Course No. – Hort366

Course Title-

Post-Harvest Management And Value Addition Of Fruits And Vegetables

Credit – 2 (1+1)

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Syllabus

Theory

Importance of fruits and vegetables, extent and possible causes of post harvest losses; Pre-harvest factors affecting postharvest quality, maturity, ripening and changes occurring during ripening; Respiration and factors affecting respiration rate; Role of ethylene; Post harvest disease and disorders; Heat, chilling and freezing injury; Harvesting and field handling; Storage (ZECC, cold storage, CA, MA, and hypobaric); Value addition concept; Principles and methods of preservation; Intermediate moisture food- Jam, jelly, marmalade, preserve, candy – Concepts and Standards; Fermented and non-fermented beverages. Tomato products- Concepts and Standards; Drying/ Dehydration of fruits and vegetables –Concept and methods, osmotic drying. Canning -– Concepts and Standards, packaging of products.

Lecture no.	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**

Lecture No. 1

Importance of fruits and vegetables, extent and possible causes of post-harvest losses

- ✓ 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.

<u>EXTENT AND POSSIBLE CAUSES OF POST-HARVEST LOSSES</u>

- 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.

(a) 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%)

(b) Estimated loss of fruits

Crop	Estimated loss (%)
Papaya	40 - 100
Grape	27
Banana	20 - 28
Citrus	20 - 95
Avufado	43
Apple	14

(c) Estimated loss of Vegetables

Crop	Estimated loss (%)
Onion	25 – 40
Garlic	8 – 22
Potato	30 – 40
Tomato	5 – 34
Chili	4 – 35
Radish	3 – 5
Carrot	5 – 9

Cabbage & Cauliflower	7.08-25.0

(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 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 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.

Lecture No. 2

Pre-harvest factors affecting postharvest quality and Maturity

<u>Quality of post harvest product</u>

- ✓ 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

<u>a) Related to plants</u>

- **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.

C. Post-harvest factors:

  - **Curing:**
- ✓ Curing is done immediately after harvesting. It strengthens the skin.
- ✓ The process is induced at relatively higher temperature and humidity, involving suberization of outer tissues followed by the development of wound periderm which acts as an effective barrier against infection and water loss.
- ✓ It is favoured by high temperature and high humidity. Potato, sweet potato, colocasia, onion and garlic are cured prior to storage or marketing.
- ✓ Potato tubers are held at 18°C for 2 days and then at 7°—10°C for 10—12 days at 90% relative humidity.
- ✓ Curing also reduces the moisture content especially in onion and garlic.
- ✓ Drying of superficial leaves of onion bulbs protects them from microbial infection in storage.
  - **Degreening**:
- ✓ It is the process of decomposing green pigment (Chlorophyll) in fruits usually applying ethylene or similar metabolic inducers to fruit.

- ✓ It is applicable to banana, citrus and tomato.
- ✓ Degreening is carried out in special treating rooms with controlled temperature and humidity in which low concentration of ethylene (20 ppm) is applied.

  - **Pre-cooling:**

- ✓ High temperatures are detrimental to keeping quality of fruits and vegetables, especially when harvesting is done during hot days.
- ✓ Pre-cooling is a means of removing the field heat. It slows down the rate of respiration, minimizes susceptibility to attack of micro- organisms, and reduces water loss.
- ✓ Peas and okra which deteriorate fast need prompt pre-cooling.

  - **Washing and drying**:

- ✓ Most of the fruits and vegetables are washed after harvesting to improve their appearance, to prevent wilting and to remove primary inoculum load of microorganism.
- ✓ Hence, a fungicide/bactericide should be used in washing water.
- ✓ Washing, improves shelf life of bananas by delaying their ripening.
- ✓ After washing, excess of water should be removed which would otherwise encourage microbial spoilage.

  - **Sorting and grading**:

- ✓ Fruits and vegetables require sorting and grading for uniform packing at field level.
- ✓ Sorting is done on the basis of size and colour while grading practice is performed as per the defect or on the basis of marketable and unmarketable produce.

  - **Disinfection:**

- ✓ Papaya, mango, melon and other fruits are susceptible to fruit fly attack.
- ✓ Disinfection is done either by vapour heat treatment (VHT) at 43°C with saturated air with water vapour for 6-8 hr by Ethylene dibromide fumigation.

  - **Waxing:**

- ✓ Fruits and vegetables have a natural layer on their outer surface which is partly removed by washing.
- ✓ An extra discontinuous layer of wax applied artificially with sufficient thickness and consistency to prevent anaerobic condition within the fruits provides necessary protection against decay organism.
- ✓ Waxing also improves the appearance and glossiness, making them more acceptable.

  - **Packing:**

- ✓ It means more than carrying multiples of an object.
- ✓ Packing not only protects the horticultural produce but also makes a favourable impression on the buyers and May able to fetch higher income.

  - **Delivery:**

- ✓ Moving the harvest produce from the farm to the customer in good condition is important. All efforts upto delivery can be invalid if the fresh fruits and vegetables reach the destination in poor condition.
- ✓ Care should be taken to protect the produce and it becomes necessary when mixing load of fruits and vegetables to prevent violating the compatibility factors.

Lecture No. 3
Ripening and changes occurring during ripening

Definition -

–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.

- **FRUIT RIPENING**

Fruit ripening is a genetically programmed stage of development overlapping with enescence. 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.

List of climacteric and non-climacteric fruits

Climacteric		**Non- Climacteric**
Apple	Cherimoya	Carambola
Apricot	Fig	Cherries
Avocado	Guava	Citrus
Banana	Plum	Grape
Ber	Persimmon	Litchi
Mango	Papaya	Loquat
Melons	Tomato	Olive
Pear	Sapota	Pineapple
Peach	Passion fruit	Pomegranate
Kiwifruit		Strawberry

CHANGES DURING FRUIT RIPENING

1. Cell Wall Changes

- Cell wall consists of pectic substances and cellulose as the main components alongwith 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

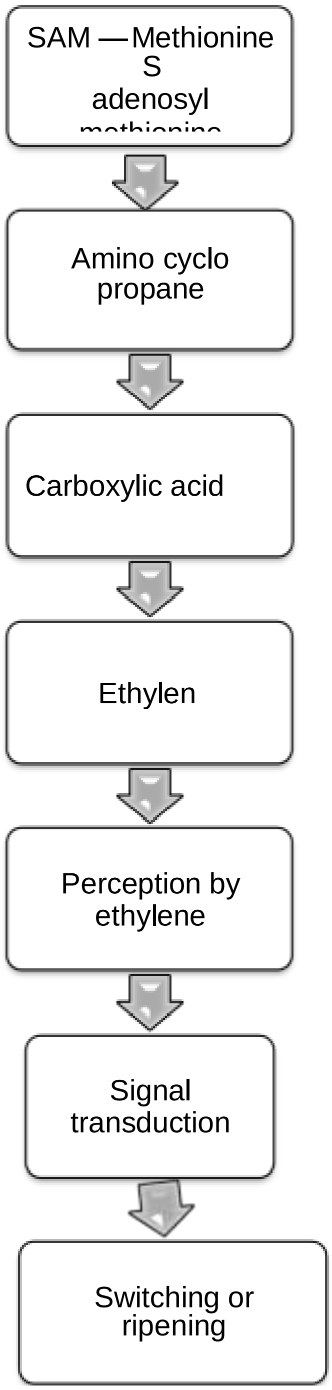
- Decrease in free amino acid which often reflects an increase in protein synthesis.
- During senescence the level of free amino acids increases reflecting a breakdown enzymes and decreased metabolic activity.

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:



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 (CO2 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:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6\ CO_2 + 6\ H_2O + \text{energy}$$

Lecture No. 4

Respiration and factors affecting respiration rate, Role of ethylene

Respiration:

- Is the process by which stores fruits and vegetable or food materials (Carbohydrates, Protein, fats) are broken down into simple end products with a release of energy.
- It is also involves degradation of food reserves, especially sugars, in order to produce chemical energy (in the form of ATP and NADH) needed to maintain cellular metabolic activity.
- Respiration and metabolism Vegetables are living commodities and continue to respire even after harvest.
- Respiration uses the stored food, leading to its depletion and consequently the loss of quality.
- Hence, storage life of vegetables is influenced by rate of respiration and is associated with biochemical activity.

Factors Affecting Respiration rate

A. Internal Factors

1. **Stage of Development:** During organ development the rate of respiration variation occurs. When fruits become bulky i.e at maturation stage degree of respiration rate decreases as compared to initial development stage. In Climateric fruit the rate of respiration is minimum at maturity stage but when ripening is about to start after harvest the respiration rate will increase to climacteric peak.
2. **Moisture Content:** If the moisture is more, respiration is less because of dimension of sugar content. Transpiration is more water loss is more so concentration of sugar is more

which less to higher respiration rate. More water loss lead to desiccation rather than more accumulation of sugar.

3. **Sugar of Fruit:** Small sized fruits have more expose surface compared to bulky fruits. So respiration rate is more in small fruits.
4. **Coating on Surface of Fruits:** More thickness of coating less the respiration rate.
5. **Type of Tissue:** Young tissues have more respiration rate.

B. External Factors

1. **Temperature**: the chemical reaction goes faster at a higher temperature, though, when the temperature is too hot, enzymes will break down and respiration will stop.
2. **Oxygen concentration**: The reaction needs oxygen, so if there is no oxygen, no respiration occurs. In general, less oxygen leads to a slower reaction rate.
3. **Carbon dioxide concentration**: The influence of carbon dioxide concentration depends strongly on the fruit or vegetable. Some might increase in respiration rate, whereas with others more carbon dioxide might lead to slower reactions.
4. **Stress in a vegetable**: Yes, vegetables can be stressed, for instance if they are cut or damaged. This will initiate all sorts of reactions, including those that accelerate respiration.
5. **Ripening**: Some fruits (and vegetables) continue to ripe after they have been harvested (climacteric fruits). During ripening the respiration rate might increase or decrease, depending on the product. This can also be linked with ethylene concentrations.
6. **Fruit Injury:** This mechanical injury is also responsible for stimulating respiration rate.
7. **Ethylene:** Application of ethylene can shift the time as to reach climacteric peak.

What is Ethylene?

–Ethylene is a gas released by some fruits and vegetables that causes produce to ripen faster. Some fruits and vegetables are more sensitive to ethylene than others.‖

- Ethylene is a natural plant hormone that the fruit itself emits as it ripens.
- Ethrel or ethaphon (2-chloroethane phosphonic acid).
- Exposure of unripe fruit to a miniscule dose of ethylene is sufficient to stimulate the naturalripening process untile the fruit itself starts producing ethylene in large quantities.
- The use ethylene to promote ripening is permitted under.

The Role of Ethylene in Fruit Ripening

- Most fruits produce a gaseous compound called ethylene that starts the ripening process.
- Its level in under-ripe fruit is very low, but as fruit develop, they produce larger amounts that speed up the ripening process or the stage of ripening known as the –climacteric.‖
- The level of ethylene and rate of ripening is a variety-dependent process.
- Some apple varieties such as McIntosh, produce prodigious amounts of ethylene and are difficult to store once this occurs.
- When harvested after the rapid rise in ethylene, they quickly soften and senesce in storage. Other varieties have a slower rise in ethylene and slower ripening rate.

- For apples that will be stored longer than two months, it is imperative to harvest them before the level of ethylene begins its rapid increase.
- Plums and peaches are also sensitive to ethylene and will continue to ripen after harvest in response to this hormone.
- Some varieties of plums, such as Shiro, ripen very slowly since ethylene production is suppressed.
- With these suppressed-climacteric types, fruit may remain under-ripe if harvested too early. Other plum varieties such as Early Golden ripen very rapidly.
- In this case, harvest should be timed more precisely so that fruit are not over-ripe when they reach the consumer.
- To measure ethylene, expensive instruments are needed.
- This is often done by specialized labs and sometimes by Cooperative Extension to determine if fruit in a general region are still at a stage where they can be stored long-term.
- Cheaper methods can be used to measure stage of ripeness, but are not as precise as measuring the level of ethylene in fruit.
- Methods of controlling ethylene in fruit include preharvest application of aminovinylglycine (ReTain), postharvest application of 1-methylcyclopropene (SmartFresh), cold storage, controlled atmosphere storage, and ethylene scubbing or removal.

Ethylene Sensitive: Apples, Asparagus, Avocados, Bananas, Broccoli, Cantaloupe, Collard, Greens, Cucumber, Eggplant, Grapes, Honeydew, Kiwi, Lemons, Lettuce, Limes, Mangos, Onions, Peaches, Pears, Peppers, Squash, Sweet Potatoes, Watermelon.

Ethylene Producers: Apples, Avocados, Bananas, Cantaloupe, Kiwi, Peaches, Pears, Peppers, Tomatoes.

Not Ethylene Sensitive: Blueberries, Cherries, Beans, (Snap) Garlic, Grapefruit, Oranges, Pineapple, Potatoes, Raspberries, Strawberries, Tomatoes, Yucca.

Lecture No. 5
Post Harvest diseases and Disorders

Postharvest diseases of fruit crops:

- Fruit crops are attacked by a wide range of microorganisms in the postharvest phase.
- Actual disease only occurs when the attacking pathogen starts to actively grow in the host. Diseases are loosely classified according to their signs and symptoms.
- Signs are visible growths of the causal agents, and symptoms the discernible responses produced by the host.
- Postharvest diseases are caused primarily by microscopic bacteria and fungi, with fungi the most important causal agent in fruit crops.
- Fungi are further subdivided into classes and are described as lower fungi, characterized by the production of sporangia which give rise to numerous sporangiospores, or higher fungi, described as ascomycetes, deuteromycetes, and basidiomycetes.

Common postharvest diseases and pathogens of fruit crops.

S. No.	Fruit crops	Disease	Pathogen
1.	**Temperate fruits**.	Blue mould	*Penicillium spp*
	Pome fruit	Gray mould	*Botrytis cinerea*
		Bitter rot	*Colletrotrichum gloeosporioides*
		Alternaria rot	*Alternaria spp.*
2.	Stone fruit	Brown rot	*Monilia spp.*
		Grey mould	*Botrytis cinerea*
		Blue mould	*Penicillium spp.*
		Alternaria rot	*Alternaria alternata*
3.	Grapes	Grey mould	*Botrytis cinerea*
		Blue mould	*Penicillium spp*
4.	Berries	Grey mould	*Botrytis cinerea*
		Cladosporium rot	*Cladosporium spp.*
		Blue mould	*Penicillium spp.*
5.	**Subtropical fruit**	Blue mould	*Penicillium italicum*
6.	Citrus fruit	Green mould	*Penicillium digitatum*
		Black centre rot	*Alternaria citri*
		Stem end rot	*Phomopsis citri*
7.	Avocado	Anthracnose	*Colletotrichum gloeosporioides,*
		Anthracnose	*Colletotrichum acutatum*
		Stem end rot	*Dothiorella spp.*
		Bacterial soft rot	*Erwinia carotovora*
8.	**Tropical fruit**	Anthracnose	*Colletrotrichum musae*
9.	Banana	Crown rot	*Fusarium spp.*
		Black end	*Nigrospora spharica*
		Ceratocystis fruit rot	*Thielaviopsis paradoxa*
10.	Mango	Anthracnose	*Colletrotrichum gloeosporioides*
		Stem end rot	*Phomopsis mangifera*
		Black mould	*Aspergillus niger*
		Alternaria rot	*Alternaria alternate*
		Grey mould	*Botrytis cinerea*
		Blue mould	*Penicillium expansum*
11.	Papaya	Anthracnose	*Colletrotrichum spp.*
		Black rot	*Phoma caricae papaya*

		Phomopsis rot	*Phomopsis caricae papaya*
12.	Pineapple	Water blister	*Thielaviopsis paradoxa*
		Fruit let core rot	*Penicillium funiculosum*
		Yeasty rot	*Saccharomyces spp.*
		Bacterial brown rot	*Erwinia ananas*

PREHARVEST FACTORS THAT INFLUENCE POSTHARVEST DIESIESES

Weather:

Weather affects many factors related to plant diseases, from the amount of inoculum that overwinters successfully to the amount of pesticide residue that remains on the crop at harvest.

Abundant inoculum and favorable conditions for infection during the season often result in heavy infection by the time the produce is harvested.

For example, conidia of the fungus that causes bull‟s-eye rot are rain dispersed from cankers and infected bark to fruit especially if rainfall is prolonged near harvest time, causing rotten fruit in cold storage several months later.

Physiological condition:

Condition of produce at harvest determines how long the crop can be safely stored.

For example, apples are picked slightly immature to ensure that they can be stored safely for several months.

The onset of ripening and senescence in various fruits renders them more susceptible to infection by pathogens.

On the other hand, fruits can be made less prone to decay by management of crop nutrition.

Fungicide Sprays:

Certain pre-harvest sprays are known to reduce decay in storage. Several studies have been done on the effectiveness of pre-harvest ziram water inactivates chlorine, and levels of chlorine must be constantly monitored.

Recently, in precisely controlled tests in water or as foam, chlorine dioxide was found to be effective against common postharvest decay fungi on fruit packinghouse surfaces (Dubey, S.R. 2012).

Postharvest Treatments:

Products used for postharvest decay control should only be used after the following critical points are considered:

Type of pathogen involved in the decay.

1. Location of the pathogen in the produce.
2. Best time for application of the treatment.
3. Maturity of the host.
4. Environment during storage, transportation and marketing of produce.

Specific materials are selected based on these conditions and fall into either chemical or biological categories listed below.

Fungicide treatments:

Several fungicides are presently used as postharvest treatments for control of a wide spectrum of decay-causing microorganisms.

However, when compared to preharvest pest control products the number is very small.

For example, intensive and continuous use of fungicides for control of blue and green mold on citrus has led to resistance by the causal pathogens of these diseases.

Chemical treatments that are presently used are thiabendazole, dichloran, and imazalil. However, resistance to thiabendazole and imazalil is widespread (Kleynen, et al. 2005) and their use as effective materials is declining.

Temperature and relative humidity:

Proper management of temperature is so critical to postharvest disease control that all other treatments can be considered as supplements to refrigeration.

Fruit rot fungi generally grow optimally at 20 to 25^0C (68 to 77^0F) and can be conveniently divided into those with a growth minimum of 5 to 10^0C (41 to 50^0F) or -6 to 0^0C (21.2 to 32^0F).

Fungi with a minimum growth temperature below -2^0C (28.4^0F) cannot be completely stopped by refrigeration without freezing fruit (Shine, et al. 2007).

High temperature may be used to control postharvest decay on crops that are injured by low temperatures such as mango and papaya.

Heating of pears at temperatures from 21 to 38^0C (69.8 to 100.4^0F) for 1 to 7 days reduced postharvest decay.

Decay in „Golden Delicious" apples was reduced by exposure to 38^0C (100.4^0F) for 4 days and virtually eliminated when treated after inoculation (Kader, A.A. 1999).

Management

Biological control:

Postharvest biological control is a relatively new approach and offers several advantages over conventional biological control.

1. Exact environmental conditions can be established and maintained.
2. The bio-control agent can be targeted much more efficiently.
3. Expensive control procedures are cost-effective on harvested food.

Several biological control agents have been developed in recent years, and a few have actually been registered for use on fruit crops.

The first biological control agent developed for postharvest use was a strain of Bacillus subtitles.

It controlled peach brown rot, but when a commercial formulation of the bacterium was made, adequate disease control was not obtained.

Integrated control of postharvest diseases:

Effective and consistent control of storage diseases is dependent upon integration of the following practices:

1. Select disease resistant cultivars where possible.
2. Maintain correct crop nutrition by use of leaf and soil analysis.
3. Irrigate based on crop requirements and avoid overhead irrigation.
4. Apply pre-harvest treatments to control insects and diseases.
5. Harvest the crop at the correct maturity for storage.

6. Apply postharvest treatments to disinfest and control diseases and disorders on produce.
7. Maintain good sanitation in packing areas and keep dump water free of contamination.
8. Store produce under conditions least conducive to growth of pathogens.

Integration of cultural methods and biological treatments with yeast biocontrols has been studied on pears

Harvest handling:

The care taken during harvesting is repaid later, because fewer bruises and other injuries mean less disease and enhanced value.

Good managers train their pickers so that they select the product at the correct stage of maturity with adequate care.

It is worthwhile reducing the amount of hard physical work required in picking fruit as far as possible.

Pre-cooling:

The harvested produce has to be transported to the packing shed without delay.

In the field the heat of the sun and the respiration of the produce combine to heat up the produce, especially in the centre of field bins.

This accumulation of –field heat‖ reduces the postharvest life of the product and has to be removed quickly.

Strawberries for example, respire nearly eight times faster at a field temperature of 25^0C as they do in a storage temperature of 0^0C.

Precooling requires a greater refrigeration capacity than doe‟s cool storage and is often best done as a separate step.

Hydrocooling with cold water drenches, forced air cooling through stacks that ensure proper air distribution and packing with ice are the systems most commonly used, with the choice depending on the individual requirements of the commodity.

Refrigeration:

Refrigeration is the most important tool for extending the life of fruit. In a typical cool store. To maintain a storage temperature of 00C the temperature of the coils will have to be appreciably below 0^0C. Moisture is therefore removed from the air and this accumulates as ice on the coils.

The lower the average temperature of the cooling coils, the more moisture will be removed. The drier and cooler air then circulates around the room where it warms and picks up moisture.

The more moisture that freezes on the refrigerator coils, the greater the frequency of defrosts cycles and these make good temperature management control more difficult to attain.

An even distribution of air produces a room with a consistent temperature, but if the flow of cooled air is –short circuited‖ back to the coiling coils, the areas starved of circulation will become warmer.

Quality control:

Most consumers have been disappointed with the quality of fresh produce they have purchased at one time or another.

Fruit are to be stored or transported over long distances may have to be picked in an immature state so that the fruit are firm and store or travel well. In recent years, much work has been done to improve the quality of fruit.

