Course No. : **HORT- 366**
Course Title : **POST – HARVEST MANAGEMENT AND VALUE ADDITION OF FRUITS AND VEGETABLES.**

Course Credits : **1+1=2**
Books recommended :

1. Preservation for fruits and vegetables. Principle and practices. By Shrivastava & Sanjeev Kumar.
2. Post harvest physiology, handling, utilization of tropical and subtropical fruits and vegetables. By Pantastico, E.R
3. Post harvest biotechnology of vegetables. By Salunke, D.K.
4. Fruits and vegetables preservation. By Girdharilal, Sidhappa and Tandon.

a) Theory

Lecture	Topic	Weightage (%)
1	Importance of fruits and vegetables, extent and possible causes of post-harvest losses	10
2	Pre-harvest factors affecting postharvest quality and Maturity	
3	Ripening and changes occurring during ripening	10
4	Respiration and factors affecting respiration rate, Role of ethylene	
5	Post-harvest diseases& disorders	
6	Heat, chilling & freezing injury	
7	Harvesting and field handling	10
8	Storage (ZECC, Cold storage, CA, MA, and Hypobaric)	10
9	Value addition concept	05
10	Principles and methods of preservation	10
11	Intermediate moisture food- Jam, jelly, marmalade, preserve, candy – Concepts and Standards	10
12	Fermented and non-fermented beverages	05
13	Tomato products- Concepts and Standards	10
14	Drying/ Dehydration of fruits and vegetables – Concept and methods, osmotic drying	05
15	Canning -– Concepts and Standards	10
16	Packaging of products	05
	Total	**100**

Chapter 1. Importance and Scope

Importance of PHT

1. **Reduction in postharvest losses** – 25% to 40% of Fruits and vegetables are wasted due to postharvest losses. Postharvest technology reduces such losses and therefore increasing production production of agricultural and horticultural crops. Minimizing PH losses can increase the supply without bringing additional land under cultivation.

2. **Reduction of cost of production** – The cost of reducing spoilage is much lower than the cost of producing same quantity and quality of produce. PHT reduces cost of production, packaging, storage, transportation, marketing and distribution etc. It lowers the price for consumers and increases the farmer's income.

3. **Reducing malnutrition** – PHT ensures availability of sufficient food to feed the ever-growing population thus reducing malnutrition and ensuring healthy growth of the nation.

4. **Economic loss reduction** – PHT reduces economic losses at grower level, during marketing and at consumer end.

5. **Availability (Temporal and Spatial)** – Availability of Fruits and vegetables in off-season and throughout India is possible because of PHT. Ex – Cold storage, processing, export-imports.

6. **Employment generation** – Employment potential in PHT and value addition sector is considered to be very high. Raw material can be provided to processing industries.

7. **Exp[ort earnings** – Export of fresh and processed horticultural commodities earn valuable foreign exchange

8. **Defense and astronauts**- Defense forces posted in remote border areas and astronauts who travel into space have special requirement for ready to eat and high energy low volume food. These requirements are fulfilled by processing horticultural produce.

9. **Infant and sports preparation** – Special infant and sports drinks and other processed preparations are available for use especially by these people. Theses preparations are done to meet specific nutritional requirement of their body.

Scope of PHT/processing

1. **Availability of raw material** - Varied agro – climatic condition available in our country makes it possible for us to produce several types of tropical, sub-tropical and temperate fruits and vegetables. Many of tropical fruits do not grow in many countries and their products are likely to find easy market in foreign countries.

2. **Product mix** – There is scope for developing new value added processed products. In India only 1-2% fresh produce is processed and packaged in contrast to 70-80% in developed countries.

3. **Manpower** – India has large reservoir of man power, but skilled labour is in short supply and productivity in general is low. Proper training good working conditions and reasonable wages will increase productivity.

4. **Capital** – In recent years Govt of India has supported various big industries; however there is scope for small scale units which require less capital.

5. **Lack of awareness** – Farmers is not aware of market for preserved products and lack technical knowledge to undertake processing themselves.

6. **Marketing facilities –** Processed products are not readily available in small towns due to reluctance of shop keepers in stocking such items. Establishment of growers co-operatives would help in marketing of such products.

7. **Transport facilities** –Considerable improvement in roads and rail transport can reduce transport time, thus reducing PH losses. There is scope for utilization of refrigerated trucks for highly perishable commodities. 97% horticultural produce is transported by roads. PHL can be reduced if they are transported by rail.

8. **Availability of container**s – Bottles and cans required by processing industries should be made easily available.

9. **Publicity** – Proper marketing and publicity is required to attract the consumers towards purchasing new processed products in market.

10. **Role of Govt**- Central and state Govts are encouraging Fruits and vegetables processing industries through various programs. Subsidies are made available for cold storage, ripening chambers etc, different training programs are conducted to train farmers in processing.

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) Extent 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. 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. 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 (15-20%)

•. Transportation (30-40%)

• Marketing (30-40%)

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 postharvest 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 lierotting 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.
- 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.

Types of Post harvest losses

A) Physical loss –

1. Physical losses can occure due to mechanical damage (bruising, cracking, cuts), microbial damage, pest and disease damage resulting in produce tissue being disrupted to a stage where it is not acceptable for fresh consumption or processing.
2. Evaporation of intercellular water also leads to direct loss in weight
3. The resulting economic loss is primarily due to reduced weight of produce available for marketing or whole batch of commodity being rejected because of small proportion of wasted items in the batch.

B) Quality loss –

1. Quality loss can occur due to physiological (respiration, transpiration) and compositional changes that alter the appearance, taste, texture and make the produce less aesthetically desirable to end users.
2. These changes may arise from normal metabolism of produce (eg. senescence) or from abnormal events (eg. Chilling injury) arising from post harvest environment.
3. Economic loss is incurred as such produce will fetch a lower price.
4. There is no demand for poor quality produce, even at reduced price in many markets which leads to total economic loss even though goods may still be edible.

Nature of Losses

1. **Loss in weight** – Mainly due to transpiration of water
2. **Shrinking and wilting** – Fruits and vegetables get shriveled, tender and leafy vegetables get wilted due to loss of water
3. **Change in color** – Loss of color due to high temperature and senescence.
4. **Change in texture** – Fruits and vegetables turn soft due to over-ripening, or hard & brittle, spongy.
5. **Change in taste** – Development of unpleasant odour and off-flavour
6. Sprouting – Onion, garlic and potato if not stored at proper temperature and humidity result in sprouting
7. **Greening** – Potatoes and Sweet potatoes turn green if exposed to sunlight due to formation of solanine which has toxic properties
8. **Rotting** – Rotting can occur due to incidence of disease and microbial growth.
9. **Bruising and cuts** – due to defective harvesting, handling, packing, transport and storage.

Chapter 2. Pre harvest factors affecting quality of the produce

1. Crops
2. Genetic / variety
3. Light
4. Temperature
5. Humidity
6. Mineral nutrition
7. Water relation/ Irrigation
8. Planting density
9. Cultural Practice - Canopy manipulation
10. Rainfall
11. Seasons / Day and day length
12. Carbon dioxide
13. Use of agrochemicals
14. Pest and diseases
15. Method of harvesting
16. Stage of harvesting

1. Crops: Quality 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.

2. Genetic / variety **–** Varieties with shorter shelf-lives are generally prone to higher post harvest losses. Varieties with thick peel, high firmness, low respiration rate and low ethylene production rates would usually have longer storage life.

