Chapter 1: IMPORTANCE OF POST HARVEST TECHNOLOGY OF HORTICULTURAL CROPS

Horticulture plays a significant role in Indian Agriculture. It contributes 30% GDP from 11.73 % of its arable land area. India is the second largest producer of both fruits and vegetables in the world (52.85 Mt and 108.20 Mt respectively). Fruits and vegetables are of immense significance to man. In India, the fruits have been given a place of honour on being offered to God at every festival and have also been mentioned in our epics like Mahabharata, Ramayana and writings of Sushrutha and Charaka. Being rich source of carbohydrates, minerals, vitamins and dietary fibres these constitute an important part of our daily diet. The dietary fibres have several direct and indirect advantages. Not only this, fruits and vegetables provide a variety in taste, interest and aesthetic appeal. Their significance in human life is being recognised increasingly in Western societies with the objective of minimizing the occurrence of the diseases related with an affluent life style. Their lesser recognized benefits relate to their role in kidney functions, prevention of cancer and cardiac disorders through contribution of ascorbic acid, β-carotene and non-starch polysaccharides besides the biochemical constituents like phenols, flavonoids and alkaloids.

A considerable amount of fruits and vegetables produced in India is lost due to improper post-harvest operations; as a result there is a considerable gap between the gross production and net availability. Furthermore, only a small fraction of fruits and vegetables are utilized for processing (less than 1%) and exported (Fruits – 0.5% and Vegetables – 1.7%) compared to other countries.

Post harvest losses in fruits and vegetables are very high (20-40%). About 10-15% fresh fruits and vegetables shrivel and decay, lowering their market value and consumer acceptability. Minimizing these losses can increase their supply without bringing additional land under cultivation. Improper handling and storage cause physical damage due to tissue breakdown. Mechanical losses include bruising, cracking, cuts, microbial spoilage by fungi and bacteria, whereas physiological losses include changes in respiration, transpiration, pigments, organic acids and flavour.

NATURE AND CAUSES OF POST-HARVEST LOSSES

Losses occur after harvesting is known as post harvest losses. It starts first from the field, after harvest, in grading and packing areas, in storage, during transportation and in the wholesale and retail markets. Several losses occur because of poor facilities, lack of know-how, poor management, market dysfunction or simply the carelessness of farmers.

(a) Extend of post-harvest loss: It is evident that the estimation of post-harvest loss is essential to make available more food from the existing level of production.

A recent joint study conducted by the management consultancy firm, McKinsey and Co. and (The Confederation of Indian Industry (CII), at least 50% of the production of fruits and vegetab1es in the country is lost due to wastage and value destruction. The wastage cost is estimated to be Rs.23, 000 crores each year. Swaminathan Committee (1980) reported the post-harvest handling accounts for 20-30% of the losses at different stages of storage, grading, packing, transport and finally marketing as a fresh produce or in the processed form. According to Chadha (2009) India loses about 35-45% of the harvested fruits and vegetables during handling, storage, transportation etc. leading to the loss of Rs. 40,000 crores per year.

(b) Important sites of post-harvest losses: Important sites where post-harvest losses are noticed in India are —

- Farmer's field (15-20%)
- Packaging (15_2004)
- . Transportation (30-40%)
- Marketing (30-40%)

(c) Estimated loss of fruits

Crop	**Estimated loss (%)**
Papaya	40100%
Grapes	27%
Banana	20-28%
Citrus	20-95%
Avufado	43%
Apple	14%

Estimated loss of Vegetables

Onion	25-40%
Garlic	08-22%
Potato	30-40°
Tomato	5-347%
Cabbage & cauliflower	7.08-25.0%
Chlli	4-35,0%
Radish	3-5%
Carrot	5-9%

(d) Causes of post-harvest losses

Horticultural crops not only provide nutritional and healthy foods to human beings, but also generate a considerable cash income for growers. However, horticultural crops typically have high moisture content, tender texture and high perishability. If not handled properly, a high-value nutritious product can deteriorate and rot in a matter of days or hours. The causes of post-harvest losses can be divided into different categories:

1. Metabolic

All fresh horticultural crops are live organs. The natural process of respiration involves the breakdown of food reserves and the aging of these organs.

2. Mechanical

Owing to their tender texture and high moisture content, fresh fruits and vegetables are very susceptible to mechanical injury. Poor handling, unsuitable containers, improper packaging and transportation can easily cause bruising, cutting, breaking, impact wounding and other forms of injury.

3. Developmental

These include sprouting, rooting, seed germination, which lead to deterioration in quality and nutritional value.

4. Parasitic diseases

High post-harvest losses are caused by the invasion of fungi, bacteria, insects and other organisms. Micro-organisms attack fresh produce easily and spread quickly, because the produce does not have much of a natural defense mechanism and has plenty of nutrients and moisture to support microbial growth.

5. Physiological deterioration

Fruits and vegetable cells are still alive after harvest and continue their physiological activity. Physiological disorders may occur due to mineral deficiency, low or high temperature injury or undesirable atmospheric conditions, such as high humidity, physiological deterioration can also occur spontaneously by enzymatic action leading to over-ripeness and senescence, a simple aging phenomenon.

6. Lack of market demand

Poor planning pr inaccurate production and market information may lead to over production of certain fruits or vegetables which can’t be sold in time. This situation occurs most frequently in areas where transportation and storage facilities are inadequate. Produce may lie

rotting in production areas, if farmers are unable to transport it to people who need it in distant locations.

7. Consumption

These losses can be due to inadequate preservation methods at home, methods of cooking and preparation such as peeling, consumption styles etc.

8. Others

— Lack of clear concept of packing house operations.

— Lack of awareness among the growers, contractors and even the policy makers.

— Lack of infrastructure.

— Late realization of its importance,

— Inadequate technical support.

— Wide gap in technologies available and in vogue.

— Inadequate post-harvest quality control.

— Unorganized marketing.

— Absence of pre-cooling and cold storage.

— Inadequate market facilities, market intelligence and market information service (MIS)

— Poor storage facilities.

(e) Impact of post-harvest losses

Post harvest losses of horticultural crops affect both the nutritious status of the population and economy of the country.

Nutrition

Fruits and vegetables are rich source of vitamins and minerals essential for human nutrition. These are wasted in transit from harvest to consumer represent a loss in the quantity of a valuable food. This is important not only in quantitative terms, but also from the point of view of quality nutrition.

Economy

Careless harvesting and rough handling of perishable bruise and scar the skin, thus reducing quality and market price. Such damaged produce also fails to attract the international buyers, and bring the exporting country less profit and bad name. This ultimately results in huge economic losses to the country.

For improving the situation, it is essential to create awareness among growers, farm workers, manager's traders and exporters about the extent of losses being incurred and their economic consequences. These groups of people involved in the fruit industry also need to learn the basic principles of fruit handling and storage. In addition, the government needs to

provide basic infra-structure like storage, handling, grading, packing, transport and marketing facilities and technical expertise. This could be carried out by the public and private sectors.

(f)Technologies for minimizing the losses

Fruits and vegetables are perishable in nature. Scientific harvesting and handling are the practical way to reduce the losses due to physical damage, spoilages, due to insect damages and microbial growth. Various protocols are standardized and available for adoption to get the best result, which will give economic benefits. Similarly, proper storage conditions, with suitable temperature and humidity are needed to lengthen the storage life and maintain quality once the crop has been cooled to the optimum storage tempera Lure. Greater emphasis need to be given on the training of farmers, creation of infrastructure for cold chain with common facilities for sorting, grading, packing and post harvest treatments in all major markets. Some technologies for extension of shelf life of fruits and vegetables are:

1. Waxing

It is used as protective coating for fruits and vegetables and help in reduction in loss in moisture and rate of respiration and ultimately results in prolonged storage life.

2. Evaporative cool storage

It is the best short-term storage of fruits and vegetables at farm level. It helps the farmers to get better returns for their produce. In this structure, horticultural crops reduce shriveling and extend their storage life.

3. Pre-packaging

This technology controls the rate of transpiration and respiration and hence keeps the commodity in fresh condition both at ambient and low temperature. It can able to bring revolutionary progress in our trade practice and also benefit the consumer and the producer because of its low cost and ready availability.

4. Cold storage

These structures are extensively used to store fruits and vegetables for a long period and employ the principle of maintaining a low temperature, which reduces the rate of respiration and thus delays ripening.

5. Modified atmosphere packaging (MAP)

These packaging modify the atmosphere composition inside the package by respiration. This technology is successful to extend the shelf life of (Cavendish banana, carrots capsicum, green chilli and tomatoes by 15, 14, 13, 8 and 15 clays as against 5, 7, 8, 4 and 7 days in control respectively, under ambient conditions. Storage of Papaya can be extended 4 weeks when stored at 10 -12 °C under modified atmosphere (MA) conditions by wrapping them in low

density polyethylene (LDPE) bag. Using this technique, the fruit can be transported to different markets in refrigerated sea containers with Temperature Sea at 10-12 °C. Fruits ripen within 3-4 days after arrival when placed at ambient temperature. While using optimum low temperature, storage life of Cavendish banana, capsicum, green chili and tomato can be extended to 42,21,28 and 30 days in comparison to 21, 10,21 and 15 days respectively.

6. Controlled Atmosphere (CA) storage

It is based, on the principle of maintaining an artificial atmosphere in storage room, which has higher concentration of CO2 and lower concentration of 02 than normal atmosphere. This reduces the rate of respiration and thus delays aging. This method of storage is very effective when combined with low temperature storage.

7. Cold chain

Following cold chain handling system for fresh horticultural crops from (arm to consumer. It helps in reducing wastages and retention of quality of commodities.

8. Irradiation

It is the newer technologies that can be gainfully employed during storage to reduce post-harvest losses and extend storage life of fruits and vegetable. When fruits and vegetables expose to ionizing radiation (such as gamma-rays) at optimum dosage delays ripening minimizes insect infestation, retards microbial spoilages, control sprouting, and rotting of onion, garlic and potato during storage. It is also used as a disinfection treatment and controls fruit fly on citrus, mango seed weevil and papaya fruit fly.

9. Edible coatings

These are continuous matrices prepared from edible materials such as proteins, polysaccharides and lipids. They can be used as film wraps and when consumed with the food, become an ingredient of the food. They not only minimize the post harvest losses but also need for energy intensive operations and controlled atmosphere storage. They can control migration of gases, moisture, oil, fat, and solutes, as well as retain volatile flavouring compounds. An edible coating improves structural integrity and mechanical handling and carry product so that they help to maintain quality and inhibit microbial growth causing deterioration of the product.

10. Others

— Facilities/ services like grading, washing, cleaning, scientific harvesting and the like, in respect of perishables at the farm level.

— Cold storage facilities should be extended to tropical fruits and vegetables.

Handling protocols should be established for crops other than mango, citrus, grapes and capsicurn to improve the shelf life and export.

— The issue relating to increasing the shelf life of horticultural products needs to he addressed.

— Appropriate packaging material for export of fresh fruits, vegetables and for modified atmosphere packaging should be developed.

— Value addition needs to be viewed in a wider perspective than mere processing to ensure better return to the producer/ farmer, besides providing better quality product to the consumer.

— Development of natural food columns, fiber, single cell protein and food grade enzymes from processing wastes will be useful.

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Lecture 2

Importance of postharvest technology for vegetables, spices, plantation crops and cut flowers.

1. Postharvest 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 defence forces
11. Special canned fruits for infants and children
12. Food supplier to the Astronauts

Importance of postharvest technology in spices

1. Spices are highly perishable invariably contains high moisture (55-85%) at the time of harvest it can be brought down to the moisture 8-12 percent by postharvest technology.
2. Adoption of postharvest technology include pre-treatments, curing, cleaning, method of processing minimize the post-harvest loss and accelerate the domestic as well as export potential.
3. Important for more foreign exchange earner.
4. Facilitate formulation of products of acceptable standard and quality, which meet the international standards, which fetch high price in international market.
5. Proper harvesting and drying methods for spices avoid the contamination give attractive appearance to final product.
6. Preserve the spices long way in reducing the post-harvest loses by processing them into durable products which not only results in their availability for longer time but also fetch high prices.
7. Postharvest technology facilitate off-season availability the spices and continuous supply to meet the demand by having good storage and ware house facilities at appropriate places and improve credibility in the market.
8. Consumer packed spices with brand image earns higher unit value for the same quantity in export.

STRUCTURE OF FRUITS AND VEGETABLES

All fruits and many vegetables being storage organs of the plant are abundant in photosynthates. Fruits are developed from the ovary of the flower and seeds are developed from ovules. The edible product of plant consists of the juicy and pulpy ovary and seeds. Fully ripened fruits are sweet with aromatic flavour.

Edible portion of vegetables include wide variety of plant parts. Vegetables are grouped into Seeds and pods (Legumes), Bulbs, roots and tubers, Flowers, buds, stems and leaves.

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.

Difference between fruit and vegetables

S.No	Fruits	Vegetables
1	Mostly woody perennial	Mostly annuals and biennials
2	Mostly propagated asexually	Mostly by seeds
3	Fruits are developed from ovary of flower	It can be leaf, stem, root, flower bud, fruits
4	Edible part of fruits is juicy, pulpy	Hard and mostly not juicy
5	More sweet	Less / Non sweet
6	Generally consumed as raw (Dessert)	Consumed as cooked
7	Fruits are acidic and are commonly called 'high acid' foods. (pH < 4.5)	Vegetables are classified as 'low acid' foods.(pH > 4.5)
8	Acidity naturally controls growth of micro organisms	Micro organisms grow in moist low acid foods which may lead to spoilage

Edible portion of fruits

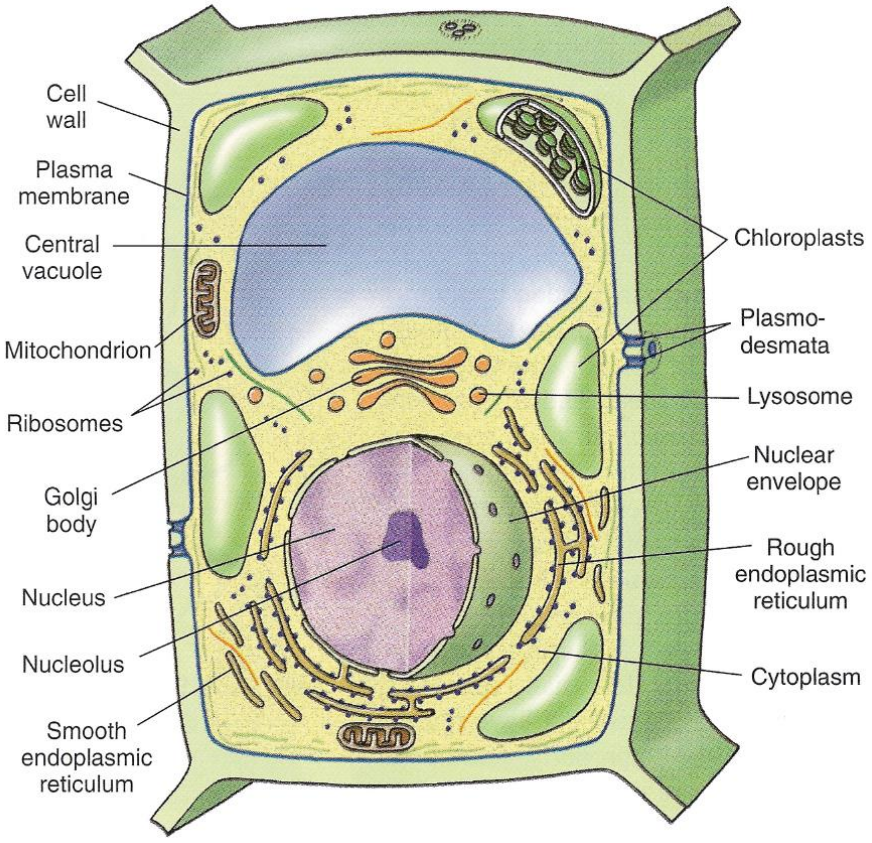
S.No.	Fruits	Edible portion	S.No.	Fruits	Edible portion
1.	Mango	Mesocarp	2.	Grapes	Pericarp
3.	Banana	Mesocarp	4.	Pineapple	Peduncle, bracts
5.	Citrus	Juicy sacs	6.	Pomegranate	Outer layer of testa (Aril)
7.	Apple	Receptacle	8.	Fig	Peduncle
9.	Pear	Receptacle	10.	Cashew apple	Pedicel
11.	Peach	Mesocarp	12.	Strawberry	Receptacle
13.	Plum	Mesocarp	14.	Mangosteen	Aril

Edible portion of vegetables

S.No.	Vegetables	Edible portion	S.No.	Vegetables	Edible portion
1.	Radish	Hypocotyl	2.	Spinach	Leaf blade
3.	Beet root	Hypocotyl, root	4.	Celery	Petiole
5.	Turnip	Hypocotyl	6.	Lettuce	Main bud
7.	Carrot	Root	8.	Brussels sprout	Auxillary buds
9.	Sweet potato	Root	10.	Artichoke	Flower buds
11.	Potato	Modified stem	12.	Broccoli	Flower buds
13.	Onion	Bulb (leaf)	14.	Cabbage	Main bud
15.	Leek	Leaf base	16.	Cauliflower	Inflorescence meristem
17.	Asparagus	Stem sprout	18.	Tomato	Fruit (Pericarp)

Plant cell

Cell wall gives rigidity to the cell. Plant cells appear to have empty space which is actually taken up by a central vacuole. Chloroplasts do photosynthesis.



Important functions of cell components

Components		Functions
A	CELL WALL	To contain cell contents, to give structural support to the cell and tissues
i.	Primary wall	Cellulose (9 - 25 %) hemicelluloses (25 - 50 %) pectin substances and protein (10 %).
ii.	Secondary wall	Cellulose (45 %), hemicelluloses (30 %) and lignin (22 - 28 %).
iii.	Middle lamella	A layer of pectin substances forms the middle lamella and acts to bind adjacent cell together
B.	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. It is responsible for yellow red pigmentation in the fruits.
iii	Leucoplast & Amyloplast	Leucoplasts are colour less plastids. In later stages, leucoplast are known as amyloplast which are sites of starch grain development
C.	Vacuoles	It contains sugars, amino acids, organics acids, tannins, flavonoids, phenolics, pigments, nitrogenous compounds
D.	Nucleus	Control centre of the cell containing genetic information (DNA)
E.	Mitochondria	Power house of the cell produces energy
F.	Golgi complex	Play an important role in synthesis of cell wall and secretion of enzymes from the cell
G.	Ribosomes	Either attached to the endoplasmic reticulum or free in the cytoplasm. Sites of protein synthesis

COMPOSITION OF FRUITS AND VEGETABLES

1. Water

Most of the fruits and vegetables contain > 80 % moisture. Cucumber, lettuce and melons contain 95 % moisture. Cassava, yam and corns contain 50 % water. The variation in the water content within the species is due to the variation of water content of individual cells.

Fruits, vegetables and flowers having more moisture content are susceptible to microbial attack. Moisture loss from leafy vegetables is responsible for deterioration of quality in terms of freshness. Minimizing the water loss is an important step to enhance the shelf life of fruits, vegetables and flowers. This can be achieved by harvesting the produce in the morning and low temperature storage. Harvesting the produce in the mid day severely affects the freshness and crisp texture.

2. Carbohydrates

Carbohydrates account for 2 - 40 % in fruits and vegetables. It is low in cucumber and high in cassava. They occur mainly as sugar, starch and structural polysaccharides like pectin, cellulose, hemicellulose. Structural polysaccharides play an important role in maintaining the texture of fruits and vegetables.

Starch is present in tuber vegetables, unripe fruits. Starch comprises α -1,4 linkages which are hydrolysed by amylases.

$$\text{Starch} \xrightarrow{\text{Amylases}} \text{D - Glucose}$$

Sources of carbohydrates (Vegetables)

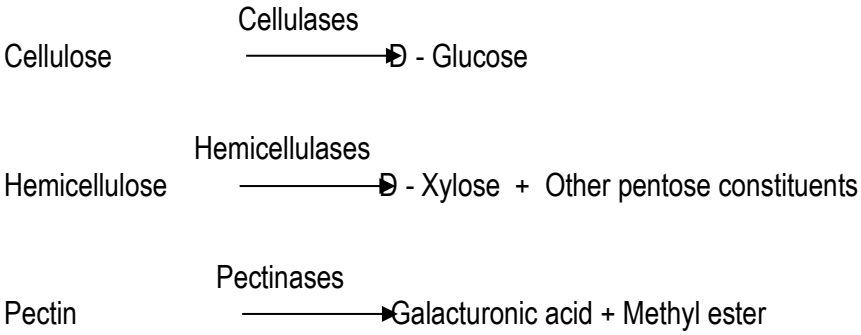
S.No.	Vegetables	Carbohydrates (%)
1.	Cassava	32.0
2.	Sweet potato	28.2
3.	Yam	27.9
4.	Potato	22.6
5.	Taro (*Colacasia esculenta*)	30.8

During ripening, starch and other polysaccharides are converted into simple sugars like sucrose, glucose and fructose which are responsible for sweetness. Sugars impart flavour, appearance and texture to the fruits. Sugar is the primary substrate for respiration to produce energy.

Sources of carbohydrates (Fruits)

S.No.	Fruits	Glucose and fructose	Sucrose
1.	Tropical and sub tropical fruits	> 10 % Banana, litchi, persimmon, pomegranate	8 - 10 % Banana, mango, jack, carambola, rambutan, pineapple, Beet
2.	Temperate fruits	> 10 % Grapes only	7 % Peach
3.	Arid fruits	56 % Dates	8 % Dates

Cellulose, hemicelluloses and pectic substances constitutes dietary fibre. Cellulose comprises β-1,4 linkages. Cellulose is not digested in the intestinal system since the degrading enzymes for these fibres are not produced by man.



3. Protein

Fresh fruits contain 1 % of protein whereas most of the vegetables contain 2 % proteins. Brassica group contains 3 - 5 % of proteins and legumes (5 %). Proteins are present as enzymes.

Sources of proteins (g / 100 g)

S.No	Nuts	Protein
1.	Pistachio nut	21.3
2.	Cashew	21.2
3.	Almond	20.8
4.	Walnut	15.6
5.	Hazelnut	14.9

4. Lipids

Most of fruits and vegetables comprise less than 1 % lipids with the exceptions of avocado (22.8 %) and olive (15 %). Nuts contain considerable amount of fats.

Sources of fats

S.No.	Nuts	Fat (%)
1.	Walnut	64.5
2.	Hazelnut	60.8
3.	Almond	58.9
4.	Cashew	46.9
5.	Pistachio nut	45.9
6.	Coconut	41.6

5. Minerals

Fruits and vegetables are good sources of minerals. Minerals are essential for growth and development of body. Calcium is present as calcium pectate in the middle lamella of the cell wall which is responsible for texture of fruits.

Sources of minerals (mg/100g)

S.No.	Calcium	Iron	Potassium	Iodine	Phosphorus
1.	Leafy vegetables	Karonda (39.1)	Banana	Bhendi	Pomegranate
2.	Almond (49)	Leafy vegetables	Leafy vegetables	Garlic	
3.	Cashew (45)	Dates (10.6)			
4.	Walnut (38) Litchi (31)	Cashew (5.0) Raisin (4.0)			

6. Vitamins

Fruits and vegetables are important source of vitamins. Fat soluble vitamins present in fruits and vegetables are A, D, E and K. Vitamins B and C are water soluble.

Sources of vitamins

Vitamin A IU	Mango (4800), papaya (2020), Persimmon (1710) Leafy vegetables, radish tops, carrot.
Thiamine (B1)	Fresh peas, beans, cabbage, bael, pomegranate, jamum.
Riboflavin (B2)	Bael (1191), papaya, (250), cashew (190), litchi (122), Banana, radish

Mg / 100 g	top, pineapple, cowpea
Niacin (B3)	Banana, strawberry, peach, cherry, green vegetables.
Vitamin C	West Indian cherry, Anola, guava, citrus, cashew apple, leafy vegetables, green chilli, drumstick
Vitamin D	Cabbage, carrot
Pyridoxine (B6)	Vegetables
Folic acid (B9)	Fresh green leafy vegetables, spinach, broccoli
Cyanocobalamin (B12)	Yeast, fermented foods.

