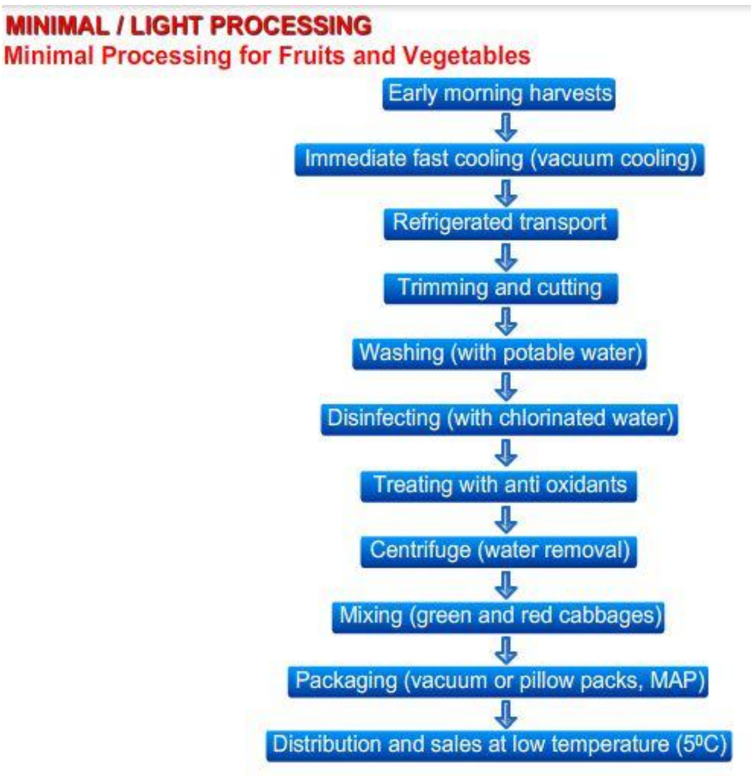
Fig. Artificial coloration in flower carnation

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.

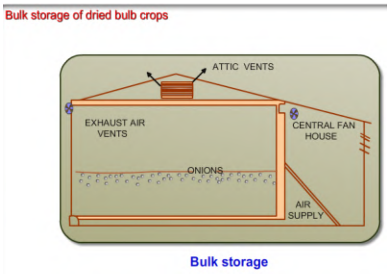
3. Bulk storage of dried bulb crops

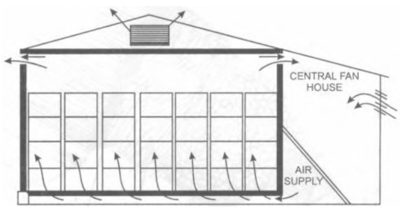
Onions, garlic and dried produce are best suited to low humidity in storage. Onions and garlic will sprout if stored at intermediate temperatures. Pungent types of onions have high soluble solids and will store longer than mild or sweet onions, which are rarely stored for more than one month.

Storage conditions for onion, garlic *etc.*

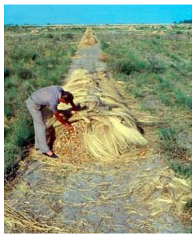
Commodity	Temp. °C	RH	Potential storage duration
Onions	0-5	65-70	6-8 months
	28-30	65-70	1 month
Garlic	0	70	6-7 months
	28-30	70	1 month
Dried fruits and vegetables	<10	55-60	6-12 months

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



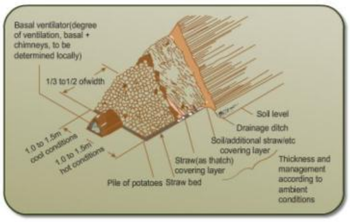
Field storage of onions in heaps

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.

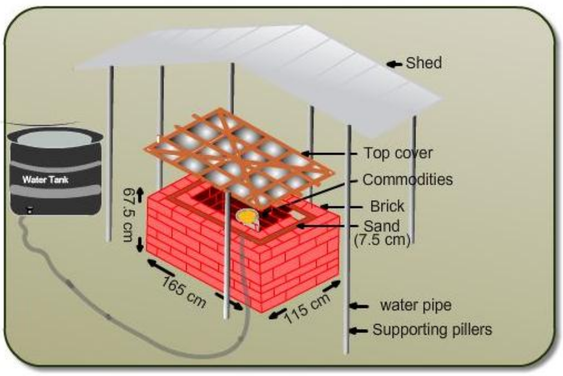
Design and Construction

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.