3. Light – light regulates several physiological processes like chlorophyll synthesis, phototropisum, respiration and stomatal opening. The duration, intensity and quality of light affect the quality of fruits and vegetables at harvest. In tomatoes, leaf shading of fruits produced a deeper red colour during the ripening than in the case of those exposed to light.

4. Temperature – all type of physiological and biochemical process related to plant growth and yield are influenced by the temperature. The higher temperature during field conditions decreases life and quality of the produce. At high temperature, stored carbohydrates of fruits, vegetables and flowers are quickly depleted during respiration and plant respires at the faster rate. The produce which is having higher amount of stored carbohydrates show longer storage/vase life.

5. Humidity – High humidity during growing season results in thin rind and increased size in some horticultural produce and this produce is more prone to high incidence of disease during post harvest period.

6. Mineral nutrition – balanced application of all nutrient elements is necessary for the maintaining growth and development of the plants. The application of fertilizers to crops influences their post harvest respiration rate. Excess or deficiency of certain elements can affect crop quality and its post harvest life. Ex. Calcium deficiency causes Bitter pit in apples and blossom end rot in tomato

7. Water relation and Irrigation – stress due to excessive or inadequate water in the medium reduce the longevity of the produce. Crops which have higher moisture content generally have poorer storage characteristics.

8. 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.

9. Cultural practice -Canopy Manipulation

A. Fruit thinning – increases fruit size but reduces total yield. It helps in obtaining better quality produce

B. Fruit position in the tree – Fruits which are exposed to high light environment possesses higher TSS, acidity, fruit size, aroma, and shelf life compared to which lies inside the canopy. Hence better training system should be practiced to circulate optimum light and air.

C. Girdling - increases the fruit size and advance and synchronized fruit maturity in peach and nectarines. Increases fruitfulness in many fruit tree species.

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

11. Seasons / Day and day length– seasonal fluctuation and time of the day at harvest will greatly affects the postharvest quality of the produce. 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.

Generally produce harvested early in the morning or in the evening hours exhibits longer PH life than produce harvested during hot time of the day.

Day length - If long days Onion (temperate) grown during short day (tropics) condition it leads to very poor storage quality.

12. Carbon dioxide - quality planting material, early flowering, more flowering, increased yield and rapid crop growth and development at higher level of CO_2.

13. Use of Agro chemicals – Pre-harvest application of chemicals such as BA, IAA, GA3, growth retardants like B-9, CCC, A-Rest and Phosphon-D have been reported to improve quality and longevity of flowers crops. Use of chemicals on the plants to prevent the pathogen will have direct impact on extending the postharvest life. Pre harvest application chemicals like MH on onion filed prevent them sprouting during storage.

14. Pest and Diseases – infection by fungi, bacteria, mites and insects reduces the longevity as well as consumer acceptability. Tissue damage caused by them show wilting and produce ethylene which leads to early senescence.

15. 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.

16. 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.

The factors affecting the quality of fruits and vegetables can be grouped into environmental and cultural.

A) Environmental factors		
Sl.No.	Factors	Quality affected
1	**Temperature**	Maturity, colour, sugar, acidity etc. High Temperature reduces the quality, e.g., citrus, radish, spinach, cauliflower, etc., and increased the quality in grapes, melons omato, etc. Low temperature cause chilling and freezing injury.
2	**Light**	Essential for anthocyanin formation. Exposed fruit to sun light develop the lighter weight, hinner peel, lower juice and acids and higher TSS than shaded fruits, e.g., citrus, mango, etc. Exposure of potato to light causes Greening (solanine formation) which has toxic properties. High sun light intensity causes Sunscald in citrus and tomatoes and reduces the pure white colour of cauliflower. Low light intensity causes thin and large leaves in leafy vegetables.
3	**Rains**	Causes cracking in grapes, dates, litchi, limes, lemon, tomato, sweet potato, etc. It reduces appearance and sweetness.
4	**Wind**	Causes brushing, scratching and corky scar (citrus fruits) on the fruit and

		damage leafy vegetables.
5	**Humidity**	High humidity reduces the colour and TSS and increases acidity in citrus, grapes, tomato, etc., but on other hand it is needed for better quality of banana, litchi and pineapple.
B) Cultural factors		
A	**Mineral nutrition**	
	Nitrogen	High nitrogen reduces the ascorbic acid content, TSS/ acid ratio and keeping quality but increases thiamine, riboflavin, carotene, e.g., Citrus and Spinach. Its deficiency reduces size of fruits.
	Phosphorous	High phosphorous decreases size, weight, vitamin C e.g., Citrus. Its deficiency causes poor appearance of fruit.
		Potassium Increase size, weight and vitamin C, e.g., Citrus. Its deficiency causes uneven ripening.
	Calcium	Increases firmness of many fruits, e.g., Apple, Mango, Guava, Tomato, etc.
	Magnesium	Increases size, weight and vitamin C, e.g., Citrus fruits
	Zinc	Increases size, weight and vitamin C, e.g., Citrus. Deficiency causes straggled cluster in Grape.
	Boron	Deficiency causes flesh browning in fruits, e.g., Anola and gummy discolouration of albedo in citrus. Fruits and vegetables become hard and misshapen. Cabbage, Turnip and cauliflower are sensitive to boron deficiency.
	Copper	Deficiency causes irregular blotch on citrus fruits and spoils the appearance.
B	**Growth Regulators**	
	Auxins	Increases fruit size in loquat (2, 4, 5-TP), mandarins (NAA) and TSS in mango (2, 4,-D).
	Gibberlic acid	Increases size and weight of grape berries, apricot, and strawberry and causes parthenocarpic fruits in fig, guava, grape, tomatoes etc. It reduces disorder of fruits, e.g., water spot and corky spot in citrus
	Cytokinin	Maintain green colour of leafy vegetables and causes parthenocarpic fruits in fig.
	Ethylene	Ethephon increases anthocyanin (coloured grape, plum, apple, chillies,

		brinjal), carotenoides (mango, guava, papaya, citrus, tomato etc), ascorbic acid and TSS and reduces tannin (grapes, dates, etc) and acidity (grape, mango, tomato, etc.)
	Growth retardant	Alar (B9) increases colour in fruits, e.g., apple, cherry, apricot, etc. Maleic hydrazide (MH) inhibits sprouting in onion bulbs
C	**Root stock**	In citrus Troyer and Carizzo (Citranges) rootstock produce the fruit of excellent quality of oranges, mandarins and lemons. In guava *P.pumilum* root stock increases sugar and *P.cujavillis* ascorbic acid content of fruits.
D	**Irrigation**	Excess irrigation causes high acidity and deficiency of moisture reduces fruit size, juice content and increases thickness of peel
E	**Pruning**	It affects the size, colour, acidity and sugar content of grape, phalsa, ber, peach, apple etc.
F	**Thinning**	Thinning in grapes, dates, peaches, plum, etc., increases size, colour, acidity and sugar content of fruits.
G	**Girdling**	In grapes, it increases size, colour and sugar content of the berries
H	**Variety**	Varieties differ in size, shape, colour and chemical composition. High yield, bright appearance and good shipping qualities are most important characters of the varieties.
I	**Diseases and pests**	Both are harmful to fruits and vegetables
J	**Pesticide**	Pesticide spray residues may give rise to flavor taints in the processed product. Excessive use of pesticides may even produce harmful metabolites and toxicity not necessarily destroyed during processing
K	**Maturity**	In general vegetables with exception of potato and onion are of higher quality when less mature because they are more tender, succulent, less fibrous or starchy. On the other hand fruits when ripe are of higher quality on account of full size, bright colour, sweetness and less acidic.
L	**Mechanical injury**	Fruits and vegetables should be in no case injured or damaged other wise injury, such as skin abrasion and tissue bruising will reduce appearance and may be source of infection.