9. Organic acids

Organic acids are stored in vacuoles which impart taste and flavour. The major acids are malic (Banana, Apple, plum, cherry, lettuce, celery, broccoli, onion, carrot), citric (Citrus, pear, pineapple, guava, beet, potato, leafy vegetables), tartaric (Grapes), oxalic acid (Spinach), isocitric acid (Black berries). Organic acids plays important role in photosynthesis, respiration and in synthesis of phenolic compounds, lipids and aroma compounds.

10. Volatiles

Volatiles are small molecular weight compounds (< 250) which produces characteristic flavour and aroma. The concentration is about 10 µg / g. The aroma compounds are esters, alcohols, acids, aldehydes and ketones. Ethanol is common to all fruits and vegetables. Esters are responsible for flavour in ripe fruits. Sulphur compounds are present in Brassica sp.

S.No.	Fruit / vegetables	Aroma compounds
1.	Banana Unripe Ripe Overripe	 2-Hexenal Eugenol Isopentanol
2.	Apple Unripe Ripe	 Ethyl 2-methyl butyrate Hexenal
3.	Lemon	Citral
4.	Brassica sp.	Glucosinolates
5.	Radish	Isothiocyanates

7. Pigments

Pigments present in vacuoles are responsible for attractive colour of fruits, vegetables and flowers. During ripening, loss of chlorophyll and synthesis of anthocyanins and/or carotenoids takes place. Anthocyanins give colour from red to blue. Carotenoids give yellow (beta carotene) and red (lycopene) in fruits and vegetables.

8. Phenolic compounds and antioxidants

The phenols are important 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.

Lecture 2: MATURITY INDICES, HARVESTING AND POST HARVEST HANDLING OF FRUITS AND VEGETABLES

I. MATURITY

It is the stage of fully development of tissue of fruit and vegetables only after which it will ripen normally. During the process of maturation the fruit receives a regular supply of food material from the plant. When mature, the abscission or corky layer which forms at the stern end stops this inflow. Afterwards, the fruit depend on its own reserves, carbohydrates are dehydrated and sugars accumulate until the sugar acid ratio form. In addition to this, typical flavour and characteristic colour also develop. it has been determined that the stage of maturity at the time of picking influence the storage life and quality of fruit, when picked immature like mango develop white patches or air pockets during ripening and lacking in normal brix acid ratio or sugar acid ratio, taste and flavour on the other hand if the fruits are harvested over mature or full ripe they are easy susceptible to microbial and physiological spoilage and their storage life is considerably reduce. Such fruits persist numerous problems during handling, storage and transportation. Therefore, it is necessary or essential to pick up the fruits or vegetables at correct stage of maturity to facilitate proper ripening, distant transportation and maximum storage life.

Horticultural maturity

It is a developmental stage of the fruit on the tree, which will result in a satisfactory product after harvest.

Physiological maturity

It refers to the stage in the development of the fruits and vegetables when maximum growth and maturation has occurred. It is usually associated with full ripening in the fruits. The Physiological mature stage is followed by senescence.

Commercial maturity

It is the state of plant organ required by a market. It commonly bears little relation to Physiological maturity and may occur at any stage during development stage.

Harvest Maturity

It may be defined in terms of Physiological maturity and horticultural maturity, it is a stage, which will allow fruits / vegetables at its peak condition when it reaches to the consumers and develop acceptable flavour or appearance and having adequate shelf life.

Table 1: Criteria of maturity for harvesting fruits and vegetables

Fruit	Physical	Chemical
Mango	Olive green colour with clear lenticels, shoulder development size sp. gravity, days from fruit set.	Starch content, flesh colour
Banana	Skin colour, drying of leaves of the plant, brittleness of floral ends, angularity of the fruit, and days from emergence of inflorescence.	Pulp/peel ratio, starch content
Citrus	Colour break of the skin from green to orange, size	Sugar/acid ratio, TSS
Grapes	Peel colour, easy separation of berries, characteristic aroma	TSS 18-12 Thompson seedless, 12-14 for Bangalore Blue, 14-16 for Anab-e-shahi
Apple	Colour size	Firmness as measured by pressure tester
Papaya	Yellow patch or streaks.	Jelliness of the seed, seed colour

Vegetables are harvested at harvest maturity stage, which will allow it to be at its peak condition when it reaches the consumer, it should be at a maturity that allows the produce to develop an acceptable flavour or appearance, it should be at a size required by the market, and should have an adequate shelf life. Time taken from pollination to horticultural maturity under warm condition, skin colour, shape, size and flavour and abscission and firmness are used to assess the maturity of the produce.

Table 2: Time taken from pollination to horticultural maturity

S.No.	Vegetables	Time to harvest Maturity (days)
1.	Ridge gourd	5 -6
2.	Squash	7 - 8
3.	Brinjal	25 - 40

4.	Okra	4 - 6
5.	Pepper (green stage)	45 - 55
6.	Pepper (red stage)	60 -70
7.	Pumpkin (mature)	65 - 70
8.	Tomato (mature green)	35 - 45
9.	Tomato (red ripe stage)	45 - 60
10.	Peas	30 - 35

Skin colour

Loss of green colour in citrus and red colour in tomato.

Shape, size and flavour

Sweet corn is harvested at immature stage, smaller cobs marketed as baby corn. Okra and cow pea are harvested at mature stage (pre fiber stage). In chilli, bottle gourd, bitter gourd, cluster beans maturity is related to their size. Cabbage head and cauliflower curd are harvested before un pleasant flavour.

Abscission and firmness

Musk melon should be harvested at the formation of abscission layer. In cabbage and lettuce should be harvested at firmness stage.

Factors affecting maturity

1. Temperature: Higher temperature gives early maturity.

e.g. Gulabi (Pink) grapes mature in 100 days in Western India but only 82 days are enough in the warmer Northern India.

Lemon and guava takes less time to mature in summer than in winter. Sun-scorched portions of fruits are characterized by chlorophyll loss, yellowing, disappearance of starch and other alcohol insoluble material, increase in TSS content, decrease in acidity and softening.

2. Soil: Soil on which the fruit tree is grown affects the time of maturity.

e.g. Grapes are harvested earlier on light sandy soils than on heavy clays.

3. Size of planting material: This factor in propagated fruits affects fruit maturity.

e.g. In pineapple, the number of days taken from flowering to fruit maturity was more by planting large suckers and slips than by smaller ones.

4. Closer spacing: Close spacing of hill bananas hastened maturity.

5. Pruning intensity: It enhanced the maturity of Flordasun and sharbati Peaches.

6. Girdling: Process of constricting the periphery of a stem which blocks the downward translocation of CHO, hormones, etc. Beyond the constriction which rather accumulates above

it. In Grape vines it hastens maturity, reduces the green berries in unevenly maturity cultivar and lowers the number of short berries. It is ineffective when done close to harvest. CPA has an additive effect with girdling

MATURITY INDEX

Maturity index

The factors for determining the harvesting of fruits, vegetables and plantation crops according to consumer's purpose, type of commodity, etc and can be judged by visual means (colour, size, shape), physical means (firmness, softness), chemical analysis (sugar content, acid content), computation (heat unit and bloom to harvest period), physiological method(respiration). These are indications by which the maturity is judged. Various index are as Follows;

1. Visual indices

It is most convenient index. Certain signals on the plant or on the fruit can be used as pointers. E.g. drying of top leaves in banana, yellowing of last leaf of Peduncle in jackfruit. Flow of sap from cut fruit stalk of mango slows down if the harvest is done after maturity but in immature fruits, exudation is more and comes with force in a jet form. in papaya, the latex becomes almost watery. The flow gets reduced on maturity in Sapota. In fruits like banana and Sapota, floral ends become more brittle and shed with a gentle touch or even on their own. In Sapota, the brown scurf on the fruit skin starts propping. In mango, lenticels become more prominent and the waxy bloom gradually disappears. Grapes develop translucent bloom. Other changes like angularity in banana, development of creamy wide space between custard apple segments and the flattening of the eyes in pineapple and tubercles in litchi serve as reliable maturity indices.

2. Seed development

It can also be used as an index of fruit maturity, e.g. endocarp hardening for stone and fiber development for dessert in mango.

3. Start of bud damage

Occasionally it can be used as an index of fruit maturity in mango.

4. Calendar date

For perennial fruit crops grown in seasonal climate which are more or less uniform from year to year, calendar date for harvest is a reliable guide to commercial maturity. This approach relies on a reproducible date for the time of the flowering and a relative constant growth period from flowering through to maturity. Time of flowering is largely dependent on temperature, and

the variation in number of days from flowering to harvest can be calculated for some commodities by use of the degree- concept.

5. Heat units

Harvest date of newly introduced fruits in a widely varying climate can be predicted with the help of heat unit. For each cultivar the heat requirement for fruit growth and development can be calculated in terms of degree days: Maturity at higher temperature is faster as the heat requirement is met earlier. This heat unit helps in planning, planting, harvesting and factory programmes for crops such as corn, peas and tomato for processing.

MATURITY OF FRUITS AND VEGETABLES

Banana

The fruit is harvested when the ridges on the surface of skin change from angularity to round i.e. after the attainment of 3% full stages. Dwarf banana are ready for harvest within 11-14 months after planting while tall cultivars takes about 14-16 months to harvest. Peel colour change from dark green to light green the remaining style ends were dry, and brittle and fruits were less angular in shape.

Guava

TSS acid ratio, specific gravity and colour are determined the maturity in guava. For e.g.

Allahabad safeda	- 35.81
Apple colour guava	- 26.39
Chittidar guava	- 28.13
Lucknow	- 49 -34.25
Specific gravity	- Less than I
Colour	- Light green to yellow.

Ber

In ber maturity is judged by colour (yellow), specific gravity (less than 1) and TSS

Pomegranate

Sugar percentage should be 12-16% and acid percentage 1.5—2.5%, variety Ganesh harvest when seed colour becomes pink. In this stage TSS 12.5% and sugar acid ratio 19.5%.

Bael

It takes one year for fruiting after flowering. It is the fruit which ripen after one year of flowering. April start harvesting and may end it start in flowering.

Mango

This can be judged when one or two mangoes ripen on the tree are fall on the ground of their own accord. This process of fallen is known as tapaca specific gravity 1,01—1.02 and TSS 10-14%.

Table 3 Maturity indices of vegetable crops

Root, bulb and tuber crops	**Maturity indices**
Radish and carrot	Large enough and crispy
Potato, onion and garlic	Tops beginning to dry and topple clown
Yams, bean and ginger	Large enough
FRUIT VEGETABLES	
Cowpea, snap bean, sweet pea, winged bean	Well filled pods that snap readily
Lima bean and pigeon pea	Well filled pods that are beginning to lose their greenness.
Okra	Desirable size reached and the tips of which can be snapped readily
Snake gourd	Desirable size reached and thumbnail can still penetrate flesh readily
Egg plant, bitter gourd, slicing cucumber	Desirable size reached but still tender
Tomato	Seeds slipping when fruit is cut, or green colour turning pink
Muskmelon	Easily separated from vine with a slight twist leaving clean cavity (full slip stage).
Watermelon	Dull hollow sound when thumped
FLOWER VEGETABLES	
Cauliflower	Curd compact
Broccoli	Bud cluster compact

II. HARVESTING

The goals of harvesting are to gather a commodity from the field at the proper level of maturity with a minimum of damage and loss, as rapidly as possible and at a minimum cost. This is achieved through hand-harvesting in most fruit, vegetable and flower crops.

1. Hand Harvesting

Hand harvesting has a number of advantages over machine harvest. People can accurately determine product quality, allowing accurate selection of mature product. This is

particularly important for crops that have a wide range of maturity and need to be harvested several times during the season. Properly trained workers can pick and handle the product with a minimum of damage. Many fresh-market products have a short shelf life if they are bruised or damaged during harvest and handling. The rate of harvest can easily be increased by hiring more workers. Hand- harvesting also requires a minimum of capital investment. The main problem with hand harvesting is labor management. Labor supply is a problem for growers who cannot offer a long employment season. Labor strikes during the harvest period can be costly. In spite of these problems, quality is so important to marketing fresh- market commodities successfully that hand harvesting remains the dominant method of harvest of most fruits and vegetables and for all cut flowers.

Effective use of hand labor requires careful management. New employees must be trained to harvest the product at the required quality and at an acceptable rate of productivity. Employees must know what level of performance and must be encouraged and trained to reach that level.

2. Mechanical Harvesting

Mechanical harvest is currently used for fresh-market crops that are roots, tubers, or rhizomes and for nut crops. Vegetables that are grown below ground (radishes, potatoes, garlic, carrots, beets and others) are always harvested only once and the soil can be used to cushion the product from machine caused mechanical injury. Tree nuts and peanuts are protected by a shell and easily withstand mechanical handling. A number of products destined for processing such as tomatoes, wine grapes, beans, peas, prunes, peachesand some leafy green vegetables are machine harvested because harvest damage does not significantly affect the quality of processed product. This is often because the product is processed quickly after harvest. These crops have also been amenable to new production techniques and breeding that allow the crop to be better suited to mechanical harvest.

The main advantage of mechanical harvest equipment is that machines can often harvest at high rates. Tree nut harvesters, for eg. attaching a shaking mechanism to the tree and remove most of the nuts in few seconds. The nuts are either caught on a fabric- covered frame or picked up from the ground by other machines. This allows an orchard to be harvested very quickly compared to handshaking with poles. Machine harvest also reduces management problems associated with workers. The commodity must be grown to accept mechanical harvest.

Demerits of Mechanical Harvesting

Machines are rarely capable of selective harvest. Mechanical harvesting will not be feasible until the crop or production techniques can be modified to allow one time harvest. Harvesting machines often causes excessive product perennial crops eg. Bark damage from a tree shaker. The harvesting machines are quite expensive.

III. POST HARVEST HANDLING

Being living organs, fruits and vegetables continue to respire even after harvesting when they have a limited source of food reserves. In addition to degradation of respiratory substrates, a number of changes in taste, colour, flavour, texture and appearance take place in the harvested commodities which make them unacceptable for consumption by the consumers if these are not handled properly. Post harvest technology starts immediately after the harvest of fruits and vegetables. The whole process of processing the commodities is categorized as Handling of fresh produce. Post harvest Technology of fresh fruits and vegetables combines the biological and environmental factors in the process of value addition of a commodity.

1. Precooling

Precooling (prompt cooling after harvest) is important for most of the fruits and vegetables because they may deteriorate as much in 1 hr at 32°C. In addition to removal of field heat from commodities, precooling also reduces bruise damage from vibration during transit. Cooling requirement for a crop vary with the air temperature during harvesting, stage of maturity and nature of crop.

There are many methods of precooling viz, cold air (room cooling, forced air cooling), cold water (hydrocooling), direct contact with ice (contact icing), evaporation of water from the produce (evaporative cooling, vacuum cooling) and combination of vacuum and hydrocooling (hydrovac cooling). Some chemicals (nutrients/growth regulators/ fungicides) can also be mixed with the water used in hydrocooling to prolong the shelf life by improving nutrient status of crop and preventing the spread of post harvest diseases.

2. Washing, Cleaning and Trimming

Before fresh fruits and vegetables are marketed various amounts of cleaning are necessary which typically involves the removal of soil dust, adhering debris, insects and spray residues. Chlorine in fresh water is often used as disinfectant to wash the commodity. Some fungicides like Diphenylamine (0.1 - 0.25%) or ethoxyquin (0.2 - 0.5%) may be used as post harvest dip to control the disorders. Eg. Apple superficial scald. For cleaning of some fruit type vegetables (melons, brinjals, tomatoes, cucumber) they should be wiped with damp cloth. Many vegetable need trimming, cutting and removal of unsightly leaves or other vegetative parts.

3. Sorting, Grading and Sizing

Sorting is done by hand to remove the fruits which are unsuitable to market or storage due to damage by insects, diseases or mechanical injuries. The remainder crop product is separated into two or more grades on the basis of the surface colour, shape or visible defects. For eg, in an apple packing house in India 3 grades viz. Extra Fancy, Fancy and standard may be packed for marketing. The fourth “cull” grade is meant for processing. After sorting and grading, 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 or of non-uniform shape) commodities, respectively.

4. Curing

Curing is an effective operation to reduce the water loss during storage from hardy vegetables viz, onion, garlic, sweet potato and other tropical root vegetables. The curing methods employed for root crops are entirely different than that from the bulbous crops (onions and garlic). The curing of root and tuber crops develops periderms over cut, broken or skinned surfaces wound restoration. It helps in the healing of harvest injuries, reduces loss of water and prevents the infection by decay pathogens.

Onions and garlic are cured to dry the necks and outer scales. For the curing of onion and garlic, the bulbs are left in the field after harvesting under shade for a few days until the green tops, outer skins and roots are fully dried.

5. Waxing

Quality retention is a major consideration in modem fresh fruit marketing system. Waxes are esters of higher fatty acid with monohydric alcohols and hydrocarbons and some free fatty acids. But coating applied to the surface of fruit is commonly called waxes whether or not any component is actually a wax. 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 adjunct to good handling.

The advantages of wax application are:

- Improved appearances of fruit.
- Reduced moisture losses and retards wilting and shrivelling during storage of fruits.
- Less spoilage specially due to chilling injury and browning.
- Creates diffusion barrier as a result of which it reduces the availability of 02 to the tissues thereby reducing respiration rate.

- Protects fruits from micro-biological infection.

- Considered a cost effective substitute in the reduction of spoilage when refrigerated storage is unaffordable.

- Wax coating are used as carriers for sprout inhibitors, growth regulators and preservatives.

The principal disadvantage of wax coating is the 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. Paraffm wax, Carnauba wax, Bee wax, Shellac, Wood resins and Polyethylene waxes used commercially.

6. Packaging

Proper or scientific packaging of fresh fruits and vegetables reduces the wastage of commodities by protecting them from mechanical damage, pilferage, dirt, moisture loss and other undesirable physiological changes and pathological deterioration during the course of storage, transportation and subsequent marketing. For providing, uniform quality to packed produce, the commodity should be carefully supervised and sorted prior to packaging. Packaging cannot improve the quality but it certainly helps in maintaining it as it protects produce against the hazards of journey. Striking developments have been in the field of packaging of horticultural produce and the gunny bags, grasses and stem leaves used so far for packaging are now being replaced by a variety of containers such as wooden boxes, baskets woven from bamboo or twigs, sack/jute bags and corrugated fibre board (CFB) boxes.

7. Storage

A number of storage techniques (ground storage, ambient storage, refrigerated storage, air cooled storage, zero energy storage, modified atmospheric storage, hypobaric storage and controlled atmosphere storage) are being used for fruits and vegetables depending upon the nature of the commodity and the storage period intended.

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,

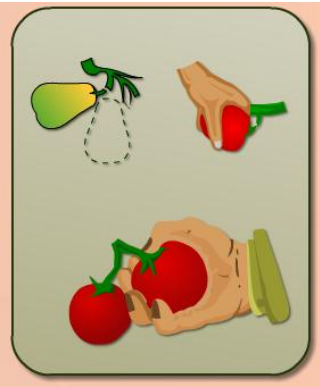
The main benefit of hand harvesting over mechanized harvesting is that humans are able to select the produce at its correct stage of ripening and handle it carefully. The result is a higher quality product with minimum damage. Examples,

- ✓ 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.

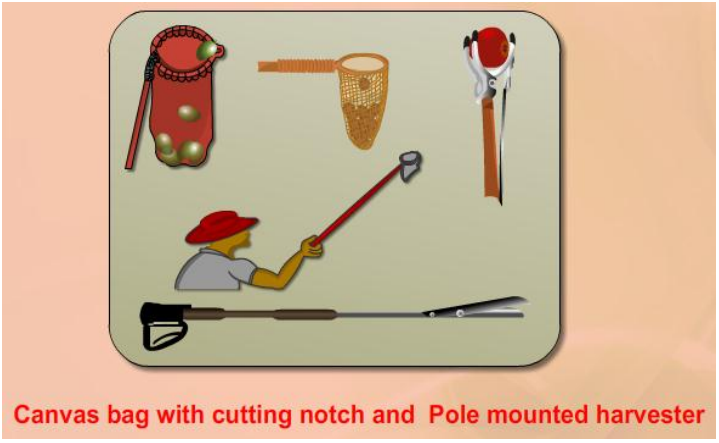
Use of bulk bins(commercial growers) - with a capacity of 250-500 kg, in which crops such as apples and cabbages are placed, and sent to large-scale packinghouses for selection, grading and packing.

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



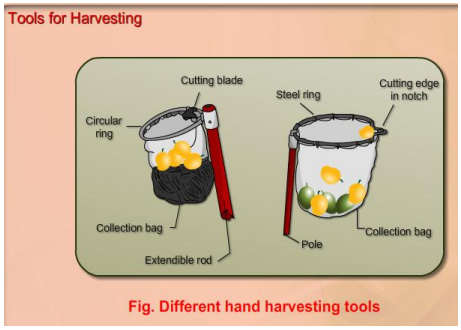


Fig. Different hand harvesting tools

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.

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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SENESCENCE AND POST HARVEST PHYSIOLOGY OF CUT FLOWERS

The senescence of cut flowers involves a series of physiological and biochemical events leading to eventual collapse and death of the petals. In cut flowers senescence is accompanied by increased respiration and ethylene production, induction of catabolic enzymes and resulting in decrease in protein, complex carbohydrate and nucleic acid content and loss of membrane function.

The cut-flower industry is extremely competitive and needs good understanding of the trade, skill, knowledge as well as experience in growing of flowers in order growers to survive. Flowers are now considered as the extreme focus point by the government of India due to its highest net return from per unit area and its greater export import value. Flowers are grown in greater part of India in about 0.116 million hectare area with a production of 0.655 million tones loose flowers and l952 million numbers cut flowers. Due to lack of knowledge of physiological processes associated with post harvest handling of flowers, the losses are estimated to be 40-50% world wide. To meet the continuous demand and fluctuation of prices in the market, the post harvest life of the cut flowers should be increased.

Shelf life/vase life/ display life/ longevity

It is a period for which cut flowers remain in presentable form without loosing its grade and quality.

Cut flowers

The flowers which are cut along with certain portion of the stalk and can be used as a individual flower is known as cut flower.

Extent of post harvest losses

Flowers are highly perishable in nature and it is estimated that about 20 per cent losses due to improper handling, 10 per cent losses due to unmarketability and are not harvested, 10-15 per cent shrinkage loses during marketing. Thus, and overall post harvest losses of flowers are 40-50 per cent.

Post harvest handling of flowers is different from fruits and vegetables, how?

Cut flowers or cut inflorescence (gladiolus, tuberose etc.) composed of many morphologically and physiologically different units, viz., sepal, petals, andreoecium, gynoecium, stem and often leaves, while most of the fruits and vegetables are single morphological units. Cut flowers have more complex organ due to its morphological and

physiological traits interaction, which influence water balance, thus, the post harvest life of the cut flower is much more affected than the fruits and vegetables.

Quality of cut flowers

There are three major components of quality are judged by consumer at the time of purchase

1. Physical appearance: It includes- shape, size, colour condition (Freshness) cleanliness of flower and stem length and its strength.

2. Chemical component: it includes fragrance but this character has become less important in the recent year.

3. Anatomical component: it includes crispiness and toughness.

4. Longevity:

Cut flowers longevity depends on the following;

1. Carbohydrate reserve in cut flower
2. Osmotic concentration and pressure
3. Potential of petal cell
4. Stomatal functioning
5. Differences in numbers thick walled supporting cell in the xylem element and phloem fibers
6. Presence and absence of complete ring of secondary thickening in flower peduncles.
7. Differences in the diffusive resistance of leaves in the field.
8. Lignifications
9. Level of plant hormone
10. Susceptible to insect pest and disease

Factors affecting the longevity of cut flowers

Unlike fruits and vegetables, flowers have complex morphology and contain calyx, petals, stamens, and pistils. The interactions among these parts determine the rate at which the senescence of petals occurs. Pre- harvest, during harvest and post harvest operations determines the potential life of a cut flower. Basically, those forces which improve crop quality before and after harvest usually improve vase life.