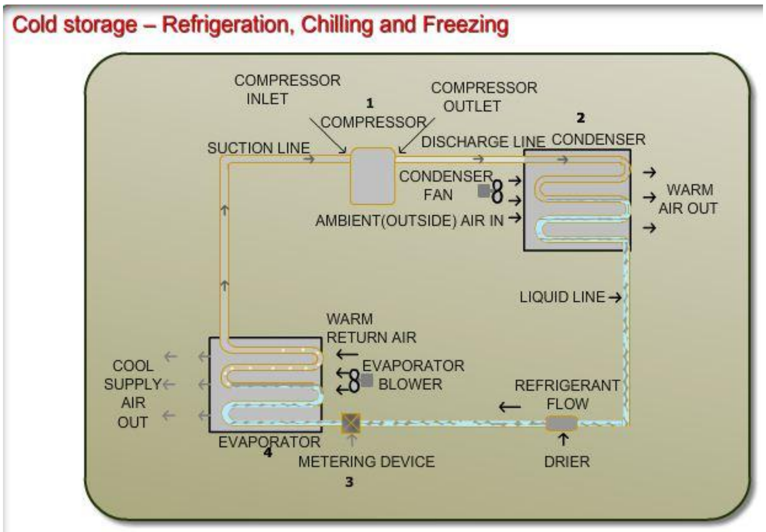


Illustration of a refrigeration cycle

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. <u>Treatments before storage</u>

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

Environmental factors affecting MA storage

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.

Lecture schedule – 26

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*.

<u>Wrapping has the following advantages</u>

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.

Lecture schedule – 27

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.

They often have sharp edges or splinters causing cut and puncture

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

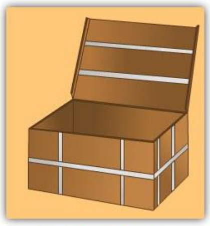
Wood is often used to make reusable boxes or crates, but less so recently because of cost. Wooden boxes are rigid and reusable and if made to a standard size, stack well on trucks.

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

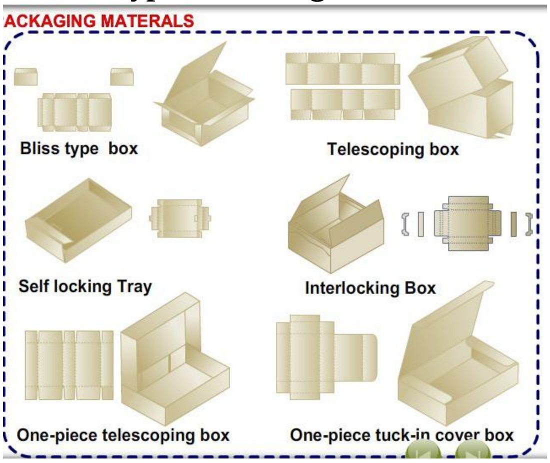
High quality, full-colour graphics may be obtained by pre-printing the linerboard before it is attached to the corrugated paperboard. Pre-printed cartons are usually reserved for the introduction of new products or new brands. Market research has shown that exporters may benefit from sophisticated graphics. 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.