New varieties have been introduced which gives consumers a wider choice and some, such as new varieties of nectarine have improved flavor.

Lecture No. 6
Heat, chilling and Freezing injury

Symptoms of freezing, chilling injury

Artichoke: Freezing injury will be initiated at 29.9°F (-1.2°C). Symptoms of light freezing injury are blistering of the cuticle and a bronzing of the outer bracts. This may occur in the field with winter-harvested buds. More severe freeze injury results in water soaked bracts and the heart becoming brown to black then gelatinous in appearance over time.

Asparagus: Freezing injury (water-soaked appearance leading to extreme softening) will likely result at temperatures of 30.9°F (-0.6°C) or lower.

The tip becomes limp and dark; the rest of the spear is water-soaked. Thawed spears become mushy. Chilling Injury occurs when spears are held more than 10 days at 32°F (0°C) and symptoms of chilling injury include loss of sheen or glossiness and graying of the tips. A limp, wilted appearance may be observed. Severe chilling injury may result in darkening near tips in spots or streaks

Snap Bean:

Freezing Injury appears as water-soaked areas that subsequently deteriorate and decay. Freezing injury occurs at temperatures of 30.7°F (-0.7°C) or below.

The typical symptom of chilling injury in snap beans stored below 41°F (5°C) but above freezing point for longer than 5-6 days is a general opaque discoloration of the entire bean.

A less common symptom is pitting on the surface.

The most common symptom of chilling injury is the appearance of discrete rusty brown spots which occur in the temperature range of 41-45°F (5-7.5°C).

These lesions are very susceptible to attack by common fungal pathogens.

Beans can be held about 2 days at 34°F (1°C), 4 days at 36°F (2.5°C), or 8-10 days at 41°F (5°C) before chilling symptoms appear.

No discoloration occurs on beans stored at 50°F (10°C).

Different snap bean varieties differ significantly in their susceptibility to chilling injury.

Bell Pepper:

Freezing injury symptoms include dead, water-soaked tissue in part or all of the pericarp surface; pitting, shriveling, and decay follow thawing.

Symptoms of chilling injury include surface pitting, water-soaked areas, decay (especially *Alternaria* spp.), and discoloration of the seed cavity.

Broccoli:

will freeze if stored at 30.6°F (-0.6°C) to 30°F (-1.0°C).

This may also occur if salt is used in the liquid-ice cooling slurry.

Frozen and thawed areas on the florets appear very dark and translucent, may discolor after thawing and are very susceptible to bacterial decay.

The youngest florets in the center of the curd are most sensitive to freezing injury.

They turn brown and give off strong odors upon thawing.

Cabbage:

Freeze damage appears as darkened translucent or water-soaked areas that will deteriorate rapidly after thawing.
Freeze damage can occur if round cabbages are stored below 30.4°F (-0.9°C) and if Chinese cabbage is stored below 31°F (-0.6°C).
Leaves become water-soaked, translucent, and limp upon thawing; the epidermis can also separate from the leaf as it does in lettuce.
Carrot:
Freeze damage includes blistered appearance, jagged length-wise cracks.
Carrot interior becomes water-soaked and darkened upon thawing.
Freeze damage occur at below 29.5°F (-1.4°C) but can vary depending on the sugar content of the carrot.
Cauliflower:
Freezing injury will be initiated at 30.6°F (- 0.8°C).
Symptoms of freezing injury include a water-soaked and greyish curd and water-soaked or wilted crown leaves.
The curd will become brown and gelatinous in appearance following invasion by soft-rot bacteria.
These brown curds have a strong off-odor when cooked.
Celery:
Freezing injury will be initiated at 31.1°F (- 0.5°C).
Symptoms of freezing injury include a water-soaked appearance on thawing and wilted leaves.
Mild freezing causes pitting or short streaks in the petiole which develop a brown discoloration with additional storage.
Leaves and petioles appear wilted and water-soaked upon thawing.
Petioles freeze more readily than leaves.
Eggplant:
Freezing injury will be initiated at 30.6°F (- 0.8°C), depending on the soluble solids content.
Symptoms of freezing injury include a water-soaked pulp becoming brown and desiccated in appearance over time.
Eggplant fruit are chilling sensitive at temperatures below 50°F (10°C). At 41°F (5°C) chilling injury will occur in 6-8 days.
Consequences of chilling injury are pitting, surface bronzing, and browning of seeds and pulp tissue.
Accelerated decay by *Alternaria* spp. is common in chilling stressed fruit.
Chilling injury is cumulative and may be initiated in the field prior to harvest.
Beet:
Freezing injury symptoms include external and internal water-soaking; sometimes blackening of conducting tissue.
Garlic:
Freezes at temperatures below 28°F (-2°C) due to its high solids content. Thawed cloves appear grayish-yellow and water-soaked.
Green Onion:
Freezing injury will be initiated at 30.6°F (-1°C).

Symptoms of freezing injury include a water-soaked appearance of bulb or leaves and wilted or gelatinous leaves, after thawing.
The bulb will become soft or gelatinous in texture in outer tissue.
Freeze injury is rapidly followed by bacterial soft-rot decay.

Lettuce Romaine and Crisphead:
Freeze damage can occur in the field and cause separation of the epidermis from the leaf.
This weakens the leaf and leads to bacterial decay during storage.
Freeze damage can occur during storage if the lettuce is held at 31.7°F (<-0.2°C).
This appears as darkened translucent or water-soaked areas that will turn slimy and deteriorate rapidly after thawing.
The blistered dead cells of the separated epidermis on outer leaves become tan and there is increased susceptibility to physical damage and decay.

Okra:
Freeze damage occurs at temperatures of 28.7°F (-1.8°C) or below.
The typical symptoms of chilling injury in okra are discoloration, pitting, water-soaked lesions and increased decay (especially after removal to warmer temperatures, as during marketing).
Different cultivars may differ in their susceptibility to chilling injury.
Calcium dips and modified atmospheres have been reported to reduce chilling symptoms.

Onion:
Freezing injury symptoms include soft water-soaked scales that rapidly decay from subsequent microbial growth.
Thawed bulbs are soft, grayish-yellow, and water-soaked in cross section; often limited to individual scales.

Potato:
Freezing injury will be initiated at 30.5°F (-0.8°C).
Symptoms of freezing injury include a water-soaked appearance, glassiness, and tissue breakdown on thawing.
Mild freezing may also result in chilling injury.
Freezing injury may not be externally evident, but shows as gray or bluish-gray patches beneath the skin.
Thawed tubers become soft and watery.
Chilling injury can occur at storage temperatures near 32°F (0°C) after a few weeks and may result in a mahogany discoloration of internal tissue and eventually complete internal breakdown.
Much longer periods (months) of storage are generally required for chilling injury at higher temperatures 36-41°F (2-5°C).

Radish:
Radish ideally stored and transported just above the freezing point 30.5°F (-1.0°C), but freeze injury is not uncommon.
Shoots become water-soaked, wilted, and turn black.
Roots appear water-soaked and glassy, often only at the outer layers if the freezing temperature is not too low.
Roots become soft quickly on warming and pigmented roots may "bleed" (lose pigment).
Thawed tissues appear translucent; roots soften and shrivel.

Spinach:
Freezing injury will be initiated at 31.5°F (-0.3°C).
Freezing injury results in water soaking typically followed by rapid decay by soft-rot bacteria.
Tomato:
Freezing injury will be initiated at 30°F (-1°C), depending on the soluble solids content. Symptoms of freezing injury include a watersoaked appearance, excessive softening, and desiccated appearance of the locular gel. In partially frozen fruits, the margin between healthy and dead tissue is distinct, especially in green fruits. Tomatoes are chilling sensitive at temperatures below 50°F (10°C) if held for longer than 2 weeks or at 41°F (5°C) for longer than 6-8 days.
Consequences of chilling injury are failure to ripen and develop full color and flavor, irregular (blotchy) color development, premature softening, surface pitting, browning of seeds, and increased decay (especially Black mold caused by *Alternaria spp*.).
Chilling injury is cumulative and may be initiated in the field prior to harvest.
Turnip:
Freezing injury symptoms include small water-soaked spots or pitting on the surface. Injured tissues appear tan or gray and give off an objectionable odor.

Commodity	Lowest safe temperature (^{0}C)	Chilling injury symptoms
Aubergines	7	Surface scald, *Alternaria* rot
Avocados	5-13	Grey discoloration of flesh
Bananas (green/ ripe)	12-14	Dull, grey-brown skin color
Beans (green)	7	Pitting, russeting
Cucumbers	7	Pitting water-soaked spots, decay
Grapefruit	10	Brown scald, piking, watery breakdown
Lemons	13-15	Pitting, membrane stain, red blotch
Limes	7-10	Pitting
Mangoes	10-13	Grey skin scald, uneven ripening
Melons: Honeydew	7-10	Pitting failure to ripen, decay
Watermelon	5	Pitting, biker flavour
Okra	7	Discoloration, water-soaked areas, piking
Oranges	7	Pitting brown stain, watery breakdown
Papaya	7	Pitting failure to ripen, off-flavour, decay
Pineapples	7-10	Dull green color, poor flavour
Potatoes	4	Internal discoloration, sweetening
Pumpkins	10	Decay
Sweet peppers	7	Pitting, *Alternaria* rot
Sweet potato	13	Internal discoloration, piking, decay
Tomatoes: Mature green	13	Water-soaked softening, decay
Ripe	7-10	Poor color, abnormal ripening, *Alternaria* rot

Management of Chilling Injury

1. **Maintaining critical temperature** - The safest way to manage chilling injury is to determine the critical temperature for its development in a particular produce and then not expose the commodity to temperatures below that critical temperature (Eg. Safe storage temperature for apple is 0-20C and care should to taken to not to store apple below this critical temperature to avoid chilling injury). However, it has been found that exposure for a short period to chilling temperatures with subsequent storage at higher temperatures may prevent the development of injury. This conditioning process has been effective in managing

- black heart in pineapple
- Woolliness in peach
- Flesh browning in plum.

2. **MAS - Modified atmosphere storage** may also reduce chilling injury in some commodities.

3. **Maintaining high RH** - both in storage at low temperature and after storage can minimize expression of chilling injury symptoms, particularly pitting (e.g. film-wrapped cucumbers).

Lecture No. 7
Harvesting and field handling

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.

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.

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%.

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 VEGETABLE	
Cauliflower	Curd compact
Broccoli	Bud cluster compact

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

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

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 Boilogical and environmental factors in the process of value addition of a commodity.

1. Pre-cooling

- Pre-cooling (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, pre-cooling 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 pre-cooling Viz, cold air (room cooling, forced air cooling), cold water (hydro-cooling), direct contact with ice (contact icing), evaporation of water

from the produce (evaporative cooling, vacuum cooling) and combination of vacuum and hydro-cooling (hydrovac cooling).

- Some chemicals (nutrients/growth regulators/ fungicides) can also be mixed with the water used in hydro-cooling to prolong the shelf life by improving nutrient status of crop and preventing the spread of post harvest diseases.

2. <u>Washing, Cleaning</u> and <u>Trimming</u>

- 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. <u>Sorting</u>, <u>Grading</u> and <u>Sizing</u>

- 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 e.g. 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. <u>Curing</u>

- 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. <u>Waxing</u>

- 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. <u>Packaging</u>

- 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. <u>Storage</u>

- 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.

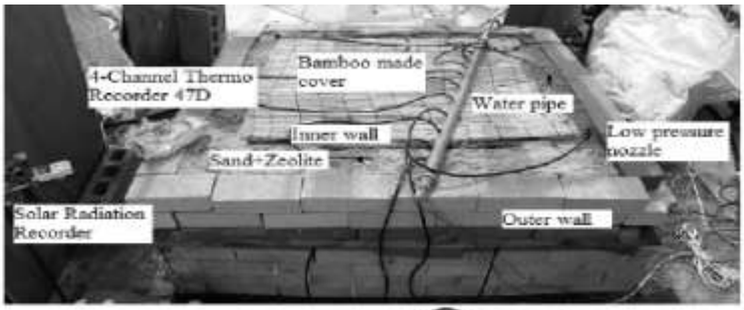
Lecture No. 8
Storage (ZECC, Cold storage, CA, MA, and Hypobaric)

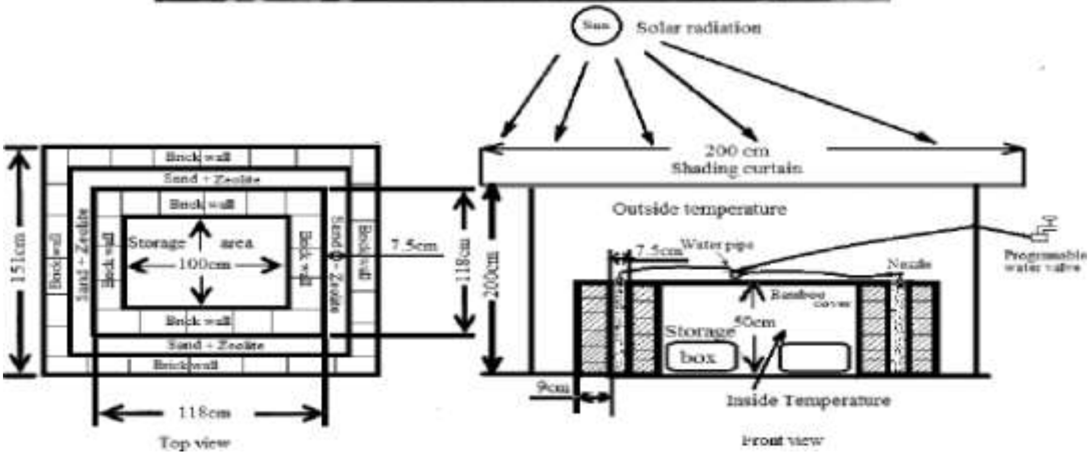
1. ZECC (Zero Energy Cool Chamber)

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

Construction

- Select an-upland having a nearby source of water supply.
- Make floor with brick 165 cm x 115 cm.
- Erect the double wall to a height of 67.5 cm leaving a cavity of 7.5 cm.
- Drench the chamber with water. Soak the fine river bed sand with water.
- Fill the 7.5 cm cavity between the double walls with this wet sand.
- Make top cover with bamboo (165 cm x115 cm) frame and 'sirki' straw or dry grass.
- Athatch/ tin shed made over chamber to protect from direct sun or rain or snow.





COST OF COOL CHAMBER (100 Kg Capacity Chamber)

COST OF COOL CHAMBER (100 Kg. capacity)	
Brick (400 Nos).	Rs.1000.00
Sand	Rs. 100.00
Bamboo, Khas-Khas, etc for top cover	Rs. 300.00
Thatched Shed	Rs. 500.00
Water tank, pipes, tubes poly sheet etc.	Rs. 600.00
Plastic Crates (6 Nos)	Rs.1200.00
Labour	Rs. 300.00
Total	**Rs. 4000.00**

Operation:

- Keep the sand, bricks and top cover of the chamber wet with water.
- Water twice daily (morning and evening) to achieve desired temperature and relative humidity.
- Alternatively fix a drip system for watering with plastic pipes and micro tubes connected to an overhead water source.
- Store the fruits and vegetables in perforated plastic crates.
- Cover crates with thin polyethylene sheet.
- Cool chamber should be reinstalled once in 3 years with new bricks
- Utilize the old bricks for other purposes.

SCOPE OF COOL CHAMBER

- Proposed Proposed cool chamber chamber can be installed installed in different different places of handling handling of fresh produce.
- In present practice fruits and vegetables arrive in the wholesale market early in the morning morning and are purchased purchased by the retailer/consumer retailer/consumer before noon.
- At present fruits and vegetables are handled in open shed the freshness is prone to considerable deterioration.
- It is suggested that a battery of such commercial size cool chambers can be installed in wholesale markets, which are located near the big metropolitan cities.
- Units can be installed in two rows with a corridor in between. Each unit will have two doors, one opening into the corridor and the other into loading/unloading platform.
- The ducts are open on the roadside as well as on the corridor. An overhead tank can perform the soaking of sidewalls and tanks.
- The trucks can perform perform the loading loading and unloading unloading on the platforms platforms of each shed.
- Fruits and vegetables stored temporarily in the cool chamber units before the transaction can retain freshness and quality.

Storage life of different commodities in zero energy cool chamber

Fruits/Vegetable	Months	Storage Life (Days)	
		Ambient Condition	Cool Chamber
Bitter gourd	May-June	2	6
Carrot	Feb- March	5	12
Cauliflower	Feb - March	7	12
Cucumber	May – June	3	8
Green chilies	May – June	3	6
Ladies Finger	May – June	1	6
Mango	July	8	15
Peas	Feb – March	5	10
Plum	June	4	10
Spinach	Feb - March	3	8

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.

2. **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.

3. **Modified atmosphere packaging (MAP) Storage**

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.

4. **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.

5. **Hypobaric System**

In hypobaric system at the low pressure the produce is placed in a vaccum- tight an refrigerated container by removing air. The process of ripening and senescence are greatly retarded by decreasing respiration and evacuation of ethylene given by out by the produce. This process is very expensive.

6. **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.

Proper pre-cooling preserves product quality by

- inhibiting the growth of decay producing microorganisms
- restricting enzymatic and respiratory activity
- inhibiting water loss
- reducing ethylene production

The importance of pre-cooling

(i) Importance of lag time between harvest and cooling

Field heat can cause rapid deterioration of some horticultural crops and therefore it is desirable to remove this heat as quickly as possible after harvesting.

When it comes to produce quality, every minute counts and that precooling is among the most cost-effective and efficient quality preservation methods available to commercial crop produces.

For example, strawberries experience increasing deterioration losses as delays between harvesting and cooling exceeds 1 h and the effects of the delay on cooling of strawberries is shown in Fig.1.

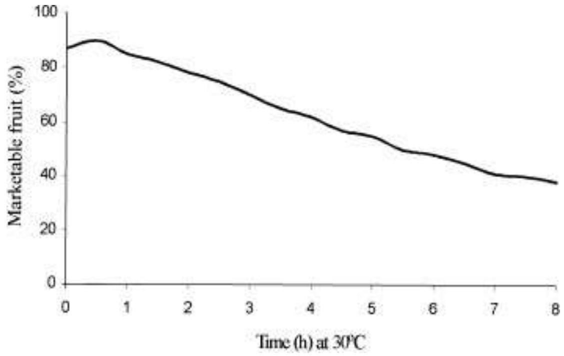


Fig.1. Effect of delay before cooling on the quality of Shasta strawberries

From this it can be seen that even after a short time of 2 h at 300C, only 80% of the strawberries are considered marketable fruit, which represents an apparent loss of approximately 10% by not cooling the produce immediately after picking. Furthermore, precooling slows down the deterioration and the rotting process by retarding the growth of decay organisms, and it reduces wilting since transpiration and evaporation occurs more slowly at low temperatures.

(ii) Influence of pre-cooling on the respiration rate

The rate of deterioration after harvest is closely related to the respiration rate of the harvested product, therefore the reduction of respiration rate is essential to preserving market quality. Since the rate of respiration is influenced by temperature , precooling to remove the field heat before storage will reduce the respiration rate and hence deterioration will decline accordingly. For example reduction in temperature of 9.5^0C in grapes halved the rate of respiration and doubled their keeping quality.

(iii) Influence on metabolism

The increase in the rate of deterioration is related to the metabolic processes of the crop. Within the plants temperature range, the rate of deterioration increases logarithmically with increasing temperature. Metabolic rates double for each 10^0C rise in temperature. From these reports, it can be seen that the quicker the temperature is reduced the less losses that can occur. Hence, precooling is essential in order to reduce metabolic changes such as enzyme activity, and to slow the maturation of perishable produce.

(iv) Effects of rapid cooing on ethylene

The reduction in temperature has the added advantage of reducing the production and sensitivity of the produce to ethylene that accelerates ripening and senescence. Therefore, the faster and more promptly the field heat and hence temperature is reduced after harvest, the quicker these deteriorative processes are retarded and hence the more of the initial quality can be maintained.

Methods for Precooling Produce

There are seven principal methods of pre-cooling fresh produce:

1) Room cooling
2) Forced-air cooling
3) Hydro-cooling
4) Ice cooling
5) Vacuum cooling
6) Cryogenic cooling
7) Evaporative cooling

Considerable loss in quality and shelf life can occur as a result of holding harvested produce in the field before pre-cooling. All methods require sufficient refrigeration capacity to reduce the temperature of the produce within the required time plus the ability to remove the normal heat gain in the facility.

1) Room cooling

Precooling produce in a cold-storage room or precooling room is an old well-established practice. This widely used method involves the placing of produce in boxes (wooden, fiberboard or plastic), bulk containers or various other packages into a cold room, where they are exposed to cold air. It is used for produce sensitive to free moisture or surface moisture. Because this type of cooling is slow, room cooling is only appropriate for very small amounts of produce or produce that does not deteriorate rapidly.