Pre-harvest factors

(a) Genetic factors : Post harvest lasting quality of flower species and cultivars vary due to difference in their genetic make-up. It is, therefore, desirable to grow different crop, different species of the flowers and different cultivars of the same species possesses long vase life. Eg: Rose has shorter vase life than chrysanthemum. Golden wave roses wilted earlier than the other cultivars of rose due to poor stomata closer of leaves under water stress condition.

(b) Environmental factors: It includes light intensity, photoperiod, temperature, relative humidity, carbon dioxide etc. Far red, radiant flux density increase photosynthates level in flower tissues.

1. Light intensity: It is very important. A crop grown under low light, such that light is a limiting factor for photosynthesis, will be low in carbohydrate content. Respiration continues after the flower is harvested, but little photosynthesis occurs, because light is limited in the packing house, florist shop and consumer's home. Optimum light intensity during growth of the crop is very important to vase life.

2. Temperature: It affects photosynthesis and respiration, which influence carbohydrate accumulation. Crops sensitive to high temperatures and having shorter vase lives due to low carbohydrate levels in flowers. When the temperature is raised to an adversely high level to force earlier flowering, the same problem occurs.

Harvesting preferred in late after noon because during the day light hours higher level of carbohydrates from photosynthesis, while in night translocates and respirates reduces the levels of carbohydrate.

Relative humidity 85-90% prolong the shelf life of the flower.

Harvest factors:

(i) Harvesting time: Flowers should always be harvested when temperature is mild because high temperature leads to faster respirates and also causes excessive water losses. Optomum time of harvest is morning or evening. In the morning time flowers are fully turgid due to low transpirates at night. Evening harvest is also advocated because higher sugar level in the stem due to high rates of photosynthesis during day time.

(**ii) Harvesting method:** Stem should always be cut with sharp knives or secateur. Stem should not be crushed. Hard wood stem should always be given slanting cut so as to expose the maximum surface area to ensure rapid water absorption. Stems of chrysanthemum should be cut at least 10 cm above the ground level because, the stem

close to the soil is hard and highly lignified and absorbs very little water. In rose stem length should be long for maximum longevity of flowers, flower quality and water uptake in vase.

(iii) Stage of harvesting: Flowers cut to immature or over mature don't open properly Stage of harvesting varies with the species, varieties, prevailing temperature conditions, distance to the market place and requirement of the consumers.

Name of flowers	Harvesting stage
Anthurium	Spades almost fully developed
Chrysanthemum Standard Spray	 outer florets fully developed Flowers open but before shedding of pollens
Rose	1-2 petals begins to unfold.
African Marigold	fully open flowers
Dahlia	fully open flowers
Phlox, Sunflower	fully open flowers
Sweet Pea	one-half florets open
Tuberose	Majority of florets open
Zinnia	fully open flowers

(iv) Consumer demand: Consumer is considered as a king of the market.

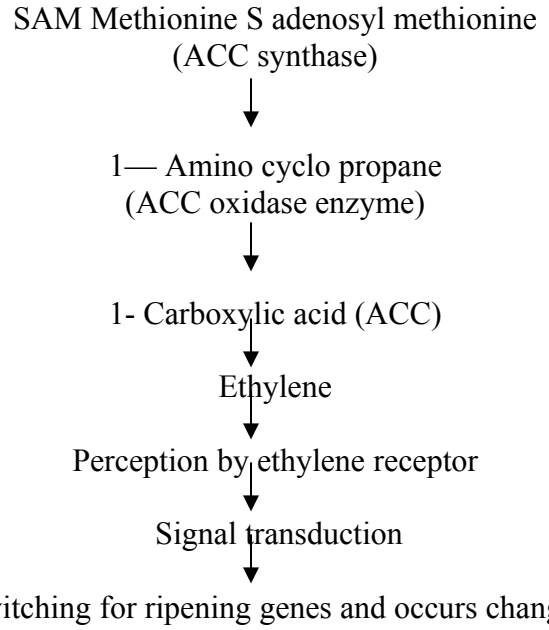
(v) Distant market: Fresh cut flowers to be transported to distant market in dry condition are often harvested at an early stage of development then sold in the local market

Post Harvest Factors

1. Temperature effect: Cut flowers should be precooled immediately after harvest, because it remove field heat generated due to high rate of respiration and open environmental conditions. When roses and carnation placed at 20 °C then respiration rate was 20 times higher than those placed at 0 °C. Low temperature reduce excessive opening of the buds, water loss, ethylene production and growth of pathogens.

2**. Depletion of carbohydrate**: It carries out its life process by expanse of reserve food (carbohydrate) due to respiration, flower stem continuous to loose carbohydrate considerably. The depletion o carbohydrate decreases its vase life. There fore deficiency can be corrected by the treatment of cut stem with preservative containing sugar.

3. Ethylene Factor: Ethylene, commonly known as a ripening hormone reduces vase life of many flowers.



- Change in respiration
- Rise in temperature
- Rise in the activity of hydrolytic enzyme
- Change in cell wall
- Synthesis of aroma.
- Change in chloroplast

Floral preservatives

Floral preservatives are chemical formulations which are used for extending the vase life of flowers and improve flower opening, size shape and colour of flowers.

Floral preservatives have four basic components

i) Water ii) Sugar iii) Biocides iv) other ingredients

Water is the most important component of floral preservatives, it affects vase life in terms of its quantity as well as quality. It is always suggest using deionized or distilled water.

Biocides: These are chemical substances which are used to inhibit microbial growth in the vase water as well as on the stem surface.

Eg. 8-hydroxyquinoline sulphate - 200—600 ppm

Silver Nitrate – 10- 200 ppm

Aluminum sulphate - 200—300 ppm

Application of Floral preservatives

Floral preservatives can be applied in three ways.

(I) Pulsing solution

(ii) Bud opening solution

(iii) Holding or Vase solution

Pulsing solution

Refers to short duration (16-24 hour) preshipment or prestorage treatment. The effect of such treatment lasts throughout the entire vase life of the flower. Sucrose is one of the main components of the pulsing solution and it is used @ 5-20 percent.

Bud opening solution

Immature buds of many flower can be made to open in chemical solutions, refer as bud opening solution. Stems are placed in solutions containing higher concentrations of sugar, plus a germicide and hormonal compounds that facilitate bud growth and development.

Holding or vase solution

To hold flowers continuously, till the termination of their vase life. The levels of sucrose in vase solutions are kept very low (0.5-2 percent).

STORAGE OF FLOWERS

Storage is highly useful to regulate the supply in the market to prevent glut, especially when the prices crash down. Storage is also useful to hold the flowers till sufficient quantities are available for shipment. There are certain factors which are responsible for storage life like- quality of flowers, stage of harvest, temperature, relative humidity, light, ethylene and pathogen.

Methods of storage: There ate three methods for the storage of flowers

1. Refrigerated storage

It has two types-wet and dry storage. In wet storage Flowers are stored with their bases dipped in water or preservative solution. It is used to hold flowers for short duration. The temperature in wet storage is kept at 2-4˚ C mean as slightly higher than the dry storage. In dry storage flowers are sealed in plastic bags to prevent the loss of moisture. Before dry storage the flowers should be precooled to remove field heat and

treated with pulsing solution Flowers should be stored at 0.5-1 °C. The temperature range for tropical flowers like- orchids, poinsettia, bird of paradiseis 10-15 °C.

2. Controlled Atmosphere (CA)

Low temperature storage in gas tight chamber under decreased levels of oxygen (02) and increased levels of carbon di oxide. One major limitation in CA storage is that the optimum levels of O2 and CO2 require for storage, vary for different flowers, hence different flowers can not be stored at the same time in same chamber.

3. Modified Atmosphere

The dry storage of flowers in sealed bags leads to reduction and increase in CO2 levels due to respiration of tissue. The storage under such condition is referred to as modified Atmosphere storage.

Storage Temperature Recommendations and Approximate Storage Life and Vase life for Fresh Cut Flowers and Florist Greens

Cut Flowers	Storage Temperature (°C)	Approximate Period	
		Storage Life	Vase life
Allium	0 to 2	2 weeks,dry	10 to 14 days
Anemone	4 to 7	2 days	4 to 8 days
Aster, China	0 to 4	1 to 3 weeks	5 to 10 days
Calendula	4	3 to 6 days	-
Candytuft	4	3 days	-
Coreopsis	4	3 to 4 days	-
Cornflower	4	3 days	6 to 10 days
Cosmos	4	3 to 4 days	4 to 6 days
Tulip	—0.5 to 0	2 to 3 weeks	3 to 6 days
Violet	1 to 5	3 to 7 days	-
Zinnia	4	5 to 7 days	6 to 10 days
Florist greens Asparagus	2 to 4	2 to 3 weeks	6 to 14 days
Asparagus	2 to 4	2 to 3 weeks	6 to 14 days
Hedera	2 to 4	2 to 3 weeks	-
Juniper	0	1 to 2 months	-
Magnolia	2 to 4	2 to 4 weeks	-

Grading of important flowers

Rose: Grading is an important aspect for cut-flower marketing. The quality cut flower in rose should have strong straight stern capable of holding the flowers in upright position,

uniform stein length, shape and size of the flower representative of cultivar, uniform stage of development, free from injuries and foliage must be healthy and good.

In USA stem length is considered the most important point for grading roses. The EEC established compulsory grades and standards in order to maintain uniformity in the grading procedures in roses. These standards are given below;

Grades and standard of cut roses as per European Economic Community

Code	Stein length (cm)	Code	Stem length (cm)
0	>5=5	40	40-50
5	5-10	50	50-60
10	10-15	60	60-80
15	15-20	80	80-100
20	20-30	100	100-120
30	30-40	120	120 or more

Chrysanthemum: Cut flowers are grouped into several grades, depending on stem length and strength, colour and diameter of flowers, etc. Pompons are graded into 250 to 340 g bunches having several stems while standards of equal sizes are generally graded in groups of 10 or 12. A metric grade specification for sprays which works well for bulk packing is given below;

Metric specification for chrysanthemum (spray type)

Grade	Stem per sleeve	Specification
Gold	10	6 flowers or more out and some to come
Silver	15	4or 5 flowers out and some to come
Bronze	20	3 flowers out and some to come
Make-up	(-)	All stems not covered above, filling sleeves to same extent as other grades.

Gladiolus: Gladiolus spikes are graded based on overall quality, length of spike and number of florets in each spike as fancy, special, standard and utility.

Grades for cut gladiolus as per North American Gladiolus Council (NAGC)

Grade	Spike length(crn)	No. of florets (miniinnnim)
Fancy	>107	16
Special	> 96 ≤ 107	15
Standard	>81 ≤ 96	12
Utility	≤ 81	10

Carnation: The grades are mainly based on stem length and physical condition of the flower. The Society of American Florists (SAF) suggested the following inspection standards for cut Carnations

• Bright, clean, firm flowers and leaves.

• Fairly tight petals near the center of the unopened flowers.

• Symmetrical flowers- shape and size characteristics of the cultivar.

• No split or mended calyx.

• No lateral bud or sucker.

• No decay or damage.

• Straight stem and normal growth.

INFLUENCE OF PRE HARVEST FACTORS ON POST HARVEST QUALITY OF FRUITS AND VEGETABLES – PRE HARVEST OPERATIONS TO EXTAND SHELF LIFE OF FRUITS AND VEGETABLES

Quality of post harvest product

Post harvest quality represents market quality, edible quality, transport quality, table quality, nutritional quality, internal quality and appearance quality. Quality means a combination of characteristics, attributes and properties that gives the values to human and enjoyments. Consumers consider good quality in relation to colour, flavour and nutrition. Quality of the produce is the final manifestation of inter-relation between the commodity and its environment. The genetic characteristics and physiological status of the commodity determine the typical post-harvest behavior and quality of the produce and these two are the major bases for the interaction. Pre-harvest factors *viz*, environmental factors such as temperature, relative humidity, water potential, light, cultural practices and pest management techniques determined the inherent quality of the produce. However, the ultimate quality is the final manifestation of inter relation between the commodity and its environment.

Several pre-harvest and post-harvest factors affect the quality of horticultural crops. Some of these factors are related to plant, others are related to environment or to cultural practices.

A. Pre-harvest factors

a) Related to plants

- **Crops: Q**uality of the fruit and vegetables are varies from crop to crop e.g. jackfruit, bael, potato, onion, pumpkin, garlic etc. having good quality in relation to shelf life, while apple, mango, cherry, strawberry, tomato, capsicum, okra, brussels sprout, chinese cabbage, carrot, radish attract more to consumers due to their attractive appearance.
- **Cultivars:** The quality of seed or plant material is an important factor that controls the quality of the fruit and vegetable produced. Several parameters of quality are controlled genetically.

• **Cultural practices**: All cultural practices have direct effect on the final quality of the produce.

• **Planting period**: Many plants are very sensitive to environmental conditions, and thus quality will not be optimized when crop is produced under adverse conditions. Producing summer plants during the winter or vice-versa will not be appropriate, unless protection practices are implemented.

• **Planting density**: It affects both the quantity and quality of the produce. High density planting increases competition between plants, reduces light availability, and thus may decrease quantity. Low density planting lead to large size, better colored fruit or vegetable which may have shorter shelf life. Larger fruits are commonly more sensitive to physiological disorders.

• **Irrigation:** Irregular watering usually reduces fruit size, increases splitting, physiological disorders, reduces water content in the plant or plant part, etc.

• **Fertilization:** Poor management of fertilizers will increase physiological disorders due to deficiencies of some minerals or increase of other leading to toxicity. In both cases, quality will be negatively affected.

• **Pruning:** It reduces the load and increases the growth of fruit and chemical use after harvest.

• **Thinning:** This operation reduces the competition between fruits or plants and thus promotes a good balance between the vegetative and fruit parts and improves quality.

• **Protection:** Pathogens and insects have a very negative effect on quality. Poor management of plant protection programmes can lead to very poor quality and reduced yield.

b) Related to environments

Temperature is the most important environmental factor that affects quality, very low or very high temperature may injure sensitive crops. Adequate high intensity and quality is important for the formation of some colour. Wind and rain may cause negative effects on some crops.

c) Related to chemicals

Many hormones and growth regulators are used in agriculture and they can affect quality in different ways.

B) During harvest factor

• **Season:** Quality of produce are greatly influenced by season e.g. Winter season harvest having more shelf life as compared to other season, while off season fruits and vegetables give more remunerative price. Harvesting during or immediately after rains should not be carried out since it creates most favourable conditions for multiplication of micro-organisms. Citrus fruits become susceptible to damage if harvested during rains as their rind becomes turgid and prone to easy bruising, sun-scald etc.

• **Time:** Fruits and vegetables should always be harvested when temperature is mild. Because, higher temperature leads to faster respiration. Morning harvest of horticultural crop prefer for local market because they are fully fresh and turgid and having dew drop in this time. Evening harvesting is preferred for distant market due to higher accumulation of reserved carbohydrates and less amount of moisture which give the better quality of the produce to consumer. Leafy vegetables harvested in the latter part of the morning or late in the afternoon, the petioles of these vegetables break less easily and their leaves are more resistant to tearing, since they have lost water through transpiration and therefore are less brittle. Cucumber is harvested in the late morning when it to be transported under less than ideal condition because it is less prone to injury when it contains less water.

• **Method of harvesting**: Selection of suitable method for harvesting of the produce is necessary otherwise bruises or injuries during harvesting may later manifest as black or brown patches making them unattractive. Latex coming out of stem in mango should not be allowed to fall on fruits as it creates a black spot. Injury to peel may become an entry point for microorganisms, causing rotting. Some harvesting gadgets have been developed, e.g. mango harvester in Lucknow (CISH).

• **Stage of harvesting**: Fruits and vegetables must be harvested at right stage of maturity. A very common cause of poor product quality at harvest and rapid deterioration thereafter is harvesting immature vegetables. Vegetables harvested immature or over mature usually do not keep long. Fruit vegetables harvested too early lose water fast and are more susceptible to mechanical damage and microbial attack. An over mature vegetable is more susceptible to decay, has passed its best eating quality, and deteriorates fast.

• **Consumer demand**: Harvesting time and harvest maturity can be altered by the requirement of the consumer's demand which may affect the quality of the produce at some extent.

Preharvest treatments

Postharvest shelf-life of fruits and vegetables is improved by pre harvest application of chemicals. Three sprays of Topsin-M (01%) or Bavistin (0.1%) at 15 days interval before harvesting can control anthracnose and stem-end rot in mango. Similarly, postharvest decay of Nagpur mandarins can be controlled by 3 preharvest sprays of 0.1% Benlate or 0.1% Topsin.M or 0.1% Bavistin at 15 days interval. Preharvest application of maleic hydrazide reduces sprouting of onions and potatoes during storage. In rabi and kharif onions, application of 1,500—2,000ppm maleic hydrazide, 75—90 days after transplanting reduces sprouting during 4—5 months of storage in ventilated structures. Postharvest diseases of tomato and onion can be controlled by 3 preharvest sprays of 0.2% Difolatan at 10 days interval. Similarly preharvest application of growth promoters such as N-benzyladenine (10—2oppm) prolongs shelf-life of leafy vegetables.

POST HARVEST PHYSICAL AND BIOCHEMICAL CHNAGES IN FRESH FRUITS AND VEGETABLES

MATURITY

It is the stage of fully development of tissue of fruit and vegetables only after which it will ripen normally. During the process of maturation the fruit receives a regular supply of food material from the plant. When mature, the abscission or corky layer which forms at the stern end stops this inflow. Afterwards, the fruit depend on its own reserves, carbohydrates are dehydrated and sugars accumulate until the sugar acid ratio form. In addition to this, typical flavour and characteristic colour also develop. It has been determined that the stage of maturity at the time of picking influence the storage life and quality of fruit, when picked immature like mango develop white patches or air pockets during ripening and lacking in normal brix acid ratio or sugar acid ratio, taste and flavour on the other hand if the fruits are harvested over mature or full ripe they are easy susceptible to microbial and physiological spoilage and their storage life is considerably reduce. Such fruits persist numerous problems during handling, storage and transportation. Therefore, it is necessary or essential to pick up the fruits or vegetables at correct stage of maturity to facilitate proper ripening, distant transportation and maximum storage life.

FRUIT RIPENING

Fruit ripening is a genetically programmed stage of development overlapping with senescence. The fruit is said to be ripe when it attains its full flavour and aroma and other characteristics of the best fruit of that particular cultivar. The words “mature “and “ripe” are essentially synonymous when used to describe these fruits that ripe on the plants known as non-climacteric. However, in case of climacteric fruits a mature fruit require period before attaining a desirable stage of edibility.

Table 1. List of climacteric and non-climacteric fruits

Climacteric	Non-climacteric
Apple	Carambola
Apricot	Cherries
Avocado	Citrus
Banana	Grape
Ber	Litchi
Cherimoya	Loquat

Fig Guava Kiwifruit Mango Melons Pear Peach Plum Persimmon Papaya Tomato Sapota Passion fruit	Olive Pineapple Pomegranate Strawberry

Changes during Fruit Ripening

1. Cell Wall Changes

Cell wall consists of pectic substances and cellulose as the main components along with sma1amounts of hemicellulose and non-cellulosic polysaccharides. In cell wall, the changes particularly in the middle lamella which is rich in pectic polysaccharides are degraded and solubilised during ripening. During this softening, there is a loss of neutral sugars (galactose and arabinose-major components of neutral protein) and acidic pectin (rhamnogalacturonan) of all cell wall. The major enzymes implicated in the softening of fruits are pectine1asterase, polygalacturonase cellulase and β-galactosidase.

2. Starch

During fruit ripening sugar levels within fruit tend to increase due to either increased sugar importation from the plant or to the mobilization of starch reserves within the fruit, depending on the fruit type and whether it is ripened on or off the plant. With the advancement of maturity, the accumulated starch is hydrolysed into sugars (glucose, fructose or sugars) which are known as a characteristic event for fruit ripening. Further breakdown of sucrose into glucose and fructose is probably mediated by the action of invertase. In vegetables like potato and peas on the other hand, the higher sucrose content which remains high at fresh immature stage, converts into starch with the approach of maturity.

3. Organic Acids

With the onset of fruit ripening there is downward trend in the levels of organic acids. The decline in the content of organic acids during fruit ripening might be the result of an increase in membrane permeability which allows acids to be stored in the respiring cells, formation of salts of malic acid, reduction in the amounts of acid translocated from the leaves, reduced ability of fruits to synthesize organic acids with fruit maturity, translocation into sugars and dilution effect due to the increase in the volume of fruit.

4. Colour

With the approach of maturation, the most obvious change which take place is the degradation of chlorophyll and is accompanied by the synthesis of other pigments usually either anthocyanins or carotenoids. They can give rise to a wide range of colours (from red to blue). The chloroplasts in green immature fruit generally lose chlorophyll on ripening and change into chromoplasts which contain carotenoid pigments. Carotenoids are normally synthesized in green plant tissue a major product being 3-carotene. However, in many fruits additional - carotene and lycopene is synthesized during ripening.

5. Flavouring Compounds

Although fruit flavour depends on the complex interaction of sugars, organic acids, phenolics and volatile compounds but the characteristic flavour of an individual fruit or vegetable is derived from the production of specific flavouring volatile. These compounds are mainly esters, alcohols, aldehydes, acids and ketones. At least 230 and 330 different compounds in apple and orange fruits have been indicated respectively.

6. Ascorbic Acid

L-ascorbic acid (Vitamin C) is the naturally occurring ascorbic acid in fruits. A reduced amount of ascorbic acid is noticed in pome, stone and berry fruits at the time of harvest. An increase in ascorbic acid content with the increase in fruit growth has been and the levels declined with the advancement of maturity and onset of fruit ripening in pear, sweet potatoes, potato, asparagus and okra during the course of post harvest handling.

7. Phenolics

The phenolic content of most fruits declines from high levels during early growth to low levels when the fruit is considered to be physiologically mature and thereafter susceptible to the induction of ripening.

8. Amino Acids and Proteins

Decrease in free amino acid which often reflects an increase in protein synthesis. During senescence the level of free amino acids increases reflecting a breakdown enzymes and decreased metabolic activity.

9. Ethylene Production and Respiration

Physiological events responsible to ripening process are as follows

(1) Ethylene production

(2) Rise in respiration

Ethylene production

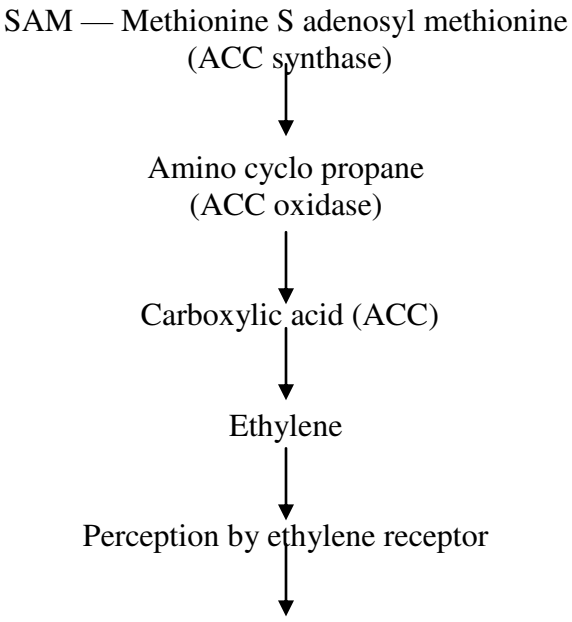
In climacteric fruits such as mango, banana, ethylene production increase and causes:

• Rise in respiration

• Rise in temperature

• Rise in activity of hydrolytic enzymes.