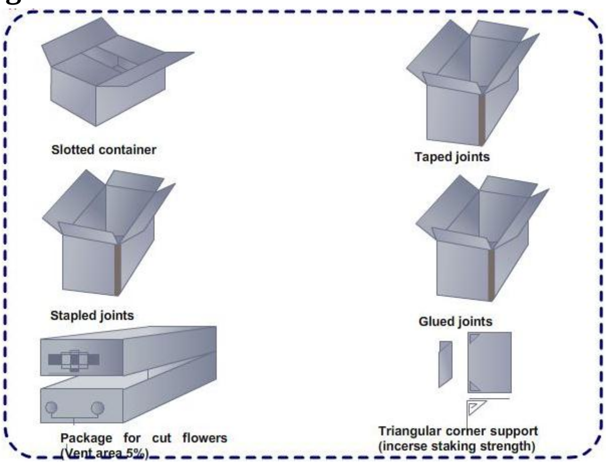


Fig. Fruits packed to avoid vibration + increase staking strength

Containers boxes of CFB, plastic and wood

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Part - 4

PLASTIC CONTAINERS AND PAPER TRAYS

Another alternative to the wood for packaging is plastics. Use of plastics in packaging of fresh horticultural produce helps in minimizing the cost of packaging materials and makes the whole process less dependent on scarce materials like wood, thereby, resulting in conservation of environment. The following are the important plastic materials that can be used for packaging of fresh fruits and vegetables.

1. Polypropylene boxes

Polypropylene corrugated board can be used easily for horticultural produce. Added advantage of this material is that it can be reused quite a few times.

2. Stretch/cling wrap

This is actually a polyethylene or polypropylene film which has the property that under tension it stretches and when the tension is released it comes back to its original form. This property helps in packaging the product tightly. The whole operation can be carried out without application of the heat. Eg. cabbage, fresh cut vegetables *etc*.



3. Moulded plastics (Plastic crate)

Reusable boxes moulded from high-density polythene are widely used for transporting produce in many countries. They can be made to almost any specifications. They are strong, rigid, smooth, easily cleaned and can be made to stack when full of produce and nest when empty in order to conserve space. Despite their cost, however, their capacity for reuse can make them an economical investment.

Fig. Multipurpose plastic crates for horticultural produce

4. Plastic Bags

Plastic bags (polyethylene film) are the predominant material for fruit and vegetable consumer packaging. Besides the very low material costs, automated bagging machines further reduce packing costs. Film bags are clear, allowing for easy inspection of the contents, and readily accept high quality graphics. Plastic films are available in a wide range of thicknesses and grades and may be engineered to control the environmental gases inside the bag. The film material "breathes" at a rate necessary to maintain the correct mix of oxygen, carbon dioxide, and water vapour inside the bag. Since each produce item has its own unique requirement for environmental gases, modified atmosphere packaging material must be specially engineered for each item that respond to temperature and control the mix of environmental gases.

5. Shrink Wrap

One of the newest trends in produce packaging is the shrink wrapping of individual produce items. Shrink wrapping has been used successfully to package potatoes, sweet potatoes, onions, sweet corn, capsicum and cucumbers. Shrink wrapping with an engineered plastic wrap can reduce shrinkage, protect the produce from disease, reduce mechanical damage and provide a good surface for stick-on labels. In this method, vegetables are wrapped in heat-shrinkable plastic film. The main advantages of film wrapping of vegetables are (i) reduced weight loss and extended shelf life, (ii) reduced chilling injury, (iii) minimized vegetable deformation, (iv) reduced decay by preventing secondary infection of packed produce.


Fig. Shrink wrapping of capsicum

6. Rigid Plastic Packages

Packages with a top and bottom that are heat formed from one or two pieces of plastic are known as clamshells. Clamshells are gaining in popularity because they are inexpensive, versatile, provide excellent protection to the produce and present a very pleasing consumer package. Clamshells are used extensively with pre-cut produce and prepared salads.


Fig. Rigid Plastic Package for cut fruits and whole fruit

7. Paper or plastic film

Paper or plastic film is often used to line packing boxes in order to reduce water loss of the contents or to prevent friction damage.

8. Paper pulp trays

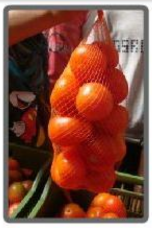
Containers made from recycled paper pulp and a starch binder is mainly used for small consumer packages of fresh produce. Pulp containers are available in a large variety of shapes and sizes and are relatively inexpensive in standard sizes. Pulp containers can absorb surface moisture from the product, which is a benefit for small fruit and berries that are easily harmed by water. Pulp containers are also biodegradable, made from recycled materials, and recyclable.

Fig. Packing individual fruit in moulded plastic

9. Paper and Mesh Bags

Consumer packs of potatoes and onions are about the only produce items now packed in paper bags. The more sturdy mesh bag has much wider use. In addition to potatoes and onions, cabbage, turnips and some specialty items are packed in mesh bags. In addition to its low cost, mesh has the advantage of uninhibited air flow. Good ventilation is particularly beneficial to onions.