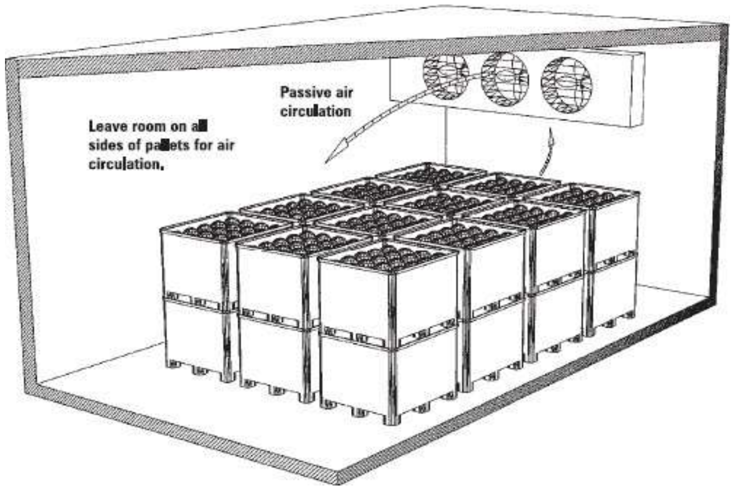


Fig.2. Room cooling

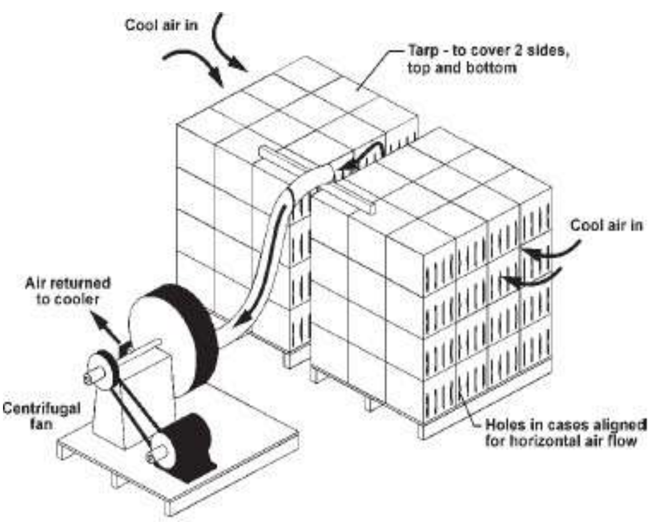
- Typically the cold air is discharged into the room near the ceiling, and sweeps past the produce containers to return to the heat exchangers.
- The cooled air is generally supplied by forced or induced draft coolers, consisting of framed, closely spaced and finned evaporator coils fitted with fans to circulate the air over the coils.
- Therefore, as to achieve fast and efficient cooling, care should be taken that the correct packaging (well vented) or containers and stacking patterns are used.

- Air velocities around the packages should be at least 60 m/min to provide the necessary turbulence to achieve heat removal and therefore attain adequate cooling.
- As much of the cooling is achieved by conduction, room cooling gives a slow and variable temperature reduction, therefore perishable produce used in this method must be tolerant of slow heat removal.
- A conventional cold store is unsuited for this operation because as much as three-quarters of the refrigerator capacity may be required simply to remove field heat and the cooling rates are frequently no better than 0.50C/h.
- The rooms commonly used for highly perishable fruit are designed to have an airflow rate of about 170 to 225 m3/min for a room with a capacity of 15,000 kg and sufficient refrigeration so as to cool the fruit to 50C in approximately 12 h.
- Containers are stacked individually so that cold air from the ceiling blows over or around the produce to contact all surfaces of the containers.
- Produce will dry out if a high relative humidity (90-95 percent) is not maintained.
- Containers should be well vented so as much air as possible can circulate through them.
- Spacing between the containers and walls must be from 6 to 12 inches, and between the boxes and ceiling, 18 to 24 inches.
- Room cooling is not recommended for bulk bins because they contain a much greater mass of produce than smaller containers.
- Proper design of the cooling room and refrigeration equipment is necessary for room cooling to work efficiently.
- The refrigeration equipment must be capable of cooling down fresh produce within 24 hours and of maintaining the storage temperature of the produce. Normally, much larger refrigeration equipment is needed to cool down the produce than to maintain the produce at a cool temperature.
- Room cooling has become increasingly difficult as more commodities are being handled in larger quantities and are packaged immediately after harvest due to better mechanization.
- These difficulties coupled with its slow and variable cooling extend the cold chain and therefore reduce the product life in subsequent storage.

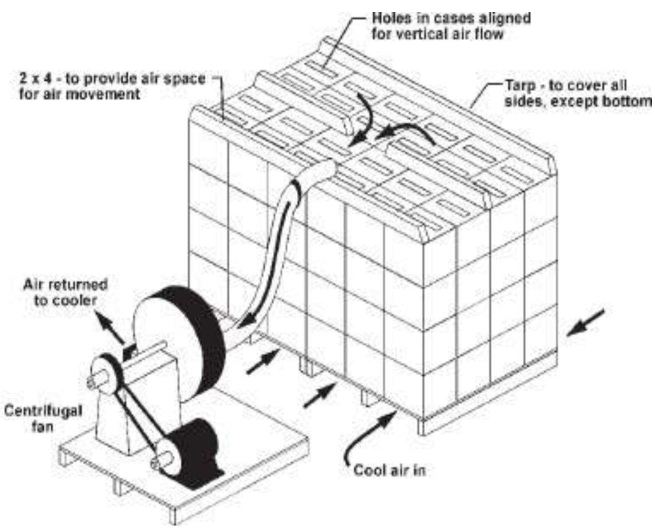
2) Forced air cooling

- Forced air cooling was developed to accommodate products requiring relatively rapid removal of field heat immediately after harvest.
- Forced air or pressure cooling is a modification of room cooling and is accomplished by exposing packages of produce to higher air pressure on one side than on the other.
- This technique involves definite stacking patterns and the baffling of stacks so that the cooling air is forced through (rather than around) the individual containers.
- For successful forced air cooling operations, it is required that containers with vent holes be placed in the direction of the moving air and packaging materials that would interfere with free movement of air through the containers should be minimized.
- A relatively small pressure difference between the two sides of the containers exists, resulting in good air movement and excellent heat transfer and hence faster cooling.
- Produce can be cooled by a variety of different forced air cooling arrangements.

- These include (a) air circulated at high velocity in refrigerated rooms, (b) by forcing air through the voids in bulk products as it moves through a cooling tunnel on continuous conveyors, and (c) by encouraging forced airflow through packed produce by the pressure differential technique.
- Each of these methods is used commercially, and each is suited for certain commodities when properly applied.
- The product cooling rate is affected by numerous variables and, therefore, the overall cost of the forced air cooling will vary.
- These variables include product size and shape; thermal properties; product configuration (bulk or packaged); carton vent area; depth of product load during cooling; initial product temperature; final desired product temperature and airflow rate, temperature, and relative humidity.
- The cooling rate in a given system depends primarily on the velocity of the cold air flowing through it, and this is the only controlling factor, since no change can be made in certain fixed factors such as size, shape and thermal properties of the produce.
- In addition, the temperature of the cold air cannot be reduced below a certain safe point to avoid chilling injury.
- In general, the cool air necessary for this type of cooling can be generated from (a) direct
- expansion refrigeration system, (b) ice bank cooling system and (c) water cascade.
- Forced air coolers utilise centrifugal (commonly known as squirrel cage) or axial fans which push the cold air around the system.
- Fans are selected based on the criteria of required airflow and static pres-sure.
- These requirements are influenced by the type of produce and quantity being cooled, the arrangement of the produce (bulk, boxes or stacking) and the cooling rate required.
- Differential pressures in use are approximately 0.6 to 7.5 mbar with air flows ranging from 0.001 to 0.003 m3/s kg product.



Forced horizontal air flow



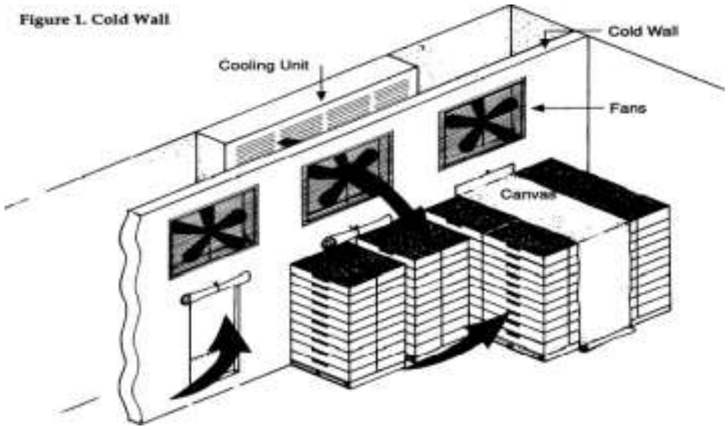
Forced vertical air flow

- The air can be channeled to flow either horizontally or vertically.
- In a horizontal flow system, the air is forced to flow horizontally from one side of the pallet load to the other through holes in the sides of the pallet bin or containers.
- Only two sides that are opposite can be open in the pallet bin or containers.
- In stacking containers, the side holes must line up for the air to pass from one side of the stack to the other.
- In this system, the top and bottom of the pallet or containers must be sealed to prevent air from by passing the produce.
- In a vertical flow system, the air is forced to flow vertically from the bottom to the top of the pallet through holes in the bottom of the pallet, and containers if used, then out the top.
- In this system, the sides must be sealed to prevent the air from bypassing the produce.
- Also, if containers are used, the holes in the tops and bottoms of the containers must line up, so the air can travel vertically from one container to the next.
- This method is faster than room cooling because a flow of chilled air is in direct contact with the produce.
- In these systems, condensation on the produce can be minimized by a simple cover placed on top of the stack of containers, which prevents the entry of ambient air during handling.
- The key to forced-air cooling is moving the cold air through the container and its contents. Important factors in container ventilation are location of container vents, stacking of containers, and size of the vents.
- Container vents should be aligned whether the containers are straight-stacked or crossstacked, to maximize air flow through the containers.
- If vents are too small or too few, air flow is slowed.
- If there are too many, the container may collapse.
- In this method, containers are stacked close together (tight).
- Five percent vent-hole space per side and/or end is best. Liners, bags, wrappers, or dividers can slow the flow of air through the container, so precooling produce is usually recommended prior to additional packing.

3) Cold Wall

A permanent false wall or air plenum contains an exhaust fan that draws air from the room and directs it over the cooling surface. The wall is at the same end of the cold room as the cooling surface. The wall is built with a damper system that only opens when containers with openings are placed in front of it. The fan pulls cold room air through the container and contents, cooling the produce.

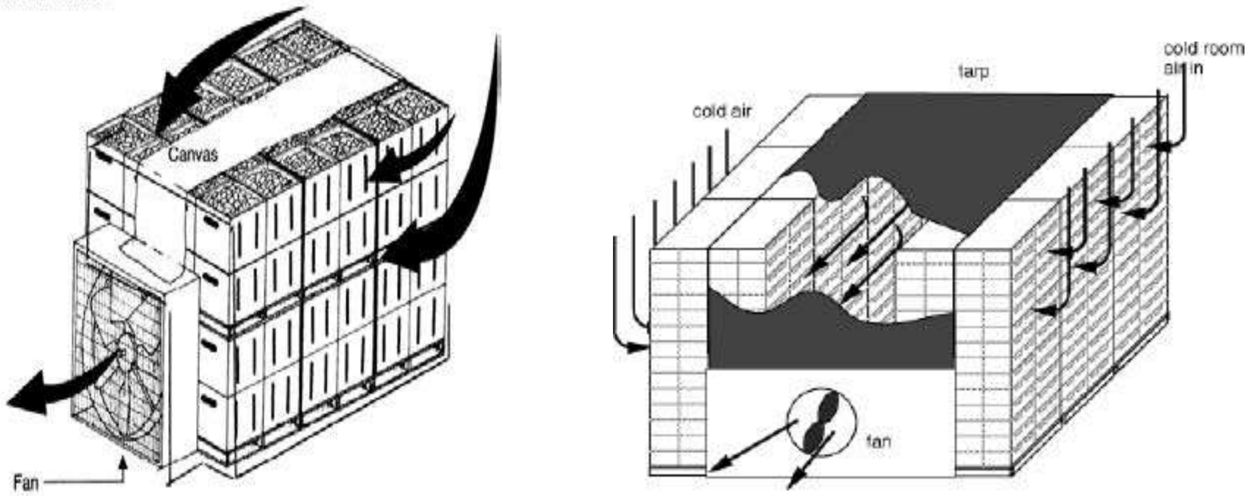
Figure 1. Cold Wall



4) Forced-air Tunnel

An exhaust fan is placed at the end of the aisle of two rows of containers or bins on pallets. The aisle top and ends are covered with plastic or canvas, creating a tunnel. An exhaust fan draws cool room air through the container vents and top . The exhaust fan may be portable, creating a single forced-air tunnel where needed, or it may be part of a stationary wall adjacent to the cooling surface, with several fans that create several tunnels.

Figure 2. Forced-air Tunnel



Serpentine Cooling

A serpentine system is designed for bulk bin cooling. It is a modification of the cold-wall method. Bulk bins have vented bottoms with or without side ventilation. Bins are stacked several high and several deep with the fork lift openings against the cold wall. Every other forklift opening—sealed with canvas—in the stack matches a cold wall opening. The alternate unsealed forklift opening allows cold air to circulate through the produce. Cold room air is drawn through the produce via the alternate unsealed openings in the stack and the top of the bin.

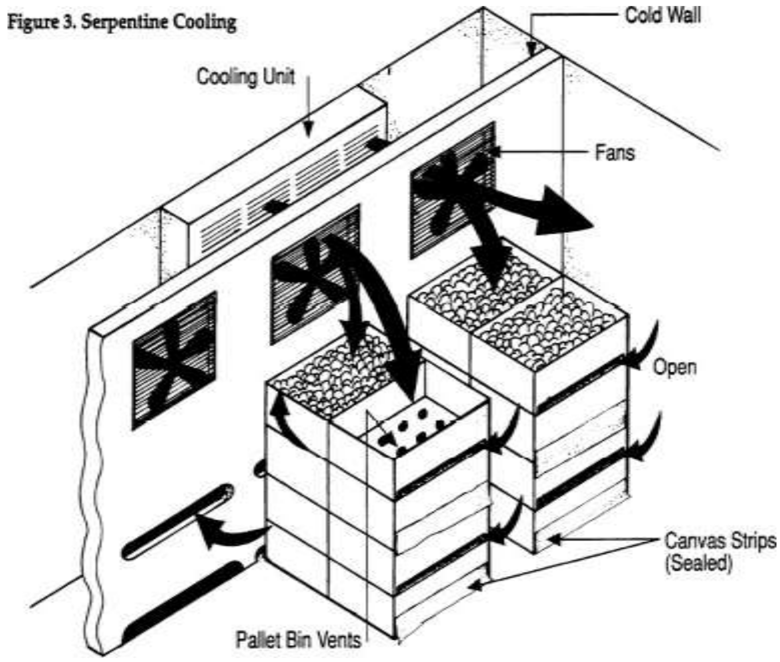


Table Recommended Pre-cooling Methods and Storage conditions for Fruits and Vegetables

Fruits and vegetables	Temperature F	Relative humidity %	Precooling method	Storage life Days	Ethylene sensitive
Apples	30-40	90-95	R, F, H	90-240	**Y**
Apricots	32	90-95	R, H	7-14	**Y**
Asparagus	32-35	95-100	H, I	14-21	**Y**
Avocados	40-55	85-90		14-28	**Y**
Bananas	56-58	90-95		7-28	**Y**
Beans, snap	40-45	95	R, F, H	10-14	**Y**
Beans, lima	37-41	95		7-10	
Beets, roots	32	98-100	R	90-150	
Blackberries	31-32	90-95	R, F	2-3	
Blueberries	31-32	90-95	R, F	10-18	
Broccoli	32	95-100	I, F, H	10-14	**Y**
Brussel sprouts	32	95-100	H, V, I	21-35	**Y**
Cabbage	32	**98-100**	**R, F**	**90 - 180**	**Y**
Cantaloupe	36-41	95	H, F	10-14	**Y**
Carrots, topped	32	98-100	I, R	28-180	**Y**
Cauliflower	32	90-98	H, V	20-30	
Celery	32	98-100	I	14-28	**Y**
Cherries, sweet	30-31	90-95	H, F	14-21	
Corn, sweet	32	95-98	H, I, V	4-6	

Cranberries	36-40	90-95		60-120	
Cucumbers	50-55	95	F, H	10-14	**Y**
Eggplant	46-54	90-95	R, F	10-14	**Y**
Endive	32	90-95	H, I	14-21	**Y**
Garlic	32-34	65-75	N	90-210	
Kiwifruit	32	95-100		28-84	**Y**
Grapefruit	50-60	85-90		28-42	
Grapes	32 85		F	56-180	
Leeks	32	95-100	H, I	60-90	
Lemons	50-55	85-90		30-180	
Lettuce	32	85-90	H, I	14-21	**Y**
Limes	48-50	85-90		21-35	
Mushrooms	32 95			12-17	
Nectarines	31-32	95	F, H	14-18	**Y**
Okra	45-50	90-95		7-14	**Y**
Onions, bulb	32	65-70	N	30-180	
Onions, green	32	95-100	H, I	7-10	
Oranges	32-48	85-90		21-56	
Peaches	31-32	90-95	F, H	14-28	**Y**
Pears	32	90-95	F, R, H	60-90	**Y**
Peas, in pods	32	95-98	F, H	I 7-10	**Y**
Peppers, bell	45-55	90-95	R, F	12-18	**Y**
Peppers, hot	45-50	60-70	R, F	14-21	**Y**
Pineapple	45-55	85-90		14-36	
Plums	32	90-95	F, H	14-28	**Y**
Potatoes, early	50-60	90	R, F	56-140	
Potatoes, late	40-50	90	R, F	56-140	**Y**
Pumpkins	50-60	50-75	N	84-160	
Radishes	32	95-100	I	21-28	
Raspberries	32	90-95	R, F	2-3	**Y**
Rutabagas	32	98-100	R	120-180	
Spinach	32	95-100	H, I	10-14	**Y**
Squash, summer	41-50	95	R, F	7-14	**Y**
Squash, winter	50-55	50-70	N	84-150	
Strawberries	32	90-95	R, F	5-10	
Sweet potatoes	55-60	85-90	N	120-210	**Y**
Tangerines	40	90-95		14-28	

Tomatoes	62-68	90-95	R, F	7-28	**Y**
Turnips	32	95	R, H, V, I	120-150	
Watermelon	50-60	90	N	14-21	

F = forced-air cooling, H = hydro-cooling, I = package icing, R = room cooling, V = vacuum cooling, N = no pre-cooling needed.

Lecture No. 9
Value addition concept

Value Addition

–Processing converts perishable **fruits and vegetables** into stable products ... addition and to improve the quality of **value added** food products for domestic ... viz. physical methods, chemical methods, fermentation, and other **means** are used.‖

Concept of Value Addition

- ✓ **Value** is **added** by changing their form, colour and other such methods to increase the shelf life of perishables.
- ✓ There are various methods of preservation of food including thermal processing, fermentation, pickling, dehydration, freezing etc.
- ✓ **Value addition** to food products has assumed vital **importance** in our country due to diversity in socio-economic conditions, industrial growth, urbanization and globalization.
- ✓ **Value** is added by changing their form, colour and other such methods to increase the shelf life of perishables.

Tomatoes

- Tomatoes are one of the most widely used and versatile vegetable crops, ranking second in importance to potatoes in many countries.
- Tomatoes are important both for its large consumption and richness in health related food components.
- Tomato (Solanum lycopersicon) is an herbaceous plant of Solanaceae family, which is one of the most popular protective foods, because of its lycopene content, outstanding nutritive value, antioxidant properties and a powerhouse of medicinal properties.
- It is a rich source of minerals like calcium, magnesium, phosphorous, iron, sodium, potassium and vitamins especially A and C.
- Tomatoes are consumed mainly as a raw staple food, as an ingredient in different types of food products and in the form of processed products such as powder, tomato juice, paste, puree, sauce, etc.
- This horticultural crop is an excellent source of health promoting compounds, being a balanced mixture of minerals and antioxidant vitamins including vitamin C and E, as well as rich in lycopene, beta carotene, thiamine, riboflavin, niacin, lutein and flavonoids such as quercetin.

- The main antioxidants in the tomatoes are the carotenoids specially lycopene which have the highest lycopene levels among fruits and vegetables, ascorbic acid and phenolic compounds.
- In addition to lycopene, violaxanthin, neoxanthin, lutein, zeaxanthin a-cryptoxanthin, b-cryptoxanthin, carotene, neurosporene, phytoene and 5, 6- epoxides are other carotenoids commonly cited in tomatoes and tomato derived products.
- Among the different carotenoids, lycopene, is the most abundant in human serum, with important antioxidant activity involved in prevention of several types of cancer and degenerative diseases such as cardiovascular diseases.
- The production of tomato, an important horticultural crop of India has increased enormously during past few decades, which emphasize more on processing and preservation of tomatoes, thereby ensuring better availability and utilization during off season.
- India is the fourth largest producer of tomatoes, accounting for 6.6 percent of the world production and second largest in acreage.
- However, due to lack of proper processing, storage and transportation facilities, enormous quantities of tomatoes are lost during the peak harvesting season in India.
- Being a perishable crop, tomatoes cannot be stored for a longer time, hence proper processing and storage in some preserved form during seasons of glut will ensure its availability and utilization during deficiency period.
- Hence, processing of tomatoes in different forms as preferred by the consumers, with long shelf life involves low cost of production.
- **Processing of fresh tomatoes can be done to prepare the following value added products like**.

- Tomato pulp
- Tomato puree
- Tomato paste
- Tomato flakes
- Canned tomatoes
- Tomato ketchup
- Tomato soup and sauce
- Tomato powder
- Dehydrated tomato

Therefore, replacement of fresh tomatoes for example, with tomato powder can facilitate the processing sector with daily cuisines and preparation during off season. Tomato powder can be used in processed products, such as soup mixes and confectionary items.

Carrots

- Carrot (Daucus Carota L.) is another popular root vegetable, which is cultivated and consumed throughout the world.
- It is well known for its nutrient contents viz., carotene and carotenoids, besides appreciable amount of vitamins and minerals such as ascorbic acid, tocopherol etc. Among roots and other vegetables, carrot is the best source of carotene, which is a precursor of vitamin A, an essential nutrient for maintaining health.