Ethylene is produced from an essential amino acid — methionine. Following the steps as below:



Signal transduction

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Switching or ripening genes

Rise in respiration

Respiration is required for releasing energy and the substrate for synthesis of several organic compounds required in the ripening process. During ripening in climacteric fruits, there is rise in respiration called climacteric. The clirnacteric peak is obtained very fast when temperature is relatively high. Respiration is a most deteriorating process of the harvested fruits and vegetables which leads to the oxidative breakdown of the complex materials (carbohydrates or acids) of cell into simpler molecules (CO_2 and water) with the concurrent production of energy required by the cell for the completion of chemical reactions. In brief, the process of respiration can be summed up with the following reaction:

$C_6H_{12}0_6 + 6O_2 \longrightarrow 6\ CO_2 + 6\ H_20 + \text{energy}$

USE OF CHEMICALS FOR INCREASING SHELF LIFE OF FRUITS AND VEGETABLE

(A) Ethylene absorbent

Ethylene is responsible for decreasing shelf life. Putting $KMNO_4$ @ 100 ppm soaked filter paper can minimized ripening and increase shelf life. In Banana this method is very useful.

(B) Antifungal Agents

- SOPP: Sodium orthophenylphenate
- Diphenyl wraps protection against moulds, stem-end rot.
- Dibromoletrachloroethane and esters give better flavour.

(C) Use of Inhibitors

Treatment	Crop	Chemical	Concentration
Post-harvest	Mango	MH	1000-2000 ppm
After fruit formation	Apple	2-Dimethyl-hydrazide	10,000 ppm

(D) Use of Auxins

Also helpful to advance in ripening and may increase shelf life.

Chemical	Concentration	Crop	Stage
2,4-D	5 ppm	Grape	Pre-harvest
2,4,5-T	25 ppm	Fig	Pre-harvest
2,4,5-T	100 ppm	Mango	After harvesting

E) Vegetables can be preserved by lactic acid and may increase the shelf life.

F) Post harvest dipping of papaya fruits either in l00 ppm GA_3 or $CaCl_2$ al 2% extended shelf life up to 9 days without any decline in quality.

Lecture 13

Ripening changes – related enzymes.

RIPENING

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

S.No.	**Events**	**Quality Parameters**
1.	Seed maturation	
2.	**Change in pigmentation**	Colour
	Degradation of chlorophyll	
	Unmasking of existing pigments	
	Synthesis of caroteniods	
	Synthesis of 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 C2H4 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 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.

1. 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.

2. 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 example Sweet corn (baby corn) have high levels of metabolic activity, because they are harvested at immature stage. Eating quality is determined

by flavour 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 fibre 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 flavour is often less important than texture, as many of these vegetables are cooked and seasoned with salt and spices.

Factors affecting ripening

1. Temperature
2. RH
3. Atmospheric composition
4. Ventilation
5. Ethylene source
6. Maturity stage
7. Auxin level
8. Physical injury
9. Chilling injury

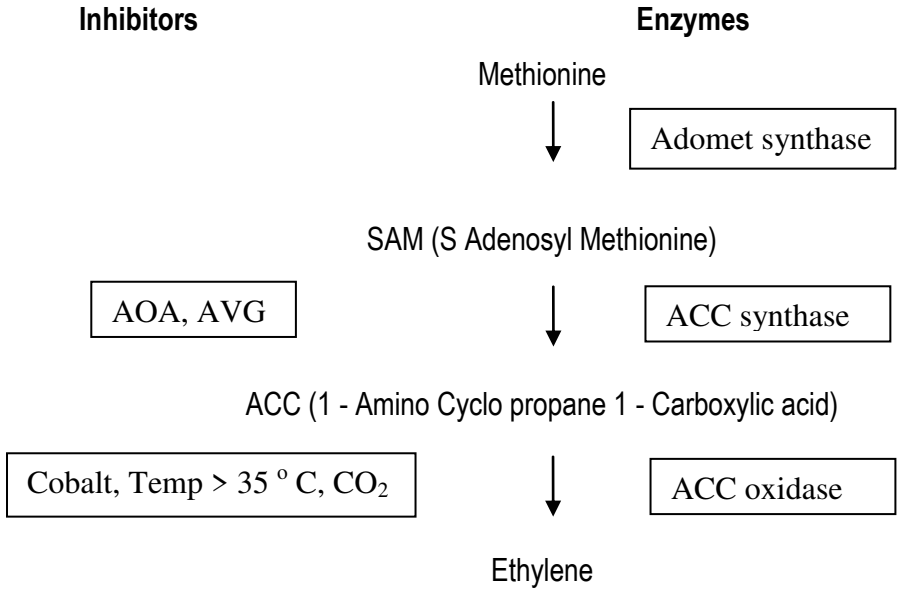
In 1901, a Russian scientist named Dimitry Neljubow showed that the active component was **ethylene** (Neljubow, 1901). Doubt **discovered** that **ethylene** stimulated abscission in 1917 (Doubt, 1917). It wasn't until 1934 that Gane reported that plants synthesize **ethylene** (Gane, 1934).

Ethylene is a natural plant hormone released by all plant tissues. It is called as Ripening hormone as it plays an important role in ripening process. 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. 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 small quantities of ethylene 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. Ethylene decides the post harvest life of fruits, vegetables and cut flowers. Synthesis of ethylene varies with maturity of fruits, vegetables and flowers. Synthesis of ethylene is less in young buds while it is more in opened and senescing fruits, vegetables and flowers.

Endogenous ethylene production takes place in the style which triggers wilting and senescence of flowers. The most accepted pathway for synthesis of ethylene is methionine pathway.

Biosynthesis of ethylene



AOA - Aminooxyacetic acid AVG - Amino ethoxy vinayl glycine

ACS - ACC Synthase ACO - ACC oxidase (Ethylene forming enzyme. EFE)

Factors governing the activity of ACC synthase

10. Stage of senescence

    Production of ethylene is less in young flowers. Production of ethylene increases during flower maturation, opening and senescence of flowers.

11. Auxin level

    During pollination, auxin is transferred from pollen to stigma. Auxin induces the production of ethylene. This auxin induced ethylene increases the synthesis of ethylene

12. Physical injury

    Physical injury induces the synthesis of ethylene

13. Chilling injury

    Chilling injury induces the synthesis of ethylene

Action of ethylene

C_2H_4 + Receptor (Copper) $\longrightarrow$ C_2H_4 - Receptor complex

Accelerate senescence

Ag^{++} replaces the copper which delays the senescence

Classification of horticultural commodities based on ethylene production rate

Class	Range at 20° C (μC_2H_4 kg / hr)	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

Sources of ethylene

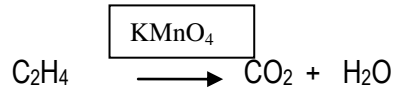
1. Ethylene gas – Pure C_2H_4 gas enclosed in the can/cylinder is sprayed /injected into chamber. Ethylene portable can which contain 3 g sufficient to ripe 2-6 ton of produce is available commercially
2. Ethephon – Used as spray/ dip, acidic in water releases C_2H_4
3. Ethylene mixture - C_2H_4 + inert 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

Harmful effects of ethylene in flowers

1. Accelerates senescence, aging of flowers
2. Abscission of leaves and flowers
3. Sleepiness in carnation
4. Fading and wilting of sepal tips in orchids
5. Blasting of buds and abscission of petals in lilies
6. Bud sleepiness and bluing of petals in tulip
7. Flowers sensitive to ethylene are carnation, alstroemeria, lily, orchids and sweet pea. These flowers are very sensitive at the concentration of 1 - 3 ppm of ethylene. Sensitivity of flowers to ethylene depends on the presence of ethylene receptors.

Removal of ethylene

1. Eliminate th ethylene sources
2. Provide proper ventilation
3. $KMnO_4$ oxidizes the ethylene



4. Brominated or activated charcoal absorbs ethylene

Ethylene inhibitors

1. Silver nitrate ($AgCl_2$)
2. Silver nitrate ($AgNO_3$)
3. Silver Thio Sulphate (STS)
4. Methyl Cyclo Propane (1- MCP)

Regulation of ethylene in storage

1. Hypobaric storage

In hypobaric storage, action of ethylene is low due to the easy movement of silver ions at low pressure.

2. Controlled atmosphere storage

The rate of ethylene synthesis is low at high CO_2 and low O_2.

Lecture 16

Hastening and delaying ripening.

REGULATION OF RIPENING

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 sometimes 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. 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^{o}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

- 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

The chamber is charged with ethylene gas at once to a concentration of 20 - 200 µ/lit. The chamber has to be ventilated after 24 hours to prevent the accumulation of CO_2. CO_2 Concentration should not exceed 5000 µ/lit. (0.5%) to allow personal 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).

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 required 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).

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

Preharvest operations to extend shelf life of fruits and vegetable crops

Mineral application

Use of Agro chemicals

Pre harvest application chemicals like MH on onion filed prevent them sprouting during storage.

Canopy Manipulation

A. Fruit thinning

B. Fruit position in the tree

C. Girdling

Effect of pre harvest treatments on the quality of fruit and vegetables

Pre harvest treatment	Fruits and vegetables	Effects on quality
Irrigation cutoff	Tomato	Improve TSS
High nitrogen application	Potato	Low SSC
	Broccoli	Hallow stem
	Sweet potato	Increased weight loss during storage
	Tomato	Grey wall, Internal browning, Soft rot
High potassium application	Citrus	Increasing in acidity and ascorbic acid
Calcium chloride sprays	Apple and pear	Reduce bitter pit and cork symptoms
Outside canopy	Peaches	Longer storage and market life
Leaf pulling	Peaches and nectarines	Reduce both fruit size and SSC
Girdling	Grapes	Improve bunch shape and berry size

Use of chemicals for increasing shelf life of Fruits and vegetable

(A) Ethylene absorbent

Ethylene is responsible for decreasing shelf life. Putting $KMNO_4$ @ 100 ppm soaked filter paper can minimized ripening and increase shelf life. In Banana this method is very useful.

(B) Antifungal Agents

- SOPP: Sodium orthophenylphenate
- Diphenyl wraps protection against moulds, stem-end rot.
- Dibromoletrachloroethane and esters give better flavour.

(C) Use of Inhibitors

Treatment	Crop	Chemical	Concentration
Post-harvest	Mango	MH	1000-2000 ppm
After fruit formation	Apple	2-Dimethyl-hydrazide	10,000 ppm

(D) Use of Auxins

Also helpful to advance in ripening and may increase shelf life.

Chemical	Concentration	Crop	Stage
2,4-D	5 ppm	Grape	Pre-harvest
2,4,5-T	25 ppm	Fig	Pre-harvest
2,4,5-T	100 ppm	Mango	After harvesting

E) Vegetables can be preserved by lactic acid and may increase the shelf life.

F) Post harvest dipping of papaya fruits either in l00 ppm GA_3 or $CaCl_2$ al 2% extended shelf life up to 9 days without any decline in quality.

Types of packaging materials

PACKAGING

- Packaging is defined as a mean or system by which a fresh produce or processed product will reach from the production center to ultimate consumer in safe & sound condition at an affordable price.



FUNCTIONS OF PACKAGING

Two main functions of packaging are:

1) To assemble the produce into convenient units for handling.
2) To protect the produce during, storage and marketing.




FEATURES OF PACKAGING MATERIALS

- ✓ Non-toxic and compatible with the specific foods
- ✓ Sanitary protection
- ✓ Moisture and fat protection
- ✓ Gas and odor protection
- ✓ Light protection
- ✓ Resistance to impact
- ✓ Transparency
- ✓ Tamper proof

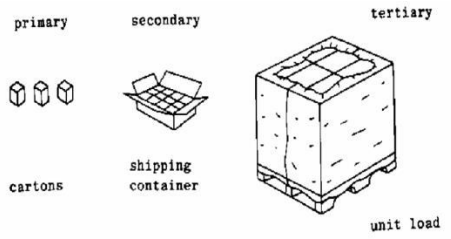
- ✓ Ease of opening
- ✓ Pouring and Reseal features
- ✓ Ease of disposal
- ✓ Appearance, printability
- ✓ Low cost

GOOD PACKAGING

- ❖ Good packaging has two purposes, which are functional and aesthetic.
- ❖ **Functional purpose** aim at extending the shelf life to the product by protecting the produce from the hazards of microbial, insect/ pest damage and physiological and biochemical changes.
- ❖ **Aesthetic aspect** of packaging aims at attracting the consumer in terms of packaging which enhances brand loyalty.

PACKAGING MATERIAL

- ❖ **Primary containers** - Those containers which directly come in contact with food. (Ex): Plastic liners
- ❖ **Secondary containers** - Don't have direct contact with food materials. (Ex): Protective cartons
- ❖ **Tertiary containers** - Generally used during shipping. (Ex): Wooden boxes, drum, cartons etc.



Packaging material for fresh produce

1. Basket made of woven strips of leaves, bamboo, plastic etc.
2. Sacks: flexible, made of plastic or jute.
    i) Bags: small size sacks

ii) Nets: sacks made of open mesh

3. Wooden crates

4. Fibreboard boxes

   i) Solid fibreboard boxes

   ii) Corrugated fibreboard boxes

5. Plastic crates

6. Biodegradable plastics

7. Pallet boxes and shipping containers

PACKAGING MATERIALS FOR PROCESSED FOODS

1. Wood
2. Glass containers
3. Metal cans
4. Aluminium foil
5. Plastic materials
6. Paper & paperboard

WOOD

- **Wood pallets-** inexpensive and discarded after a single use.
- **Pallet Bins-** primarily used to move produce from the field or orchard to the packing house.

- **Wire-Bound Crates** - sturdy, rigid and have very high stacking strength used for commodities that require hydro cooling.




- **Wooden crates and lugs-** Extensively used for apples, stone fruit and potatoes have been almost totally replaced by other types of containers.


- **Wooden Baskets and Hampers** -Durable and nested for efficient transport when empty. However, cost, disposal problems, and difficulty in efficient palletization have severely limited their use.


PAPER

- Plain paper is not used to protect foods for long periods due to poor barrier properties and is not heat sealable.
- When used as primary packaging, paper is always treated, coated, laminated or impregnated with materials such as waxes, resins or lacquers to improve functional and protective properties.

Types of Paper:

- ✓ Kraft paper- Flour, sugar and dried fruits and vegetables.
- ✓ Sulphite paper- Biscuits and confectionary
- ✓ Parchment paper- Fats such as butter and lard
- ✓ Greaseproof- Cookies, candy bars and other oily foods
- ✓ Glassine- Biscuits, cooking fats, fast foods & baked goods

PAPERBOARD

- Commonly used to make containers for shipping (secondary and tertiary packaging) - such as boxes, cartons and trays and seldom used for direct food contact.

Types of paperboard

- ✓ ***Whiteboard*:** Only form of paperboard recommended for direct food contact. Typically used as the inner layer of a carton.
- ✓ ***Solid board*:** Used to package fruit juices and soft drinks.
- ✓ ***Chipboard*:** Used to make outer layers of cartons for foods. Unsuitable for direct contact with food.
- ✓ ***Fibreboard*:** Widely used for shipping bulk food and case packing of retail food products due to its resistance to impact abrasion and crushing damage.
- ✓ ***Paper laminates*:** Dried products such as soups, herbs etc.

CORRUGATED FIBERBOARD

- ❖ Most widely used due to its relativity low cost and versatility.
- ❖ Both cold temperatures and high humidity reduce the strength of fiberboard containers.
- ❖ Cabbage, melons, potatoes, pumpkins, and citrus have all been shipped successfully in these containers.

PULP CONTAINERS

- ❖ Pulp Containers made from recycled paper pulp and a starch binder are mainly used for small consumer packages of fresh produce.

- Pulp containers can absorb surface moisture from the product, are also biodegradable, made from recycled materials, and recyclable.


PLASTICS

Two major categories of plastics.

1) **Thermosets** are polymers that solidify or set irreversibly when heated and cannot be remoulded. Not in use in food packaging applications.
2) **Thermoplastics** are polymers that soften upon exposure to heat and return to their original condition at room temperature.
    - Easily shaped and moulded into various products such as bottles, jugs and plastic films - **ideal for packaging processed fruits and vegetables.**
    - Virtually all thermoplastics are recyclable.

- Multiple types of plastics are being used as materials for packaging of food, including polyolefin, polyester, polyvinyl chloride, polyvinylidene chloride, polystyrene, polyamide, and ethylene vinyl alcohol.
- Polyolefin and polyester are the most common.

Polyolefin:

- Collective term for polyethylene (PE) and polypropylene (PP).
- Most widely used in the packaging of processed fruits and vegetables.
- PE & PP possess combination of properties like flexibility, strength, lightness, stability, moisture & chemical resistance and easy process ability.

- They can be recycled and reused.

Polyesters:

- Polyethylene terephthalate (PET), polycarbonate and polyethylene naphthalate (PEN) are polyesters.

POLYESTERS

PET:

Mainly used for beverages and mineral waters.

- Packaging containers (bottles, jars and tubs)
- Semi rigid sheets (trays and blisters)
- Thin-oriented films (bags and snack food wrappers)

Polycarbonate:

- Mainly used as a replacement for glass in items such as water bottle sand sterilisable baby bottles.

PEN:

- It has barrier properties for CO_2, O_2 & water vapours
- Superior to those of PET.
- PEN provides protection against transfer of flavours and odours and well suited for manufacturing of bottles for beverages such as beer.

Advantages

- Chemically inert/resistant, inexpensive and lightweight with a wide range of physical and optical properties.
- Offers considerable design flexibility.
- Can be formed like pots, jars, bottles, pouches, sheets etc.
- Many plastics are heat sealable, easy to print and can be integrated into production processes where the package is formed, filled and sealed in the same production line.

Disadvantages

- Variable permeability to light, gases, vapors and low molecular weight molecules

PLASTIC BAGS (POLYETHYLENE FILM)

- Very low cost material for fruit and vegetable packaging.
- Film bags are clear, allowing for easy inspection of the contents, and readily accept high quality graphics.
- Net bags are used to provide desired ventilation and allow free air movement for the produce such as citrus fruits, onions, potatoes, etc.

RIGID PLASTIC PACKAGES

- Also known as clamshells.
- Packages with a top and bottom.

- Most often used for high value produce items like small fruit, berries, mushrooms, etc.,

PLASTIC FIELD BOXES

- Usually made of PVC or polyethylene.
- Durables and can last many years.
- They can nest inside each other when empty to facilitate transport.

SLEEVE PACK

- These combine the low cost of bags and protective qualities and sales appeal of tray packs.
- The main advantage in sleeve packs is that they immobilise the produce at a fraction of cost of tray packs and the produce can be seen from all sides without damage to the fruit.

SACKS

- These are flexible shipping containers which are generally used in food industries to transport raw materials viz. fruits and vegetables from the field.
- The commonly used materials for sacks are cotton, jute, flan, woven plastics (HDPE, Polypropylene).
- These sacks are advantageous to use as they cost less, have high strength, reusable and require little space for the empties.

INNOVATIVE PACKAGING FOR FRUITS AND VEGETABLES

SHRINK WRAP

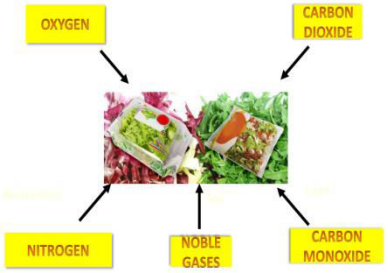
- Shrink wrap (shrink film) is a material made up of polymer plastic film. On heating, it shrinks tightly over whatever it is covering.
- Heat can be applied with a hand held heat gun and film can pass through a heat tunnel on a conveyor.
- Benefits include **prolonged shelf life, protect the produce from disease, reduce mechanical damage and provide a good surface for stick-on labels**.
- Successfully used to package potatoes, sweet potatoes, apples, onions, sweet corn.

Modified Atmospheric Packaging

- MAP is the replacement of the normal atmosphere within the package with a single gas or mixture of gases that is suited to the food in question
- Modifying the atmosphere surrounding a food product by
    - Vacuum
    - Gas flushing
    - Controlled permeability of the pack.
- Result in controlling the biochemical, enzymatic and microbial actions so as to decrease the main degradation that might occur.

GAS MIXTURES USED IN MAP

- Gas combinations added comprise **carbon dioxide, oxygen and nitrogen**.
- There are three types of gas mixtures used in MAP
    - Inert packaging (N_2)
    - Semi-reactive blanketing (CO_2/N_2 or $O_2/CO_2/N_2$)
    - Fully reactive blanketing (CO_2 or CO_2/O_2)



Advantages of MAP

- Longer durability and shelf life of perishable food / Decrease of spoilage
- Reduces the growth of microorganisms
- Natural color of the product is preserved
- Little or no need for chemical preservatives
- Product retains its vitamin content, taste and fat content
- Reduction in retail waste
- Improved presentation-clear view of product
- Hygienic stackable pack, sealed and free from product drip and odor

VACUUM PACKAGING

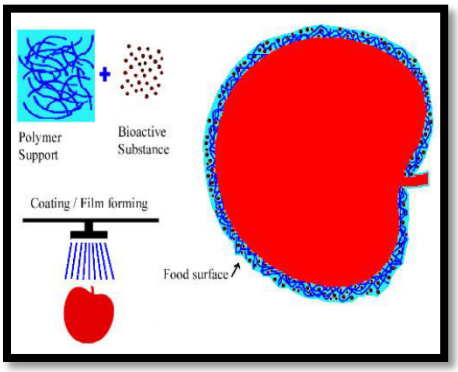
- It is a method of packaging that removes air from the package prior to sealing.
- It involves placing items in a plastic film package, removing air from inside, and sealing the package.
- The intent is usually remove oxygen from the container to extend the shelf life of foods and, with flexible package forms, to reduce the volume of the contents and package.

ANTIMICROBIAL PACKAGING

- Use of **anti-microbial compounds** incorporated in edible coatings

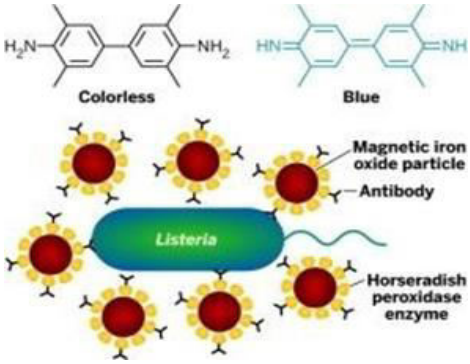
  Examples

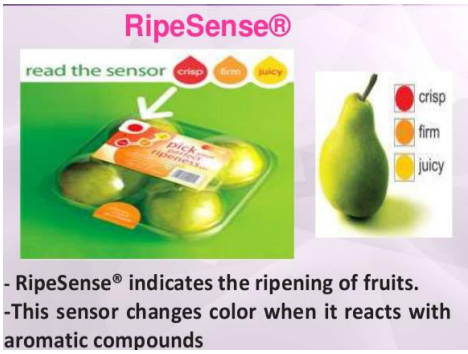
  - Organic acids
  - Fatty acid esters
  - Polypeptides
  - Plant essential oils.



INTELLIGENT PACKAGING

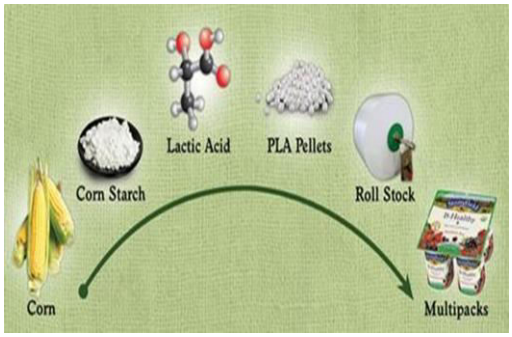
- Package function switches on and off in response to changing external or internal conditions and communicate to the consumer about the status of the product
- Communicate the degradation of product or microbial contamination.
- Provides real-time status of food freshness (e.g) Ripesense, onvu.