However, bags of any type have several serious disadvantages. Large bags do not palletize well and small bags do not efficiently fill the space inside corrugated fibreboard containers. Bags do not offer protection from rough handling. Mesh bags provide little protection from light or contaminants. In addition, produce packed in bags is correctly perceived by the consumer to be less than the best grade.



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

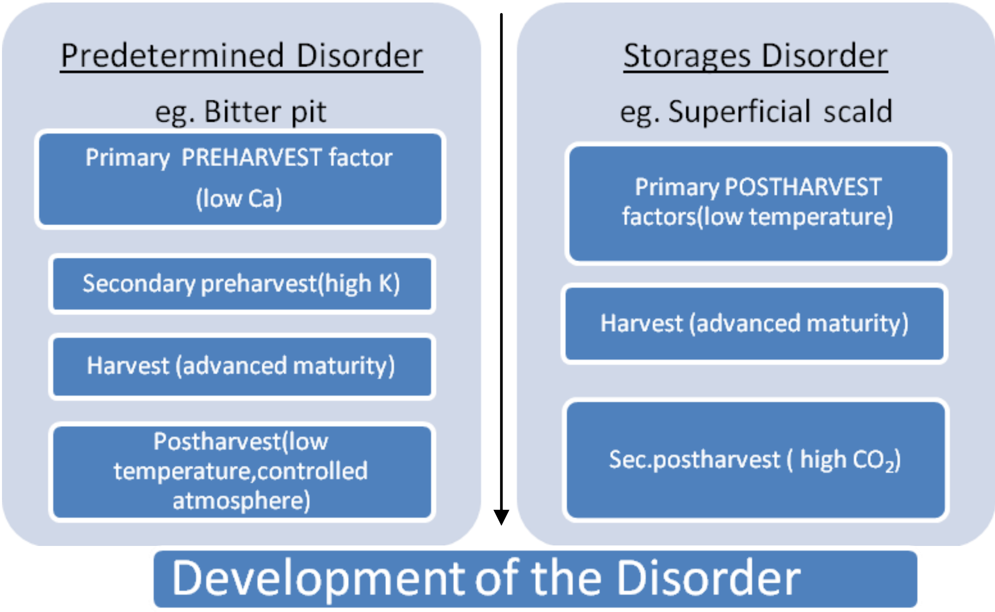


Fig.1 Model for the development of postharvest disorders

(**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

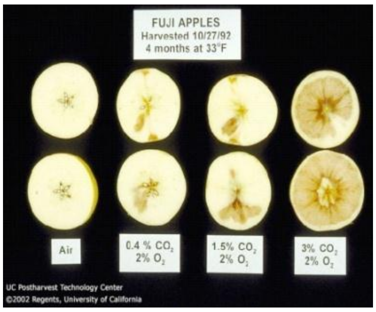
Potassium

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.

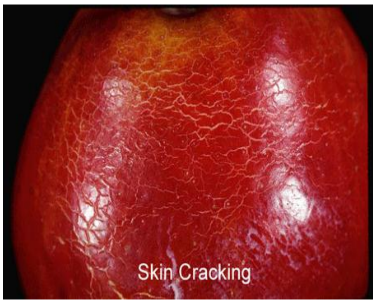
Heavy metals- Copper

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.