- Carrot posses nutraceutical properties such as antimutagenic, chemo preventive, photo protective and immune enhancing aspects.
- The presence of high concentration of antioxidant carotenoids, especially beta-carotene, may account for the biological and medicinal properties of carrots.
- Carrot is also rich in fiber content and has been reported to be effective for its multifaceted applications, which have resulted in development of various processing operation for making different products.
- Carrots are widely used as an ingredient for making curry, sweet meats and soups.
- Carrots have been reported to be effective in the elimination of uric acid.
- Carrots not only prevent vitamin A deficiency, but also cancer and other diet related human diseases.
- It has greater cytotoxic effect against cancer cells and reduces the enzymes that promote conversion of precarcinogens to carcinogens.
- It may also enhance the immune system protect against stroke, high blood pressure, osteoporosis, cataract, arthritis, heart disease and urinary tract infections.
- Processing of carrots would ensure its availability round year and reduction in cost of transportation and storage.
- During winter season, when carrots are available in plenty, different processed products may be prepared and stored in air tight containers, which may be incorporated in various recipes.

Different processed products of carrots are:

- Carrot juice
- Carrot powder
- Carrot flakes
- Canned carrot
- Carrot candy
- Carrot Halwa
- Carrot grits
- Carrot soup
- Carrot Dalia
- Fabricated baby foods

Carrot powder prepared by dehydrating carrots is often incorporated in traditional food products to enhance the nutritional value, and thereby produce value added products such as paratha, porridge and laddu. These processed carrot products are not only nutritionally adequate, but also qualitatively sound for an extended period, as indicated by the research study.

Spices (Ginger)

- Spices have a special significance in various ways in human life, because of their specific flavor, aroma, taste and keeping quality.
- Spices are generally used in a pulverized form as condiments for seasoning or garnishing foods and beverages.
- These are considered to act as preservative, besides improving texture and flavor of foods.

- Ginger (Zingiber Officinale) is one of the five most important spices of India, standing next to chilli, garlic and turmeric.
- Ginger is an underground stem of the zingiberous herbaceous plant. It is cultivated in several parts of the world, including India.
- Though ginger is grown throughout India, Kerala is the highest ginger producing state.
- In the year 2002, the total ginger production in India was 281.16 million tones, with Kerala and Meghalaya being the highest producing states.
- Among various spices grown in Uttarakhand, ginger occupies an important place with the production of 27,340 tonnes from an area of 2,250 hectare in year 2006-07.
- Ginger rhizomes are available for harvesting every 7-9 months after planting and stages of maturity of the rhizome have a significant influence in its quality and processing.
- Ginger is commonly used as a food additive, and as spice, it is used in food preparation to impart its characteristic flavor.
- It has been attributed with antioxidant properties, proteolytic activity and tenderizing effect. It has been attributed with antioxidant properties which widens its use in preservation of meat and meat products.
- Ginger has been used to treat numerous types of nausea and vomiting.
- Ginger‘s therapeutic properties effectively stimulate circulation of the blood, remove toxins form the body, clean the bowels and kidneys and nourish skin.
- Other uses for ginger root include the treatment of asthma, bronchitis and other respiratory problems.
- Besides therapeutic properties, ginger has been attributed with antioxidant properties, proteolytic activity and tenderizing effect.
- Ginger widens its use in preservation of meat and meat products, besides being used in fresh form.
- Ginger is used in various food preparations to impart its characteristic flavor and is probably the only spice being used in production of beverages like ginger beer, ginger ale and ginger wine.
- Although ginger production is very high, but due to lack of proper storage and transportation facilities, about 20 percent of fresh ginger crop gets damaged due to respiration and microbial spoilage.
- Hence, it becomes necessary to process the surplus ginger in different preserved forms, which is available throughout the year.

The different processed products from ginger include

- Paste
- Candy
- Preserve
- Pickle
- Chocolates
- Beverages
- Powder
- Juice
- Ice cream
- Oleoresin
- Ginger ale

The research study involved development of value added products such as ginger powder, ginger ale, ginger tea.

Fenugreek Leaves

- Green leafy vegetables are gaining importance, because of being good sources of vitamins, minerals and dietary fiber.
- Fenugreek (Trigonella foenum graecum) is a popular green leafy vegetable available in plenty, at lower cost during winter season.
- Blanching treatment is used to preserve the color and nutritional value of GLVs.
- Fenugreek leaf powder obtained by dehydrating fenugreek leaves has been used to prepare paratha and saag in study conducted.

Potato

- Potato (Solanum tuberosum) is an important and extensively grown horticultural crop in India.
- Potato is a versatile food, which can be eaten as a staple food, as a complementary vegetable, as a snack item or processed into several forms, and in any of these roles, it enhances the nutritional quality of the diets of people.
- Among the root crops, potatoes top the list and have the distraction of occupying largest area under any single vegetable in the world.
- Potatoes are versatile as they can be consumed in various forms as boiled, fried, baked, roasted, steamed and even in several pressed forms such as French fries, chips, papad, flakes, dice, cubes, granules, flour, canned potatoes etc.
- Potatoes contribute significantly to the nutritive value of a meal, as it is not only a rich source of energy, but contain good quality edible grade protein, dietary fiber, several minerals and trace elements, essential vitamins and little or negligible fat.
- However, besides this added advantage, the principal disadvantage associated with the crop is that, it is seasonal and the crop produced has a shorter storage life.
- Hence, under such circumstances, the post harvest processing of the bulky, perishable potatoes into dehydrated potato products helps to extend the storage life and a serve as a means to increase the supply in off-seasons in different forms, in a price effective manner.
- With this view in mind, the research work was carried out to produce different processed **products of potatoes such as**

- potato flour
- potato grits
- potato flakes
- potato granules
- potato cubes

The research studies on potatoes involved preparation of different value added food products by incorporating potato flour such as idli, biscuit, sev, extruded snacks, etc. and thereby, increasing the nutritional value of the products, also potato cubes are used in preparation of different vegetables

Sweet Potato

Sweet potato (Ipomoea batatas) belongs to the morning glory family Convulacae.

Sweet potato, a commonly grown root vegetable of winter season is valued for its high nutritive value, flavors and digestibility.

Sweet potato is widely used is India, for food consumption after boiling, baking or frying. However, in other countries, flour of the sweet potato is often used in biscuits, cakes and pudding.

The advantage of sweet potato over other vegetables is that it has got the shorter growth period, and adverse weather conditions rarely cause a complete crop loss.

Sweet potatoes often referred to as ―poor people's food‖ or ―poor men's crop‖ has difficulties in marketing and processing.

Processing of sweet potato tuber increases their availability and reduces post harvest wastage.

The processed products of sweet potato include:

- Sweet potato flour
- Sweet potato granules
- Canned sweet potatoes

- Sweet potato flour can be incorporated in wheat flour for bread and biscuit baking, hot cakes, gruel, noodles, candy, puddings and other preparations. It can be mixed with wheat flour for making chapatti and bread.
- This flour functions as a stabilizing agent in ice-creams.
- Sweet potatoes are an important source of dietary protein, substantial amount of vitamins (Beta carotene, B complex and vitamin C) minerals, trace elements and high energy value.
- Research study involved different value added product formulated from sweet potato like kheer, gulabjamun, chapatti and puri.

Lecture No. 10
Principles and Methods Of Preservation

Definition:

"Preservation refers to any one of a number of techniques used to prevent food from spoiling**."**

OR

―Preservation is the process of treating and handling food to stop or greatly slow down spoilage (loss of quality, edibility, or nutritive value).‖

- <u>**IMPORTANCE AND SCOPE OF FRUIT AND VEGETABLE PRESERVATION**</u>

- Fruits and vegetables are an important supplement to the human diet as they provide the essential minerals, vitamins and fibre required for maintaining health.
- In India, the total fruits and vegetable production is about 137 million tonnes per year i.e. 46 MT fruits and 92 MT vegetables.

- The varied agro climatic conditions available in our country make it possible for us to produce several types of tropical, subtropical and temperate fruits and vegetables.
- It has been variously estimated that 20 to 30% of the horticultural produce is lost before consumption which accounts for Rs. 5000 crores because of poor harvesting, handling, storage, transportation and marketing practices.
- The fruits and vegetables are highly perishable commodities and the ambient high temperature obtained in the tropical country like ours makes them more susceptible for rapid development of senescence, decay and rotting.
- Both respiratory and transpiratory rates are proportional to temperature, increases and so that the produce quickly dries, wilts and spoils unless properly preserved.
- Two approaches are possible for solving this problem.
- One is the creation / expansion of cold storage facilities in the fruit and vegetable producing regions themselves, as also in the major urban consumption centres, to ensure supply of fresh fruits and vegetables throughout the year.
- Another approach is to process the fruits and vegetables into various products which could be preserved for a long time and add to the value of the product.
- With increasing urbanization rise in middle class purchasing power, change in food habits and the dyeing out of the practice of making preserves in individual homes, there is increasing demands for factory made jams, jellies, fruit beverages, dehydrated foods, pickles etc. in the domestic market.
- Moreover, there is considerable demand for some of these products in foreign markets e.g.
- mangoes both fresh and canned, fruit juices, salted cashew are good foreign exchange earners.
- The production of fruit and vegetable products in India are canned, bottled fruits and vegetables, jams, jellies, marmalades, fruit juices, fruit pulps, squashes, crashes, cordials, fruit
- syrups, fruit nectars, RTS fruit beverages, fruit juice concentrates, chutneys, pickles, mango slices in brine preserves, candied and crystallized fruits and peels, dehydrated fruits and vegetables, frozen fruits and vegetables, tomato products, sauces, soups etc.
- In India there are 4000 processing industries are functioning. But a marginal quantity of 1.0 to 2.0 % of the produce is processed and packaged in contrast with developed and developing countries i.e., 70 to 80%. The total annual consumption of processed fruits and
- vegetable products in the country is rockened at only 50,000 tonnes of which defence and star hotels account for 15,000 tonnes and the remaining 35,000 tonnes to the public, i.e. a percapita/year.
- Thus we can see on enormous scope and potential for the expansion of fruits and vegetable industries in India in the future.

Export of fruits and vegetables from India

- In terms of global trade, India‘s share in agricultural export is insignificant.
- While India contributes 8.56% and 13.5% respectively to world‘s fruits and vegetables production, its share in global exports of these products is less than 1.0%.

- Delhi, Bombay and Trivandrum are the three main parts for air freighting of fruits and vegetables.
- These are mainly exported to Kuwait, Dubai and Saudi Arbia.
- Grapes are exported in large quantities from Bombay during January to March, while mango is exported during April to June.
- West Asia, the Far East and West Europe are the main export markets for Indian fruits and vegetables.
- Fruits juices, fruit pulp and pickles are mainly imported by the USSR, Yemen, Arab Republic.
- The other markets for processed fruits are UK, UAE, Saudi Arabia, Kuwait, Germany, USA, Holland and Switzerland.
- Nearly half of India‘s processed fruit exports are mango based fruit juice, canned and bottled fruits.
- Fresh onions and mangoes are the main commodities entering in export trade.
- The other important fruits exported are melon, sweet melon, grapes, pomegranate, sapota, custard apple, orange, papaya, pineapple.
- Among other vegetables the principal items are tomato, ladies finger bitter gourd, chillies, fresh beans, cabbage, brinjal etc.

Principles Of Food Preservation

Principles for F&V Food Preservation

- Prevention or delay of microbial decomposition
- Keeping out microorganisms (asepsis)
- Removal of microorganisms e.g. by filtration.
- Hindering the growth and activity of microorganisms e.g. by low temperature, drying, anaerobic conditions or chemicals.
- Killing the microorganisms e.g. by heat or radiations.
- Prevention or delay of self decomposition of food
- Destruction or inactivation of food enzymes e.g. by blanching.
- Delay of chemical reactions e.g. by prevention of oxidation by means of an antioxidant.
- Prevention of damage caused by insects, animals and mechanical causes.

CLASSIFICATION OF PRESERVATION METHODS

A) Physical Methods

a) By Removal of Heat
   (Preservation bye cold)
   i. Refrigeration
   ii. Freezing Preservation
   iii. Dehydro freezing preservation
   iv. Carbonation

b) By Addition of Heat
   (thermal processing)
   i. Stationary Pasteurization

ii. Agitating pasteurization/Sterilization
iii. Flash pasteurization/HTST processing etc.

c) By removal of water (evaporation or dehydration)
   i. Sun drying
   ii. Dehydration
   iii. Low temperature evaporation or concentration
   iv. Freeze-drying
   v. Accelerated freeze-drying
   vi. Foam-mat drying
   vii. Puff drying etc .

B) Chemical Methods

a) By Addition of acid such as vinegar or lactic acid
   - Pickled vegetable, fish and meat

b) By salting or bringing
   - Vegetable/Fruit pickles, salted fish etc.
   - Salt-cured meat and pork etc.

c) By adding of sugar and heating
   - Frits preserve, Jams, jellies, marmalades, etc.

d) By addition of chemical preservatives
   - Using water soluble salts of sulphur dioxide, benzoic acid and a few like hydrogen peroxide, etc. which are permitted as harmless in food.
   - By means of substances of bacterial origin such as tylosin, resin, etc. Which are permitted to limited extent, some cases as harmless additives.

C) By Fermentation
   - **Alco**holic and acetous fermentation as in the cases of fruit wines, apple cider, fruit, vinegar etc.

D) By other methods
   - A judicious combination of one or more of the methods mentioned above for synergistic preservation.

<u>Methods of Preservation:</u>

There are two methods of preservation –

1. Temporary Preservation
2. Permanent Preservation

1. **<u>TEMPORARY PRESERVATION</u>**

   Preserved for few Hours, Days or few month

1. Asepsis or Absence of infection

The number of microorganisms present in food product largely initiate spoiling process while handling the fruits and vegetables for manufacture of the products. The general cleanliness while packaging, grading, and transporting of raw material increase the keeping quality of fruits and vegetables. Washing or wiping of the fruits and vegetables before using in manufacture should be strictly followed as the dust particles adhering to the raw material accompany microorganisms. Maintain hygienic conditions at all stages during preservation.

2. **Low Temperature**

The low temperature, 0^0 to 4.4 ^{0}C (32 to 40 ^{0}F), check the growth, multiplication and actively of microorganism but do not kill them. It also retards chemical changes to a greater extent Ex. Cold storage.

3. **Exclusion of moisture**

Moisture is one of the favourable things for the growth of microorganisms specially moulds. It plays a great role in dried products as it collect on the surface of result in microorganisms growth. Moisture is also responsible for to diluted the concentrated sugar solution which are generally without preservatives. It is, therefore, essential to save the product the form moisture and should be stored in the dry atmosphere

4. **Exclusion of air**

The air is also necessary for growth of microorganisms. If the products are saved from air they prolong the keeping qualities especially fruit products. Aerobic organisms cause great spoilage if they get external air. So fermented products and pickles must be created in air-tight containers to check their growth.

5. **Mild antiseptics**

The use of antiseptic in small quantities prevents the growth of micro organisms either osmosis or by poison or both for a short time or several weeks after opening the bottles.

6. **Pasteurization**

This is a process in which the product is subjected to a temperature that kills a great many, but not all of the micro organisms present.

Pasteurization is a heat treatment that kills part but not all the microorganisms present and the temperature applied is below 100oC. The heating may be by means of steam, hot H_2O, dry heat or electric currents and the products are cooled promptly after the heat treatments. The surviving microorganisms are inhibited by low temperature (or) some other preservative method if spoilage is to be prevented.

Preservative methods used to supplement pasteurization include

(1) refrigeration e.g. of milk

(2) keeping out microorganisms usually by packaging the product in a sealed container

(3) maintenance of anaerobic conditions as in evacuated, sealed containers

(4) addition of high concentration of sugar, as in sweetened condensed milk and

(5) presence (or) addition of chemical preservatives e.g. the organic acids on pickles.

<u>Methods of pasteurization</u>

HTST method - High temperature and short time (above 70oC).

LTH method - Low temperature and higher time (or) Holding method (60-70oC).

2. **<u>PERMANENT PRESERVATION</u>**

The principle used in permanent preservation is to eliminate complete or to prevent the activities of the microorganisms capable for destroying the product.

1. **Preservation By Heat**

Application of heat to the foods leads to the destruction of microorganisms. The specific treatment varies with:

i) The organisms that has to be killed.
ii) The nature of the food to be preserved and
iii) Other means of preservation that may be used in addition to high temperature.

a) Sterilization or Processing:

i. By this method all microorganisms are completely destroyed due to high temperature.
ii. The time and temperature, necessary for sterilization vary with the type of food. Temperatures above 100oC can only be obtained by using steam pressure sterilizers such as pressure cookers and autoclaves.
iii. Fruits and tomato products should be noted at 100oC for 30 min. so that the spore forming bacteria which are sensitive to high acidity may be completely killed.
iv. Vegetables like green peas, okra, beans, etc. being non acidic and containing more starch than sugar, require higher temperature to kill the spore forming organisms.
v. Continuous heating for 30-90 min. at 116oC is essential for their sterilization.
vi. Before using, empty cans and bottles should also be sterilized for about 30 min. by placing them in boiling water.

Difference between Pasteurization and Sterilization:

Pasteurization	Sterilization
1. Partial destruction of microorganism	Complete destruction of microorganism
2. Temperature below 100oC	Temperature 100oC and above
3. Normally used for fruits	Normally used for vegetables

b) Preservation by Antiseptic:

Foods may be preserved permanently by addition of antiseptics like sugar, salt, and vinegar and chemicals in sufficient concentration to prevent the growth of microorganisms either by osmosis or by poison or by both.

a. **Sugar** – If the concentration of sugar in the preserved material is increased about 66%, the water content is decreased to such an extent that the multiplication of microorganisms is checked and the present ones die in due course.
   Example – Jellies, Preserve, etc
b. **Salt –** Strong salt solutions never allow the microorganisms to grow in the preserved products. It acts both by osmosis and as a poisons and it is more effective than sugar. A brine solution of 10 to 15 % is sufficient for permanent preservations of most of the products.
   Example – Pickles and Canned Vegetables.
c. **Vinegar –** Acetic acid of vinegar is most effective then sugar and salt and acts as a poison for microorganisms. A solution of about 2 % of acetic acid prevents most of the products from spoilage.
   Example – Pickles, Sauces.

2. Preservation By Chemicals

A preservative is defined as only substance which is capable of inhibiting, retarding or arresting the growth of microorganisms. Microbial spoilage of food products is also controlled by using chemical preservatives. The inhibitory action of preservatives is due to their interfering with the mechanism of cell division, permeability of cell membrane and activity of enzymes. Pasteurized squashes, cordials and crushes have a cooked flavour. After the container is opened, they ferment and spoil within a short period, particularly in a tropical climate. To avoid this, it is necessary to use chemical preservatives. Chemically preserved squashes and crushes can be kept for a fairly long time even after opening the seal of the bottle. It is however, essential that the use of chemicals is properly controlled, as their indiscriminate use is likely to be harmful. The preservative used should not be injurious to health and should be non-irritant. It should be easy to detect and estimate.

Two important chemical preservatives are permitted to beverages according to the FPO (1955).

1. Sulphur dioxide and
2. Benzoic acid

Sulphur dioxide

It is widely used throughout the world in the preservation of juice, pulp, nectar, squash, crush, cordial and other products. It has good preserving action against bacteria and moulds and inhibits enzymes, etc. In addition, it acts as an antioxidant and bleaching agent. These properties help in the retention of ascorbic acid, carotene and other oxidizable compounds. It also retards the development of nonenzymatic browning or discolouration of the product. It is generally used in the form of its salts such as sulphite, bisulphate and metabisulphite.

Potassium metabisulphite (K2O 2So2 (or) K2S2O5) is commonly used as a stable source of So2. Being a solid, it is easier to use than liquid (or) gaseous So2.It is fairly stable in neutral (or) alkaline media but decomposed by weak acids like carbonic, citric, tartaric acid and malic acids. When added to fruit juice (or) squash it reacts with the acid in the juice forming the potassium salt and So2, which is liberated and forms sulphurous acid with the water of the juice.

The reactions involved are as follows

Potassium meta bisulphate + Citric acid ⟶ Potassium Citrate + Sulphur dioxide + H_2O

$SO_2 + H_2O$ H_2SO_3 (Sulphurous acid)

SO_2 has a better preservative action than sodium benzoate against bacteria and moulds. It also retards the development of yeasts in juice, but cannot arrest their multiplication, once their number has reached a high value.

It is well known that fruit juices with high acidity do not undergo fermentation readily. The preservative action of the fruit acid its due to is hydrogen ion concentration. The pH for the growth of moulds ranges from 1.5 to 8.5, that of yeasts from 2.5-8.0, and of bacteria from 4.0 to 7.5.As fruit beverage like citrus squashes and cordials have generally a pH of 2.5 to 3.5, the growth of moulds and yeasts in them cannot be prevented by acidity alone. Bacteria, however, cannot grow. The pH is therefore, of great importance in the preservation of food product and by regulating it, one or more kinds of microorganisms in the beverage can be eliminated. The toxicity of So2 increases at high temperature. Hence its effectiveness depends on the acidity, pH, temperature and substances present in fruit juice. According to FPO, the maximum amount of So2 allowed in fruit juice is 700 ppm, in squash, crush and cordial 350 ppm and in RTS and nectar 100 ppm. The advantages of using So2 are a) It has a better preserving action than sodium benzoate against bacterial fermentation b) it helps to retain the colour of the beverage for a longer time than sodium benzoate (c) being a gas, it helps in preserving the surface layer of juices also (d) being highly soluble in juices and squashes, it ensures better mixing and hence their preservation and (e) any excess of So2 present can be removed either by heating the juice to about 71oC or by passing air through it or by subjecting the juice to vacuum. This causes some loss of the flavouring materials due to volatilization, which can be compensated by adding flavours.

Disadvantages (or) limitations

a. It cannot be used in the case of some naturally coloured juices like those of jamun, pomegranate, strawberry, coloured grapes, plum etc. on account of its bleaching action.

b. It cannot also be used for juices which are to be packed in tin containers because it not only corrodes the tin causing pinholes, but also forms H2S which has a disagreeable smell and reacts with the iron of the tin container to form a black compound, both of which are highly undesirable and

c. So2 gives a slight taste and colour to freshly prepared beverages but these are not serious defects if the beverage is diluted before drinking.