Chapter 3. Ripening and changes occurring during ripening

Ripening is the process by which fruits attain their desirable flavour, quality, colour, palatable nature and other textural properties. Ripening is associated with change in composition i.e. conversion of starch to sugar. On the basis of ripening behavior, fruits are classified as climacteric and non-climacteric fruits.

Climacteric fruits: Climacteric fruits are defined as fruits that enter 'climacteric phase' after harvest i.e. they continue to ripen. During the ripening process the fruits emit ethylene along with increased rate of respiration. Ripe fruits are soft and delicate and generally cannot withstand rigours of transport and repeated handling. These fruits are harvested hard and green, but fully mature and are ripened near consumption areas. Small dose of ethylene is used to induce ripening process under controlled conditions of temperature and humidity.

Climacteric fruits are:

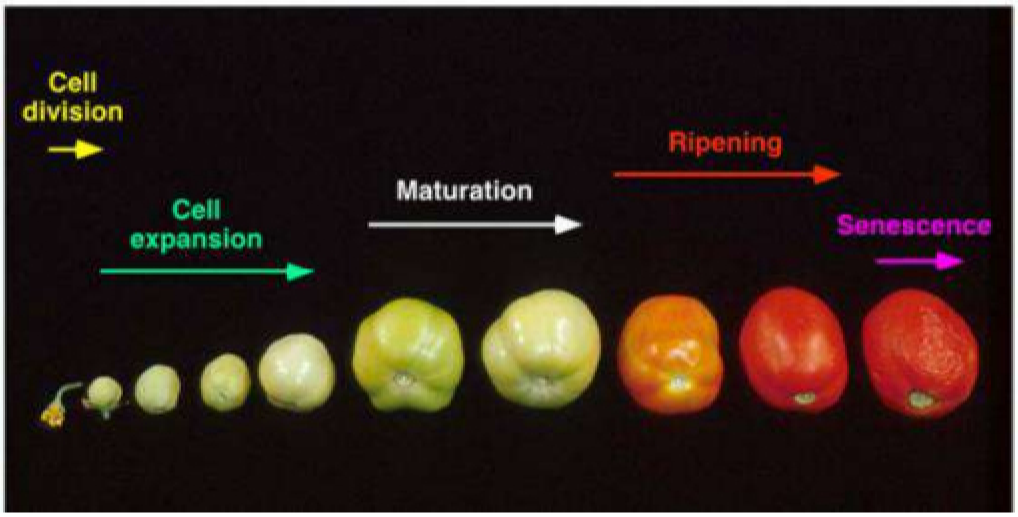
*Mango *Banana *Papaya *Guava *Sapota *Kiwi *Fig *Apple *Passion fruit *Apricot *Plum *Pear

These fruit in fully ripe state are too delicate to withstand transportation over long distances and should preferably be ripened near the consumption area.

Non-Climacteric fruits: Non-climacteric fruits once harvested do not ripen further. Nonclimacteric fruits produce very small amount of ethylene and do not respond to ethylene treatment. There is no characteristic increased rate of respiration or production of carbon dioxide. In order to improve external skin colour and market acceptance, citrus like orange, lemon, mousambi and kinnow can be treated with ethylene, as a de-greening agent. Ethylene treatment breaks down the green chlorophyll pigment in the exterior part of the peel and allows the yellow or orange carotenoid pigments to be expressed.

Non-Climacteric fruits are:

*Orange *Mousambi *Kinnow *Grapefruit *Grapes *Pomegranate *Litchi *Watermelon *Cherry *Raspberry *Blackberry *Strawberry * Carambola *Rambutan * Cashew



Several processes take place as fruit ripen and become edible, and then senesce. These changes may take place while fruit are still attached to the plant or after harvest. Tomato, banana and avocado are examples of fruit that at harvest can be at a mature green but unripe stage and are inedible until subsequent ripening processes have occurred. In contrast, strawberry, orange, boysenberry and grape are examples of fruit that need to stay on the tree or vine until ready to eat in order to have their desired eating characteristics.

The maturity has been divided into two categories i.e. physiological maturity and horticultural maturity.

1. Physiological maturity: It is the stage at which a plant or plant part continues ontogeny (complete developmental history of an organism from egg/spore/ bud etc. to an adult individual) even if detached from the parent plant or the point of origin. It can also be defined as the stage at which a plant or plant part is capable of further development or ripening when it is harvested i.e. ready for eating or processing. Ex. A French bean pod or okra pod is at its physiological maturity when the seeds are fully developed and the pod is lignified which will dehisce with little pressure.

2. Horticultural maturity / Harvest maturity: It may be defined as the stage at which a plant or plant part possesses all the prerequisites for use by consumers for a particular purpose, i.e. local, distant, export market (**shipping** maturity) or exhibition or processing (processing maturity), culinary maturity, desert maturity etc. Ex. A pod vegetable is matured when it is tender with maximum size. Horticultural maturity stage of tomato if harvested for long distance transportation would be the "turning stage of skin from green to red", while the optimum stage of harvesting of the same crop for home use or local markets would be "when the fruits have attained full red colour".

Several major changes take place as fruits ripen, and taken collectively they characterise ripening processes.

These changes make the ripe fruit attractive to animals, which in eating the fruit will disperse the seeds and enlarge the range and improve the survival chances of the next generation of the plant. Lignified pits and seeds encased in a fibrous core might be discarded after eating the flesh, whereas smaller seeds might pass through the animal's digestive system and be deposited with the animal's excrement.

1. **Change in carbohydrate composition -** The ripening induces the breakdown of carbohydrate polymers, by various carbohydrases and leads to near total conversion of starch to sugars. This has the dual effect of altering the taste and texture of the produce. The increase in sugar renders the fruit much sweeter and therefore more acceptable.

2. **Change in color** - Pigments are essential for the attractiveness of fruits and accumulate most often in the skin during the ripening process. Color is often the major criteria used by consumers to determine whether the fruit is ripe or unripe. As fruit matures and ripen, green colour decline and develops yellow, red or other colours due to the presence of accessory pigments, which are characteristic of the various cultivars.

- **Formation of pigments:** During ripening there is formation of pigments mainly carotenoids and anthocyanins. Carotenoids include β-carotene, xanthophyll esters, xanthophylls and lycopene while anthocyanins include cyaniding, pelargonidin, petunidin etc
- **Degradation of pigments:** Climacteric fruits show rapid loss of green colour with attainment of optimum eating quality. Some non-climacteric fruits also exhibit a marked loss of green colour with attainment of optimum quality. The green colour loss is due to the degradation of chlorophyll structure. The main factors responsible for chlorophyll degradation are: pH changes, oxidative systems and enzyme chlorophyllase.

3. **Flesh softening and textural changes -** Textural change is the major event in fruit softening, and is the integral part of ripening, which is the result of enzymatic degradation of structural as well as storage polysaccharides. Cell walls of fruit undergo a natural degradation during fruit ripening, reducing cell wall firmness and intercellular adhesion. This leads firstly to the attainment of a desirable eating texture and then, as senescence begins, to a loss of this desirable texture. Enzymatic degradation of structural as well as storage polysaccharides occurs - pectin, cellulose, and hemicelluloses.