BIODEGRADABLE/EDIBLE PACKAGING

- Use of bio-degradable polymers to overcome environmental problems arising out of the use of non bio-degradable materials
- Biodegradable polymers from such as vegetable oil, corn-starch, potato-starch or microbia were under research.
    - **Polylactic Acid (PLA) plastics**
    - **Polyamides 11**



Common Package Recommended

Produce	**Common package recommended**
Soft fruits	Semi rigid containers
Hard fruits	Open tray
Stem products	Bags or wrappers
Root vegetables	Polyethylene bags

Green vegetables	Polyethylene or polystyrene bags

COMMON PACKING MATERIAL

Package material	**Vegetable and Fruits**
Gunny bags	Lemon, Lime, Raw mango, Sand Pear, Sweet Orange, Capsicum, Cabbage, Peas, Potato, Sweet potato , Radish , beetroot , turnip
Bamboo basket	Grape, Guava, Mango, Papaya, Lemon, Okra, Radish, Carrot
Earthen pots	Custard apple, Grape
Wooden boxes	Apple, Apricot, Cherry, Litchi, Mango, Mandarin, Pear, Plum, Sapota, Tomato, Capsicum,
CFB	Apple, Cherry, Grape, Pomegranate and fruits for export, Capsicum, Chilly
Rigid plastic crates	Loose fruits for public distribution system

CUSHIONING MATERIALS

- Defined as "**anything that provides support against mechanical damages during, harvest, handling, storage and transport**"

FUNCTIONS

Main functions of cushioning materials are:

1) Protection from mechanical damage
2) Protection from damage due to vibration and compression
3) Protection of commodity from rubbing against each other.
4) Protection from infection transfer
5) Protections of moisture vapor barriers at point of contact
6) Filling of void space in the container

PROPERTIES OF IDEAL MATERIALS

1)Should have flexibility

2) Should be able to dissipate heat of respiration of produce
3) Should be free from infection
4) Physiologically inactive
5) Non hygroscopic and should not promote corrosion
6) Environment compatible and cost-effective
7) Provide mechanical protection against impact, compression and rubbing.
8) Should not contain substances and materials which could eventually interfere with the packed commodities.

NATURAL CUSHIONING MATERIALS

- Derived from plants
- Mostly **used in packaging fresh horticultural produce.**
- **Examples**

- Paper shreds

- Agricultural wastes like straw, hulls, leaves etc.


PADDY STRAW

- Paddy straw is a natural cushioning material
- widely used for packaging of fruits and vegetables for near or in country markets.
- paddy straw is done by keeping the cushioning materials between rows of fruits and layers of fruits inside the boxes.
- It prevent them from damaging, when there is a vibration and impact.
- It also serves as a cushion during unloading the produce on the ground

COCONUT FIBER

- Coir or coconut fibre is a natural fibre extracted from the husk of coconut and used as a cushioning material for perishable produce .
- Coconut fiber and wood straw is being used to prevent damages to papayas and mangoes during the distribution.

LEAVES

- Leaves of various plants (particularly Cassia, Polyalthia, Litchi and Mango) are used as cushioning materials.

- banana leaves and teak leaves as wrapping materials - guava
- neem (*Azadiracta indica*) leaves, rice straw, and bamboo leaves as cushioning materials for guava fruits during storage.
- leaves of *Azadiracta*, melia, mentha, walnut, banana and camphor were also used as cushioning materials in apple packages.

Advantages

- Low cost, Easily available, environment friendly
- Good damping characteristics
- Good shock absorption capacity
- Some have anti-fungal and anti-bacterial effects.

Disadvantages

- Become wet and they lose their cushioning property
- Provide good medium for growth of fungi and bacteria.
- Resilience is poor
- Poor fungus resistance
- High compression set

SYNTHETIC CUSHIONING MATERIALS

TRAY OR CELL PACKING

- It are used for packing and transportation of apples, pears, tomatoes, melons, stone fruit and many other fruits .
- They are recyclable, efficient and sustainable.
- generally made from moulded pulp paper or plastic.

- Tray or cell packing offers protection of produce from stacking pressure as well as from impact with each other.

CRATE LINERS

- Crate liners are used as cushioning materials in plastic crates during transport and storage and provide cushioning to individual commodities and liners.
- These are made of three ply corrugated fibre board to reduce the bruising and other duration damage of fruits and vegetables .

FOAM NET

- The most common are: expanded polystyrene, polypropylene, polyethylene, and polyurethane.
- This makes the fruits attractive and provides the necessary cushioning and separation of fruits from each other.
- These are soft, light in weight and provide sufficient ventilation .

BUBBLE FILMS

- It consist of two plastic films; one of which is completely flat and the other has small, round .
- Used inside packaging containers to form the lining of the container and acts as a heat deflector and insulator.
- It provides protection from damage caused by shock, vibration or abrasion, easy to use.
- Easy to handle, non-hygroscopic, versatile, and insensitive to extreme climatic conditions , ideal shock absorption characteristics.
- Disadvantage - susceptible to pointed and sharp objects which make it subject to puncture.

Synthetic foams


Thermoformed plastic trays


Advantages

- Highly resilient

- Good shock absorption capacity
- Some are resistant to moisture
- Can be molded according to produce
- Resistant to microbial infection
- Retains cushioning ability in unfavorable circumstances

Disadvantages

- High cost
- Not easily available at farm level
- Take high time to degrade
- Non environment friendly

CUSHIOING MATERIAL FOR CUT FLOWER

CUT FLOWER	CUSHIOING MATERIAL
Alstroemeria	CFB sleeve
Anthurium	Shredded newspaper and other shredded paper
Bird of paradise	Waxed Paper Bags or moist shredded paper
Red Ginger	Moistened shredded newspaper
Heliconia	Moistened shredded newspaper
Orchids	Shredded Paper ,Shredded Wax Paper
Roses	Palstic + waxed paper + soft corrugated card sleeves

CUSHIOING MATERIAL FOR ROSE

- Packaging and cushioning of fruits and vegetables is an essential part of processing - **ensures the safety and maintains value of food.**
- Good packaging helps to **reduce post harvest losses** in post harvest fruits and vegetables.
- Proper understanding of packaging materials/containers used for processed fruits and vegetables will help food processor to choose appropriate packaging system thereby reducing the losses.

Types of cushioning materials

Definition

Cushioning material may be defined as "anything that provides support against mechanical damages during, harvest, handling, storage and transport."The fundamental role of a cushioning material is to reduce the forces created during sudden contact of one surface with another, which prevents compression or deforming damages and minimizes damaging impact forces.

Functions of cushioning materials

- Protection from mechanical damage
- Protection from damage due to vibration and compression
- Protection of commodity from rubbing against each other.
- Protection from infection transfer
- Protections of moisture vapour barriers at point of contact
- Filling of void space in the container

Properties of cushioning materials

- ★ Flexibility
- ★ Dissipate heat of respiration of produce
- ★ Free from infection
- ★ Physiologically inactive
- ★ Non hygroscopic
- ★ Environment compatible & cost effective
- ★ Mechanical protection
- ★ Must preserve the commodities inherent properties.

CLASSIFICATION OF CUSHIONING MATERIALS

Cushioning materials can broadly be classified into two ways:

1) Based on uses and

2) Based on origin.

On the basis of uses three basic categories of cushioning materials are - space fillers, resilient cushioning materials and non-resilient and rigid cushioning materials. On the basis of origin cushioning materials can be classified into – natural and synthetic types.

Space Fillers

These are mainly used to fill the voids in the packages as dunnage to prevent reorientation of the items and sometimes to absorb liquid commodities spilled from the broken unit containers.

Resilient cushioning materials

These are used to protect packed commodities from damage due to repeated shocks. Materials falling in this group have compressibility and must be able to return to their original condition after each shock. They should be able to absorb shock energy without exerting too much force on the item. The force displacement curve of the resilient cushioning materials falls into three groups as linear, tangent and anomalous type

Non resilient and rigid cushioning materials

These are used for protecting packaged items from a single severe shock as is experienced in an air dropping. These materials absorb shock by the collapse of their structure and cannot return to their original shape after the shock. The force displacement curve of these materials falls in the category of anomalous type. The force is constant upto the collapse of their structure. They are normally used to cushion items intended for air dropping.

CLASSIFICATION BASED ON ORIGIN

On the basis of origin the cushioning materials can be classified as- natural and synthetic.

Natural cushioning materials

The natural cushioning materials are derived from plants and widely used in packaging fresh commodities. Natural cushioning materials are mostly used for fresh horticultural produce. The examples of natural cushioning material are paper shreds and agricultural waste commodities like straw, hulls, leaves etc.

Paper shreds

Sheets of newspaper or shredded newsprint are commonly used as a lining material in bamboo and plastic crates or CFB boxes (FAO, 2011). Shredded papers or tissues are the most economical and eco-friendly packaging solution for packaging perishable produce safely to transport them over long distances .

Cushioning of fruits with shredded newspaper

Agricultural waste

Agricultural waste, such as paddy straw, leaves, coconut fiber, cotton and rice hulls, are sustainable and compostable. Rice hulls, coconut fiber and wood straw have been used to prevent damages to papayas and mangoes during the distribution Banana leaves and Teak leaves have been used as cushioning materials for guava fruits during storage . These are examples of the sustainability movement.

Paddy straw

Paddy straw is a natural cushioning material and widely used for packaging of fruits and vegetables for near or in country markets. Cushioning by paddy straw is done by keeping the cushioning materials between rows of fruits and layers of fruits inside the boxes. The function of paddy straw is to fix the fruits and vegetables inside the packages and prevent them from damaging, when there is a vibration and impact. It also serves as a cushion during unloading the produce on the ground .

Coconut fiber

Among all the natural fibers available for cushioning material, coconut fiber is becoming one of the most used in the development of environmentally friendly produces, probably due to its characteristic of being an agricultural waste. In general, coconut fiber presents good properties in reinforcing composite, acoustic and thermal insulation materials. Coir or coconut fibre is a natural fibre extracted from the husk of coconut and used as a cushioning material for perishable produce . Coconut fiber and wood straw is being used to prevent damages to papayas and mangoes during the distribution.

Leaves

Leaves of various plants (particularly Cassia, Polyalthia, Litchi and Mango) are used as cushioning materials. Banana leaves and teak leaves as wrapping materials for guava while neem (*Azadiracta indica*) leaves, rice straw, and bamboo leaves as cushioning materials for guava fruits during storage. In a study leaves of *Azadiracta*, melia, mentha, walnut, banana, basooti, and camphor were also used as cushioning materials in apple .

Rice hulls

Rice hulls are natural and environmental friendly waste commodities. They are light, bio-degradable, difficult to burn and less likely to allow moisture to propagate. Two types of rice hulls are used- loose rice hulls and bagged rice hulls. The problem with loose rice hulls is when they are subjected to moisture they become denser thus less effective in shock absorption and are harder to handle due to its small grain and light weight. In addition they tend to stick to the commodities inside the bag. Bagged rice hulls increase the shock absorption capacity, easier to handle and provides double protection.

Loose and bagged rice hulls to be used as cushioning material

Advantages of naturally derived cushioning materials

Low cost, environment friendly

- Good damping characteristics
- Good shock absorption capacity
- Easily available, naturally derived
- Some of them have anti-fungal and anti-bacterial effects.

Disadvantages of naturally derived cushioning materials are-

- When they become wet they lose their cushioning property
- Provide good medium for the growth of fungi and bacteria.
- resilience is poor

- poor fungus resistance
- High compression set

SYNTHETIC CUSHIONING MATERIALS

Tray or Cell packing

Pulp trays and cells are used for packing and transportation of apples, pears, tomatoes, melons,stone fruit and many other fruits. Each tray is designed specifically to offer the maximum cushioning and protection to the produce and available in a wide range of colours and sizes.These are recyclable, efficient and sustainable. Produce is placed in an individual compartmentof a tray or cell stacked in a transport container. Trays are generally made from moulded pulp paper or plastic. Cells are usuallyformed from corrugated board. Produce should be of uniform size in order to fit properly inmoulded tray compartments. The tray pack pattern has become increasingly common for produce packing as it is a simple and convenient system, with an appealing appearance.

Crate liners

Crate liners are used as cushioning materials in plastic crates during transport and storage and provide cushioning to individual commodities and liners. These are made of three ply corrugated fibre board to reduce the bruising and other duration damage of fruits and vegetables.

Foam net

Several types of polymeric foams are used for cushioning. The most common are, expanded polystyrene, polypropylene, polyethylene, and polyurethane. This makes the fruits attractive and provides the necessary cushioning and separation of fruits from each other. Theseare soft, light in weight and provide sufficient ventilation. Good interior packaging as the one which treats a fruit as separate units, avoids fruit-to-fruit contact and absorbs the impact energy. At present, foam nets function well as one of the commercial packaging solutions. Foam nets are also being used in 'Pattern packing or Placepacking'. It is a kind of packing in which produce is generally placed by hand in a pattern, in the package. This kind of packaging generally provides higher density packing ascompared to random packing. Pattern packs are less vulnerable to produce damage, are more uniform and are more appealing in appearance. Pattern packing is generally used for relatively expensive, premium quality produce for high-end or export markets

Bubble films

Bubble films consist of two plastic films; one of which is completely flat and the other has small,round indentations. These two films have been heat sealed together, containing the necessary air.Bubble films are mainly used inside packaging containers to form the lining of the container and acts as a heat deflector and insulator. Bubble cushioning material provides outstanding protection from damage caused by shock, vibration or abrasion, easy to use. Bubble films are easy to handle, non-hygroscopic, versatile, and insensitive to extreme climatic conditions and have idealshock absorption characteristics. The major disadvantage is that these are susceptible to pointed and sharp objects which make it subject to puncture. Plastic bubble film is used as cushioning inbetween the banana hands and to line the inside faces of the box

Thermoformed plastic trays

These are trays made from thermoplastics which can be softened by heating and hardened by cooling. These are generally made of polystyrene, polypropylene (PP) and polyvinyl chloride(PVC). This offers rigid

packaging as well as a great cushioning effect and immobilizes the produce within the pack . These trays are clean, neat in appearance and light in weight.They give a cushioning effect to the commodities packed inside. The trays can be easily moulded in any size and shape. The materials used can be easily cleaned, re-used and is also recyclable.

Advantages of synthetic cushioning materials

- ★ Highly resilient
- ★ Good shock absorption capacity
- ★ Some are resistant to moisture
- ★ Can be moulded according to produce
- ★ Resistant to microbial infection
- ★ Retain their cushioning ability in unfavourable circumstances also

Disadvantages of synthetic cushioning materials

- ★ High cost is a constraintNot easily available at farm level
- ★ Take high time to degrade
- ★ Non environment friendly

Moisture Absorber

Moisture Absorbers are internationally used in containers and protects valuable produce againstfungi and corrosion; used in exports of fruits and vegetables, spices, groundnuts and tea. Singh *et al.* (2016) used desiccant mixture of bentonite 0.55 g + sorbitol 0.25 g + CaCl2 0.20 g/g asmoisture absorber to increase the shelf life of white button mushrooms .

Operation specific use of cushioning material for fruits and vegetables

Cushioning materials are used in many stages during postharvest handling operations. However, in order to maintain postharvest quality of produce it becomes necessary at three main stages:

i) At the time of keeping harvested produce into any rigid storage container . All crates have hard surfaces and while keeping produce inside, there is a chance of dropping off from little height, causing impact bruising popularly called touching marks;

ii) During transportation from field to pack houses. In general, plastic crates are used for transportation from field to pack house and the distance may vary from very short too long. Based on the road conditions,there would be impact and vibration bruising; this type of bruising may not be visible immediately, but after few days, browning/pitting or blackening symptoms may developresulting in rotting of produce. Cushioning materials if used in plastic crates reduce thesebruising and touching marks drastically;

iii) During transportation of packed produce frompack house to destination markets. Loading, unloading, and transportation jerks are alsoresponsible for bruising.

Therefore, it is recommended to use cushioning material in packages topreserve postharvest quality of fresh produce (Ahmed and Siddiqui, 2015).Generally cushioning materials are used during harvesting, handling and transportation of produce.

Cushioning materials for cut flowers

Cushioning materials are equally important for cut flowers as they are very sensitive tomechanical damages. There are many shapes of packing containers for cut flowers, but most are long and flat and a full telescoping design .This design restricts the depth of the flowers in the box, which may in turn reduce physical damage of the flowers. In addition, flower heads can be placed at both ends of the container for better use of space. With this kind of flower placement, whole layers of newspaper have often been used to prevent the layers of flowers from injuring each other.

The use of small pieces of newspaper to protect only the flower heads, however, is a better practice, since it allows for moreefficient cooling of flowers after packing. It is critically important that containers be packed insuch a way that transport damage is minimized.Materials used for sleeving include paper (waxed or unwaxed), corrugated card (smooth sidetowards the flowers) and polyethylene (perforated, unperforated and blister). Sleevescan be preformed (although variable bunch size can be a problem), or they can be formed around each bunch using tape, heat sealing (polyethylene), or staples.

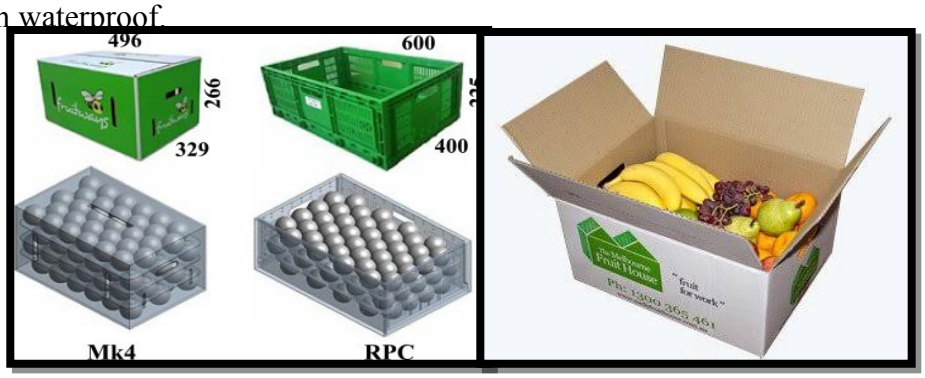
Preparation for market, pre–cooling, cooling, storage

Pre-Cooling

It means removal of **field heat** from freshly harvested fruits and vegetables to reduce loss in quality of produce. Important step in post harvest stage of Perishable produce industry. Entire products must be precooled as early as possible to recommended Storage temperature and Relative humidity.

Pre-cooling depends on the following factors

- Air temperature during harvesting.
- Time between harvest and precooling.
- Nature of the crop.
- Difference in temperature between crop and cooling medium. Cooling medium used are air, water or gas.
- Nature/velocity of cooling medium.
- Rate of transfer of heat from crop to cooling medium.
- Types of Package materials used are Water proof ventilated boxes for good air circulation in room, Plastic boxes or fibre board cartons treated with wax is benefit than waterproof.



Heat within the Crop comes in two Ways

1. Through the convection from surrounding air mainly from the sun in the form of radiation.
2. From the metabolic heat from chemical reactions within the crop(Respiration).

PRE-SORTING

- It is usually done to eliminate injured, decayed and other unwanted produce before cooling and handling.

MECHANISM OF PRE-COOLING

Conduction and Convection are the two main heat transfer mechanisms used for cooling of produce. Potatoes apples, cauliflower, oranges and other fruits (Bigger mass & lesser surface area) and vegetables require more time to precool than produce having smaller mass & large surface area like lettuce, peas, corn etc. The rate of precooling depends on individual volume &exposed surface of product. The difference in temperature between product and refrigerating medium also needed. For Eg: Large exposed surfaces, leafy

vegetables cool almost 5 times faster than large fruit such as melons(more volume, less surface).

TYPES OF PRE-COOLING

1. Using Cold Air

- Room cooling
- Forced air cooling/Pressure cooling

2. Cold water / Hydro cooling

3. Top icing

4. Evaporation of water from produce:

- Evaporative cooling
- Vacuum cooling

5. Hydrovac cooling

ROOM COOLING: Heat is transferred slowly from the mass of the produce(by convection) to the cold air being circulated around the stacked containers. Most common & widely used method. Here cold air is passed from the fan & cool by convection process. Here cold air from evaporator enters the room, moves horizontally & passes through the produce containers and return to the evaporator. Its common use is for products with relatively long storage life & marketed soon after harvest.

ADVANTAGES

- Produce can be cooled & stored in the same room without the need of transfer and it is economical.
- Eg :All fruits and vegetables ,mainly used crops are citrus, potato, onion, garlic.

DISADVANTAGES

- It takes more time to cool the products, removal of heat slowly makes this system unsuitable for highly perishable commodities.

FORCED AIR COOLING /PRESSURE COOLING

- 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.Air is blown at high velocity leading to desiccation of crop,to minimize this effect air is blown through cold water sprays.Adequate airflow is necessary.Also called as High Humidifier,high RH of 90-95%maintained in precooler to avoid dehydration during cooling.
- Example: Baby corn =5-6 hr cooling at 2-4^{o}c
  Leafy vegetables =1-2 hr cooling at 6-8^{o}c.
- Crops pre cooled by Forced air cooling:

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

HYDRO COOLING/COLD WATER COOLING:

- Principle : “The transmission of heat from solid to liquid is faster than transmission of heat from solid to gas”. Using cold water, there is quick cooling of fruits and vegetables. Avoids water loss and may even add water to the fruit. 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 or improve nutrient status and prevent post harvest disease of the produce.
- Cooling Time : For eg: 2minutes for asparagus (long & narrow) and leafy vegetables(more surface to volume ratio)
  10minutes for small produce like capsicum (large & globular), cherries, tomato and upto 1 hour for large products such as melons.

HYDROCOOLERS

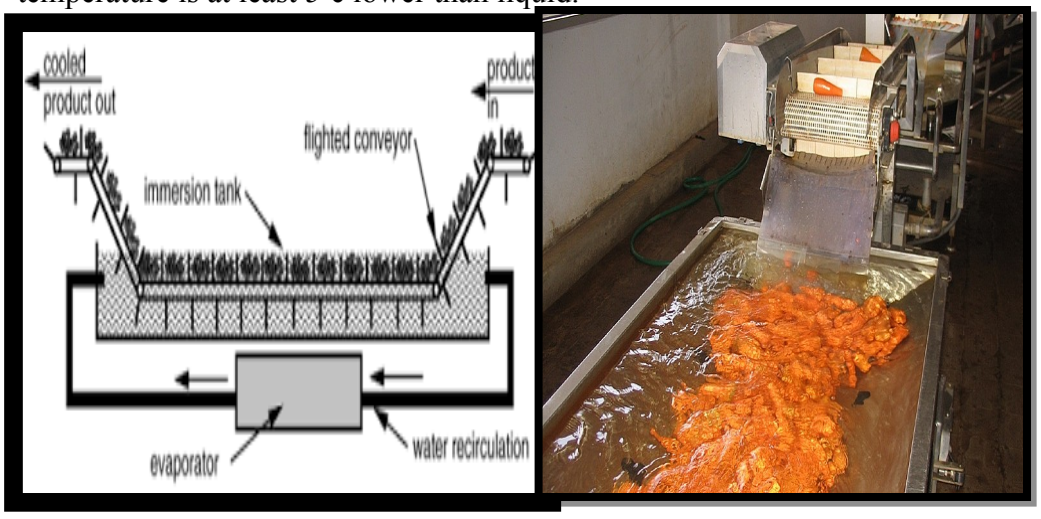
1.Shower / Batch type 2.Immersion type

SHOWER/ BATCH:

- The water showers over the commodity may be in bins/boxes or loosen a conveyor belt. Common design is to transport the crop on a perforated conveyor belt (speed of it can be adjusted to time required to cool the crop) and cold water is pumped from tank & allowed to fall on the produce in sprinkled type and then falls through the tank below them, filtered, recycled, recooled. Efficient cooling depends upon adequate water flow over product surface.

IMMERSION:

- Simplest type of hydrocooler 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 water. Best suited for products do not float. Immersion hydrocoolers convey product against the direction of water and often have a system for agitating the water. Depth of water tank should be >30 cm and water tends to penetrate inside fruits particularly those that are hallow such as peppers. It is recommended that fruit temperature is at least 5^{o}c lower than liquid.



ADVANTAGES OF HYDROCOOLING

- Helps in cleaning the produce, provides fast, uniform cooling to commodities. Faster than forced air cooling. Achieved by immersion or through chilled water shower.