Benzoic acid

It is only partially soluble in H2O hence its salt, sodium benzoate is used. One part of sodium benzoate is soluble in 1.8 parts of water at ordinary temperature, whereas only 0.34 parts of benzoic acid is soluble in 100 parts of water. Sodium benzoate is thus nearly 170 times as soluble as benzoic acid, pure sodium benzoate is tasteless and odourless.

The antibacterial action of benzoic acid is increased in the presence of Co2 and acid e.g. *Bacillus subtilis* cannot survive in benzoic acid solution in the presence of Co2. Benzoic acid is more effective against yeasts than against moulds. It does not stop lactic acid and acetic acid fermentation.

The quantity of benzoic acid required depends on the nature of the product to be preserved, particularly its acidity. In case of juices having a pH of 3.5-4.0, which is the range of a majority of fruit juices, addition of 0.06 to 0.10% of sodium benzoate has been found to be sufficient. In case of less acid juices such as grape juice atleast 0.3% is necessary. The action of benzoic acid is reduced considerably at pH 5.0. Sodium benzoate is excess of 0.1% may produce a disagreeable burning taste. According to FPO its permitted level in RTS and nectar is 100 ppm and in squash, crush and cordial 600 ppm.

In the long run benzoic acid may darken the product. It is, therefore, mostly used in coloured products of tomato, jamun, pomegranate, plum, watermelon, strawberry, coloured grapes etc.

3. Preservation by drying

It is the most popular method of preservation. Drying by dehydration is more rapid process as artificial heat or higher temperature is provided. the fruits and vegetables are dried to such an extent that the moisture content is reduced and microorganisms fail to survive on them and it checks the action of enzymes as well.

Drying (removing moisture) helps in preservation of foods. Microbes can not grow and multiply in absence of sufficient water in their environment many of the enzymatic reactions are hydrolytic in nature ,requiring water. Chemical reaction in food material are slowdown when the reaction are in solid state. hence by removing water from the commodity, it should be possible to preserve them by checking the important spoilage agent. This principle forms the basis for dehydrated foods and for osmotic, dehydration where high sugar or salt act as a preservative. Fruits and vegetables may be dried in air, super heated steam ,in vaccum ,in inert gases or by direct application of heat.

Drying, dehydration and concentration ;

Removal of moisture by applying of heat is called ‗Drying'. Dehydration is drying by artificially heating under controlled temperature ,humidity and air flow . the basic drying process are classified as sun drying ,atmospheric dehydration and vaccum dehydration .sun drying is still in use. These methods are accompanied by removing by water. Moisture may be removed from food by any of the methods.

Dehydration (below 5%) moisture helps to preserve nutritive value of the product although heat- labile vitamins losses are more. Low moisture preserved material can be fortified with vitamins under proper storage conditions. The products have more shelf-life if properly packed and stored.

Retention of nutrients and overall quality is better in modern methods of dehydration as there are little changes in physico-chemical composition.

Sun-drying of fruits and vegetables is practiced by solar energy widely in tropical and subtropical regions, in indirect solar drying, the fruits and vegetable are sprayed on trays, which are kept in close compartment or in cabinet drier. In solar dryer, the air is heated by direct sunrays and carried to the dryer from bottom and goes out from the top of chimney. The drying condition are influenced by temperature and the velocity of the air flow. this solar dryers may be with chimney or with amber coloured glass .for drying fruits and vegetables at home ,the home dryer is ideal.

Packaging and Storage;

The fruits dried as per the directives given in table below should be put into tins sealed air tight with solder or wax depending upon the duration or storage.

The schedule for dehydration of some important fruit and vegetables given below:

S. N.	Fruits	Preparation	Pre treatment dipping in lye etc.	Time of sulphuring	Finishing temp. (^{0}C)
1.	Apple	Peel, core, trim and cut into 3-5 mm thick slices	Nil	15-30 min	55-55
2.	Grape	Wash	10-20 seconds and wash	10-15 min	55-60
3.	Banana	Wash, peel, cut into 1-2 mm thick slices	Nil	2hr	55-60
4.	Pineapple	Wash, peel cut into 6mm thick slices	Nil	2hr	55-60
5.	Papaya	Wash, peel cut into 6 mm thick slices	Nil	2hr	60-63
6.	Litchi	Wash remove skin	Dip in 1% KMS soln for	-	50-55

			16hrs		

DRYING OF VEGETABLES:

The steps in dehydration of vegetables are preparation(washing, peeling, and slicing),blanching, sulphiting and drying. Blanching may be carried out either in boiling water or in steam, but in the case of green vegetable like green peas, split field beans, spinach and fenugreek leaves, blanching in boiling water containing 0.1 % magnesium oxide, 0.1 % sodium carbonate and 0.5 % potassium meta bisulphate (KMS) is recomamded to ensure maximum retention of natural green colors in the dehydrated vegetables. In other cases, sulphiting may be carries out immediately after blanching by steeping in half the weight of KMS solution of appropriate (0.10 to 0.25 %) concentration. While beet root is not sulphited. Onion and garlic are neither blanched nor sulphited. For drying, generally 5-10 kg material is loaded per sq. m, of the area in trays.

Schedule For Drying of Vegetables

S. N.	**Vegetable**	**Preparation**	**Pre- treatment**	**Max. drying temp (^{0}C) in home drier**
1.	Potato	Peel and cut into 1 cm thick slices	Blanch in boiling water or steam for 3-4 min. and sulphite in 0.125% potassium metabisulphite (KMS) soln. for 10 min. using 0.5 kg of solution per kg of slices	65
2.	Cabbage	Remove outer leaves, cores and cut into 4-8 mm thick shreds	Blanch in boiling Water or steam for 3-4 min. and sulphite in 0.25% poyassium metabusulphite (KMS) solution for 10 min.	55
3.	Onions	Remove tops and tails, peel and cut into 4-8 mm thick shreds	Nil	55
4.	Okra(Sliced)	Remove both ends with stainless steel knife and cut into 6 mm thick slices	Blanch in boiling water for 4-5 min. and sulphite in o.25% KMS solution for 10 min.	60
5.	Bitter gourd	Remove both ends with stainless steel knife and cut into 6 mm thick slices	Blanch in boiling water for 8 min.	60
6.	Green pea	Remove pod and prick with a small nail or pin	Blanch 3-4 min. in boiling water containing 0.5% KMS, 0.1 % Magnesium oxide and 0.1% Sodium bicarbonate.	60

7.	Spinach	Sort wash thoroughly and cut in to 10-12 mm portions using a stainless steel knife	Blanch as above for 2 min.	60
8.	Fenugreek	Sort, wash thoroughly and removes stalks and stem	Blanch as above for 2 min.	60

4. **Preservation by Fermentation:**

   Microorganisms and enzymes are used for the carbohydrates and the process in termed as –FERMENTATION‖.

a. **Alcoholic fermentation:**

   The keeping quality of alcoholic beverage directly depends upon the alcohol present. Yeasts play an important role in this type of fermentation.

   $C_6H_{12}O_6$ + Yeast $\longrightarrow$ $2C_2H_5OH$ + $2CO_2$

   (Dextrose) (Alcohol)

b. **Acetic fermentation:**

   This type of fermentation follows alcoholic fermentation and is completed by vinegar bacteria and Acetic acid is produced which acts as a preservatives for various products such as pickles, sauce etc.

   C_2H_5OH + O_2 $\longrightarrow$ CH_3COOH + H_2O

   (Alcohol) (Oxygen) (Acetic acid)

c. **Lactic fermentation:**

   In this process dextrose sugars are decomposed into lactic acid and presence the pieces after fermentation.

   $C_6H_{12}O_6$ $\longrightarrow$ $2C_3H_6O_3$

   (Dextrose) (Lactic acid)

Lecture No. 11

Intermediate moisture food – Jam, Jelly, Marmalade, Preserve candy – Concepts and Standard

INTERMEDIATE MOISTURE FOOD:

A Food Products that has a water activity below that which is required for the growth of microorganisms; or a food containing unavailable water. IMF foods have water activity in B/W 0.6 – 0.9 or 10 to 50 % moisture.

OR

–IMF in terms of aw values and moisture content vary within wide limits (0.6-0.90 aw, 10-50% moisture), and the addition of preservatives provides the margin of safety against spoilage organisms tolerant to low as. Of the food poisoning bacteria, *Staphylococcus aureus* is one of the organisms of high concern since it has been reported to tolerate aw as low as 0.83-0.86 under aerobic conditions.‖

Concept of IMF

- Traditional intermediate moisture foods (IMF) can be regarded as one of the oldest foods preserved by man.
- The mixing of ingredients to achieve a given aw, that allowed safe storage while maintaining enough water for palatability, was only done, however, on an empirical basis.
- The work done by food scientists approximately three decades ago, in the search for convenient stable products through removal of water, resulted in the so-called modern intermediate moisture foods.
- These foods rely heavily on the addition of humectants and preservatives to prevent or reduce the growth of microorganisms.
- Since then, this category of products has been subjected to continuous revision and discussion.
  Many of the considerations on the significance of microorganisms in IMF are made in terms of as limits for growth.
- However, microbial control in IMF does not only depend on aw but on pH, *E*h, *F* and *T* values preservatives, competitive micro flora, etc.
- Which also exert an important effect on colonizing flora.

Advantages

- Intermediate moisture foods have an aw range of 0.65-0.90, and thus water activity is their primary hurdle to achieving microbial stability and safety.
- IMF foods are easy to prepare and store without refrigeration.
- They are energy efficient and relatively cheap.
- They are not readily subject to spoilage, even if packages have been damaged prior to opening, as with thermo stabilized foods, because of low as.
- This is a plus for many developing countries, especially those in tropical climates with inadequate infrastructure for processing and storage, and offers marketing advantages for consumers all over the world.

Disadvantages

- Some IMF foods contain high levels of additives (i.e., nitrites sulphites, humectants, etc.) that may cause health concerns and possible legal problems.
- High sugar content is also a concern because of the high calorific intake.
- Therefore, efforts are been made to improve the quality of such foods by decreasing sugar and salt addition, as well as by increasing the moisture content and aw, but without sacrificing the microbial stability and safety of products if stored without refrigeration.
- This may be achieved by an intelligent application of hurdles (Leistner, 1994).

What is Water Activity:

Water activity is a thermodynamic property which is defined as the ratio of vapour pressure of water in a food system and vapor pressure of pure water at the same temperature.

Purpose of Intermediate Moisture food:

- The purpose is to achieve a desirable water activity by the various ingredients so that food product maintain enough water for palatability and can be stored safely.
- Addition on preservatives provides the margin of safety against spoilage organisms.
- Staphylococcus aureus is one of the organisms of high concern which can tolerate as low as 0.83-0.86 under aerobic conditions.

Procedure for IMF

Partial drying

- To achieve 0.6-0.84 water activity in food products, partial drying is employed for raw food that naturally have a high amount of humectants such as raisins, apricots, prunes and sultanas.
- Humectants are solutes (such as sugar or salt) that immobilize water in food.
- The drying process removes free water, and the humectants in the product bind the rest of the water, not allowing it to be utilized for chemical reactions or for microbial use.

Osmotic drying using a humectant

- Osmotic dehydration is the process of soaking food in highly concentrated solutions of humectant.
- Salt and sugar are commonly used humectants for this process.
- Water diffusion from the food to the humectant solution is caused by osmotic pressure.
- The water is replaced by the humectant, which results in a lowered water activity for the food product.
- Osmotic dehydration process results in two way mass transfer in regards to the moisture lost and the solids gained, with moisture loss being much greater than the addition of solids.
- Advantages of osmotic dehydration include low processing temperatures, short drying times, and 20-30% lower energy consumption than typical dehydration processes.Sugar is used as the humectant for candied intermediate moisture fruits, and salt is used for intermediate moisture vegetables and fish.
- Additionally, a mixture of humectants can be formulated to manipulate the sensory properties of the food product.
- Osmotic drying using a humectant results in a soft texture in the final product.[2]

Dry infusion

- Dry infusion is the combination of partial dehydration and osmotic dehydration using a humectant.
- The food product is first dehydrated and then the resultant product is added to a humectant solution to reach the desired water activity.

- This method is desirable because it results in a higher quality and more appealing product.
- However, more energy is used for this method because it is two processing steps combined. Dry infusion is primarily employed by the U.S military and NASA for production of IMF to produce safe, palatable food that can be consumed much later than it is produced.

Formulated intermediate moisture foods

- Many types of food are specially formulated to achieve water activity in the IMF range.
- Food ingredients are mixed with salt and/or sugar, and additives (such as propylene glycol and potassium sorbate) and then subjected to processing methods such as cooking, extrusion or dehydration to result in an intermediate moisture final product.

Candy

- Aonla fruit can be utilized for making excellent quality candies or intermediate moisture food (IMF).
- Pathak (1988) described the technology for preparation of aonla candy.
- Aonla candies are becoming popular because of minimum volume, higher nutritional value and longer storage life.
- Tandon *et al*. (2003) found that candy prepared from lye-peeled fruits of aonla showed decreased content of ascorbic acid compared to blanched fruits.
- The candy prepared from ‗Lakshmi-52', ‗Kanchan' and ‗Chakaiya' was found the best quality.
- Singh *et al*. (2005e) prepared aonla candy with four different techniques (whole and segmented fruits with either sugar or pectin coatings).
- Candy prepared from segmented fruit with pectin coating recorded the highest organoleptic score because of its attractive colour and flavour, followed by whole fruit candy with pectin coating.

Jelly making

- To make a jelly, the fruit should be softened into a pulp to allow the juices to run Place the washed fruit in a pan and heat over a low heat to soften the fruit and allow the juice to be released.
- Add a little water to prevent the fruit burning or sticking to the bottom of the pan.
- Do not add too much water because you need to remove it all later during the boiling stage. Transfer the softened fruit to a jelly bag (a bag made from muslin cloth that is tied and suspended above a bowl into which the fruit juice drips).
- Allow the juice to drip out from the cloth - this may take overnight.
- Make sure that the juice cannot be contaminated by insects and dust while it is dripping.
- Do not squeeze the bag as this makes the juice cloudy.
- Measure the volume of juice extracted.
- Weigh out the sugar (you should have equal amounts of juice and sugar) and add it to the juice.

Jam making

- To make jam, the fruit also needs to be softened into a pulp Place the washed fruit in a pan and heat over a low heat to soften the fruit and allow the juice to be released.
- Some fruits will need a little water to be added at this stage to prevent the fruit burning or sticking to the bottom of the pan.
- Do not add too much water because you need to remove it all later during the boiling stage. When the fruit has all softened and there is juice in the pan, add the sugar and continue to heat gently until all the sugar has dissolved.

Marmalade

Marmalade is a mixture brought to a suitable gelled consistency of sweetening agents and one or more of the following products obtained from citrus fruits – pulp, purée, juice, aqueous extract, and peel. The fruit content must be at least 20 g per 100 g, and at least 7.5 g of this must be derived from the endocarp (center) of the fruit.

Lecture No. 12
Fermented and Non- fermented Beverage

Fermented beverages:

–**Fermented beverages** are complex solutions of thousands of chemical compounds originating from the fruit itself, from the **fermentation** process, from the yeast and other microbial metabolism during **fermentation**, and from post fermentation steps (including secondary fermentations and chemical reactions during aging)‖

Non-Fermented beverages:

–Fruit juices which do not undergo alcoholic fermentation are termed as **non-fermented beverages**. They include natural and sweetened juices, RTS, nectar, cordial, squash, crush, syrup, fruit juice concentrate and fruit juice powder."

Non-fermented beverages

I. FRUIT BEVERAGE

A. SQUASH

This is a type of fruit beverage containing at least 25 per cent fruit juice or pulp and 40 to 50 per cent total soluble solids, commercially. It also contains about 1.0per cent acid and 350 ppm sulphur dioxide or 600 ppm sodium benzoate. It is diluted before serving.

Mango, orange and pineapple are used for making squash commercially. It can also be prepared from lemon, bael, papaya, etc. using potassium metabisulphite (KMS) as preservative or from jamun, passion-fruit, peach, plum, raspberry, strawberry, grapefruit, etc. with sodium benzoate as preservative.

FLOWCHART FOR PROCESSING OF SQUASH

Fruits

↓

Washing

↓

Trimming

↓

Cutting or grating

↓

Juice extraction

↓

Straining

↓

Juice measuring

↓

Preparation of syrup

(Sugar + water + acid, heating just to dissolve)

↓

Straining

↓

Mixing with juice

↓

Addition of preservative

(0.6 g KMS or 1.0 g sodium Benzoate / litre squash)

↓

Bottling

↓

Capping

↓

Storage

B. READY-TO-SERVE (RTS)

This is a type of fruit beverage which contains at least 10 per cent fruit juice and 10 per cent total soluble solids besides about 0.3 per cent acid. It is not diluted before serving, hence it is known as ready-to-serve (RTS).

FLOW-SHEET FOR PROCESSING OF RTS BEVERAGES

Fruit

(Pulp / juice)

↓

Mixing with strained syrup solution

(Sugar + water + acid, heated just

to dissolve) according to recipe

↓

Homogenization

↓

Bottling

↓

Crown corking

↓

Pasteurization

(at about 90°c) for 25 minutes

↓

Cooling

↓

Storage

D. NECTAR

This type of fruit beverage contains at least 20 per cent fruit juice / pulp and 15 per cent total soluble solids and also about 0.3 per cent acid. It is not diluted before serving.

S.N.	Fruits	Juice / Pulp (%)	Quantity of water required (Liter)
1	Mango	20	Quantity of finished product (litre) – Quantity of (juice (litre) + sugar (kg) + acid (kg) used
2	Papaya	20	
3	Guava	20	
4	Beal	20	
5	Jamun	20	
6	Aonla (blend)	Aonla pulp 20 Lime juice 2 Ginger juice 1	

For preparing the above beverages, the total soluble solids and total acid present in the pulp/juice are first determined and then the requisite amounts of sugar and citric acid dissolved in water are added for adjustment of TSS and acidity.

C. CORDIAL

It is a sparkling, clear, sweetened fruit juice from which pulp and other insoluble substances have been completely removed. It contains at least 25 per cent juice and 30 per cent TSS. It also contains about 1.5 per cent acid and 350 ppm of sulphur dioxide. This is very suitable for blending with wines. Lime and lemon are suitable for making cordial.

FLOWCHART FOR PROCESSING OF CORDIAL

Fruits
↓
Washing
↓
Cutting into halves
↓
Juice extraction
↓
Straining
↓
Addition of preservative
(KMS 1g/litre juice)
↓
Storing in glass container for 10-15 days
For clarification
(suspended material settles down)
↓
Symphonizing off the
supernatant clear juice
↓
Straining and measuring
↓
Preparation of syrup
↓
Straining

Mixing of juice with syrup
↓
Addition of preservative
(KMS 0.6 g/litre product)
↓
Bottling
↓
Capping
↓
Storing in cool and dry place

Fermented Beverages

Fruit juices which have undergone alcoholic fermentation by yeasts include wine, champaigne, port, sherry, tokay, muscat, perry, orange wine, berry wine, nira and cider.

1. WINE **FLOWCHART FOR PROCESSING OF WINE**

Ripe grapes
↓
Removal of stems
↓
Crushing (Basket press)
↓
Filling jar up to three – fourths
↓
Addition of sugar (20-24% TSS)
↓
Adjustment of pH (0.6 to 0.8% acid)
↓
Addition of preservative (KMS 1.5 g /10 kg grapes)
↓
Keeping for an hour
↓
Addition of wine yeast (S.E. 20 ml/5 kg grapes)
↓
Fermentation (for 2 days)
↓
Filtration
↓
Fermentation (for 10 days)
↓
Racking (Syphoning off clear liquid)
↓
Fining and filtration (Bentonite)
↓
Aging (maturation) (6-8 months)
↓
Pasteurization at $82^{o}C$ (for 2 min.)
↓
Bottling
↓
Crown corking
↓
Pasteurization at $82^{o}C$ (for 20 min)
↓
Cooling
↓
Storage

2. JAM, JELLY, MARMALADE

A. JAM

Jam is a product made by boiling fruit pulp with sufficient amount of sugar to a reasonably thick consistency, firm enough to hold the fruit tissues in position. Apple, pear, sapota (chiku), peach, papaya, karonda, carrot, plum, straw-berry, raspberry, mango, tomato, grapes and muskmelon are used for preparation of jams. It can be prepared from one kind of fruit or from two or more kinds.