4. **Taste:** Taste depends on the proper proportion of sugars and acids. So, it is convenient to measure taste as sugar-acid ratio (Brix-acid ratio). Acidity and astringency gradually disappear, while sweetness increases due to conversion of starch to sugars during the course of fruit ripening. Starch content of banana decreases from initial 21% to about 15% in ripened fruit. This is accompanied by accumulation of sugars mainly sucrose to the extent up to 20% by fresh weight.

5. **Flavour changes -** The increase in flavor and aroma during fruit ripening is attributed to the production of a complex mixture of volatile compounds and degradation of bitter principles, flavanoids, tannins, and related compounds.

6. **Aroma:** Aroma plays an important part in the development of optimal eating quality in most fruit. It is due to synthesis of many volatile organic compounds (often known merely as volatiles) during ripening phase. Together with taste, it constitutes flavour. Aroma usually develops during ripening but occasionally in storage also. During ripening enzymes break

down large organic molecules into smaller one that can be volatile (evaporate into the air) and can be detected as an aroma. The flavouring compounds are found to be different in different types of fruit but all of them are volatile. The aroma of fruit is not due to a single chemical compound but it is a mixture of no. of chemicals, which may be derived from aliphatic compounds, alcohols, acetates, ketones or esters and terpinoides.

7. **Change in organic acids -** In oranges and grapefruits the acid content drops during ripening, while in lemons, there is an increase in acids. Synthesis of ascorbic acid also occurs in many fruits during ripening. Generally, the acidity decreases during ripening as organic acid are utilized in respiration of fruits.

8. **Ethylene and respiration –** Climacteric peak (increase in ethylene and respiration rate) is observed during ripening in climacteric fruits. Respiration is essential for ripening as it provides the energy required to drive many of the reactions and changes. If respiration is inhibited, ripening is also inhibited.

9. **Abscission:** During ripening the pectinase enzyme also unglue the cells of the abscission zone (the layer of cells in the pedicels often called abscission zone). So, the cells in this zone become weak and the weight of the fruit will cause it to all from the plant.
10. **Development of surface wax:** The delicate waxy or powdery substance develops on the surface of certain fruits like grape and berries.

Chapter 4 – Respiration

Metabolic activity in fresh fruits and vegetables continues for a short period after harvest. The energy required to sustain this activity comes from the respiration process (Mannapperuma, 1991). Respiration involves the oxidation of sugars to produce carbon dioxide, water and heat. The storage life of a commodity is influenced by its respiratory activity. By storing a commodity at low temperature, respiration is reduced and senescence is delayed, thus extending storage life (Halachmy and Mannheim, 1991). Proper control of the oxygen and carbon dioxide concentrations surrounding a commodity is also effective in reducing the rate of respiration.

There are mainly two types of respiration: aerobic respiration and anaerobic respiration, depending upon availability of oxygen. In aerobic respiration, oxygen (O2) is the final electron acceptor while in anaerobic respiration, or fermentation, some other compound is the final electron acceptor.

Aerobic respiration

Aerobic respiration is the major biochemical process supplying energy. It involves the oxidation of certain organic compounds i.e. glucose, maleic acid, stored in the tissues. The compounds that are oxidised during this process are known as respiratory substrates. Aerobic respiration occurs in three phases: glycolysis or Embden-Meyerhoff-Parnas (EMP) pathway, the Krebs or Tri-carboxylic acid cycle and the electron transport chain.

In glycolysis, a molecule of the six-carbon sugar glucose is oxidized to two molecules of the three-carbon pyruvate. The Krebs cycle completes the oxidation of pyruvate to produce carbon dioxide (CO2) and reduced electron carriers. In the electron transport chain, a proton (H+) gradient drives the production of even more ATP and is coupled with the transfer of electrons to oxygen (O2), producing water (H2O). After the entire process of respiration is complete, much of the energy released from the glucose is recaptured in the production of ATP.

Glucose is the most favoured substrate for respiration. All carbohydrates other than glucose are converted into glucose first before they are used for respiration. Fats are metabolized into glycerol and fatty acids first and then to acetyl CoA and glyceraldehyde-3- phosphate, respectively. Proteins are degraded individual amino acids (after deamination) and then enter the respiratory pathway. The respiration is exothermic in nature and theoretically, 60% of the bond energy is lost as heat. However, calorimetry studies have shown that respiration in postharvest tissues often results in even more dissipation of energy as heat loss (90% or more) and less ATP synthesis. This heat contributes to an increase in the temperature of the commodity and is known as **vital heat or heat of respiration**. Heat of respiration is a primary consideration in designing the storage for horticultural crops.

Anaerobic respiration

Aerobic respiration is preferred energy producing pathway in fruits and vegetables. But under the limiting O2 conditions, fermentation becomes increasingly important. During this process, pyruvic acid produced during the glycolysis is converted to lactic acid, ethanol or acetaldehyde. Increase in fermentation helps the cell meet its ATP requirement under anaerobic conditions. Anaerobic respiration produces much less energy than aerobic pathway and elevated CO2 concentrations have deteriorative effect on the product quality. Anoxia results in injuries to tissue. High concentrations of fermentative metabolites are also associated with various physiological disorders like necrosis, discoloured tissues, offflavours, off-odours etc. The oxygen concentration at which anaerobic respiration starts is called extinction point. It varies between the tissue types and also species, cultivar, development stage, maturity etc.

SIGNIFICANCE OF RESPIRATION

Respiration plays a major role in the postharvest life of fresh fruits and vegetables. Respiration continues even after harvest. After harvest the produce is dependent entirely upon its own food reserves as no replenishment is there. Therefore, losses of respiratory substrates and moisture are not made up and deterioration has started. Produce' possessing a high respiration rate can be stored for longer time duration. An enhanced respiration rate is associated with perishability of food. The significant effects of respiration are:

- **Loss of substrates:** The process of respiration utilizes various substrates and thus results in loss of food reserves in the tissue, loss of taste quality and food value. During the extended storage the loss in weight can be highly significant.
- **Oxygen consumption:** For aerobic respiration, presence of oxygen is must. Reduction of oxygen concentration is a useful tool for controlling respiration rate and slowing down the senescence.
- **Carbon Dioxide production:** Accumulation of CO2 produced due to respiratory metabolism can be beneficial or harmful. Carbon dioxide concentration is also used as an effective measure for delaying senescence.
- **Release of Heat:** As respiration is exothermic in nature, heat generated raises the temperature of produce. The heat generated is one of the prime consideration for designing the packaging/ storage of horticultural crops.
- **Shelf life indicator:** Respiratory process indicates the metabolic activity of living produce and determines the post-harvest physiology and deteriorative ability of plant produce. Respiration rate is well correlated with rate of deterioration, and thus is a good measure of the storage potential of the plant produce. Generally, a higher respiration rate indicates shorter shelf life.
- **Change in quality:** The physiological processes leading to enhanced quality (e.g., color development, softening, astringency loss, and aroma production) are deeply influenced by respiration. Extremes in respiration rate results in the development of specific physiological disorders, resulting in loss of quality. Respiration is beneficial in providing carbon skeleton

intermediates for pigment synthesis, flavor development, formation of ripening enzymes, fats, sterols etc.