DISADVANTAGES

- Tank water can be contaminated through microbes result in increased level of spoilage during subsequent storage or marketing, so chlorine should be added to avoid problems.
-

Crops suitable for Hydrocooling:

Artichoke	Carrot	Kiwifruit	Early potato
Asparagus	Cassava	Kohlrabi	Pomegranate
Beet	Celery,Cherries	Leek	Radish
Belgian endive	Chinese cabbage	Limabean	Rhubarb
Broccoli	Cucumber	Orange	Snap beans
Brussels sprout	Eggplant	Parsley	Spinach
Cantaloupe	Green onion	Parsnip	Summer squash
Cauliflower	Jerusalem artichoke	Peas	Sweetcorn

TOP ICING

Direct contact with ice and also called Package icing.It is one of the oldest ways to reduce field temperature. Commonly applied to boxes of produce by placing a layer of crushed ice directly on top of the crop. It can be applied as an "Ice Slurry"made from 60% finely crushed ice, 40%water, 0.1%Nacl to lower the melting point of ice. Ice slurry give greater contact between the produce and ice results in quicker cooling. Top-ice on loads should be applied in rows rather than solid mass. Ratio of water to ice= 1:1to1:4.Direct contact between the produce & ice provides fast, initial conduction cooling. As an ice melts, an air space is created between ice and produce and the conduction cooling stops. Subsequent cooling is by radiation and convection both of which are slower process than conduction. It is important not to block air circulation inside transport vehicle. The main use is for road and transport and can be applied shortly after harvest.

- Package ice can be used only with :
  - During transport to maintain a high RH for certain products.
  - Water tolerant, non chilling sensitive products.
  - With water tolerant packages such as Waxed fibre board, plastic/ wood.
  - It also increases costs because of heavier weight for transportation and need for oversized packages. In addition,as water melts, storage areas, containers, shelves become wet.

Crops suitable for Package icing

Belgian endive	Chinese cabbage	Leek
Broccoli	Carrot	Parsley
Brussels sprouts	Green onion	Peas
Cantaloupe	Kohlrabi	Spinach, Sweetcorn

BROCCOLI PACKAGE ICING FREEZING DAMAGE BROCCOLI FLORETS

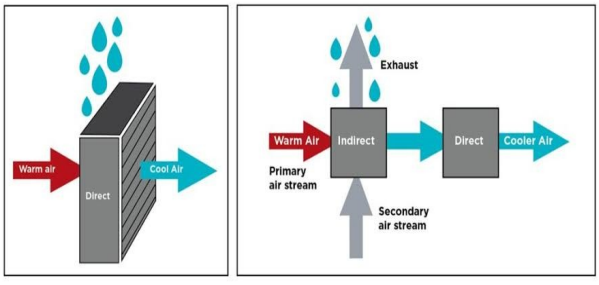
EVAPORATIVE COOLING

Evaporative cooling is a low cost technology for storage of fruits and vegetables. It is cost effective method of lowering produce temperature and increase the shelf life of produce. It is most effective in areas where humidity is low. Dry air is drawn through moist padding or fine mist of air, then through vented containers of produce. The incoming air should be less than 65% RH.As water changes from liquid to vapour, it absorbs heat from air, thereby lowering the produce temperature. It will only reduce temperature 10-15^{o}F.This method is suitable for warm season crops requiring warmer storage temperatures (45-55^{o}c) such as tomatoes,cucumbers,brinjal etc.

- **Two methods of Evaporative cooling**: 1.Direct 2.Indirect

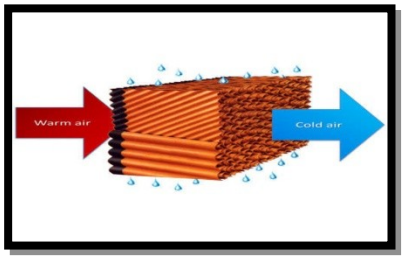
1.**Direct Evaporative Cooling**: Air is passed through a water saturated media /wetting pad and cooled by evaporation.T he cooled air is circulated by a blower. It adds moisture to airstream until the airstream is close to saturation. Then the temperature drop occurs.

2.**Indirect Evaporative Cooling** : Here two streams of air is used-Primary and Secondary.Secondary air stream is cooled by water. The cooled secondary air stream goes through a heat exchanger ,where it cools the primary air stream.The cooled primary air is circulated by a blower.Moisture content of the supply air remains constant here,while it temperature drops.Temperature drop obtained is more than direct evaporative cooling.

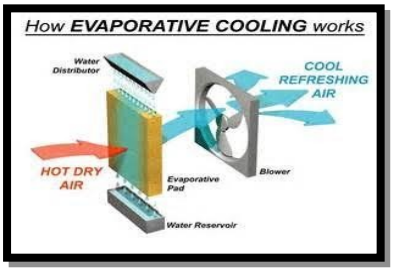


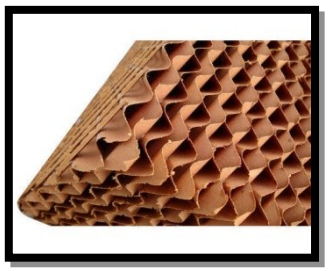
- When the heat is removed by way of evaporative cooling then the fresh produce must be sealed in moisture proof like polythene bags.
- There are two forms of direct evaporative cooling Passive and active.

1.**Passive direct evaporative cooling:** Cooling pads are placed over the entrance of the store and keep moist.



2.**Active direct evaporative cooling**: Air is drawn into the store by a fan through a cooling pad,keep moist by constantly pumping water over it.Cooling pads commonly used are Cellulose, Celdek cooling pad.





CELDEK COOLING PAD CELLULOSE COOLING PAD

- The two technologies work on the principle of direct evaporative cooling are:

1. **Zero Energy Cool Chamber**(**ZECC**) : It is developed by IARI,NewDelhi so it also called as Pusa zero energy cool chamber.

Design and Construction:

The floor of the storage space is made with a single layer of bricks over which a double walled rectangular structure is with approximately 7.5 cm space between inner and outer brick walls.Outer dimension should be 165*115*67.5cm.The cavity between two walls is filled with river sand.The top of storage space is covered with gunnycloth in a bamboo frame structure.The chamber should be constructed under a shed with lot of aeration and should be closer to water surface.

Operation :

After construction the whole structure is made wet bby sprinkling water once in evening till it saturated to mantain lower temperature and gigher 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 ,wet and dry thermometer are placed in chamber to note temperature and RH in cool chamber.

Storage life:

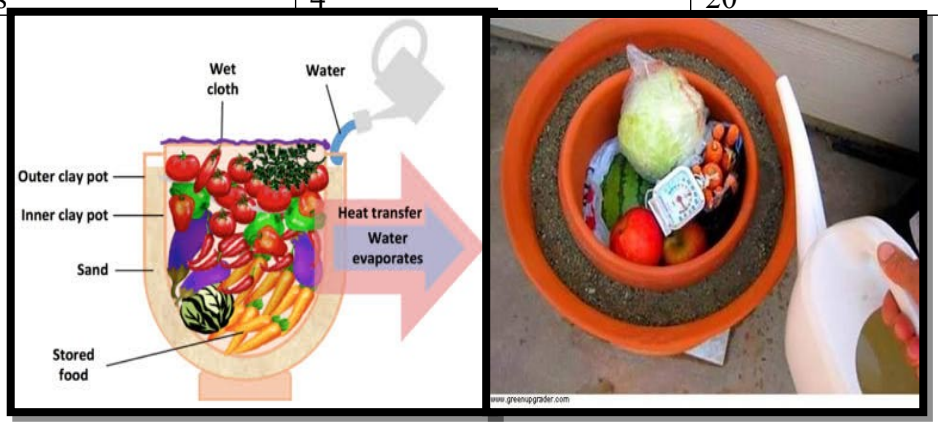
Storage life of different commodities can be increased by 2-3 times as compared to ambient conditions during summer.Examples are:Bitter gourd,cauliflower,carrot,cucumber,peas,spinach,green chillies,Okra etc.

Vegetables	Storage life (days)Ambient	Storage life(days) ZECC

Bitter gourd	2	6
Carrot	5	12
Cauliflower	7	12

2. **Clay Pot Cooler/ Pot in Pot refrigerator/ Zeer pot**: It is an refrigeration device which does not use electricity.It uses a porous outer clay pot (lined with sand) containing an inner pot (which can be glazed to prevent penetration by the liquid)within which the food is placed.The device cools as the water evaporates,allowing refrigeration in hot,dry climate.It must be placed in a dry,ventilated space for the water to evaporate effectively towards outside.

Produce	Shelf life without Zeer pot(days)	Shelf life with Zeer pot(days)
Tomatoes	2	20
Guava	2	20
Okra	4	17
Carrots	4	20



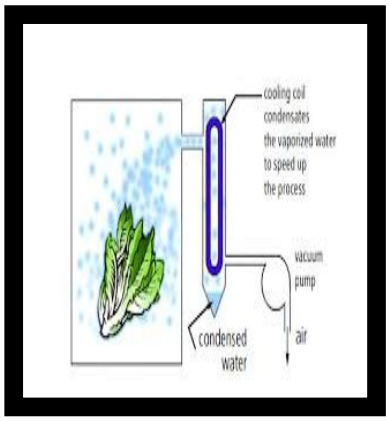
VACUUM COOLING

It takes place by water evaporation from the product at very low air pressure. 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 atmosphere around the product. It causes the water in the produce to vapourize. Cooling occurs because heat energy for vapourization comes from produce. Most rapid and uniform methods of cooling products that easily or rapidly release water may cool down rapidly. Tomato with low ratios between mass and surface area are not suitable. Water barrier like wax on surface is also not suitable. It causes about 1% product weight loss for each 50g of cooling. High cost and sophistication is needed. For leafy vegetables it is more suitable.

Crops suitable for Vacuum cooling

Beans	Corn	Mushrooms	Spinach
Carrot	Capsicum	Lettuce	Celery

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



HYDROVAC COOLING: Combination of hydro and vacuum cooling.

PRE-COOLING OF CUT FLOWERS: It is done by hydrocooling,room cooling,forced air cooling,vacuum cooling.After pre cooling it is placed in cold storage without packing or in open boxes. Pre- cooling temperature for cut flowers:

Crops	Pre- cooling Temperature(^{o}c)
Rose	1-3
Anthurium	13
Gerbera	4
Carnation	0.5-1
Chrysanthemum	0.5-4
Dendrobium	5-7
Cymbidium	0.5-4
Gladiolus	4-5
Bird of Paradise	7-8

BENEFITS OF PRE-COOLING:

- Removes field heat.
- Reduces fruit respiration rate and extends crop storage life.
- Reduce or inhibits the growth of various microorganisms ,reducing the possibility of post harvest diseases.
- Restriction of enzyme activities.
- Reduction of waterloss from harvested produce.
- Prevent wilting.
- Reduce ethylene production.
- Eases the load on the cooling system(refrigeration)of transport or storage chamber.

COLD STORAGE

One of improved storage methods , includes that refrigeration,chilling,freezing.It is a low temperature storage.Best known effective and most widely used method for extending the storage life and long term storage of fruits ,vegetables,flowers.System with thermal insulation and refrigeration in which perishable 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 produce throughout the year for direct consumption as well as processing.
  - To reduce losses due to wastage.
  - To produce the seasonal produce and selling during offseasons to get higher returns.
- Factors involved for effective cold storage of produce:
  - Product quality
  - Temperature
  - Relative humidity
  - Air circulation and package spacing.
  - Respiration rates,heat evolution,refrigeration.
  - Weight loss in storage.
  - Sanitation and air purification.
  - Temperature management.

- Refrigeration ton/tonne (RT or TOR) is the unit used to quantify the refrigeration load.
- 1 ton of refrigeration=3.517kW=210KJ/min.1 ton of refrigeration is needed to cool 18T of produce.

- **COLD STORAGE DESIGN:**
  - Selection of site
  - Orientation and building form
  - Size
  - Space requirement
  - Design of building
  - Thermal insulation=Insulating materials used are polystyrene,polyurethane,polyisocyanurate foam.
  - Refrigeration system

- Two types of refrigerants are primary and secondary refrigerants

➢ **Primary refrigerants**

It directly absorbs heat from storage space and undergo a refrigeration cycle. Example: Halocarbon compounds are R-11,R-12(CFC),R-22(HCFC) sold in market trade name as **Freon**, Azeotropes R-502(a CFC), Inorganic compound Ammonia (R-717), Air (R-729),Water (R-118) CO_2(R-744) etc.

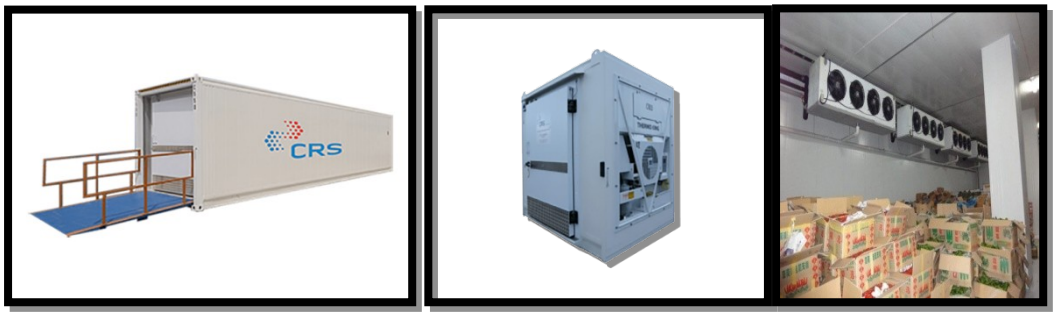
- **Secondary refrigerants:**

  It is first cooled by primary refrigerant and then absorb heat from storage space.Example:**Brine(high concentration Nacl solution**) commonly used,Cacl solution,water,ethylene glycol.

Types of Cold Storage

❖ **Refrigerated Containers**: It comes in a variety of sizes from 10-45 feet and have a temperature range of -40 to +10^{o}c.Most cold store units are portable and can be used to safely transport goods.

- **Blast freezers and Chillers**: For business, distribute frozen fruits or vegetables, rapid freezing blast chillers are a great option. Mini blast freezers are also available for small business for short space.
- **Cold Rooms**: Grade A specification cold rooms are ideal for use as both hygienic food processing areas and for fresh produce storage. Cold rooms are great solution for any business looking for custom cold storage of fruits and vegetables.



Optimum Cold Storage condition for fruits and vegetables

Fruits or vegetables	Temperature (˚C)	RH (%)	APPROX.STORAGE LIFE (WEEKS)
Apple	0-2	85-90	20-30
Avacado			
1.Chilling tolerant varieties	4.4	85-90	4
2.Chilling sensitive varieties	12.5	85-90	2
Banana 1.Cavendish green	13	85-90	3-4
2.Cavendish ripe	12	85-90	1-5
3.Neipoovan green	12	85-90	2-3
4.Neipoovan ripe	8	85-90	1
Ber	5-6	85-90	4
Citrus 1.Coorg Mandarin(main crop)	8	85-90	8
2.Coorg mandarin (rainy season)	8	85-90	6
Mosambi	8	85-90	16
Lime yellow	12-13	85-90	8
Lime green	12-13	85-90	7
Grape fruit	13-14	85-90	12
Custard apple	15	85-90	1.5
Dates	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 1.Alphonso	12-13	85-90	4
2.Banganapalli	12	85-90	5-6
Papaya green	10	85-90	3-4

Passion fruit	6-7	85-90	3
Pineapple all green	9-10	85-90	4-6
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
Snap beans	8-10	85-90	3-4
Winged beans	10	85-90	8-10
Beetroot	0-1	90-95	8-10
Brinjal	10	90-95	2
Cabbage(wet season)	0-2	90-95	4-6
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
Cucumber	10-11	90-95	2
Garlic bulbs dry	0	65	28-36
Ginger	8-10	75	16-20
Bottle gourd	8-9	85-90	4-6
Snake gourd	18-20	85-90	2
Leaf lettuce	0	95	1
Mushroom	0	95	1.5
Muskmelon	7-8	85	4-5
Okra	10	90	1.5
Red onion	0	85	20-24
Green pea	0	90	2-3
Potato	4	65-70	30-34
Pumpkin	12-15	65-70	24-36
Radish topped	0	90-95	3-5
Squash	0	70-75	8-24
Sweet potato	10-12	80-90	13-20
Spinach	0	70-75	10-14
Tomato(red ripe)	5-6	85-90	2
Watermelon	12-15	80-90	2
Yam	16-20	60-70	3-5

CARROT IN COLD STORAGE

SMALL ONION

BELLARY ONION

APPLE

CITRUS

GARLIC

BANANA PACKED AND STORED IN COLD STORAGE

POTATO

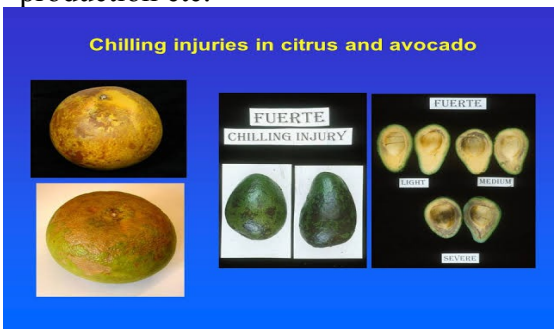
LOW TEMPERATURE INJURIES

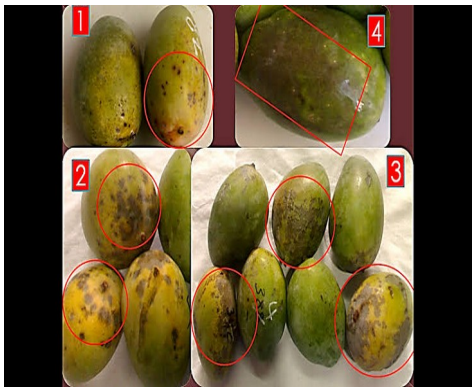
- Majority of tropical horticultural produce are injured when stored at very low temperature, due to chilling injury.
- Optimum low temperature for storage should be above freezing temperature and not to cause chilling injury.
- Chilling injury occurs when commodities of tropical and sub tropical origin as mango, banana, tomato are held at temperature above their freezing point and below 5-50^{o}c depending on commodities.

SYMPTOMS

- Surface of pitting.
- Discolouration – Browning, blackening etc of external/ internal tissues.
- Appearance of water soaked areas.
- Development of necrotic areas.
- Failure of mature fruits to ripen.

- Increased susceptibility to delay.
- Reduction in storage life.
- Loss of characteristic flavour.
- Increase in certain physiological activities like increase in respiration rate,ethylene production etc.





MANGO

- Reduction of Chilling injury: Storage of optimum temperature or above the critical temperature for a particular commodity is safest method to avoid this injury.

- **Treatments to reduce Chilling Injury:**

A) Before Storage:

- ✓ Temperature conditioning-gradual lowering of storage.
- ✓ Ethylene treatment of fruits.
- ✓ Exposure to elevated CO_2.
- ✓ Modified Atmospheric Packaging.

B) During Storage:

- ✓ Intermittent exposure to higher temperature.
- ✓ Holding under modified atmospheric/ controlled atmosphere.
- ✓ Holding under low pressure(Hypobaric storage).
- ✓ Maintenance of high RH.

TRANSPORTATION AND MARKETING SYSTEMS FOR DOMESTIC AND EXPORT MARKET, QUALITY STANDARS IN EXPORT TRADE AND CONSTRAINTS IN DOMESTIC AND EXPORT MARKETING OF HORTICULTURAL COMMODITIES

I. Transport

Timely and speedy delivery of vegetable and fruit with minimum spoilage and reasonable cost is an essential feature of effective marketing. Vegetable and fruit production areas can effectively be extended if potential areas can be brought under good transport network. Due to improper transport system, vegetable and fruit growers are not able to avail good climate, soil condition and distant market. In West Bengal early cauliflower in September — October, tomato in April — June and onions in winter months are available due to effective transport from Ranchi, Bangalore, Maharashtra, respectively. These vegetables are not normally produced in plains of West Bengal in the mentioned period due to climatic disfavor. Tomatoes are harvested at their peak during December — January in West Bengal can effectively be transported to North India where they are not normally available at that time due to very low temperature.

System and drawbacks

In India transportation system is very weakly developed as for as perishables like-fruit and vegetable are concerned.

• Major portion of fruits and vegetables come from villages, they are transported to the city markets mainly by road.

• More than 90% of the product is transported by road and Bullock cart followed by Truck and Tractors.

• Delay in transport coupled with improper packaging is accounted to be the causes huge post-harvest spoilage in transit.

• Road transportation by truck or tractors is now very costly due to price hike in fuel and spares which consequently increases the price of the produce at the consumers' end.

• Rail transport which is 8-10 times more efficient than road transport.

• Concepts of refrigerated transport for perishable are yet to be developed. Government should take immediate steps to strengthen the cold chain and at the same time to provide quick, efficient and cost effective transport network at least in potential vegetable areas.

II. Marketing system

Marketing of fruit and vegetables faces a number of constraints due to high perishability, seasonal market arrivals and bulky nature. Assembling and subsequent marketing of the produces further lops deer due to lack of proper storage facilities and quick transport systems. Very often the producers are forced to dispose of their produce at very nominal price when there arises seasonal gluts due to these bottlenecks several intermediaries who dominate the trade and reap huge profit. Consequently, producers' margin in the consumers' price become very low.

In marketing, four channels are predominant in vegetables.

1) Producer ⇨ Commission agent ⇨ Wholesale trader ⇨ Retailer ⇨ Consumer

2) Producer ⇨ Wholesale trade ⇨ Retailer ⇨ Consumer

3) Producer ⇨ Commission agent ⇨ Wholesaler ⇨ Consumer

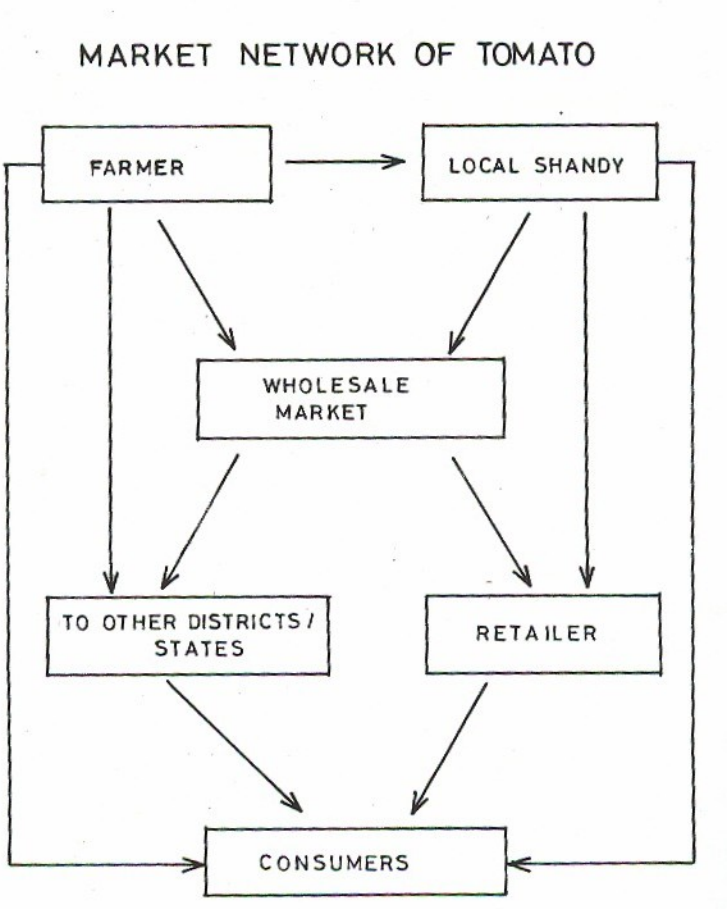
4) Producer ⇨ Retailer ⇨ Consumer

Defects in marketing

1. Poor transport facilities
2. Complete lack in refrigerated transport
3. Lack of storage facilities
4. Preponderance of intermediaries in the marketing channel
5. No provision for the fixation of floor prices at least for some vegetable and fruit and for this reason, the producers are often cheated by clever middleman.
6. Lack of grading aid quality control system.
7. Concept of consumer packaging is practically unknown in the domestic markets.
8. Lack in co-ordination between production targets of state agricultural department and action plan of marketing directorate.
9. Primitive methods of selling like — secret sale, private negotiation, under cover etc., are much in vogue.
10. Government and other co-operative marketing agencies participation in marketing is meager.