FLOWCHART FOR PROCESSING OF JAM

Ripe firm fruits

↓

Washing

↓

Peeling

↓

Pulping
(remove seed and core)

↓

Addition of sugar (add water if necessary)

↓

Boiling
(with continuous stirring)

↓

Addition of citric acid

↓

Judging of end-point

↓

By further cooking
Up to 105°C or 68-70% TSS or
By sheet test

↓

Filling hot into sterilized bottles

↓

Cooking

↓

Waxing

↓

Capping

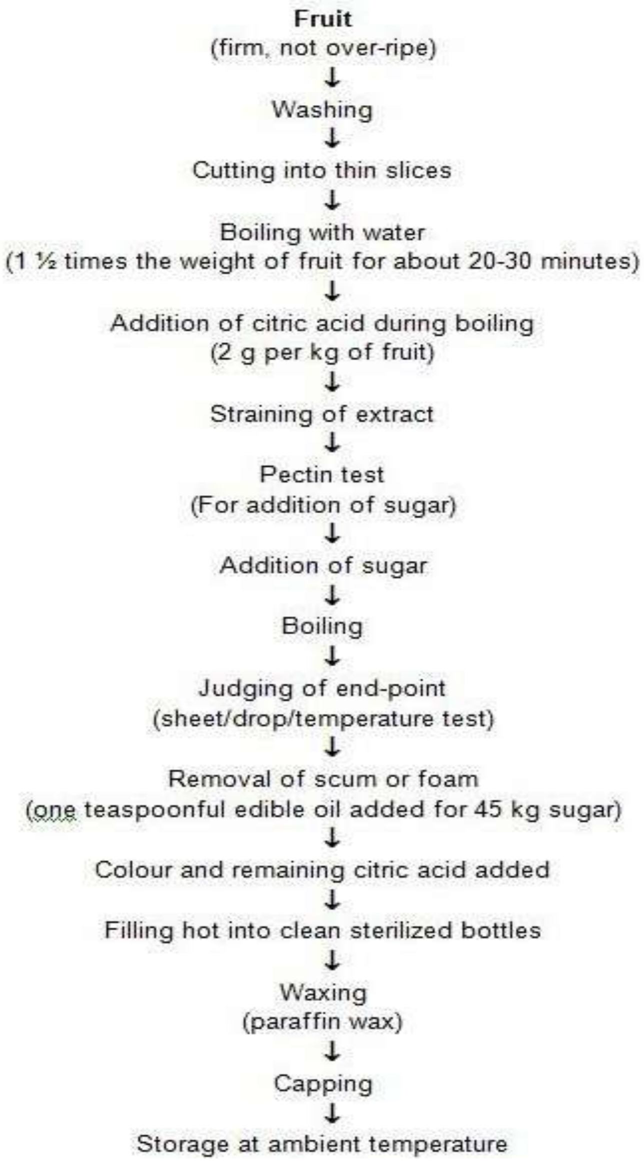
↓

Storage
(at ambient temperature)

B. JELLY

- A jelly is a semi-solid product prepared by boiling a clear, strained solution of pectin-containing fruit extract, free from pulp, after the addition of sugar and acid. A perfect jelly should be transparent, well-set, but not too stiff, and should have the original flavour of the fruit. It should be of attractive colour and keep its shape when removed from the mould. It should be firm enough to retain a sharp edge but tender enough to quiver when pressed.
- Guava, sour apple, plum, karonda, wood apple, loquat, papaya and goose-berry are generally used for preparation of jelly. Apricot, pineapple, strawberry, raspberry, etc. can be used but only after addition of pectin powder, because these fruits have low pectin content.

FLOWCHART FOR PROCESSING OF JELLY



C. MARMALADE

This is a fruit jelly in which slices of the fruit or its peel are suspended. The term is generally used for products made from citrus fruits like oranges and lemons in which shredded peel is used as the suspended material. Citrus marmalades are classified into
(i) jelly marmalade, and (ii) jam marmalade.

Jelly marmalade

The following combinations give good quality of jelly marmalade:

i. Sweet orange (Malta) and khatta or sour orange (Citrus aurantium) in the ratio of 2:1 by weight. Shreds of Malta orange peel are used.
ii. Mandarin orange and khatta in the ratio of 2:1 by weight. Shreds of Malta orange peel are used.
iii. Sweet orange (Malta) and galgal (***Citrus limonia***) in the ratio of 2:1 by weight. Shreds of Malta orange peel are used.

Jam marmalade

The method of preparation is practically the same as that for jelly marmalade. In this case the pectin extract of fruit is not clarified and the whole pulp is used. Sugar is added according to the weight of fruit, generally in the proportion of 1:1. The pulp-sugar mixture is cooked till the TSS content reaches 65 per cent.

FLOWCHART FOR PROCESSING OF MARMALADE

D. CANDY

A whole fruit / vegetable or its pieces impregnated with cane sugar or glucose syrup, and subsequently drained free of syrup and dried, is known as candied fruit / vegetable. The most suitable fruits for candying are aonla, karonda, pineapple, cherry, papaya, apple, peach, and peels of orange, lemon, grapefruit and citron, ginger, etc.

The process for making candied fruit is practically similar to that for preserves. The only difference is that the fruit is impregnated with syrup having a higher percentage of sugar or glucose. A certain amount (25-30 per cent) of invert sugar or glucose, viz., confectioners glucose (corn syrup, crystal syrup or commercial glucose), dextrose or invert sugar is substituted for cane sugar. The total sugar content of the impregnated fruit is kept at about 75 per cent to prevent fermentation. The syrup left over from the candying process can be used for candying another batch of the same kind of fruit after suitable dilution for sweetening chutneys, sauces and pickles and in vinegar making.

Glazed candy

Covering of candied fruits / vegetables with a thin transparent coating of sugar, which imparts them a glossy appearance, is known as glazing.

Cane sugar and water (2:1 by weight) are boiled in a steam pan at 113-114°C and the scum is removed as it comes up. Thereafter the syrup is cooled to 93°C and rubbed with a wooden ladle on the side of the pan when granulated sugar is obtained. Dried candied fruits are passed through this granulated portion of the sugar solution, one by one, by means of a fork, and then placed on trays in a warm dry room. They may also be dried in a drier at 49°C for 2-3 hours. When they become crisp, they are packed in airtight containers for storage.

Crystallized candy

Candied fruits/ vegetables when covered or coated with crystals of sugar, either by rolling in finely powdered sugar or by allowing sugar crystals to deposit on them from a dense syrup are called crystallized fruits. The candied fruits are placed on a wire mesh tray which is placed in a deep vessel. Cooled syrup (70 per cent total soluble solids) is gently poured over the fruit so as to cover it entirely. The whole mass is left undisturbed for 12 to 18 hours during which a thin coating of crystallized sugar is formed. The tray is then taken out carefully from the vessel and the surplus syrup drained off. The fruits are then placed in a single layer on wire mesh trays and dried at room temperature or at about 49°C in driers.

Lecture No. 13

Tomato Products- Concepts and Standards

Tomato Products

1. Tomato Paste
2. Tomato Sauce / Ketchup
3. Tomato Chutney
4. Tomato Soup Mix
5. Dehydrated Tomato

1.TOMATO PASTE:

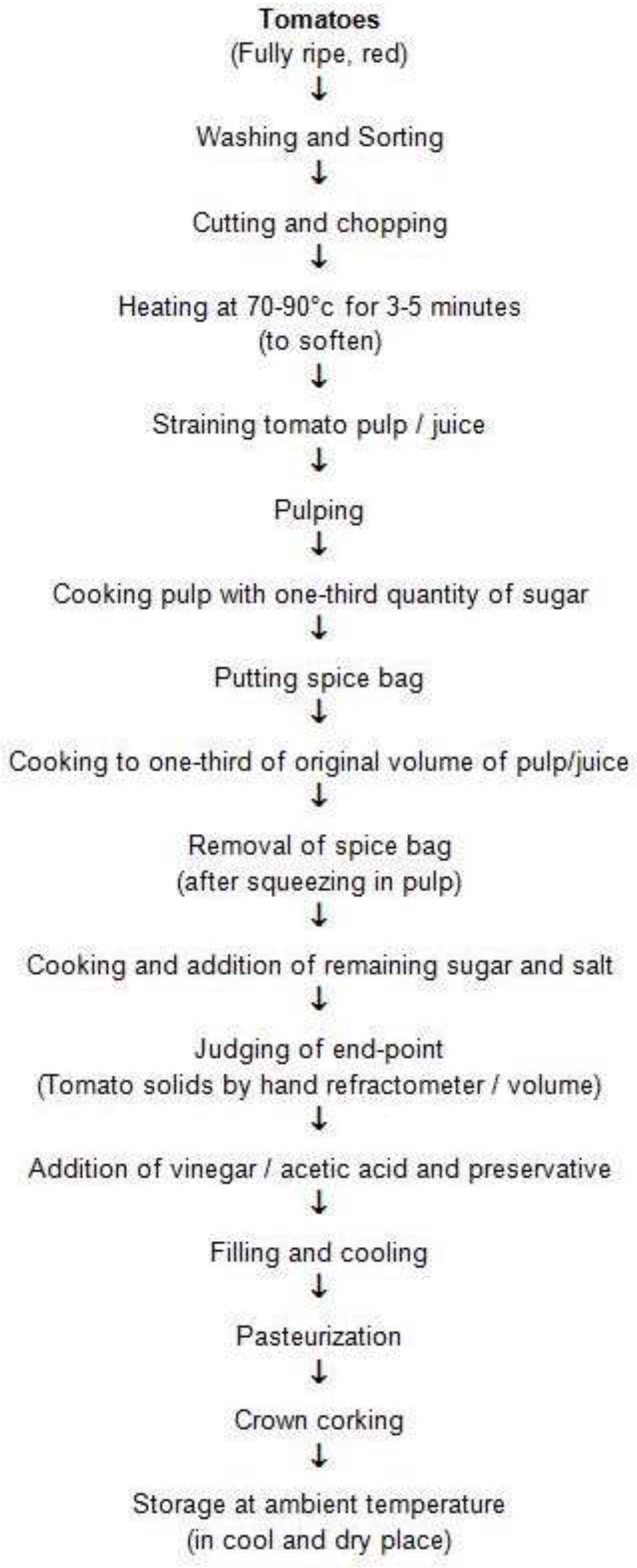
FLOW-SHEET FOR TOMATO PASTE

Tomato juice
(strained)
Cooking to desired consistency (Kettle/vacuum pan)
↓
Judging the end point for puree or paste
(Tomato solids by hand refractometer or
reduction in volume by measuring stick)
↓
Filling hot into bottles or cans (82 -88°C)
↓
Pasteurization in boiling water for 20 minutes
↓
Cooling
↓
Storage at ambient temperature
↓
Packing and storage
↓
Marketing

3. TOMATO SAUCE / KETCHUP:

It is made from strained tomato juice or pulp and spices, salt, sugar and vinegar, with or without onion and garlic, and contains not less than 12 per cent tomato solids and 25 per cent total solids.

FLOW CHART FOR TOMATO SAUCE/KETCHU



4. <u>TOMATO CHUTNEY:</u>

PROCESSING FLOW CHART FOR TOMATO CHUTNEY

Tomatoes
(Fully ripe, red)

↓

Washing

↓

Sorting

↓

Blanching for 2 minutes

↓

Putting quickly in cold water
(to crack skin)

↓

Peeling

↓

Crushing

↓

Addition of ingredients except salt and vinegar and cooking gently to desired consistency

↓

Addition of salt and vinegar and cooking for 5 minutes

↓

Addition of preservative

↓

Filling in hot bottles

↓

Sealing

↓

Storage at ambient temperature
(in cool and dry place)

5. TOMATO SOUP MIX:

Preparation of tomato powder

Fully ripe and firm tomatoes were washed well in running tap water. Then it was cut into small pieces and dried in the cabinet drier at 80oC for 10 hours. The dehydrated pieces were then ground into powder in a mix.

Preparation of tomato soup mix

Ingredients:

Tomato powder	5.0 g
Onion powder	0.5 g
Corn flour	2.0 g
Cumin powder	0.5 g
Pepper powder	0.3 g
Salt	1.5 g
Aginomotto	0.5 g.

Method: All the ingredients were mixed thoroughly and packed in polythene bags.

Preparation of onion powder:

1. Disease free big onions were selected and the skin was peeled off.
2. Then it was washed in the running tap water and cut into small pieces.
3. It was dried in the cabinet drier at 60oC for 7 hrs.
4. The dehydrated flakes were ground into powder and packed in polythene bags.
5. Ten gram of the prepared tomato soup mix was added to 150 ml of boiled water and stirred thoroughly.

Lecture No. 14

Drying / Dehydration of fruits and Vegetables – Concept And Methods, Osmotic drying.

DRYING:

Fruits and Vegetables drying is a method of food preservation in which food is dried (dehydrated or desiccated).

Drying inhibits the growth of bacteria, yeasts, and mold through the removal of water.

DHYDRATION:

Fruit and Vegetables dehydration is the process of removing water from fruit by circulating hot air through it, which prohibits the growth of enzymes and bacteria.

PRESERVATION BY DEHYDRATION /DRYING

- The practice of drying of food stuffs, specially fruits and vegetables, for preserving them is very old.
- The term _drying‘ and _dehydration‘ means the removal of water.
- The former term is generally used for drying under the influence of non-conventional energy sources like sun and wind.

- If fruits (or) vegetables are to be sun dried, they (or) their pieces should be evenly spread in single layer (on) trays or boards and exposed to the sun.
- In sun drying there is no possibility of temperature and humidity control.
- The hottest days in summer are, therefore, chosen so that the foods dry very fast, thus preventing them from getting spoiled due to souring.
- Souring (or) turning acidic is usually due to growth of microorganisms which convert the carbohydrates in the food to acid.
- Quick removal of moisture prevents the growth of the microorganisms.
- Dehydration means the process of removal of moisture by the application of artificial heat under controlled conditions of temperature, humidity and air flow.
- In this process a single layer of fruits (or) vegetables, whole or cut into pieces (or) slices are spread on trays which are placed inside the dehydrator.
- The initial temperature of the dehydrator is usually 43^{o}C which is gradually increased to 60 66^{o}C in the case of vegetables and 50-71^{o}C for fruits.

Advantages of dried / dehydrated foods

1. Dried foods are in more concentrated form than foods preserved in other ways.
2. They are less costly to produce than canned or preserved food, because of lower labour costs and because of no sugar is required.
3. Due to reduction in bulk of the product, it requires less storage space.
4. The weight of a product is reduced to 1/4th to 1/9th its original (or) fresh weight and thus the cost of its transport is reduced.

Methods of Drying/Dehydration:

1. Sundrying
2. Drying by mechanical driers,
3. Osmotic dehydration,
4. Spray drying,
5. Foam mat drying,
6. Freeze drying

1. SUN DRYING

Sun drying of fruits and vegetables is practiced widely in tropical and subtropical regions where there is plenty of sun shine and practically little or no rain during the drying season. Sun drying in direct (or) diffused sunlight (shade drying), one of the earliest method of food preservation, is still used for the production of dried fruits, and also for drying nuts. It was originally limited to fruits high in sugar content, which when harvested, would dry naturally without hazard of loss from fermentation and molding.

Process for drying of fruits

Fruits (mature and free from insects and disease→ Washing → Peeling / removal of outer skin → Preparation → Pretreatments → Spreading on flat wooden trays → Sulphuring → Drying → Sweating → Packaging in air tight tin containers (or) polythene bags → Storage (at ambient temperature).

<u>Pretreatments</u>

Lye peeling

Dipping the fruits (grapes and dates) in 0.5% to 2.5% boiling caustic soda solution for 0.5 to 2.0 minutes depending on their nature and maturity. Hot lye loosens the skin from the flesh by dissolving the pectin. The peel is then removed easily by hand. Any trace of alkali is removed by washing the fruit thoroughly in running cold water (or) dipping it for a few seconds in 0.5% citric acid solution.

Sulphuring

Sulphuring is done only for fruits and not vegetables. So2 fumes act as a disinfectant and prevent the oxidation and darkening of fruits on exposure and thus improves their colour. This phenomenon is generally seen in sliced fruits which darken due to oxidation of the colouring matter. Sulphur fumes also act as a preservative, check the growth of molds etc. and prevent cut fruit pieces from fermenting while drying in the sun. Vitamins in sulphured fruits are protected but not in unsulphured ones.

The whole fruits, slices (or) pieces are exposed to the fumes of burning sulphur inside a closed chamber known as sulphur box for 30-60 min. or in small airtight rooms. Sulphur box is a closed airtight chamber of galvanized iron sheet. It is fitted in a wooden frame work having runways on both sides to hold the trays. For small scale sulphuring, a box of size of 90 x 60 x 90 cm which can hold 11 trays, each of 80 x 60 x 5 cm size is suitable. A box holding 10 trays will require burning of about 3 g of sulphur in one charge.

Sweating

Keeping dried products in boxes or bins to equalize moisture content.

Sun drying of fruits

1. Banana

Dried ripe banana is known as _banana fig‘. The fruit is peeled, sliced lengthwise, sulphured and dried in the sun. Unripe bananas are peeled after blanching in boiling water and cut into discs for drying. The dried slices are either cooked or fried. They can also be converted into banana flour which can be used as such or in combination with cereal flours.

2. Date

In the hard dried dates, sucrose sugar predominates, whereas in the soft dried dates, invert sugars predominates. Dates are picked in the dung stage, that is when the tip of the fruit has turned a translucent brown. They are spread on mats for 5 to 8 days for curing. This is rather expensive as several pickings have to be made as the date attain other proper stage of ripening. Scientists have found that dates could be picked 3 to 4 days before the –dung‖ stage and then dipped for ½ to 2 min in 0.5-2.5 % caustic soda solution before placing them for drying in order to get a good dried product.

3. Fig

The fruits are allowed to ripen on the tree and gathered when they drop. They are then spread thinly on the drying yard for 3 to 4 days for drying. After drying they are sorted and packed. Figs are treated with salt and lime (1 kg of each per 1000 litrs of water) to remove the hair from the skin and also to soften the flesh. They are then dried without sulphuring, till there is exudation of juice on pressing the dried fig between the fingers.

4. Grapes

Large quantities of seedless grapes known as kishmish grapes are imported into India from Afghanistan. Ripe bunches of grapes are hung inside dark rooms known as kishmish khanas till the berries acquire a greenish or light amber tint. These shade dried grapes are considered to be a far superior to the ordinary sundried (or) dehydrated grapes. The other important dried grape called _Monucca' (or) Rasisin is prepared from the large seeded Haitha grapes which are lye dipped prior to the sun drying. For efficient drying, grapes should have a high sugar content of 20 to 24 degree brix. From this point of view, some of the varieties of grapes are not suitable for drying. The higher sugar content grapes are dried without any sulphuring till there is no exudation of juice on pressing dried grape between the fingers. The yield and quality of the final dried product depend on the brix of the fresh grape taken for drying.

In California, the Sultanina (or) Thompson seedless varieties of grapes are dried. The grapes are sometimes dipped for 3-6 seconds in caustic soda and sodium bicarbonate, covering the surface of a solution with a thin layer of olive oil. This treatment removes only the wax and the bloom on the grapes without cracking the skin. The dried product has a glossy appearance. Lye dipped grapes are sometimes treated with sulphur fumes, for 3-5 hrs for bleaching them, because certain markets prefer such glossy product.

In Australia, potassium carbonate solution with a layer of olive oil (or) sometimes grape seed oil itself, is used for dipping the grapes. The drying is carried out on wire net racks arranged inside a shed. In this way, the grapes are dried without direct exposure to the sun. Drying takes 10-20 days depending upon the variety of grape. The dried product is generally of high quality.

5. <u>Jack fruit</u>

Jack fruit bulbs of ripe fruit are sliced and the seeds removed. The slices are dried with (or) without sulphuring. The bulbs can also be made into a fine pulp, which can be dried in the form of sheets or slabs.

6. <u>Mango</u>

Unripe, green mangoes are peeled, sliced and dried in the sun. The dried product is used for the preparation of mango powder which is added as a relish in various food preparations. Ripe mangoes are taken and the juicy pulp squeezed by hand. The pulp is spread on Bamboo mats and a small quantity of sugar sprinkled over it. Whet the first layer has dried, another layer of pulp is spread over it for drying. This process is repeated until the dried slab is 1.2 to 2.5 cm thick. The dried product has a light yellow amber colour and possess a delicious taste.

<u>Other fruits</u>

Pomegranate seeds are dried, and the dried product known as anardana is sued as a savoury and acidulant like tamarind in cooking. Apple rings are threaded and dried by hanging them out to dry in the sun. The cereals, pulses and oilseeds are usually sundried in most of the areas after harvesting from the crop. Sundried vegetables results poor quality in physical and chemical characteristics during storage.

TYPES OF DRIER

Drier type	Usual food type
I. Air convection driers	
1. Kiln drier	Pieces
2. Cabinet, tray or pan drier	Pieces, purees, liquids
3. Tunnel drier	Pieces
4. Continuous conveyor belt drier	Purees, liquids
5. Belt trough drier	Pieces
6. Air lift drier	Pieces, granules

7. Fluidized bed drier Small	pieces, granules
8. Spray drier	Liquids, purees
II. Drum (or) Roller drier	
1. Atmospheric driers	Purees, liquids
2. Vacuum driers	Purees, liquids
III. Vacuum driers	
1. Vacuum shelf	Pieces, purees, liquids
2. Vacuum belt	Purees, liquids
3. Freeze driers	Pieces, liquids

2. DRYING BY MECHANICAL DRIERS,

a) Air convection driers

All air convection driers have some sort of insulated enclosures, a means of circulatingvair through the enclosure and a means of heating this air. They also will have various means of product support, special devices for dried product collection, some will have air driers to lower drying air humidity.

Movement of air generally will be controlled by fans, blowers and baffles. Air volume and velocity will affect drying rate, but its static pressure also is important since products being dried become very light and can be blown off trays or belts.

The air may be heated by direct or indirect methods. In direct heating the air is in direct contact with flame (or) combustion gases. In indirect heating the air is in contact with a hot surface, such as being blown across pipes heated by steam, flame or electricity. The important point is that indirect heating leaves the air uncontaminated. On the other hand in direct heating the fuel is seldom completely oxidized to CO2 and water. Incomplete combustion leaves gases and traces of soot and this is picked up by the air and can be transferred to the food product.

Direct heating of air also contributes small amounts of moisture to the air since moisture is a product of combustion but this is usually insignificant except with very hygroscopic foods. These disadvantages are balanced by the generally lower cost of direct heating of air compared to indirect heating, and both methods are widely used in food dehydration.

b) Kiln drier

Kiln driers of early design were generally two storey constructions. A furnace or burner on the lower floor generated heat, and warm air would rise through a slotted floor to the upper story. Foods such as apple slices would be spread out on the slotted floor and turned over periodically. This kind of drier generally will not reduce moisture to below about ten per cent. It is still in use for apple slices.

c) Cabinet, Tray and Pan driers

Food may be loaded on trays or pans in comparatively thin layers upto a few centimeters. Fresh air enters the cabinet is drawn by the fan through the heated coil and is then blown across the food trays to exhaust. In this case the air is being heated by the indirect method. Screens filter out any dust that may be in the air. The air passes across and between the trays in this design. The air is exhausted to the atmosphere after one pass rather than being recirculated within the system. The moisture laden air, after evaporating water from the food, would have to be dried before being recirculated, or else it would soon become saturated and further drying of the food would stop.