- Classification: Respiration rate is an important criterion to compare perishability of fruits and vegetables. Depending upon respiratory rate Kader and Barrett classified fruits and vegetables into five different classes, rate as shown below:

Classification of Fruits and Vegetables Based on Respiration Rate

Class	Respiration Rate (mg carbon dioxide/kg h) 10°C	20°C	Examples
I. Very low	<10	<40	Nuts, dates, dried fruits
II. Low	10	40	Potatoes, onions, cucumbers, apple, pear, kiwi fruit, pomegranate, Chinese date
III. Moderate	10–20	40–80	Peppers, carrots, tomatoes, eggplant, citrus fruits, banana
IV. High	20–40	80–120	Peas, radish, apricot, fig, ripe avocado, cherimoya, papaya
V. Very high	>40	>120	Mushrooms, green onions, cauliflower, dill, parsley, melons, okra, strawberry, blackberry, raspberry

Source: Data from I. Burzo. *Acta Hortic.* 116:61, 1980; A. A. Kader and D. M. Barrett. In *Processing Fruits: Science and Technology, Vol. 1, Biology, Principles, and Applications*. (L. P. Somogyi, H. S. Ramaswamy, and Y. H. Hui, Eds), Technomic Publishing Co., Pennsylvania, 2003, p. 1.

Respiratory Quotient The ratio of moles of CO_2 produced per mole of O_2 consumed is called the respiratory quotient. RQ is as an indication of which substrates are being used in the respiratory pathway. RQ is 1 for glucose (carbohydrate) catabolism. When substrates other than glucose are respired, the RQ is different than 1. The complete oxidation of malate by the TCA cycle results in a RQ of 1.6 (oxidation of respiratory malic acid, leads to the production of additional CO_2). The RQ can also exceed 1 when O_2 is not involved, such as in fermentation. RQ values below 1 are expected when lipids or proteins, molecules often containing less oxygen than carbohydrates, are respired.

Respiratory Substrate – carbohydrates, lipids, and organic acids.

$$\text{Respiratory quotient (RQ)} = \frac{CO_2 \text{ evolved}}{O_2 \text{ consumed}}$$

• RQ range from 0.7 to 1.3 for aerobic (with O_2) respiration.

• RQ is much greater if tissue goes into anaerobic (without O_2) respiration.

• Carbohydrates: RQ = 1
• Lipids: RQ < 1
• Organic Acids: RQ > 1

Factors affecting Respiration

1. **Temperature:** Typically, for every 10 °C increase, respiration increases between 2 and 3 fold (Van't Hoff Rule). The temperature dependence of respiratory rate varies among and within commodities. Generally, the respiration increases significantly as the storage temperature increases. Within the physiological range of temperature (0°C–30°C), the rate of respiration increases exponentially, and a large amount of heat is produced as heat of respiration.

   Heat Stress: If the temperature rises beyond the physiological range, respiration rate falls. When tissue reaches its thermal death point, metabolism is disordered as enzyme proteins are denatured. Continued exposure to high temperatures causes phytotoxic symptoms and tissue collapse.

   Chilling stress: Although respiration is normally reduced at low, but non-freezing temperatures, certain commodities particularly those originating in the tropics and subtropics, exhibit abnormal respiration when their temperature falls below 10 to 12 °C. Respiration may increase dramatically at the chilling temperatures or when the commodity is returned to nonchilling temperatures. Enhanced respiration rate is cells' effort to detoxify metabolic intermediates that accumulated during chilling, as well as to repair damage to membranes and other sub-cellular structures. Enhanced respiration is one of the symptoms that signal the onset of chilling injury.

2. **Oxygen and carbon dioxide:** Low O_2 concentrations reduce respiration. High CO_2 also reduced respiration. Reduction of O2 concentration below 2%–3% gives beneficial reduction in rates of respiration and other metabolic processes for most produce. However, complete removal of O2 is not recommended as anaerobic environment is detrimental to the quality of the produce as it leads to fermentation, decay and development of off flavor, and change in color and texture. Increasing the CO2 level around some commodities reduces respiration, delays senescence and retards fungal growth. Different commodities vary widely to their ability to tolerate high CO2

3. **Ethylene:** Climacteric & Non-Climacteric fruits differ in their response to ethylene in the environment. Exposure of climacteric tissues during their preclimacteric stage to ethylene (C2H4) shortens the time to the start of the climacteric rise in respiration. Once the respiratory rise has begun, the tissue's endogenous rate of C2H4 production increases and the internal C2H4 concentration also increases, reaching levels that saturate its biological activity. In contrast, C2H4 treatment of non climacteric tissues, in which endogenous C2H4 levels are very low, induces a climacteric-like rise in respiration that is proportional to C2H4 concentrations. However, unlike the case in climacteric tissues, endogenous C2H4 production remains unaffected. Removal of C2H4 results in a return of the respiration rate to its pretreatment level. The respiratory response of nonclimacteric tissues to C2H4 can be repeatedly induced throughout their postharvest life

4. **Stage of development:** Respiration rates vary due to stage of the development. Storage organs such as nuts and tubers have low respiration rates. Tissues with vegetative or floral meristems such as asparagus and broccoli have very high respiration rates. The commodities harvested during active growth, such as many vegetables and immature fruits, have high respiration rates. Mature fruits, dormant buds and storage organs have relatively low rates. After harvest, the respiration rate typically declines; slowly in non-climacteric fruits and storage organs, rapidly in vegetative tissues and immature fruits. The rapid decline presumably reflects depletion of respirable substrates that are typically low in such tissues.

5. **Stress/ Injury:** Physical stress during cultivation, harvesting, and postharvest handling influences respiratory behaviour significantly. Tissue injury increases the rate of respiration and induces ethylene production, which may further catalyse an increase in respiration with consequent loss of quality. The extent of increase in respiration rate is usually proportional to the severity of bruising. Water stress which is induced by lower than optimal relative humidity in air surrounding the commodity can increase its respiration rate. Biological stress like disease also increases the respiration rate. Other stresses that stimulate the respiration rate of vegetables including exposure to ionizing radiation and to various chemicals such as methyl bromide (fumigant) etc.

6. **Surface of tissue:** Thickness of surface dermal system, wax composition and arrangement, number and distribution of stomata on the tissue influences the respiration rate. More the thickness of coating, less is the respiration rate.

7. **Surface to volume ratio:** Smaller fruits have large surface area leading to high respiration rate.

8. **Growing conditions:** Cultural practices, irrigation, fertilizer also influence the respiration rate. High nitrogen fertilizer increases respiration while high calcium fertilizer decreases respiration.

9. **Application of chemicals:** Certain chemicals like malic hydrazide (MH), methyl cyclo-propene (MCP), polyamines like putrescine, spermidine and spermine slows down the rate of the ethylene production and respiration while application of ethylene, acetylene, propylene, ethephon has a positive effect on respiration rate due to positive impact on ethylene (ripening hormone) generation.

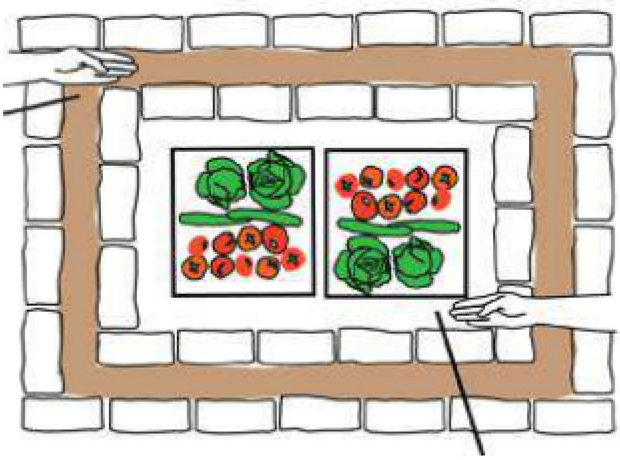
Chapter 5. Methods of Storage

Evaporative cool storage – This is one of the simple and effective methods for short term storage of fruits and vegetables at farm level. This reduces shriveling, extend storage life and prevent losses during marketing and storage. Such type of storage maintains high relative humidity with temperature nearer to wet bulb and thus reduces the weight loss considerably in stored fruits and vegetables. It is one of the low cost technologies developed which can be installed anywhere and any time. Though cold storage is the best yet, due to highly energy extensive, huge capital investment and perennial power shortage, most of the small farmers find it difficult and are forced to sell produce at distress price soon after harvest. Under these conditions the evaporative cool storage help the farmers to get better returns for their produce.