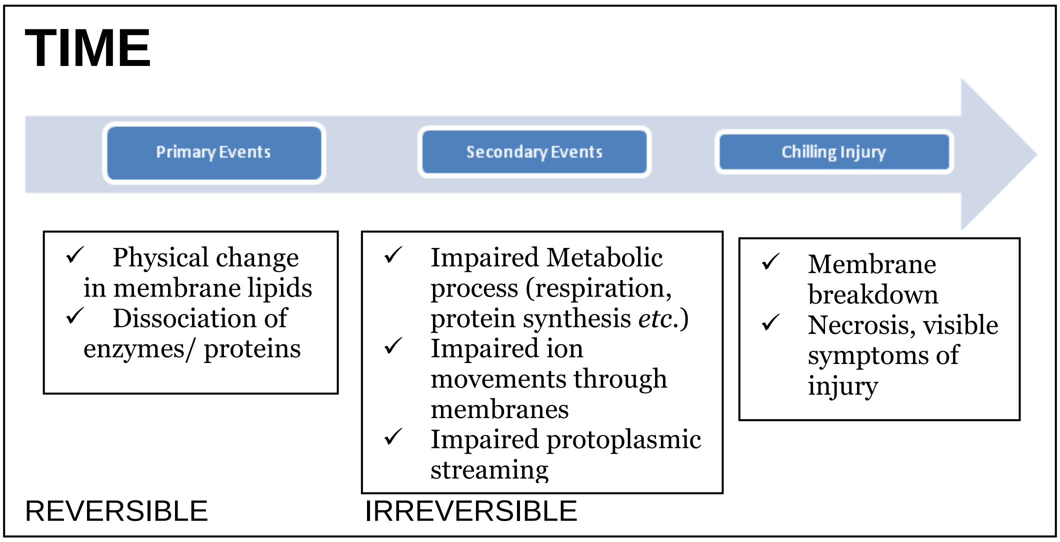


Fig. 2. Time Sequence of events leading to chilling injury

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.

<u>Susceptibility to disorder depends on various factors</u>

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.

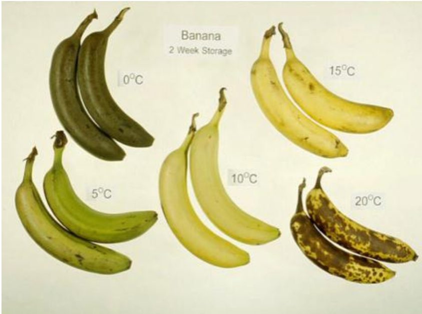
Illustration of some physiological disorders

Apple Scald (inside good)