Losses in Market network

The produce is brought by the farmers to the local shandies or direct to the wholesale market. At local shandy and wholesale market, the produce is inspected by transferring to another basket and bidding is done. At both stages, the produce undergoes post harvest losses due to handling for inspection, grading, repackaging, loading, transportation and unloading. Eg. In tomato, an average post harvest loss of 7-8 per cent was found for improved varieties and 6-7 percent for hybrids at local shandies.



Refrigerated Vehicles

Fresh fruits and vegetables are increasingly demanded in international markets. Meeting the requirements of these international markets, presents a considerable challenge to the post harvest handling of fresh produce. Packaging plays a major role in meeting this challenge. Modified atmosphere (MA) packaging and controlled atmosphere (CA) packaging can be used for different fruit and vegetables. MAP creates a steady atmosphere of O2 and CO2 around the produce within the MAP package, while CA provides an optimum atmosphere of oxygen and carbon dioxide around the packaged

produce. MAP has been developed to match specific produce requirements, and can be combined with CA storage. Moreover, mixed produce can be loaded by design systems in which some MAP material is impregnated with minerals in order to absorb and remove ethylene production. The mixed produce should be compatible with respect to their level of ethylene production. Temperatures should also be maintained at an optimal level during transportation. Recently MAP packaged produce has been transported in CA containers at suitable temperatures and relative humidities. These systems have resulted in extending shelf life, retaining fresh produce quality and reducing losses. However, the problem of moisture condensation within the MAP bags still arises. New packaging innovations designed to control this, include condensation control packaging (CCP) and compact controlled atmosphere packaging (CCAP).

The following are examples of situations where MAP packaged fruit are transported at low temperatures in CA storage systems:

Mangoes	Stored in CA of 3–5% O_2 and 5–8% CO_2 at 10°C.
	(ripe) Shelf life extended up to 20 days, when compared to 5–7 days for control fruit.
Broccoli	Stored in CA of < 1% O_2 and 10% CO_2 at 1–2°C. Shelf life extended up to 25 days when compared to 3–5 days after harvest.
	Produce retains fresh green florets and crispness.

Overcome

1. Horticultural producers' co-operative marketing societies should be established at village and district level to control the activity of the intermediaries and to regulate marketing.
2. NAFED — National Agricultural Coo-operative Marketing Federation, TRIFED and primary co-operative marketing societies have taken up procurement of potato, onion, garlic, ginger.
3. NHB should take initiative regarding information of prices at various wholesale markets on daily basis.
4. NHB and National Horticulture Mission will have to concentrate on increasing yield and quality.

5. Closer co-ordination among Agricultural Marketing Board, NI-TB, and State department of Agriculture/Horticulture should be ensured to formulate an action plan for marketing.

6. Co-operative societies should be extended to the grass-root level.

7. To take full advantage of Hi-tech horticulture and precision farming opportunities, adequate emphasis has to be given to human resource development at various levels.

8. Establishment of vocational training centers in 1-lorticulture.

9. Commodity Boards viz., Rubber Board, Coconut Development Board, Tea Board, Coffee Board, Spices Board etc have to boost up their activities on international trade, certification etc to facilitate export of horticultural crops and also price stabilization brand promotion etc.

QUALITY STANDARDS IN EXPORT TRADE

Food safety regulations have been implemented by various Ministries and/or departments within India. These regulations serve two main purposes: 1) regulation of specifications for foods and 2) regulation of hygienic conditions of processing and/or manufacturing. Some of these food safety regulations are mandatory while others are voluntary:

a) The Prevention of Food Adulteration Act (PFA) implemented by the Ministry of Health, outlines specifications for various food products and is mandatory.

b) The Agriculture Produce (Grading & Marking) Act implemented by the Ministry of Rural Development is voluntary. This particular act set forth the specifications for various agricultural commodities including some processed foods.

c) The Bureau of Indian Standards (BIS) is the largest body responsible for the creation of standards for various food products. BIS standards are voluntary.

d) A number of quality control orders have been issued under the essential Commodities Act. These include the Food Product Order (FPO), Milk and Milk Products Order (MMPO), Meat Product Order and Vegetable Oils Control Order. These orders are mandatory and are mainly meant for regulating hygienic conditions.

The Fruit Products Order

The Fruit Products Order-1955, promulgated under Section 3 of the Essential commodities Act, 1955, aims to regulate sanitary and hygienic conditions for the

manufacture of fruit and vegetable products. Licensing under this Order lays down the minimum requirements for:

1. Sanitary and hygienic conditions of premises, surroundings and personnel
2. Water to be used for processing
3. Machinery and equipment
4. Product standards

Maximum limits of preservatives, additives and contaminants have also been specified for various products. This Order is implemented by the Ministry of Food Processing Industries through the Directorate of Fruit & Vegetable Preservation in New Delhi.

The Central Fruit Products Advisory Committee consists of officials of concerned Government Departments, technical experts, representatives of the Central Food Technology Research Institute, the Bureau of Indian Standards, Fruit and the Vegetable Producers and Processing Industry, is responsible for recommending amendments to the Fruit Product Order.

Codex Alimentarius

Codex Alimentarius is a Latin term, which means food code. Codex Alimentarius brings together the collaboration of technical experts, scientists, governments, consumers and industry representatives to assist in developing standards for food manufacturing and trade. The standards, guidelines and recommendations of Codex Alimentarius are recognized worldwide for their primary role in protecting the consumer and in helping to bring about international trade. The Codex Alimentarius contact point in India is the Directorate General of Health Services (DGHS) which is situated in the Ministry of Health. The Ministry of Food Processing Industries is closely associated with the activities of Codex Alimentarius.

Hazard Analysis and Critical Control Point (HACCP)

India has instituted Hazard Analysis and Critical Control Point (HACCP) as an important element of its quality assurance systems. HACCP ensures that products are safe and of good quality. HACCP systems are extremely important as a part of the changing quality requirements in international trade. The Ministry of Food Processing

Industries provides grants which cover up to 50% of the cost toward the implementation of Total Quality Management (TQM), which includes HACCP certification.

METHODS OF STORAGE OF HORTICULTURAL PRODUCE

Many horticultural crops are seasonal in nature and 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..

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

- Pre harvest factors
- Maturity at harvest
- Harvesting and handling process
- Pre storage treatments
- Temperature and humidity in storage room
- 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.

PRINCIPLES OF STORAGE

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

★ **Control of transpiration**

Fresh produce continues to lose water even after harvest resulting in wilting or shrivelling 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.

★ **Prolonging the Dormancy period/Control of sprouting and rooting**

Some root and tuber type vegetables after harvest enter into a resting phenomenon known 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 unfavourable conditions is the principle for extending the storage life of this type of produce.

★ **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.

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.

Table. 1. Storage conditions for onion and garlic

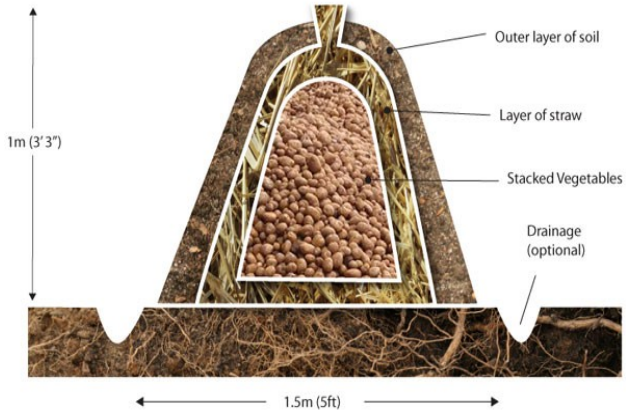
Commodity	Temp °C	RH	Potential storage duration
Onion	0-5	65-70	6-8 months
	28-30	65-70	1 month
Garlic	0	70	6-7 months

	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.

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
Sweet potato	12-14	85-90	6 months
Ginger	12-14	65-75	6 months

5. Storage using evaporative coolers/ Evaporative cooling :

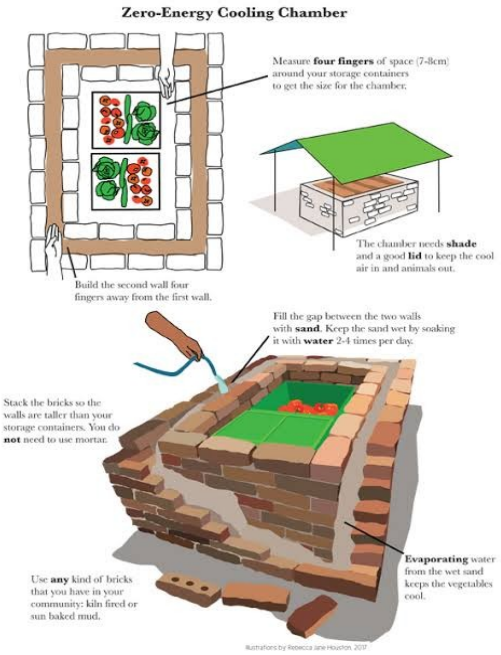
The principle of evaporation can be used to cool stores by first passing the air into the store through a pad of water. The degree of cooling depends on the original humidity of the air and the efficiency of evaporating surface. Both active and passive evaporative cooling systems are used. In a passive 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.

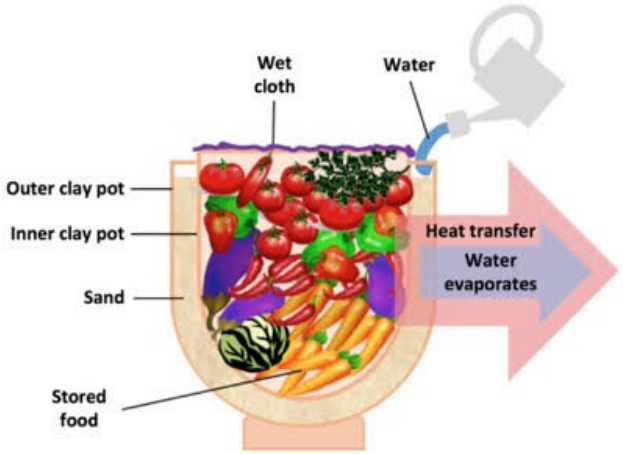
Zero Energy Cool Chambers (ZECC)

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.

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

Table. 2. Storage life of different commodities in ZECC

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.

HIGH COST STORAGE TECHNOLOGY / IMPROVED STORAGE METHODS

1. 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.

Terminologies/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 00C.

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

1kg of melting ice absorbs 325kj of heat

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.

2. 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 m2) 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.

3.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.

4. Low pressure storage / Hypobaric storage

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

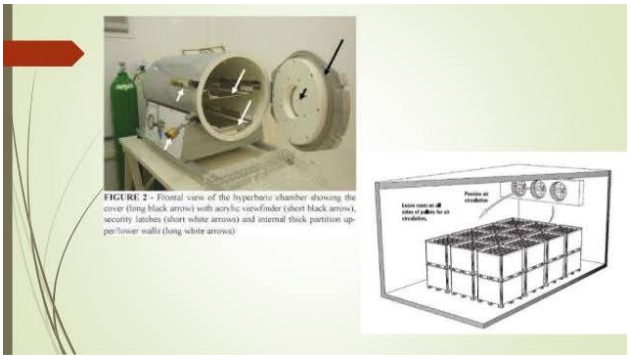
Mechanism

Reduced O2 supply slows down the respiration. When presser reduced from the 1 atm to 0.1atm the effective O2 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 CO2, acetaldehyde, acetic acid, ester *etc*. are removed / reduced.



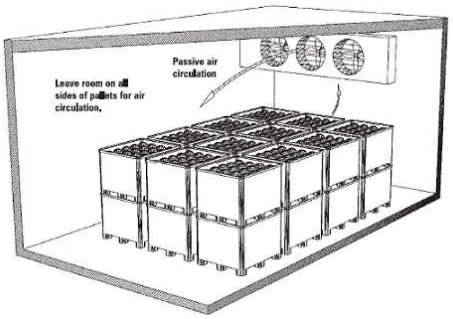


Table. 3. Comparative storage life (in days) of produce stored in refrigeration and under hypobaric conditions

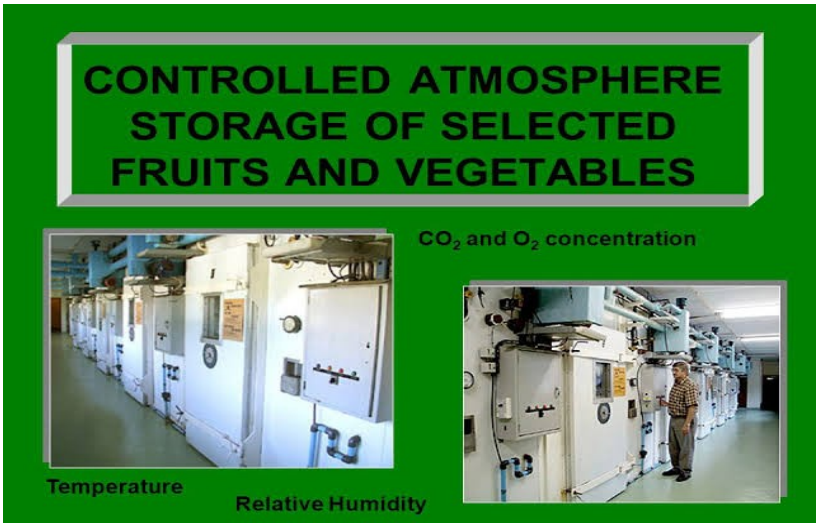
Commodity	Cold storage	Hypobaric storage
Fruits (fully ripe)		
Pine apple (ripe)	9-12	40
Grapefruit	30-40	90-120
Strawberry	5-7	21-28
Sweet cherry	14	60-90
Fruits (unripe)		
Banana	10-14	90-150
Avocado	23-30	90-100
Apple	60-90	300
Pear	45-60	300
Vegetables		
Green pepper	16-18	50
Cucumber	10-14	41
Beans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

5. 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

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

6. 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

Table. 4. Summary of recommended MA conditions during transport and storage of selected vegetables

Commodity	Temperature range (°C)	Modified Atmosphere	
		% O2	% CO2
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
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
Tomato (partially ripe)	8-12	3-5	0

METHODS OF STORAGE - LOW AND HIGH COST TECHNOLOGIES

LOW COST STORAGE TECHNOLOGIES

- Simple field warehouse
- Underground Storage
- Pit Storage
- Clamp Storage
- Pusa Zero Energy Cool Chamber

SIMPLE FIELD WAREHOUSE

- Farmers can store their crops by using barns, cellars, farm sheds or other simple field structures that are usually made of locally available materials.
- Simple field warehouses are mainly used for storing hay, grains, root, and tuber crops.


Smallholder farmers who can't afford fully equipped storage facilities use simple field warehouses, usually made of locally available materials

UNDERGROUND STORAGE

- Underground storage is a **farm practice of leaving the crops in the ground until needed**.
- This method is used mainly for storing potatoes and carrots.
- Efficient in preserving crop quality for some time in well-drained soils.

Underground storage can preserve the quality of root and tuber crops

PIT STORAGE

- In order to preserve their crops, farmers often dig pits.
- The pits are usually used for storing grains, tuber and root crops.
- The costs of storing crops in the pits are usually lower than in above-ground structures.
- It provides **relatively low and constant temperature** and preserve the crops from rodents and insects

CLAMP STORAGE

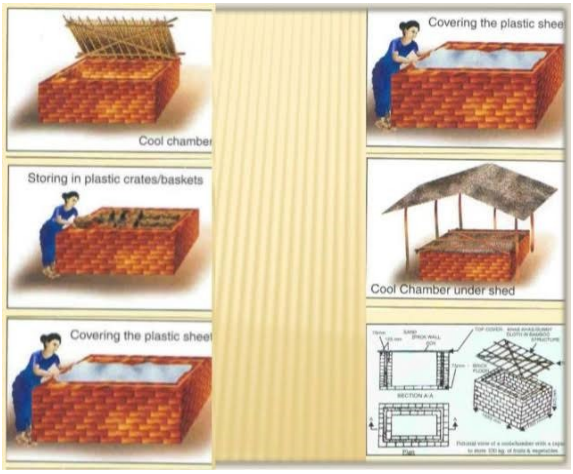
- Clamp storage is a low-cost method for preserving root and tuber crops that is based on **insulation of crops with a layer of straw and a dry layer of soil or sand.**
- The selected site should be free from rainfall or Snowmelt

Carrots preserved in clamp storage

Creating clamp storage for potatoes

ZERO ENERGY COOL CHAMBER :

- Low cost environmental friendly
- On-farm storage chamber for flowers,fruits and Vegetables
- Zero energy cool chambers stay 10- 15° C cooler than the outside temperature and maintain about 90% RH
- It is based on the Direct Evaporative Cooling



HIGH COST STORAGE TECHNOLOGY

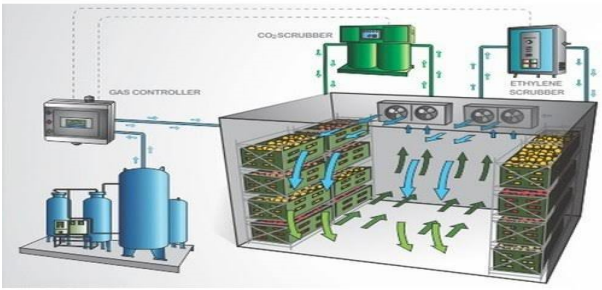
- Cold storage - Refrigeration, Chilling and Freezing
- Controlled Atmosphere Storage(CA Storage)
- Modified Atmosphere Storage (MA Storage)
- Low Pressure Storage / Hypobaric Storage

COLD STORAGE

- Storage at the temperature lower than the ambient temperature.

CONTROLLED ATMOSPHERIC STORAGE

- It refers to the constant monitoring and adjustment of the CO_2 and O_2 levels within gas-tight stores or containers.
- CA is most effective when combined with temperature control.



HYPOBARIC STORAGE

- Hypobaric Storage refers to the storage of fruits and vegetables under reduced atmospheric pressure.
- The storage life of many fruits and vegetables can be extended by reduced pressure under refrigeration due to low respiration rate and evacuation of ethylene.
- This is form of Controlled Atmospheric storage (CAS)
- This was first proposed by Burg and Burgl in 1966.
- Fruits were held at about 0.2 to 0.5 atmospheric pressure at 15 to 24°C.

- There was reduction in level of ethylene in the fruits and the oxygen in the chamber.
- It was found that

  i. Reduced oxygen supply slows down respiration and production of ethylene.

  ii. Flushing of ethylene removed from the fruits out of the storage.

  iii. Removal of other volatiles produced from fruits and vegetables.

Post-harvest diseases, pest and disorders of fruits and vegetables

- Many of the fungi which cause post-harvest disease belong to the phylum, Ascomycota
- *Rhizopus and Mucor* are important genera of post-harvest pathogens in the Phylum *zygornycota. Rhizopus stolonifer* is a common wound pathogen of a very wide range of fruits and vegetables, causing a rapidly spreading watery soft rot.
- Bacterial soft rots are very important post-harvest diseases of many vegetables, although they are generally of less importance in most fruits.,

Sr. No.	Name of Vegetables and Fruits	Common Name	Pathogen
1.	*Alium cepa*	Onion	*Aspergillus niger*
2.	*Brassica oleracea var botrytis*	Cauliflower	*Fusarium, Alternaria brassicola, Botrytis cin*
3.	*Capsicum frutescens*	Chilli	*Alternaria solani*
4.	*Dacus carota*	Carrot	*Mucor, Alternaria dau Rhizopus, Aspergillus,*
5.	*Dolichos lablab var lignosus*	Field bean	*Aspergillus sp. ,Phythi*
6.	*Dolichos lablab* var *typicus*	Indian butter bean	*Phythium sp. Fusarium Alternaria, Aspergillus*
7.	*Lycopersicum esculantum*	Tomato	*Alternaria solani*
8.	*Pisum sativum*	Pea	*Fusarium, Alternaria, Pernospora viciae, Asc pinoides, Erysiphe sp.*
9.	*Solanum melongena*	Brinjal	*Alternaria, Botrytis cin Phoma lycopersici*
10.	*Solanum tuberosum*	Potato	*Fusarium*
11.	*Achras sapota L*	Sapota	*Rhizopus*
12.	*Citrus aurantifolia*	Lemon	*Penicillium digitatum*
13.	*Citrus sinensis*	Sweet orange	*Penicillium digitatum*
14.	*Citrus reticulata*	Orange	*Penicillium digitatum*
15.	*Zizipus mauritiana*	Indian jujube	*Aspergillus*
16.	*Vitis vinifera*	Grapes	*Aspergillus niger, Peni sp. Rhizopus stolonifer Botrytis cinerea*

Table 1: Major postharvest diseases of temperate fruits and causal agents

Name of the disease	Causal pathogen	Affected Temperate fruits	Reference (s)
Bitter rot	*Colletotrichum gloeosporioides*	Pome and stone fruits	Masoud *et al*[34].,
Black lesion, dark spots	*Stemphylium botryosum*	Pome fruits, grape etc.	Toselli *et al*[63].,
Blue mold	*Penicillium expansum*	Mainly pome and stone fruits	Masoud *et al*[34].,
Brown rot	*Monilinia fructicola*	Mainly stone fruits	Sisquella *et al*[53].,
Fruit rot, dark spot, sooty mold	*Alternaria alternata*	Apple, pear, peach, plum, cherry,	Kadam[27]
Gray mold	*Botrytis cinerea*	Cherry, grapes, apple, pear, peach, plum,	McLaughlin *et al*[36].,
Lenticel rot	*Gloeosporium album*	Apple, pear etc.	Edney *et al*[14].,
Olive-green moold, sooty mold	*Cladosporium herbarum*	Apple, pear, cherry, plum, peach and stone fruits	Latorre *et al*[28].,
Pink mold	*Trichothecium roseum*	Pome and stone fruits	Wang *et al*[65].,
Watery white rot	*Rhizopus stolonifer*	Apple, pear, peach, plum, cherry	Zhang *et al*.,

Management

- There is a close relationship between ripening and the development of post-harvest disease, post-harvest disease development can be managed indirectly by delaying the onset, and reducing the rate of ripening (Prusky and Keen, 1993).
- As a climacteric fruit, mango undergoes profound biochemical changes as it ripens.
- Ripening is a process in fruit senescence that is associated with and enhanced by increased ethylene production (Brecht and Yahia, 2009; Snowdon, 1990).
- Ripening can also be inhibited by modified atmosphere (MA) storage (usually reductions in O2 levels and increased CO2)

Heat control:

- Hot water, vapour heat and forced hot air are post-harvest treatments for fruit flies, which are quarantine pests for fruit in much of the world.
- The times and temperatures that are needed to achieve prescribed lethal levels depends of the size and shape of the fruit that are treated.

- Benefit of heat treatment to satisfy insect quarantines is its reduction of anthracnose and other post-harvest decays.

Post Harvest Pests

- The ability of the pest to infest the host depends on the effectiveness of its mechanisms of invasion. In many ways, the pest is dependent on the host's susceptibility and environmental factors.
- The development of a pest infestation depends on favourable conditions in the environment, the host and the pest.
- The host's suitability for pest infestation can depend on natural resistance, cultural practices, or the presence of wounds. The environment can be manipulated easily after harvest to provide a temperature or an atmosphere that is unfavorable to pests.

Mango fruit fly:

In mago of fruit fly lay eggs when the fruits are young or immature.

- • With the development of fruit ripening the eggs of fruit fly hatch and the larvae emerged
- to feed on the inside of fruit
- • The damage of the fruit due to the larvae of fruit flies may continuing to the post harvest
  stages and in the storage

Root – Tuber Borers

- The adult insects may lay eggs in the soil or in the stem.
- Then the emerged larvae may getting into the root or Tubers and the damage is continued to the post harvest stages.

Management

- The preharvest control of insect infestation in the fruit ecosystem is one of important steps for maintaining quality of fruit, enhancing shelf life and marketing of toxic residue–free fruit.
- Basically, insect pests, microorganism enzymes, temperature, relative humidity, and moisture content are deteriorating the quality of fruit and reduce the shelf life.
- For example, orchard sanitation, physical and biological control, trapping and spraying of poison bait, sterile insect techniques, male annihilation techniques, and horticultural ecosystem analysis based integrated pest management of insects along with newer and safest molecules of insecticides, which are economical, ecofriendly, and efficient in control of insect population, as well as optimize yield by preharvest management.