When water evaporates from the liquid phase into the vapour phase energy is required. This principle can be used to cool stores by first passing the air introduced into the storage room through a pad of water. The degree of cooling depends on the original humidity of the air and the efficiency of the evaporating surface. If the ambient air has low humidity and is humidified to around 100% RH, then a large reduction in temperature will be achieved. This can provide cool moist conditions during storage.

Zero Energy Cool Chambers –

Zero energy cool chambers are based on the principal of evaporative cooling and developed for short term storage of fruits and vegetables. The raw materials used for construction of cool chambers are bricks (400 bricks) and river bed sand (10 bags) to hold about a quintal of fruits and vegetables. The floor of the storage space is made with a single layer of bricks. The side wall is made with a double layer of bricks leaving a space of 7.5 cm between the bricks which are filled with sand. The top cover of storage space is made with gunny bags or khas in bamboo frame structure. After the construction, the brick, sand and top cover of cool chamber are kept completely wet by sprinkling water prior to storage. Sprinkling of water once in the morning and once at evening maintain the temperature (with ± 2°C internal temperature) and humidity (90%) throughout the year.



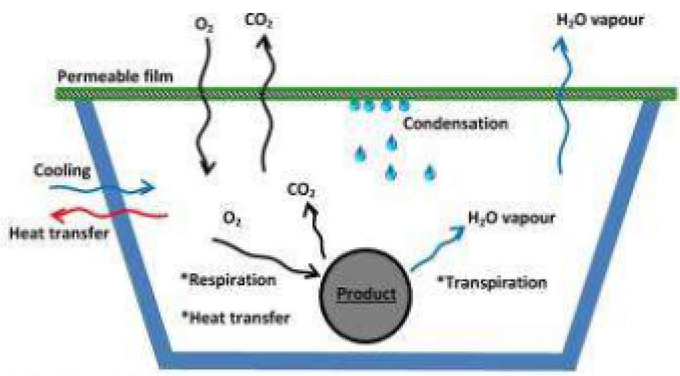
Controlled Atmosphere (CA) storage

The CA storage technique is the most important innovation in fruit and vegetable storage. CA is a supplement and not as a substitute for proper temperature and relative humidity management. Such storage works on the principle of maintaining an artificial atmosphere in storage rooms which have a higher concentration of CO_2 and lower concentration of O_2 than normal atmosphere. It is important to control the level of CO_2 since at very high level anaerobic reaction leads to fermentation. CA storage reduces the rate of respiration and thus delays aging. Such storage is very effective when combined with low temperature storage. Some simple methods for controlling or modifying the composition of air in the storage environment are given below. Air coming into the store room is being recirculated within the room and must pass through a monitoring and control system. Carbon dioxide CO_2 can be increased through dry ice and pressurized cylinder. Level can be decreased by sodium hydroxide scrubber and hydrated lime @0.6 kg to treat air used to ventilate 100 kg of fruits and vegetables. Oxygen can be decreased through purging with nitrogen from liquid nitrogen through an evaporator. Ethylene gas can be controlled by potassium permanganate and activated charcoal.

Modified atmosphere storage

Modified atmosphere packaging (MAP) has been defined as packaging of food 'in an atmosphere which has been modified so that its composition is other than that of air'. Modified atmosphere storage also requires a decrease in O_2 and an increase in CO_2 or N_2 but there is no control of atmosphere at specific concentration. Hence, it differs with CA storage only in degree and control method. **Active MAP** involves **modification** of the gas composition through initial gas flushing **or** the introduction of a gas scavenging system within the **package**; in **passive MAP** the gas composition is altered due to the combined effects of product respiration **and** permeability (diffusion) of the **packaging** film.

Oxygen scavengers – iron powders- ferrous compounds, ascorbic acid
Carbon dioxide scavengers – Activated charcoal, Sodium hydroxide, Calcium hydroxide, Lime
Ethylene scavengers – Potassium permanganate, silicones



Hypobaric storage

This is also known as reduced atmospheric/low pressure storage/ sub atmospheric storage/ vaccum storage. The principles of such storage is to remove ethylene gas from the storage atmosphere and lowering the partial pressure of O_2 which leads to slow ripening, hence fruits can be kept longer. It is a type of CA storage with emphasis on reducing the pressure of $O_2$and ethylene gas. Low oxygen reduces the respiration rate and low ethylene delays the ripening, as a result fruits are stored for longer time. In such storage fruits like mango, banana, pineapple, guava, apple, pear, avocado, and lemon fruits have better storage life. This system is used in transportation of fruits also. Low pressure of O_2 (102 mm Hg) reduces the growth of pathogenic disorders such as *Rhizopus nigricans, Aspergillus niger, Botrytis* species and *Alternaria* species.

Cold Storage

Cold or low temperature storage is most reliable and extensively used for retention of freshness and extending the shelf life of fruits and vegetables for a long period. Low temperature storage employs the principles of maintaining a low temperature which reduces the rate of respiration, thermal decomposition and thus delays ripening. Each fruit and vegetable has to be kept at an optimum temperature. Both temperature and relative humidity are controlled in such storage. The basic equipment for mechanical refrigeration consists of compressure (compressed refrigeration), condenser (cooling) expansion valve (for expansion) and evaporator (evaporation of a compressed liquefied gas).

Chapter 6 Principles and methods of preservation

Preservation: Preservation means just protect the foods against the spoilage, but scientifically it may be defined as a science which deals with the process for prevention of decay or spoilage of the food is called preservation.

Principles of preservation--- There are three main principles:

1. Prevention or delay the microbial decomposition of the food.
2. Prevention or delay the self decomposition of the food.
3. Prevention or damage by insects, animals, mechanical causes.

1. Prevention/delay the microbial decomposition of the food:

1. By keeping out the micro organisms ---Asepsis
2. By removal of micro organisms ---Filtration
3. By hindering the growth and activity of micro organisms ---Anaerobic condition
4. By killing the micro organisms ---Exposing at high temperature

A. Asepsis: It means preventing the entry of micro organisms by maintaining of general cleanliness, while picking, grading, packing and transporting of fruits and vegetables, increase their keeping quality and the product prepared from them will be superior quality.

B. Filtration: Fruit juice, bear, soft drinks, wines etc. enter through a bacteria proof filter which is made of asbestos pad or unglazed porcelain type of materials. These filters contain the micro organisms and allow the water or juice to percolate through with or without pressure.