Cabinet, tray and pan driers are usually for small scale operations. They are comparatively inexpensive and easy to set in terms of drying conditions. They may run upto 25 trays high, and will operate with air temperatures of about 93oC dry bulb and air velocities of about 2.5 to 5.0 M/5 across the trays. The commonly are used to dry fruit and vegetable pieces, and depending upon the food and the desired final moisture, drying time may be of the order or 10 of even 20 hr.

d) Tunnel and continuous belt drier

For larger operations we elongate the cabinet, place the trays on carts. If drying time to the desired moisture is 10 hr then each wheeled cart of trays will take 10 hr to pass through the tunnel. When a dry cart emerges it makes room to load another wet crat into the opposite end of the tunnel. Such an operation becomes semi continuous.

A main construction feature by which tunnel driers differ has to do with the direction of air flow relative to tray movement. The wet food carts move from left to right. The drying air moves across the trays from right to left. This is the counter flow or countercurrent principle. Its significance is that the air, when it is hottest and driest, contacts the nearly dry product, whereas the initial drying of entering carts gets cooler, moisture air that has cooled and picked upto moisture going through the tunnel. This means that the initial product temperature and moisture gradients will not be as great and the product is less likely to undergo case hardening or other surface shrinkage leaving wet centers. Further, lower final moistures can be reached since the driest product encounters the dried air. In contrast, there also are concurrent flow tunnels with the incoming hottest, driest and travelling in the same direction. In this case rapid initial drying air slow final drying can cause case hardening and internal splits and porosity as centers finally dry, which sometimes is desirable in special products. Just as carts of trays can be moved through a heated tunnel, so a continuous belt may be driven through a tunnel or oven enclosure. Then we have a continuous belt or conveyor drier and a great number of designs are possible.

e) Belt trough drier

A special kind of air convection belt drier is the belt trough drier in which the belt forms a trough. The belt is usually of metal mesh and heated air is blown up through the mesh. The belt moves continuously, keeping the food pieces in the trough in constant motion to continuously expose new surface. This speeds drying and with air of about 135oC, vegetable pieces may be dried to 7-5% moisture in about 1 hr.

But not all products may be dried this way since certain sizes and shapes do not readily tumble. Fragile apple wedges may break. Onion slices tend to separate and become entangled. Fruit pieces that exude sugar on drying tend to stick together clump with the tumbling motion. These are but a few additional factors that must be considered in selecting a drier for a particular food.

f) Air lift drier

Several types of pneumatic conveyor driers go a step beyond tumbling to expose more surface area of food particles. These generally are used to finish dry materials that have been partially dried by other methods, usually to about 25% moisture, or at least sufficiently low so that the material becomes granular rather than having a tendency to clump and mat.

g) Fluidized bed drier

Another type of pneumatic conveyor drier is the fluidized bed drier. In fluidized bed drying, heated air is blown up through the food particles with just enough force to suspend the particles in a gentle boiling motion. Semidry particles such as potato granules enter at the left and gradually migrate to the right, where they are discharged dry. Heated air is introduced through a porous plate that supports the bed of granules. The moist air is exhausted at the top. The process is continuous and the length of time particles remain in the drier can be regulated by the depth of the bed and other means. This type of drying can be used to dehydrate grains, peas and other particulates.

3. OSMOTIC DEHYDRATION

The moisture is drawn out from all cell tissues. The water is then bound with the solute, making it unavailable to the microorganisms. In osmotic dehydration of fruits, the method involves the partial dehydration of fruits by osmosis in a concentrated sugar solution or syrup.

Fruits Suitable For Osmotic Dehydration:

Fruits such as apple, banana, cherry, citrus, grapes, guava, mango, papaya, pineapple, plum, etc. Osmotic Dehydration can remove 30-50% of the water from fresh ripe fruits e.g mangoes, pineapple, banana, sapota and papayas. The final drying of these osmotically dehydrated fruits by vacuum drying provides a product which has good quality, attributes with respect to appearance, taste, flavour and colour as compared to sun drying.

Advantages of Osmotic dehydration

- Minimum loss of colour and flavour.
- Browning is prevented.
- Sweetening of the product.
- Reduces the water removal load
- Increases the solid density of the product
- Textural quality will be better
- Simple facility and equipments are required
- The process is less expensive.

Limitations of Osmotic dehydration

Limitations of Osmotic dehydration:

- The reduction in acidity level reduces the characteristic taste of some products
- Sugar uptake may not be desirable in certain product.

Factors influencing Osmotic dehydration

- Pre-treatments.
- Osmotic agents
- Concentration
- Temperature.
- Agitation /circulation
- Duration of osmosis
- Size and thickness
- Variety and maturity of fruits used.

Products made through Osmotic dehydration

The product is suitable as a ready to eat snack item. Also the dehydrated product could be powdered if desired, and mixed with milk powder for making other products and confectionery items.

4. SPRAY DRIERS

The most important kind of air convection drier is the spray drier. Spray driers turn out a greater tonnage of dehydrated food products than all other kinds of driers combined, and there are various types of spray driers designed for specific food products.

Spray driers are limited to foods that can be atomized, such as liquids and low viscosity pastes or purees. Atomization into minute droplets results in drying in a matter of seconds with common inset air temperatures of about 200oC. Since evaporative cooling seldom permits particles to reach above about 80oC (180oC) and properly designed systems quickly remove the dried particles from heated zones, this method of dehydration can produce exceptimally high quality with many highly heat sensitive materials, including milk, eggs and coffee. In typical spray drying we introduce the liquid food as a fine spray or mist into a tower or chamber along with heated air. As the small droplets make intimate contact with the heated air they flash off their moisture, become small particles and drop to the bottom of the tower from where they are removed. The heated air which has now become most is withdrawn from the tower by a blown or fan. The process is continuous in that liquid food continues to the pumped into the chamber and atomized, along with dry heated air to replace the moist air that is withdrawn, and the dried product is removed from the chamber as it descends. Milk and coffee powder is usually dried in the spray drier. Thermoplastic materials /substances viz., fruit juices are spray dried in a specially developed BIRS spray drier.

a) Drum (or) Roller driers

In drum (or) roller drying, liquid foods, purees pastes and mashes are applied in a thin layer onto the surface of a revolving heated drum. The drum generally is heated from within by steam. Drier may have a single drum or a pair of drums. The food may be applied between the nip where two drums come together, and then the clearance between the drums determines the thickness of the applied food layer, or the food can be applied to other areas of the drum. Food is applied continuously and the thin layer loses moisture. At a point on the drum or drums a scraper blade is positioned to peel the thin dried layer of food from the drums. The speed of the drum is so regulated that the layer of food will be dry when it reaches the scraper blade, which also is referred to as a doctor blade. The layer of food is dried in one revolution of the drum and is scrapped from the drum before that position of the drum returns to the point where more wet food is applied. Using steam under pressure in the drum, the temperature of the drum surface may be well above 100^{o}C, and is often held at about 150^{o}C. With a food layer thickness commonly less than 2 mm, drying can be completed in 1 min or less, depending on the food material. Other features of drum driers include hoods above drums to withdraw moisture vapor and conveyers in troughs to receive and move dried product.

Typical products dried on drums include milk, potato mash, heat tolerant purees such as tomato paste, and animal feeds. But drum drying has some inherent limitations that restrict the kinds of foods to which it is applicable. To achieve rapid drying, drum surface temperature must be high, usually above 120^{o}C. This gives products a more cooked flavour and colour than when they are dried at a lower temperature. Drying temperature can, of course, be lowered by constructing the drums within a vacuum chamber but this increases equipment and operating costs over atmospheric drum or spray drying.

A second limitation is the difficulty of providing zoned temperature control needed to vary to drying temperature profile. This is particularly important with thermoplastic food materials. Whereas dried milk and dried potato are easily scraped from the hot drum in brittle sheet form, this is not possible with many dried fruits, juices and other products which tend to be sticky and semi molten when hot. Such products tend to crimp, roll up, and otherwise accumulate and stick to the doctor blade in a taffy like mass.

This condition can be substantially improved by a cold zone to make the tacky material brittle just prior to the doctor blade. But zone controlled chilling is not as easy to accomplish on a drum of limited diameter and therefore limited arc, as it would be in perhaps 6 m of length of a horizontal drying belt 45 m long. One means of chilling is by directing a stream of cool air onto a segment of the product on the drum prior to the doctor blade.

For relatively heat resistant food products, drum drying is one of the least expensive dehydration methods. Drum dried foods generally have a somewhat more cooked character than the same materials spray dried; thus drum dried milk is not up to beverage quality but is satisfactory as an ingredient in less deligately flavoured manufactured foods. More gentle vacuum drum drying or zone-controlled drum drying increases dehydration costs.

b) Vacuum driers

Vacuum dehydration methods are capable of producing the highest quality dried products, but costs of vacuum drying generally also are higher than other methods which do not employ vacuum. In vacuum drying, the temperature of the food and the rate of water removal are controlled by regulating the degree of vacuum and the intensity of heat input. Heat transfer to the food is largely by conduction and radiation.

All vacuum drying systems have four essential elements. These include a vacuum chamber of heavy construction to withstand outside air pressures, that may exceed internal pressures by as much as 9800 kg/cm2; means to supply heat; a device for producing and maintaining the vacuum; and components to collect water vapour as it is evaporated from the food.

The vacuum chamber generally will contain shelves or other supports to hold the food and these shelves may be heated electrically or by circulating a heated fluid through them. The heated shelves are called platens. The platens convey heat to the food in contact with them by conduction, but where several platens are one above another they also radiate heat to the food on the platen below. In addition, special radiant heat sources such as infrared elements can be focussed onto the food to supplement the heat conducted from platen contact.

The device for producing and maintaining vacuum will be outside the vacuum chamber and may be a mechanical vacuum pump or a steam ejector. A steam ejector is a kind of aspiration in which high velocity steam jetting past an opening draws air and water vapour from the vacuum chamber by the same principle that makes an insect spray gun draw fluid from the can.

The means of collecting water vapour may be a cold wall condenser. It may be inside to vacuum chamber or outside the chamber but most come ahead of the vacuum pump so as to prevent water vapour from entering and fouling the pump. When a steam ejector can condense water vapour as it is drawn along the air from the vacuum chamber and so a cold wall vapour condenser may not be needed except where a very high degree of efficiency is required.

Degree of vacuum

Atmospheric pressure at sea level is approximately 15 psi, or sufficient pressure to support a 30 inch column of mercury. This is equivalent to 760 mm of Hg or 1 in Hg is approximately 25 mm. At 1 atmp or 30 in., or 760 mm of Hg, pure water boils at 100^oC. At 10 in or 250 mm of Hg pure water boils at 72^oC. At 2 in. or 50 mm of mercury pure water boils at 38^oC. High vacuum dehydration operates at still lower pressures such as fractions of mm of Hg. Freeze drying generally will operate in the range of 23 mm down to about 0.1 mm of Hg.

There are two kinds of vacuum drier.

1. Vacuum shelf driers

Batch type

If liquids such as concentrated fruit juices are dried above about 55 mm Hg, the juice boils and splatters, but in the range of about 3 mm Hg, and below, the concentrated juice puffs as it loses water vapour. The dehydrated juice then retains the puffed spongy structure. Since temperature well below 40oC can be used, in addition to quick solubility there is minimum flavour change or other kinds of heat damage. A vacuum shelf drier is also suitable for the dehydration of food pieces. In this case, the rigidity of the solid food prevents major puffing, although there also is a tendency to minimize shrinkage.

2. Continuous vacuum belt drier

Continuous type drier

This drier is used commercially to dehyderate high quality citrus juice crystals, instant tea and other delicate liquid foods. The drier consists of a horizontal tank like chamber connected to a vacuum producing, moisture condensing system. The chamber is about 17 m long and 3.7 m in diameter. Within the chamber are mounted two revolving hollow drums. Around the drum is connected a stainless steel belt which moves in a counter clock wise direction. This drum on the right is heated with steam confined within it. This drum heats the belt passing over it by conduction. As the belt moves, it is further heated by infrared radiant elements. The drum to the left is cooled with cold H_2O circulated within it and cools the belt passing over it. The liquid food in the form of a concentrate is pumped into a feed pan under the lower belt strand. An applicator roller dipping into the liquid continuously applies a thin coating of the food onto the lower surface of a moving belt. As the belt moves over the heating drum and past the radiant heaters, the food rapidly dries in the vacuum equivalent to about 2 mm Hg. When the food reaches the cooling drum, it is down to about 2% moisture. At the bottom of the cooling drum is a doctor blade which scrapes the cooled, embrittled product into the collection vessel. The belt scrapped free of product receives additional liquid food as it passes the applicator roller and the process repeats in continuous fashion.

Products dried with this equipment have a slightly puffed structure. If designed, a greater degree of puffing can be achieved. This has been done in the case of milk by pumping nitrogen gas under pressure into the milk prior to drying. Some of the gas goes into solution in the milk. Upon entering the vacuum chamber this gas comes out of solution violently and further puffs the milk as it is being dried.

5. FOAM MAT DRYING

The foam is deposited on a perforated tray or belt support as a uniform layer approximately 3 mm thick. Just before the perforated support enters the heated oven it is given a mild air blast from below. This forms small craters in the stiff foam which further expands foam surface and increases drying rate. At oven temperatures of about 82oC foam layers of many foods can be dried to about 2 to 3% moisture in approximately 12 min.

6. FREEZE DRYING

Freeze drying can be used to dehydrate sensitive high value liquid foods such as coffee and juices, but it is especially suited to dry solid foods of high value such as straw berries, whole shrimp, chicken dice, mushroom slices and sometimes food pieces as large as steaks and chops. These types of foods, in addition to having delicate flavours and colors, have textural and appearance attributes which cannot be well preserved by any current drying method except freeze drying. Any conventional drying method that employs heat would cause considerable shrinkage distortion and loss of natural strawberry structure (texture), upon reconstitution such as dried strawberry would not have the natural colour, flavour or turgor and would be more like a strawberry preserve or jam. This can be largely prevented by drying from the solidly frozen state, so that in addition to low temperature, the frozen food has no chance to shrink or distort while giving up its moisture.

The principle behind freeze drying is that under certain conditions of low vapor pressure, water can evaporate from ice without the ice melting. When a material can exist as a solid, a liquid and a gas but goes directly from a solid to a gas without passing through the liquid phase. The material is said to sublime. Dry ice sublimes at atmospheric pressure and room temperature. Frozen water will sublime if the temperature is 0^oC or below and the frozen H_2O is placed in a vacuum chamber at a pressure of 4.7 mm (or) less. Under such conditions the H_2O will remain frozen and water molecules will leave the ice block at a faster rate than water molecules from the surrounding atmosphere reenter the frozen block. Within the vacuum chamber heat is applied to the frozen food to speed sublimation and if the vacuum is maintained sufficiently high usually within a range of about 0.1 to 2 mm g and the heat is controlled just short of melting the ice, moisture vapour will sublime at a near maximum rate. Sublimation takes place from the surface of the ice, and so as it continues the ice front recedes towards the center of the food piece; i,e. the food dries from the surface inward. Finally, the last of the ice sublimed and the food is below 5% moisture. Since the frozen food remains rigid during sublimation, escaping H_2O molecules leave voids behind them, resulting in porous sponge like dried structure. Thus freeze dried foods reconstitute rapidly but also must be protected from ready absorption of atmospheric moisture and O_2 by proper packaging.

A heating plate is positioned above and below the food to increase heat transfer rate but an open space is left with expanded metal so as not to seal off escape of sublimed H_2O molecules. Nevertheless, as drying progresses and the ice front recedes, drying rate drops off for several reasons. Thus the porous dried layer ahead of the reducing ice layer acts as an effective insulator against further heat transfer and the porous layer slows down the rate of escape of H_2O molecules subliming from the ice surface.

Lecture No. 15
Canning – Concept and Standards

<u>CANNING:</u>

"The process of sealing food stuffs hermetically in containers and sterilizing them by heat for long storage is known as canning".

In **1804, Appert in France** invented a process of sealing foods hermetically in containers and sterilizing them by heat. In honour of the inventor, **canning is also known as appertizing**. **Saddington** in England was the first to describe a method of canning of foods in 1807. In **1810 Peter Durand, another Englishman, obtained the first British Patent on canning of foods in tin containers**. In **1817, William Underwood** introduced canning of fruits on a commercial scale in U.S.A.

Fruits and vegetables are canned in the season when the raw material is available in plenty. The canned products are sold in the off-season and give better returns to the grower.

Principles and Process of Canning

Principle

Destruction of spoilage organisms within the sealed container by means of heat.

Process

Selection of fruits/vegetables → Grading → Washing → Cooling

Blanching → Cutting → Peeling → Filling and Syruping or Brining

Exhausting → Storage → Cooling → Processing → Sealing

(1) Selection of fruits and vegetables

- Fruits and vegetables should be absolutely fresh.
- Fruits should be ripe, but firm, and uniformly mature.
- Over-ripe fruits should be rejected because they are infected with microorganisms and give a poor quality product.
- Unripe fruits should be rejected because they generally shrivel and toughen on canning.
- All vegetables except tomatoes should be tender.
- Tomatoes should be firm, fully ripe and of deep red colour.
- Fruits and vegetables should be free from dirt.
- They should be free from blemishes, insect damage or mechanical injury.

(2) Grading

The selected fruits and vegetables are graded according to size and colour to obtain uniform quality. This is done by hand or by machines such as screw grader and roller grader. Fruits like berries, plums and cherries are graded whole, while peaches, pears, apricots, mangoes, pineapple, etc., are generally graded after cutting into pieces or slices.

(3) Washing

It is important to remove pesticide spray residue and dust from fruits and vegetables. One gram of soil contains 1012 spores of microorganisms. Therefore, removal of microorganisms by washing with water is essential. Fruits and vegetables can be washed in different ways. Root crops that loosen in soil are washed by soaking in water containing 25 to 50 ppm chlorine (as detergent). Other methods of washing are spray washing, steam washing, etc.

(4) Peeling

The objective of peeling is to remove the outer layer. Peeling may be done in various ways.

Hand peeling

It is done mostly in case of fruits of irregular shape, e.g., mango and papaya, where mechanical peeling is not possible.

Steam peeling

Free-stone and clingstone peaches are steam peeled in different ways. The former are cut and steam washed. Potatoes and tomatoes are peeled by steam or boiling water.

Mechanical peeling

This is done in case of apples, peaches, pineapples and cherries and also for root vegetables like carrots, turnips and potatoes.

Lye peeling

Fruits like peaches, apricots, sweet oranges, mandarin oranges and vegetables like carrots and sweet potatoes are peeled by dipping them in 1 to 2 per cent boiling caustic soda solution (lye) for 30 seconds to 2 minutes depending on their nature and maturity. Hot lye loosens the skin from the flesh by dissolving the pectin. The peel is then removed easily by hand. Any trace of alkali is removed by washing the fruit or vegetable thoroughly in running cold water or dipping it for a few seconds in 0.5 per cent citric acid solution. This is a quick method where by cost and wastage in peeling is reduced.

Flame peeling

It is used only for garlic and onion which have a papery outer covering. This is just burnt off. Vegetables like peas are shelled, carrots are scarped, and beans are snipped or trimmed.

(5) Cutting

Pieces of the size required for canning are cut. Seed, stone and core are removed. Some fruits like plum from which the seeds cannot be taken out easily are canned whole.

(6) Blanching

It is also known as scalding, parboiling or precooking. It is usually done in case of vegetables by exposing them to boiling water or steam for 2 to 5 minutes, followed by cooling. The extent of blanching varies with the food. Generally fruits are not blanched.

This brief heat treatment accomplishes the following:

1. Inactivates most of the plant enzymes which cause toughness, discolouration (polyphenol oxidase), mustiness, off-flavour (peroxidase), softening and loss of nutritive value.
2. Reduces the area of leafy vegetables such as spinach by shrinkage or wilting, making their packing easier.
3. Removes tissue gases which reduce sulphides.
4. Reduces the number of microorganisms by as much as 99%.
5. Enhances the green colour of vegetables such as peas, broccoli and spinach.
6. Removes saponin in peas.
7. Removes undesirable acids and astringent taste of the peel, and thus improves flavour.
8. Removes the skin of vegetable such as beetroot and tomatoes which helps in their peeling.

Disadvantages

1. Water-soluble materials like sugar and anthocyanin pigments are leached by boiling water.
2. Fruits lose their colour, flavour and sugar.

(7) Cooling

After blanching, the vegetables are dipped in cold water for better handling and keeping them in good condition.

(8) Filling

Before filling, cans are washed with hot water and sterilized but in developing countries these are subjected to a jet of steam to remove dust and foreign material. Automatic, large can filling machines are used in advanced countries but choice grades of fruits are normally filled by hand to prevent bruising. In India, hand filling is the common practice. After filling, covering with syrup or brine is done and this process is called syruping or brining.

A 1-b butter size can should hold 230 285 g of fruit slices and a A 2 ½ size can 510 to 565 g. The blanched vegetables are packed in sterilized cans which should hold the drained weight of vegetables as specified below:

1 lb butter size can - 269-283 g
A 2 ½ size can - 538-566 g
Pint size glass jar - 283-311 g

(i) Syruping

A solution of sugar in water is called a syrup. Normally sucrose syrup is used in canning. Syrup is added to improve the flavour and to serve as a heat transfer medium for facilitating processing. Syruping is done only for fruits. Strained, hot syrup of concentration 20 to 55o Brix is poured on the fruit. Fruits rich in acid require a more concentrated syrup than less acid ones. The syrup should be filled at about 79 to 82oC, leaving a head space of 0.3 to 0.5 cm. Sometimes citric acid and ascorbic acid are also mixed with the syrup to improve flavour and nutritional value, respectively.