Water Core

Low O_2 injury

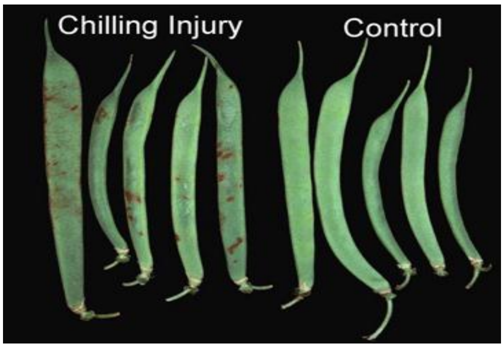

Freezing Injury



Banana Chilling Injury

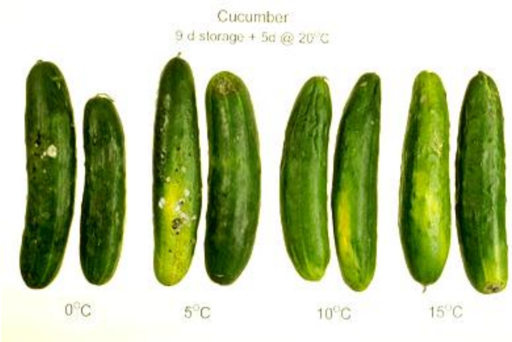
Mango Chilling Injury

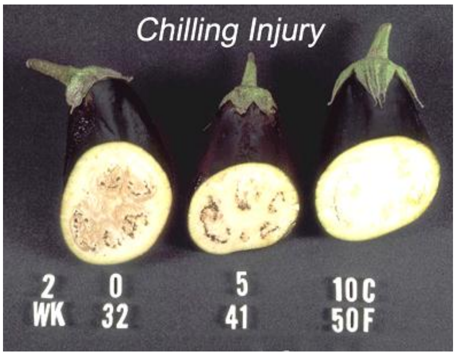

Pineapple Chilling Injury

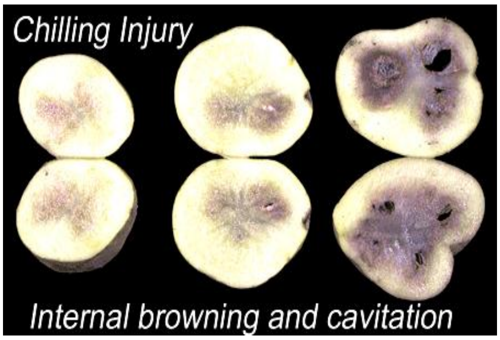


Beans chilling Injury

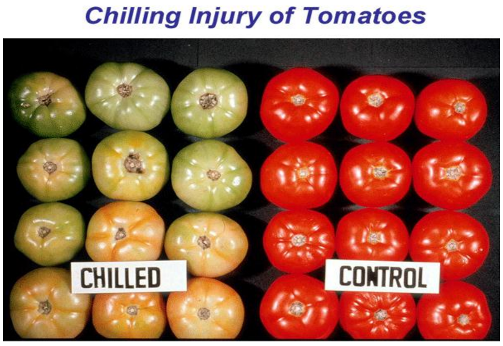

Capsicum chilling Injury







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.

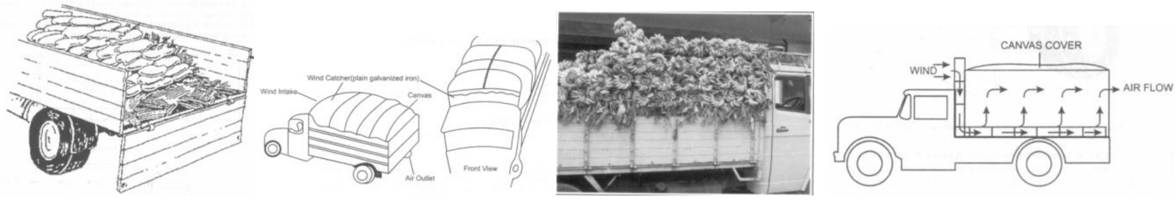


Fig. Unrefrigerated road transport vehicles

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.

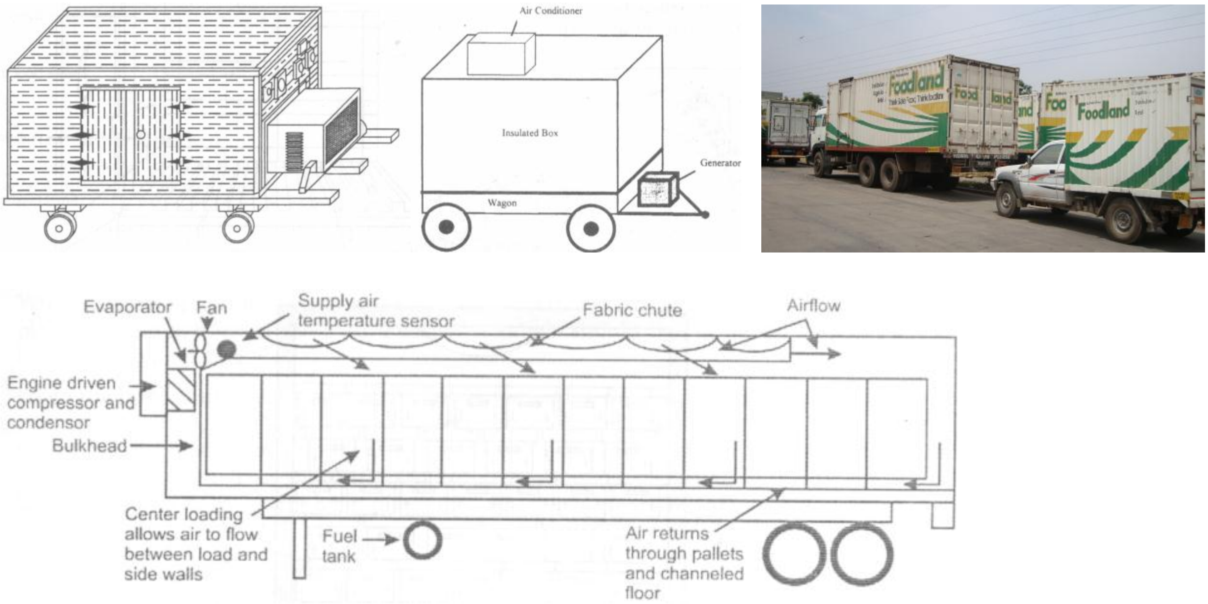


Fig. Refrigerated road transport vehicles

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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