C. Anaerobic conditions: It can be maintained by:

- Replacing the O2 by CO2 ---------- Carbonation
- Evacuating the sealed container (fruit juice)
- Use of oils from top of the food (pickles)

D. Exposing at high temperature: Fruits can be exposed to high temperature such as;

- **Canning:** Food is exposed to a high temperature (>100OC) which reduces spoilage and inactivate the enzyme present in the food. The process of sealing food stuffs hermitically (air tight, protecting from out side agencies) in containers and sealing them by heat for longer storage is called canning.
- **Irradiation:** In case of irradiation, the food is exposed to the radiations to kill the surviving micro organisms by ionising and non-ionising radiation like α, β and γ rays. Here, food is exposed to electromagnetic or ionizing radiation or various frequencies ranging from low

frequency electromagnetic rays to high frequency i.e. gamma rays which destroy the micro organisms present in the food.

2. prevention/delay the self decomposition:

a. By destruction or inactivating the enzyme – Blanching.

b. Prevention / delay the non-enzymatic chemical reactions – Antioxidant

A. Blanching: Treatment of fruits and vegetables with boiling water or steam for short periods followed by cooling prior to canning is called" **blanching**".

 It is a primary treatment which has to soften the tissues to facilitate packaging.

 To preserve the original colour and flavour.

 To destroy certain enzymes which are undesirable.

 Elimination of the air.

 Mostly done for vegetables.

 Remove micro organisms

 Remove astringent taste and toxins.

B.Antioxidant: Anti-oxidants are substances which are used to protect the food
against deterioration caused by exposure to the air.

 BHA- Butylactic Hydroxy Anisole & BHT- Butylactic Hydroxy Toluene (vegetable oils)

 Gellales : Animal fat, Vegetable oil

 Tocopherols: Animal fat

 Ascorbic acid: Fruit juices, Citrus oil, Wine, Beer etc.

 Lactic acid: Processed fruits and vegetables, canned fruits.

 Phosphoric acid: Vegetable oil, Animal fat and Cola drinks.

3. Prevention or damage by insects, animals, mechanical causes: This principle of preservation deals with the prevention of damage caused by various external agencies other than micro-organisms and enzymes i.e. animals, man, insects, rodents etc.These agencies generally cause physical damage to the food material eg.rats may eat peels of oranges in a storage, animals may also eat the food if kept within their reach etc. But in none of these cases these damages are deleterious to human health. If you consume a half eaten apple or orange you are generally never going to die or experience any health risks, but if the food is spoilt by micro organisms, and you consume the spoilt food your health shall definitely be at risk. The damage of food by animals, man, insects, rodents etc. may later on give way for the initiation of microbial and self decomposition. Proper packing of the food is predominantly the effective solution for prevention of damage caused by the agencies considered under this principle of preservation. Over all from the food processors point of view the three principles are to be considered in decreasing order of importance and emphasis. Highest emphasis is given on control of microbial decomposition followed by self decomposition, ultimately followed by damage caused by animals, insects, rodents etc

Methods of preservation of fruits and vegetables

A. TEMPORARY PRESERVATION

1 Ascepsis
2 Low temperature storage
3 Exclusion of moisture/drying
4 Use of mild antiseptic
5 Pasteurization

B. PERMANT PRESERVATION

1 Sterilization
2 By chemical preservative
3 By antiseptics
4 By fermentation
5 By irradiation
6 By carbonation
7 By filtration
8 By antibiotic

The important methods of preservation of fruits and vegetables are:

A)Temporary preservation

a) **Asepsis:** prevention of microbial infection during handling processing and till sealing and during storage of cans by observing strict cleanliness throughout the entire process is kown as asepsis.

Precautions-

1 Take proper care during picking and packing of fruits and vegetables discarding the diseased and damaged produce.

2 Removed bruised or damaged fruits and vegetables select the material which is free from blemishes.

3 Remove the dirt and microorganisms present superficially on fruit and vegetables by through washing or cleaning for preservation.

4 maintain strict cleaniness and hygienic condition during preparation of produce and during sealing and processing of cans.

5 Store in cool and dry place. Storing in cool place help to maintain proper misture content in product as well hamper microbial growth.

(3) Preservation by low temperature-- Low temperature retards the microbial growth and enzyme reaction because it retards the chemical reactions. This is not a permanent method because some micro organisms can also grow at low temperature.

1. Cellar storage: (Above 15^0C)
2. Refrigerated storage: (0 to 5^0C)
3. Freezing storage: (-18 to -40^0C)

1) **Cellar Storage:** Cellar Storage (about 150C). The temperature in cellar ((underground rooms) where surplus food is stored in many villages is usually not much below that of the outside air and is seldom lower than 150C. Root crops, potatoes, cabbage, apples, onions and similar foods can be stored for limited periods during the winter months.

2) **Refrigeration:** Refrigerated (or) chilling (0.to 5^0C). Chilling temperature are obtained and maintained by means of ice or mechanical refrigeration. Most perishable foods, including eggs, dairy products, meats, sea foods, vegetable and fruits may be held in chilling storage for a limited time with little change from their original condition. Enzymatic and microbial changes in the foods are not prevented but are slowed considerably. Fruits and vegetables can be stored for 2-7 days. Semi-perishable crops, such as potatoes, apples etc. can be stored, in the commercial cold storage with proper ventilation, automatic controlled temperature for one year.

3) **Freezing:** Freezing (-18 to -40^0C). At temperature below the freezing point of H2O, growth of microorganisms and enzyme activity are reduced to minimum. But, sometimes enzymes are active even below the 00C. In this case before freezing, 'Blanching' is necessary for vegetable freezing. Most perishable foods can be preserved for several months. Fruits, vegetables, juices and fleshy foods (meat, poultry, fish and sea foods) can be preserved in this method.

(3) Preservation by drying --- Drying is just removal of moisture from the food to a certain level at which micro organisms cannot grow is called drying, It can be done by two methods:

(i) Application of heat :(a) Sun drying (b) Mechanical drying (c) Vacuum drying (d) Freeze drying, (ii) Binding the moisture in the food : (a) Use of Sugar & (b) Use of Salt, (i) Application of heat **:**

(a) Sun drying: Sun drying is the method in which food is directly exposed to sunlight. It is generally done in the places where plenty of sunshine is available for long period e.g. Rajasthan. The dried product in this method is inferior in quality**.**

(b) Mechanical drying: This is a method of drying where application of heat is applied by a mechanical dryer under the controlled conditions of temperature, humidity and air flow.

(c) Vacuum drying: The temperature of the food and the rate of water removal are controlled by regulating the degree of vacuum and intensity of heat input.

(d) Freeze drying: In this method, the food is dried by sublimation process, i.e., just converting the food into ice without passing through the liquid form of water by means of vacuum plus heat applied in the drying chamber. In this method, the product is first frozen, then water is removed by vacuum and application of heat which occurs simultaneously in same chamber.

(4) Use of mild antiseptic: The use of antiseptics in small quantities prevents growth of microbes either by osmosis or by poison or by both actions for a short time. Sugar, salt, vinegar. Oil etc are example of mild antiseptic.

(5) Pasteurization: It is a mild heat treatment. By pasteurization milk is pasteurized by HTST at 72^0C for 15 sec. Fruit juices are pasteurized at such temperature and for such periods as would render them sterile, without impairing their flavor. Usually, the juices are pasteurized at about 850C for 25-30 min., according to the nature of the juice and the size of container. Acid fruit juices require lower temperature and less time for pasteurization than the less acid ones.

Juices can be pasteurized in two ways

(1) By heating the juice at a low temperature for a High time (LTHT) and

(2) By heating the juice at high temperature for a short time only (HTST).