Physiological disorder of fruits and vegetables:

Physiological or abiotic disorders are distinguished from other disorders in that they are not caused by living organisms (viruses, bacteria, fungi insects etc), but are caused by non-living, abiotic situations and cause a deviation from normal growth.

Freezing Injury

Occurs when the temperatures of the tissue falls below its freezing point. Because of the 'freezing point depression fruits and vegetables have slightly lower freezing points as compared to the freezing point of water .

Commodity	Freezing point range °C
Apple	-2-2 - -1.7
Pear	-1.5
Asparagus	-1.4 - -1.1
Sweet cherry	-4.3 - -3.8
Sour cherry	-1.0
Citrus fruits	-1.5
Cucumber	-0.9 - -0.8
Grape	-5.3 - -2.9
Lettuce	-0.6 - -0.3
Onion	-1.3 - -0.9
Orange	-2.3 - -2.0
Potato	-1.8 - -1.7
Tomato	-1.0 - -0.7

Bitter pit or corky spot

Bitter pit is a common disorder that causes dark spots on apples late in the season or in storage. This condition is related to lack of calcium in fruit and is often as a result of dry soil conditions.

Water core

Water core is a serious physiological disorder of apples that occurs on the tree. It is typified by water-soaked areas of the cortex, which cause the tissue to become translucent

Russetting

Russeting or russetting is an abnormality of fruit skin which manifests in russet-colored (brownish) patches that are rougher than healthy skin. It is a common feature in apples and pears.

Storage scald

Husk scald

Internal breaking

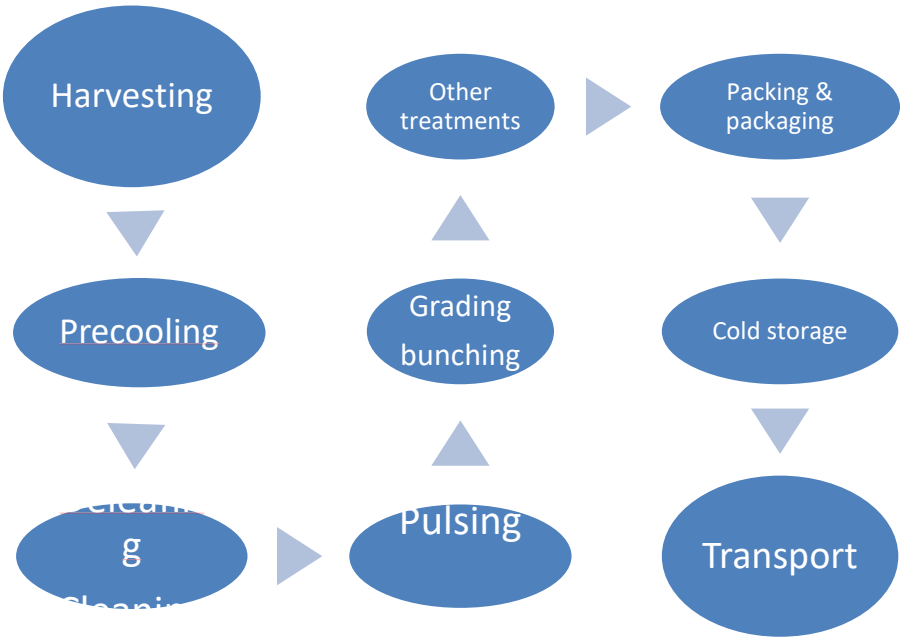
Core breakdown

POST HARVEST PEST, DISEASE , DISORDER , CONSTRAINTS IN POST HARVEST MANAGEMENT UNDER THRUST AREAS FOR FLOWERS

IMPORTANCE OF POST HARVEST HANDLING OF FLOWERS:

- The quality of flowers, which reaches the final consumer, depends on the preharvest and post-harvest handling.
- Quality is the pillar for creating value and customer satisfaction
- The flowers are highly perishable need utmost care.
- When flowers are detached from the plant, they deprived of food, water, minerals and hormones.
- About 30% of flowers perish during handling.

POST HARVEST OPERATIONS



PHYSIOLOGICAL DISORDERS

ROSE

- **Bull rose**- Flattened or distorted flowers

Causes : low temperature , genetic control , high vigorous stems .

- **Blind shoots** – abortion of flower buds

Causes : abortion of flower buds

BULL ROSE

BLIND SHOOT

CARNATION

- **Calyx splitting**-abnormal calyx expansion , Proliferation of petals

Causes : low N & Boron , High ammonical nitrogen,Temperature variations .

- **Sleepiness**-upward curling , cupping or bending of petals

Causes : Ca deficiency,sensitive to ethylene

- **Curly tip**

Causes : Boron deficiency

CALYX SPLITTING

SLEEPINESS

CHRYSANTHEMUM

- Crooked neck- Bending of neck

Causes: day night temperature variations

- Bronze colour foliage – pb deficiency
- Quillings of flower petals

Causes : low temperature , light intensity , low storage

- Crown buds

Causes : insufficient light intensity

- Bract buds

Causes : day night temperature exceeds

Quillings of flower petals

Lily

- **Bud drop**

Causes : insufficient light conditions

- **Leaf scorch**

Causes : Ca deficiency

- **Puffy foliage-** stunted flowers

Causes : frost injury

- **Bud blast**

Causes : low light intensity , high nitrate level.

Gladiolus

- **Fluoride injury** – burn symptoms

Sensitive variety : snow princess

ORCHIDS

- **Dry sepal injury**

Causes : high humidity and smog

- **Deformed flowers**

Causes : low temperature and chilling injury

Deformed flower

Dry sepal injury

Alstromeria

- Flower abortion or blast

*Causes : E*xcessive salt

GERBERA

- Drooping
- Stem break

MAJOR DISEASE

- **Botrytis cinerea(Gray mold or botrytis blight)**
- **Symptoms:**

water soaked or tan spots that eventually produce fuzzy gray fungal growth on petals , stems.

Aeging flowers particullarly susceptible .

MAJOR PEST

- JASMINE BUD WORM:*Hendecasis duplifascialis*

Symptoms of damage

- Caterpillar makes hole on the flower bud and feeds on the inner content.
- Larva attacks 2 -3 buds
- Petals are eaten by the larvae.

Management

- Collect and destroy the damaged buds with larvae

- Use light trap to attract and kill the adult moths
- Spray NSKE 5% or malathion 50EC 2ml/lit
- Proper pruning and hygienic maintenance of bushes

PROBLEMS IN STORAGE

- **Flower senescence** : Early death of flowers is a common cause of quality loss and reduced vase life for cut flowers
- Eg : Tulip , Iris ,Narcissus .
- **Leaf yellowing** : yellowing of leaves and other organs (bud , stems) commonly associated with the end of display life in some cutflowers.
- Eg : Alstroemeria and lilies
- **Shattering or abscission** also a common problem in cut flowers.
- Water uptake is major problem in Anthurium .
- **Highly sensitive to ethylene** : carnation ,lilly ,orchids , alstromeria , freesia , gypsophilla ..
- **Highly sensitive to chilling injur**y : anthurium , bird of paradise .
- **Highly suceptible to grey mould** : Gladiolus , bird of paradise
- **Geotropism** : Gladiolus , Snap dragon , lisianthus , stock rose , Gerbera (bending away from gravity)
- Transported in upright position .
- **Air embolism** – Rose

- **Light requiring flowers** - chrysanthemum , alstromeria , margurite daisy .

MAJOR CONSTRAINTS IN FLOWER EXPORT

- The production for exports at present has suffered due to a few constraints. While our growers have been successful in producing world class quality at low cost, high air freight rates, low cargo capacity available, imposition of import duties, inadequate export infrastructure etc. have reduced their competitiveness.

- There is also a shortage of trained manpower to handle commercial floriculture activity.

- While long experience of flower growing in the open field conditions enable sufficient flower production for domestic markets, the quality of the produce, in view of its exposure to various kinds of biotic and abiotic stresses, is not suitable for the export market.

- The production technology for flowers under protected environment of green houses needs to be standardized.

- Availability of surplus flowers from exports for sale in the domestic market has increased the appreciation of quality produce and the demand for good quality flowers is increasing.

Postharvest pests, diseases and disorders, constraints in postharvest management and thrust areas - spices and plantation crops

1. Black pepper

Pest : Pollu beetle *(Longitarsus nigripennis)*
Symptoms
Grubs bore into the berries and cause black Colour and they crumble when pressed.

Diseases

1. Pollu disease (C*olletotrichum gleosporioides).*

Symptoms

Brown sunken patches seen in the young berries ,develops characteristics cross splitting and finally turn to balck in colour and dry.
Control measure
Spray 1% bouredox mixture

Turmeric

Rhizome scale (*Aspidiella cucumae)*
This is one of the important pest infesting the ginger & turmeric both in field and in storage.

Management

To ensure the seed material free from the scale infection. The rhizome can be treated with any one of the insecticide (Monocrotophos, Phosalone at 0.05%).

Coriander

Disease : Grain mould / storage disease
Helminthosporium sp, Alternaria sp, Carvularia sp, and Fusarium sp.
Control measure : grain mould can be controlled by spraying Carbendazim 0.1%.20 days after grain storage.

Cardamom

Disease

Azhukal or capsule rot *Phytophthora meadii*

Symptoms

Occurs in heavy rain zones , affected capsules turn brownish black in colour.

Control measure : Trashing and removal of infected capsules.

During premonsoon months sprays 1%boredeaux mixture during May and repeat again in August.

Tamarind

Pest

Storage beetle *(Pachymeres gonagra*)

It can be controlled by spraying Quinalphos 25EC .1ml/lit at the time of fruiting season.

Coffee

Pest

Berry borer : carry out timely and thorough harvest

Remove off-season berries to save the main crop
Prune plant properly to facilitate better ventilation and illumination.

Coconut

Pest :

Coconut eriophyid (*Aceria guerreronis)*


Pest population occur round the year but population maximum during June - sep (on set of monsoon)
Oozing of gummy exudation from the affected surface of the nuts
Control measure
Collect and destroy the fallen buttons of affected palm.

Disease : Leaf blight *(Lasiodiplodis theobromae)*

Leaf blight causes serious damage in seedlings ,leaves and nuts of adult plant
Dark grey to brown lesions with wavy to undulated margins appear from the Apex of the nuts.

Control measure
Root feeding of carbendazin 2g Or tridemorph 2ml + 100 ml water .(3times at 3 months).

Physiological disorder

1. Crown choking or button shedding : boron deficiency and button shedding is also due to lack of pollination and fertilization
2. Rosette /little leaf : zinc deficiency.

Arecanut

Disease : Koleroga /mahali /fruit rot : *Phytophthora arecae*

Symptoms: water soaked lesions on the surface of fruit, later the lesions spread over to other lesions giving dark green Colour
Control measure: spraying of COC (Copper Oxychloride) / Blitox @ 3g / liter of water.
Tying of plastic bags / straw /areca leaf sheath : the fruit bunches at different stages of maturity are tied with plastic bags at the on set of monsoon after drenching with 1% Bordeaux mixture..

Physiological disorder

Band /hidimundige disease

This disorder is a major problem in Konkan coast of Maharashtra
Symptoms : Reduction in internodal length and tapering off stem towards the apex.
Mostly unproductive nuts, if at all produced are small and malformed.
Control measure : better soil management and improvement in drainage
Correction of acidity and incorporation of mixture of copper sulphate and lime.

Cocoa

Pests
1. Tropical warehouse moth - *Ephestia cautella*
2. Cigarette beetle - *Lasiodrema serricone*
3. Corn sap beetle - *carpophims dimiduatus*
4. Rusty grain beetle - *cryptolestes ferrugineus*
5. Coffee bean weevil- *Araeocerus fasciculatus*
6. Red flour beetle - *Tribolium cadtaneum*
7. Rodent

1. Tropical warehouse moth

Symptoms
1. Presence of worms in the chocolate
2. The moths in grain result in reduced grain weight and contamination by fecal material and webbing

Control measures
1. Pheromon traps are commercially available for monitoring.
2. Fumigation but this can be done only on emergency.

2. Coffee bean weevil

Symptoms : Cause little damage to stored product as the Kerbal become too hard.

3. Cigarette beetle

Symptoms : Larval feeding causes s direct damage to food products and non food items.
Contamination by larvae, pupae, cocoons
Control measure
Use of pheromones
Use of fungicide such as methyl bromide.

4. Corn sap beetle

Symptoms : The larva and adult feed on the germ /endosperm. Spreading the fungal spores in the stored product

Control
Cooling the grain at (-7°C) for at least 3 weeks

5. Red flour beetle

Give the product foul smell which may also cause market losses to the store product
Control measure
Careful sanitation is the best method to avoid any stored product pest.

Food safety standards for export market

- The purpose of any food safety programme is to ensure that all processed products and the conditions under which they are manufactured leads to the production of safe food.
- The safety of agri-food products produced in any country is the ultimate responsibility of the food industry, the role of government agencies is vital to ensure food safety.
- Standardization and quality control of the processed food for both domestic consumption and export is essential from the view of safety , hygiene, nutrition, keeping quality and other aspects.
- Food standards are something that are set up by experts or an authority for measuring quantity , weight , extend , value , quality of a substance.
- Each country regulates food differently and it has its own food regulatory framework.
- Various agencies like AGMARK , BIS (ISI) PFAA(1954) , FPO(1955) , Export act of (1963) were involved in formulating and implementing food standards in india.
- Now all agencies are merged into single one as FSSAI act(2006).

International organisations governing food safety

- WHO
- WTO
- FAO
- Cordex Alimentarus Commission
- International Organisation For Standardisation
- International commission for microbial specifications for food

International food standards

- Cordex Alimentarus Commission is the principle organisation of the world wide food standards programme set by FAO and WHO
- Estd in 1962 for the purpose of developing , promoting , harmonising standards for food in order to facilitate international trade.
- Codex standards are based on sound science provided by independent international risk assessment bodies or ad-hoc consultations organized by FAO and WHO.

- Codex standards and related texts are not a substitute for, or alternative to national legislation.
- Every country's laws and administrative procedures contain provisions with which it is essential to comply.
- Codex standards and related texts contain requirements for food aimed at ensuring for the consumer a safe, wholesome food product free from adulteration, correctly labelled and presented.

Purpose of CAC

- To present internationally accepted food standards in a uniform manner
- To protect consumers health
- To educate consumers
- To make international trade easy

Scope of CAC

- It includes standards for all categories of food(processed semi processed raw)for distribution to consumer
- It also covers factors like materials used for food processing , food hygiene, food additives, pesticide residues, labelling, methods of analysis and sampling.

HACCP – Hazard analysis and critical control point

- The highest priority of CA is to protect the health of the consumer and ensure fair practices in food trade and became a benchmark for international trade

The HACCP is a scientific , rational , systemic approach to identify , and control hazards during production , processing , preparation and use of food

7 basic principles of HACCP

- Conduct hazard analysis
- Determine critical control point
- Establish critical limits
- Establish corrective action
- Establish documentation for all procedures and records.

Food and Drug Administration

- The **Food and Drug Administration** (**FDA** or **USFDA**) is a federal agency of the United States Department of Health and Human Services
- The FDA is responsible for protecting and promoting public health through the control and supervision of food safety, tobacco products, dietary supplements, pharmaceutical etc.

International standard organization

- **ISO** 22000 is a Food Safety Management System that can be applied to any organization in the food chain, farm to fork.
- Becoming certified to **ISO** 22000 allows a company to show their customers that they have a food safety management system in place.
- This provides customer confidence in the product.
- ISO and its member countries used the Quality Management System approach, and tailored it to apply to Food Safety, incorporating the widely used and proven HACCP principles and Good Manufacturing Principles .

ICMSF

- The **International Commission** on **Microbiological Specifications** for **Foods** (ICMSF) is a group of experts formed in 1962 to provide timely, science based guidance to government and industry on appraising and controlling the **microbiological** safety of **foods**.

Food standards in India

- They are formulated along the line of cordex alimentarus commission
- 1 . Compulsory standards
- 2. Voluntary standards

Compulsory standards

- The Prevention of Food Adulturation Act -1954

- Essential commodities act 1955
- Fruit products order 1955
- Meat products order of 1973
- Milk and milk products order of 1992

FSSAI

- **Food Safety and Standards Authority of India (FSSAI)** is an autonomous body established under the Ministry of Health & Family Welfare, Government of India.
- The FSSAI has been established under the Food Safety and Standards Act, 2006
- FSSAI is responsible for protecting and promoting public health through the regulation and supervision of food safety

Voluntary standards

- AGMARK 1937: the director of marketing and inspection grades commodities as 1234 – special , good, fair , ordinary.
- Bureau of Indian Standards
- These are evolved after chemical, physical and biological sampling

When exporting fresh fruit and vegetables to Europe, we have to comply with the requirements below:

Limited use of pesticides

To avoid health and environmental risks, the European Union (EU) has set maximum residue levels (MRLs) for pesticides in and on food products. Products containing more pesticides than allowed will be withdrawn from the European market.

- Supermarket chains are the strictest and demand 33% to 70% of the legal MRL.Shipments are checked before they are sent to the retailer.

Avoiding contaminants

- Contaminants are substances that have not been intentionally added to food, but may be present as a result of the various stages of its production, packaging, transport or holding.
- Similar to the MRLs for pesticides, the European Union has set limits for several contaminants.

- Especially the limits for nitrate (in spinach and lettuce) and heavy metals such as cadmium, lead, mercury and inorganic tin, are relevant for fresh fruit and vegetables.

- For most fresh fruit or vegetables the limit for lead contamination is 0,10 mg/kg and for cadmium 0,050 mg/kg.

Microbiological criteria for pre-cut fruit

- When supplying pre-cut fruit and vegetables, as well as unpasteurised juices or sprouted seeds, you must take into account microbiological hazards such as salmonella and *E. coli*.

- These substances should be absent when testing your product.

Plant health

- Fruit and vegetables exported to the European Union must comply with European legislation on plant health.

- The European Union has laid down phytosanitary requirements to prevent the introduction and spread of organisms harmful to plants and plant products in Europe.

- These requirements are managed by the competent food safety authorities in the importing and exporting countries

- . Most importantly, your home country needs to have phytosanitary agreements with the European Union in place. Otherwise, it will not be allowed to export to Europe.

The following fruit and vegetables are subject to health inspections and require phytosanitary certificates prior to shipping:

- Leafy vegetables (celery, basil);
- Citrus fruit
- Kumquat
- Eggplant
- persimmon (kaki)
- apple
- pear
- mango
- passion fruit
- plums
- guava
- currants
- blueberry
- several exotic products such as rose apple, quince and bitter cucumber.

MINIMAL PROCESSING OF FRUITS &VEGETABLES

MINIMAL PROCESSING

* Minimally processed operations are those procedures such as washing, sorting, trimming, peeling, slicing, chopping, anti-oxidants treatments and packing etc. that do not affect the quality of fruits & vegetables.

* It is also called as Lightly processed, Partially processed, Ready to Eat or Ready to Cook.

REASON FOR MINIMAL PROCESSING

*Minimal handling of fruits and vegetables

*Economical

*Ease of shopping

*No waste

*Fruits and vegetables of choice

* Attractive

MINIMALLY PROCESSED FRUITS

- Chilled – peach, strawberry, mango
- Sliced – mango, pineapple, guava, orange, lemon

MINIMALLY PROCESSED VEGETABLES

- Lettuce
- Carrot
- Tomatoes
- Broccoli
- Cauliflower
- Potatoes
- Spinach
- Leek
- Cabbage

MINIMALLY PROCESSED OPERATIONS:

- Sorting
- Washing
- Trimming
- Peeling
- Slicing
- Chopping
- Anti-oxidants treatments
- Packing

SORTING:

* Sorting is the preliminary step for segregating the acceptable and non- acceptable products. It is done to remove the physiological defects from the produce. It is usually carried out manually and done before washing.

WASHING:

* Washing of fruits and vegetables is the utmost desired. It removes the dirt and some microbes present on the surface of products**.** Chlorinated water is used for rinsing the peeled fruits and vegetables.

* During washing, contact period needs to be consider for an effective operation. The concentration of chlorine should be kept between 50 and 100 ppm and the temperature should be maintained at around 0 °C.

TRIMMING:

Fruits and vegetables showing damage and spoilage are generally trimmed. Areas heavily contaminated with micro-organisms are removed.

PEELING:

It is one of the common operations used for fruits, such as apple, sapota and for vegetables, such as carrots, potato and onion. Peeling is usually carried out by hand or by abrasive peelers. Hand peeling provides the high quality product but often leads to expensive labour.

SLICING AND CHOPPING:

Chopping boards and knives are used to create the desired size and shape of the desired products. Sharp knife reduces physical damage of cut fruits and vegetables.

ANTI-OXIDANT TREATMENT:

Treatment with ascorbic acid to prevent oxidative browning of fruits and vegetables. Ascorbic acid lowers the pH of the product thus reducing browning.

PACKAGING:

1)MODIFIED ATMOSPHERE STORAGE:

Fresh meat and fish, prepared foods, and baked foods are packed in modified atmosphere, with high concentrations of CO_2.Permeability of the packaging material to CO_2 is important to control. Fresh and prepared foods are distributed and stored in the atmosphere with high CO2 concentration (5–10%) and low O2 (3-5%)

Active packaging:

Active packaging methods actively influence the shelf-life of the food during storage. The best-known example is the oxygen absorbers or scavengers, which reduce the head space and permeating oxygen levels.Fe^{2+} ions are mostly used as active packaging. Other types of active packaging systems are ethanol vapor generators. The ethanol absorbed on silicon dioxide powder and contained in paper sachets prevents the growth of molds.

Edible Coatings:

Coatings made from films of proteins, starches, or waxes. The coating will protect against oxygen, aroma components, and moisture to the product, reducing the requirements on packaging Most films are sensitive to moisture, which limits their application to dry, frozen, and semimoist foods.

MINIMAL PROCESSING TECHNIQUES:

THERMAL METHOD:

- Thermal methods can inactivate the lethal organisms and enzymes. It can form aromatic and flavor compounds. Optimum heat treatments can make the food microbiologically safe and nutrient enriched

NON- THERMAL METHOD:

*Pulsed electric fields

*High pressure processing

*Thermosonication

*Ozone technology

Pulsed electric fields:

*The technique was confined to kill microorganisms with optimized parameters such as electric field, pulse shape, pulse width and treatment time. Food products are subjected to a high voltage electrical field such as 20–70 kV/cm for a few microseconds to kill micro organisms.

High pressure processing:

*Elevated pressures (up to 600 MPa), with or without the addition of external heat (up to 120 °C) is used to achieve microbial inactivation or to alter food attributes.

Thermosonication:

*By combining ultrasound treatment at 20–40 kHz with heat treatment at moderate temperatures, the inactivation of microorganisms can be strongly enhanced. Thermosonication is also efficient for enhancing enzyme inactivation.

Ozone technology:

*Ozonization is non thermal method of killing micro-organisms using ozone, through the oxidization of cell membranes. Most of the pathogenic food borne microbes are susceptible to oxidizing effect.

HURDLE TECHNOLOGY:

Hurdle approach is the most feasible and reliable for controlling the microbial growth and it ensures the minimum reduction of food quality. Hurdle technology uses combination of preservation methods and it provide desired safety of the food products. Glucose, fructose, sodium, potassium chloride, and citric acid, tartaric acid, and benzoic acid are used. Coupling of pasteurization and blanching can result in complete eradication of the microorganisms.

ADVANTAGES:

*Convenience in terms of easy and quick preparation of meals

*Maintain quality as freshly prepared meals or products

*Maintain products nutritive values

*Provide varied shelf-life depending on the types of preservation use.

DISADVANTAGES:

*Not all processed food is good for consumption because their days/ periods for consumption are numbered.

*50-80% important nutrients and vitamins are lost in each processing step.

*Most of the pressure processed foods need low temperature storage and distribution to retain their sensory and nutritional qualities.