B) Permant preservation

1 1. **Preservation by high temperature**

Sterilization: Process of killing of all the form of microbial life is called as sterilization. Sterilization products are sealed to prevent empty of live microbes from outside. The temperature and time required for sterilization varies with the types of product. The various methods of sterilization are as follow.

a) Sterilization below $100^{O}C$- eg used for fruit juices.
b) One time heating at $100^{o}C$ –for long period
c) Intermitted processing- at $100^{o}C$.

eg Canning: Canning is done at or above 1000C. In case of fruits which are acidic, they are canned at $100^{0}C$, while in case of vegetables those are non-acidic; they are canned at above $100^{0}C$. Here, high temperature can be obtained by using steam pressure; time varies according to the type of foods. Due to anaerobic condition any survivable organism would not grow.

(2)Preservation by use of chemical preservatives-- Chemical preservatives are substances which are added to food just to retard, inhibit or arrest the activity of micro organisms such as fermentation, pacification and decomposition of the food.

Chemical preservatives are of two types:

Class-1 preservatives: common salt, sugar, dextrose, spices, vinegar, Ascorbic acid etc.

Class-2 preservatives : Benzoic acid and its salt, SO2 and the salts of sulphuric acid, nitrates, ascorbic acid and its salts, propeonic acid and its salts, lactic acid and its salts. Among the class-2 preservatives, only two chemical preservatives are used in fruits and vegetables preservation:

(i) KMS(Potassium Meta bisulphate) :

(1) It releases the SO2 and it is unstable.

(2) It is used for the fruit which have non water solvent pigment (colourless).

(3) It can not be used in naturally coloured juices such as phalsa, jamun because they have the Anthocynin pigment.

(4) It can not be used in the product which is packed in container because it acts on the tin containers and oil, Hydrogen Sulphide (H2S) which has an unpleasant smell and also form a black compound with the base plate of containers.

(5) Best to control moulds than bacteria.

(6) 350 ppm KMS is mostly used in fruit juice products.

(ii) Sodium Benzoate :

(1) It is a salt of benzoic acid and soluble in water.

(2) It delays the fermentation in the juices.

(3) It is commonly used in the product which are having natural colour such as anthocynin pigment.

(4) It is more effective against the yeast.

(5) 750 ppm Sodium benzoate is mostly used in fruit juices, squashes and cordials.

(3) Preservation by use of antiseptics (Sugar, Salt, acids and vinegar):

Food additives are substances or mixture of substances other than basic foodstuffs, which are present in the foods as reagent of any aspects of production, processing, storage, packaging etc. Food additives are (i) **sugar**, (ii) **salt**, (iii) **acids**, (iv) **spices**.

In case of sugar and salts, they exert osmotic pressure and water diffuses from the product through a semi-permeable membrane until the concentration reached equilibrium. They kills the micro organisms or do not allow them to multiplly.

(i) Sugar: The concentration of 68-70% is used for preparation of jam, jelly, marmalades etc. Sugar act as a preservative by osmosis and not as a true poison for micro organisms. It absorbs most of the available water, so little water available for the growth of micro organisms.

(II)Salt: The concentration of 15-20% is used for the preparation such as pickles. Salt inhibits enzymatic browning and discolouration and also acts as an anti-oxidant. It exerts its preservative action by:

(i) Causing high osmotic pressure resulting in the plasmolysis of microbialcells.

(ii) Dehydrating food and micro organisms by tyeing up the moisture.

(iii) Ionizing to yield the chloride ion which is harmful to micro organisms, and

(iv) Reducing the solubility of oxygen in water, sensitizing, and the cells against CO2.

(III)Acids: Many processed foods and beverages need the addition of acids to impart their characteristic flavor and taste in the final product because acids provide desired flavour and taste. They adjust the sugar and acid ratio in the food .proper balance of flavor of the food. They are also playing the role for controlling the pectin-gel formation.

Main acids are the following: Acetic acid (Vinegar), Citric acid (Lime juice.

1. Acetic acid: It is commonly used for pickles, chutney, sauce and ketchup, just to inhibit the growth of micro organisms.

2. Citric acid: It is used for the preparation of jam, jelly, squash, nectar etc. just to increase the acidity.

(IV) Oil A layer of oil on the surface of any food produces anaerobic conditions which prevent the growth of moulds and yeasts. Eg., pickles

(4) Preservation by fermentation -- Decomposition of carbohydrates by microorganisms or enzymes is called fermentation. Foods are preserved by the alcohol or organic acid formed by microbial action. The keeping quality of alcoholic beverages, vinegars, and fermented pickles depends upon the presence of alcohol, acetic acid and lactic acid respectively. Wines, beers, vinegar, fermented drinks, fermented pickles etc., are prepared by these processes. In wines – 14% alcohol acts as a preservative. About 2% acetic acid prevents spoilage in many products.

(5) Preservation by irradiation-- Sterilization of food by ionizing radiations is a recently developed method of preservation. The unacceptable flavor of some irradiated foods and the fear that radioactivity might be induced in such food has come in the way of its greater use. When gamma rays (or) electron beams pass through foods there are collisions between the ionizing radiation and food particles at atomic and molecular levels, resulting in the production of ion pairs and free radicals. The reactions of these products among themselves and with other molecules results in physical and chemical phenomena which inactivate microorganism in the food. Thus irradiation of food can be considered to be a method of "Cold Sterilization" i.e. food is free of microorganism without high temperature treatment. Radiation dose of up to 1 *Mrad* is not hazardous. Ionizing radiations can be used For sterilization of foods in hermetically sealed packs, Reduction of the spoilage organisms in the perishable foods, delays ripening of fruits, Inhibits sprouting of root vegetables and controls infestation (insects) in stored cereals

(6)Preservation by Carbonation -Carbonation is the process of dissolving sufficient CO_2 in water or beverage so that the product when served gives off the gas as fine bubbles and has a characteristic taste. Fruit juice beverages are generally bottled with CO_2 content varying from 1 to 8 g/ l, it is sufficient for supplementing that effect of acidity on pathogenic bacteria. For complete inhibition of microbial activity (14.6 g CO_2/ l) creating an anaerobic condition, which reduces the oxidation of ascorbic acid and prevents browning.

Although carbonated beverages contain sugar much below 66%, the absence of air and the presence of CO_2 in them help to prevent the growth of moulds and yeasts. The keeping quality of carbonated fruit beverages is enhanced by adding about 0.005% sodium benzoate. The level of carbonation required varies according to the type of fruit juice and type of flavor.

(7)Preservation by filtration -- Filtration is the only successful method for the complete removal of organisms and its use is limited to clear liquids. The liquid is filtered through a previously sterilized 'bacteria proof' filter made of sintered glass, diatomaceous earth, unglazed porcelain, membrane pads, (or) similar material and the liquid is forced through by positive or negative pressure. This method has been used successfully with fruit juices, beer, soft drinks, wine and water.

(8) Preservation by Antibiotics--- Certain metabolic products of microorganisms have been found to have germicidal effect and are termed as antibiotics.

Nisin is an antibiotic produced by *Streptococcus lactis*. Commonly found in milk, curd, cheese and other fermented milk products. It is non-toxic. Used in the food industry especially for preservation of acid foods in which it is more stable. Used in canning of mushrooms, tomatoes and milk products.

Subtilin - an antibiotic obtained from certain strains of *Bacillus subtilis* is used in preservation of asparagus, corn, and peas. It is most effective against *gram*positive bacteria and spore-forming organisms.

Pimaricin- an antifungal antibiotic can be used for treating fruits and fruits juices