(ii) Brining

A solution of salt in water is called brine. The objective of brining is similar to that of syruping. Only vegetables are brined. Common salt of good quality free from iron should be used. Hot brine of 1 to 3 per cent concentration is used for covering vegetables and is filled at 79 to 82^{o}C, leaving a head space of 0.3 to 0.5 cm. The brine should be filtered through a thick cloth before filling.

After syruping or brining the cans are loosely covered with lids and exhausted. Lidding has certain disadvantages such as spilling of the contents and toppling of the lids. Hence lidding has now been modernized by _clinching‘ process in which the lid is partially seamed. The lid remains sufficiently loose to permit the escape of dissolved as well as free air from the can and also the vapour formed during the exhausting process.

(9) Exhausting

The process of removal of air from cans is known as exhausting. After filling and lidding or clinching, exhausting is essential. The major advantages of exhausting are as under:

a) Corrosion of the tinplate and pinholing during storage is avoided.

b) Minimizes discolouration by preventing oxidation.
c) Helps in better retention of vitamins particularly vitamin C.
d) Prevents bulging of cans when stored in a hot climate or at high altitude.
e) Reduces chemical reaction between the container and the contents.
f) Prevents development of excessive pressure and strain during sterilization.

Containers are exhausted either by heating or mechanically. The heat treatment method is generally used. The cans are passed through a tank of hot water at 82 to 87^oC or move on a belt through a covered steam box. In the water exhaust box, the cans are placed in such a manner that the level of water is 4-5 cm below their tops. The exhaust box is heated till the temperature of water reaches 82 to 100^oC and the centre of the can shows a temperature of about 79^oC. The time of exhausting varies from 6 to 10 minutes, depending on the nature of the product. In the case of glass jars or bottles, vacuum closing machines are generally used. The bottles or jars are placed in a closed chamber in which a high vacuum is maintained.
It is preferable to exhaust the cans at a lower temperature for a longer period to ensure uniform heating of the contents without softening them into pulp. Exhausting at high temperature should be avoided because the higher the temperature, the more is the volume of water vapour formed, and consequently the greater the vacuum produced in the can.

(10) Sealing

Immediately after exhausting the cans are sealed airtight by means of a can sealer. In case of glass jars a rubber ring should be placed between the mouth of the jar and the lid, so that it can be sealed airtight. During sealing the temperature should not fall below 74^oC.

(11) Processing

Heating of foods for preserving is known as processing, however, in canning technology processing means heating or cooling of canned foods to inactivate bacteria. Many bacterial spores can be killed by either high or every low temperature. Such drastic treatment, however affects the quality of food. Processing time and temperature should be adequate to eliminate all bacterial growth. Moreover, over-cooking should be avoided as it spoils the flavour as well as the appearance of the product.

Almost all fruits and acid vegetables can be processed satisfactorily at a temperature of 100^oC, i.e., in boiling water. The presence of acid retards the growth of bacteria and their spores. Further, they do not thrive in heavy sugar syrup which is normally used for canning of fruits. Vegetables (except the more acid ones like tomato and rhubarb) which are non-acid in nature, have a hard texture, and proximity to soil which many infect them with spore-bearing organisms processed at higher temperatures of 115 to 121^oC.
The sourness of fruits and vegetables is due to their acid content (measured in pH) which has a great influence upon the destruction of microorganisms. The lower the pH the greater is the ease with which a product can be processed or sterilized. Fruits and vegetables can be classified into the following four groups according to their pH value.

Class	pH	Product
Low acid (called non-	Above 5.0	Vegetables such as peas, lima bean,

acid)		asparagus, cauliflower, potato, spinach, beet, corn, french bean
Medium acid	4.5-5.0	Turnip, carrot, okra, cabbage, pumpkin, beet, green bean, etc., and products like soups and sauces
Acid	3.7-4.5	Tomato, pear, banana, mango, jackfruit, pineapple, sweet cherry, peach, apple and other fruits
High acid	Below 3.7	Citrus juice, rhubarb, prune, sauerkraut, pickle, chutney, etc

Bacterial spores can be more easily destroyed at pH 3.0 (fruits) than at pH 5.0 to 6.0 (vegetables, except tomato and rhubarb). Bacterial spores do not grow or germinate below pH 4.5. Thus, a canned product having pH less than 4.5 can be processed in boiling water but a product with pH above 4.5 requires processing at 115 to 121oC under a pressure of 0.70 to 1.05 kg/cm2 (10 to 15 lb/sq inch). It is essential that the centre of the can should attain these high temperatures.

The temperature and time of processing vary with the size of the can and the nature of the food: the larger the can, the greater is the processing time. Fruits and acid vegetables are generally processed in open type cooker, continuous non-agitating cookers, while vegetables (non-acid) are processed under steam pressure in closed retorts known as automatic pressure cookers and continuous agitating cookers. In India, small vertical stationary retorts (frontispiece) are generally used for canned vegetable processing. The sealed cans are placed in the cookers, keeping the level of water 2.5 to 5.0 cm above the top of the cans. The cover of the cooker is then screwed down tightly and the cooker heated to the desired temperature. The period of sterilization (process) should be counted from the time the water starts boiling. After heating for the required period the cooker is removed from the fire and the petcock is opened. When the pressure comes down to zero the cover is removed and the cans are taken out.

(12) Cooling

After processing, the cans are cooled rapidly to about 39^{o}C to stop the cooking process and to prevent stack-burning. Cooling is done by the following methods.

(i) Dipping or immersing the hot cans in tanks containing cold water.

(ii) Letting cold water into the pressure cooker specially in case of vegetables.

(iii) Spraying cans with jets of cold water; and

(iv) Exposing the cans to air.

Generally the first method, i.e. dipping the cans in cold water, is used. If canned products are not cooled immediately after processing, peaches and pears becomes dark in colour, tomatoes turn brownish and bitter in taste, peas become pulpy with cooked taste and many vegetables develop flat sour (become sour).

(13) Storage

After labelling the cans, they should be packed in strong wooden cases or corrugated cardboard cartons and stored in a cool and dry place. The outer surface of the cans should be

dry as even small traces of moisture sometimes induce rusting. Storage of cans at high temperature should be avoided, as it shortens the shelf-life of the product and often leads to the formation of hydrogen swell.
The marketable life of canned products varies according to the type of raw materials used. Canned peach, grapefruit, pineapple, beans, spinach, pea, celery, etc. can be stored for about two years, while pear, apricot, carrot, beetroot, tomato, etc. can be stored for a comparatively long period.

Lecture No. 16
Packaging of Products

Packaging fresh fruits and vegetables is one of the more important steps in the long and complicated journey from grower to consumer. Bags, crates, hampers, baskets, cartons, bulk bins, and palletized containers are convenient containers for handling, transporting, and marketing fresh produce. More than 1,500 different types of packages are used for produce in the U.S. and the number continues to increase as the industry introduces new packaging materials and concepts. Although the industry generally agrees that container standardization is one way to reduce cost, the trend in recent years has moved toward a wider range of package sizes to accommodate the diverse needs of wholesalers, consumers, food service buyers, and processing operations.

Packing and packaging materials contribute a significant cost to the produce industry; therefore it is important that packers, shippers, buyers, and consumers have a clear understanding of the wide range of packaging options available. This fact sheet describes some of the many types of packaging, including their functions, uses, and limitations. Also included is a listing, by commodity, of the common produce containers standard to the industry.

The Function of Packaging or Why package Produce?

A significant percentage of produce buyer and consumer complaints may be traced to container failure because of poor design or inappropriate selection and use. A properly designed produce container should contain, protect, and identify the produce, satisfying everyone from grower to consumer.

PACKAGING POINTS

Recyclability/Biodegradability

A growing number of U.S. markets and many export markets have waste disposal restrictions for packaging materials. In the near future, almost all produce packaging will be recyclable or biodegradable, or both. Many of the largest buyers of fresh produce are also those most concerned about environmental issues.

Variety

The trend is toward greater use of bulk packages for processors and wholesale buyers and smaller packages for consumers. There are now more than 1,500 different sizes and styles of produce packages.

Sales Appeal

High quality graphics are increasingly being used to boost sales appeal. Multi-color printing, distinctive lettering, and logos are now common.

Shelf Life

Modern produce packaging can be custom engineered for each commodity to extend shelf life and reduce waste.

Containment

The container must enclose the produce in convenient units for handling and distribution. The produce should fit well inside the container, with little wasted space. Small produce items that are spherical or oblong (such as potatoes, onions, and apples) may be packaged efficiently utilizing a variety of different package shapes and sizes. However, many produce items such as asparagus, berries, or soft fruit may require containers specially designed for that item. packages of produce commonly handled by hand are usually limited to 50 pounds. Bulk packages moved by fork lifts may weigh as much as 1,200 pounds.

Protection

The package must protect the produce from mechanical damage and poor environmental conditions during handling and distribution. To produce buyers, torn, dented, or collapsed produce packages usually indicate lack of care in handling the contents. Produce containers must be sturdy enough to resist damage during packaging, storage, and transportation to market. Because almost all produce packages are palletized, produce containers should have sufficient stacking strength to resist crushing in a low temperature, high humidity environment. Although the cost of packaging materials has escalated sharply in recent years, poor quality, lightweight containers that are easily damaged by handling or moisture are no longer tolerated by packers or buyers. Produce destined for export markets requires that containers to be extra sturdy. Air-freighted produce may require special packing, package sizes, and insulation. Marketers who export fresh produce should consult with freight companies about any special packaging requirements. Additionally, the USDA and various state export agencies may be able to provide specific packaging information.

Damage resulting from poor environmental control during handling and transit is one of the leading causes of rejected produce and low buyer and consumer satisfaction. Each fresh fruit and vegetable commodity has its own requirements for temperature, humidity, and environmental gas composition. Produce containers should be produce friendly - helping to maintain an optimum environment for the longest shelf life. This may include special materials to slow the loss of water from the produce, insulation materials to keep out the heat, or engineered plastic liners that maintain a favorable mix of oxygen and carbon dioxide.

Identification

The package must identify and provide useful information about the produce. It is customary (and may be required in some cases) to provide information such as the produce name, brand, size, grade, variety, net weight, count, grower, shipper, and country of origin. It is also becoming more common to find included on the package, nutritional information, recipes, and other useful information directed specifically at the consumer. In consumer marketing, package appearance has also become an important part of point of sale displays.

Universal Product Codes (UPC or bar codes) may be included as part of the labeling.
The UPCs used in the food industry consist of a ten-digit machine readable code. The first five digits are a number assigned to the specific producer (packer or shipper) and the second five digits represent specific product information such as type of produce and size of package.

Although no price information is included, UPCs are used more and more by packers, shippers, buyers, and Example of a UPC retailers as a fast and convenient method of inventory control and cost accounting. Efficient use of UPCs requires coordination with everyone who handles the package.

Types of Packaging Materials

Wood

Pallets literally form the base on which most fresh produce is delivered to the consumer. Pallets were first used during World War II as an efficient way to move goods. The produce industry approximately 190 of the 700 million pallets produced per year in the U.S.. About 40 percent of these are single-use pallets. Because many are of a nonstandard size, the pallets are built as inexpensively as possible and discarded after a single use.

Although standardization efforts have been slowly under way for many years, the efforts have been accelerated by pressure from environmental groups, in addition to the rising cost of pallets and landfill tipping fees.

Over the years, the 40-inch wide, by 48-inch long pallet has evolved as the unofficial standard size. Standardization encourages re-use, which has many benefits. Besides reducing cost because they may be used many times, most pallet racks and automated pallet handling equipment are designed for standard-size pallets. Standard size pallets make efficient use of truck and van space and can accommodate heavier loads and more stress than lighter singleuse pallets. Additionally, the use of a single pallet size could substantially reduce pallet inventory and warehousing costs along with pallet repair and disposal costs. The adoption of a pallet standard throughout the produce industry would also aid efforts toward standardization of produce containers.

In the early 1950s, an alternative to the pallet was introduced. It is a pallet-size sheet (slipsheet) of corrugated fiberboard or plastic (or a combination of these materials) with a narrow lip along one or more sides. packages of produce are stacked directly on this sheet as if it were a pallet. Once the packages are in place, they are moved by a specially equipped fork lift equipped with a thin metal sheet instead of forks.

Slipsheets are considerably less expensive than pallets to buy, store, and maintain; they may be re-used many times; and they reduce the tare weight of the load. However, they require the use of a special fork-lift attachment at each handling point from packer to retailer.

Depending on the size of produce package, a single pallet may carry from 20 to over 100 individual packages. Because these packages are often loosely stacked to allow for air circulation, or are bulging and difficult to stack evenly, they must be secured (unitized) to prevent shifting during handling and transit. Although widely used, plastic straps and tapes may not have completely satisfactory results. Plastic or paper corner tabs should always be used to prevent the straps from crushing the corners of packages.

Plastic stretch film is also widely used to secure produce packages. A good film must stretch, retain its elasticity, and cling to the packages. Plastic film may conform easily to various size loads. It helps protect the packages from loss of moisture, makes the pallet more secure against pilferage, and can be applied using partial automation. However, plastic film severely restricts proper ventilation. A common alternative to stretch film is plastic netting, which is much better for stabilizing some pallet loads, such as those that require forced-air cooling. Used stretch film and plastic netting may be difficult to properly handle and recycle.

A very low-cost and almost fully automated method of pallet stabilization is the application of a small amount of special glue to the top of each package. As the packages are stacked, the glue secures all cartons together. This glue has a low tensile strength so cartons may be easily separated or repositioned, but a high shear strength so they will not slide. The glue does not present disposal or recycling problems.

Pallet Bins

Substantial wooden pallet bins of milled lumber or plywood are primarily used to move produce from the field or orchard to the packing house. Depending on the application, capacities may range from 12 to more than 50 bushels. Although the height may vary, the length and width is generally the same as a standard pallet (48 inches by 40 inches). More efficient double-wide pallet bins (48 inches by 80 inches) are becoming more common in some produce operations. Most pallet bins are locally made; therefore it is very important that they be consistent from lot to lot in materials, construction, and especially size. For example, small differences in overall dimensions Pallet bin can add up to big problems when several hundred are stacked together for cooling, ventilation, or storage. It is also important that stress points be adequately reinforced. The average life of a hardwood pallet bin that is stored outside is approximately five years. When properly protected from the weather, pallets bins may have a useful life of 10 years or more.

Uniform voluntary standards for wood pallets and other wood containers are administered by the National Wooden Pallet and Container Association, Washington, DC. Additionally, the American Society of Agricultural Engineers, St. Joseph, Michigan, publishes standards for agricultural pallet bins (ASAE S337.1).

Wire-Bound Crates

Although alternatives are available, wooden wire-bound crates are used extensively for snap beans, sweet corn and several other commodities that require hydrocooling. Wire-bound crates are sturdy, rigid and have very high stacking strength that is essentially unaffected by water. Wire-bound crates come in many different sizes from half- bushel to pallet-bin size and have a great deal of open space to facilitate cooling and ventilation. Although few are re-used, wire-bound crates may be dissembled after use and shipped back to the packer (flat). In some areas, used containers may pose a significant disposal problem. Wirebound crates are not generally acceptable for consumer packaging because of the difficulty in affixing suitable labels.

Wooden Crates and Lugs

Wooden crates, once extensively used for apples, stone fruit, and potatoes have been almost totally replaced by other types of containers. The relative expense of the container, a greater concern for tare weight, and advances in material handling have reduced their use to a few specialty items, such as expensive tropical fruit. The 15-, 20-, and 25-pound wooden lugs still used for bunch grapes and some specialty crops are being gradually replaced with less costly alternatives.

Wooden Baskets and Hampers

Wire-reinforced wood veneer baskets and hampers of different sizes were once used for a wide variety of crops from strawberries to sweet potatoes. They are durable and may be nested for efficient transport when empty. However, cost, disposal problems, and difficulty in efficient palletization have severely limited their use to mostly local grower markets where they may be re-used many times.

Corrugated Fiberboard

Corrugated fiberboard (often mistakenly called cardboard or pasteboard) is manufactured in many different styles and weights. Because of its relativity low cost and versatility, it is the dominant produce container material and will probably remain so in the near future. The strength and serviceability of corrugated fiberboard have been improving in recent years. Most corrugated fiberboard is made from three or more layers of paperboard manufactured by the kraft process. To be considered paperboard, the paper must be thicker than 0.008 inches. The grades of paperboard are differentiated by their weight (in pounds per 1,000 square feet) and their thickness. Kraft paper made from unbleached pulp has a characteristic brown color and is exceptionally strong. In addition to virgin wood fibers, Kraft paper may have some portion of synthetic fibers for additional strength, sizing (starch), and other materials to give it wet strength and printability. Most fiberboard contains some recycled fibers. Minimum amounts of recycled materials may be specified by law and the percentage is expected to increase in the future. Tests have shown that cartons of fully recycled pulp have about 75 percent of the stacking strength of virgin fiber containers. The use of recycled fibers will inevitably lead to the use of thicker walled containers.

Double-faced corrugated fiberboard is the predominant form used for produce containers. It is produced by sandwiching a layer of corrugated paperboard between an inner and outer liner (facing) of paper-board. The inner and outer liner may be identical, or the outer layer may be preprinted or coated to better accept printing. The inner layer may be given a special coating to resist moisture. Heavy-duty shipping containers, such as corrugated bulk bins that are required to have high stacking strength, may have double- or even triple-wall construction. Corrugated fiberboard manufacturers print box certificates on the bottom of containers to certify certain strength characteristics and limitations. There are two types of certification.

The first certifies the minimum combined weight of both the inner and outer facings and that the corrugated fiberboard material is of a minimum bursting strength. The second certifies minimum edge crush test (ETC) strength. Edge crush strength is a much better predictor of stacking strength than is bursting strength. For this reason, users of corrugated fiberboard containers should insist on ECT certification to compare the stack ability of various containers. Both certificates give a maximum size limit for the container (sum of length, width, and height) and the maximum gross weight of the contents.

Both cold temperatures and high humidities reduce the strength of fiberboard containers. Unless the container is specially treated, moisture absorbed from the surrounding air and the contents can reduce the strength of the container by as much as 75 percent. New anti moisture coatings (both wax and plastic) are now available to substantially reduce the effects of moisture. Waxed fiberboard cartons (the wax is about 20 percent of fiber weight) are used for many produce items that must be either hydrocooled or iced. The main objection to wax cartons is disposal after use— wax cartons cannot be recycled and are increasingly being refused at landfills. Several states and municipalities have recently taxed wax cartons or have instituted rigid back haul regulations. Industry sources suggest that wax cartons will eventually be replaced by plastic or, more likely, the use of ice and hydrocooling will be replaced by highly controlled forced-air cooling and rigid temperature and humidity maintenance on many commodities.

In many applications for corrugated fiberboard containers, the stacking strength of the container is a minor consideration. For example, canned goods carry the majority of their own weight when stacked. Fresh produce usually cannot carry much of the vertical load without some damage. Therefore, one of the primarily desired characteristics of corrugated fiberboard containers is stacking strength to protect the produce from crushing. Because of their geometry, most of the stacking strength of corrugated containers is carried by the corners. For this reason, hand holes and ventilation slots should never be positioned near the corners of produce containers and be limited to no more than 5 to 7 percent of the side area. Interlocking the packages (cross stacking) is universally practiced to stabilize pallets. Cross stacking places the corner of one produce package at the middle of the one below it, thus reducing its stacking strength. To reduce the possibility of collapse, the first several layers of each pallet should be column stacked (one package directly above the other). The upper layers of packages may be cross stacked as usual with very little loss of pallet stability.

There are numerous styles of corrugated fiberboard containers. The two most used in the produce industry are the one piece, regular slotted container (RSC) and the two piece, full telescoping container (FTC). The RSC is the most popular because it is simple and economical.

However, the RSC has relatively low stacking strength and therefore must be used with produce, such as potatoes, that can carry some of the stacking load. The FTC, actually one container inside another, is used when greater stack- ing strength and resistance to bulging is required. A third type of container is the Bliss box, which is — constructed from three separate pieces of corrugated fiberboard. The Bliss box was developed to be used when maximum stacking strength is required. The bottoms and tops of all three types of containers may be closed by glue, staples, or interlocking slots.

Almost all corrugated fiberboard containers are shipped to the packer flat and assembled at the packing house. To conserve space, assembly is usually performed just before use. Assembly may be by hand, machine, or a combination of both. Ease of assembly should be carefully investigated when considering a particular style of package. In recent years, large double-wall or even triple- wall corrugated fiberboard containers have increasingly been used as one-way pallet bins to ship bulk produce to processors and retailers. Cabbage, melons, potatoes, pumpkins, and citrus have all been shipped successfully in these containers. The container cost per pound of produce is as little as one fourth of traditional size containers. Some bulk containers may be collapsed and re-used. For many years, labels were printed on heavy paper and glued or stapled to the produce package. The high cost of materials and labor has all but eliminated this practice. The ability to print the brand, size, and grade information directly on the container is one of the greatest benefits of corrugated fiberboard containers. There are basically two methods used to print corrugated fiberboard containers:

Post Printed

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

Preprinted

High quality, full-color graphics may be obtained by preprinting the linerboard before it is attached to the corrugated paperboard. Whereas the cost is about 15 percent more than standard two color containers, the eye catching quality of the graphics makes it very useful for many situations. The visual quality of the package influences the perception of the product because the buyer's first impression is of the outside of the package. Produce managers especially like high quality graphics that they can use in super market floor displays. Preprinted cartons are usually reserved for the introduction of new products or new brands. Market research has shown that exporters may benefit from sophisticated graphics. The increased cost usually does not justify use for mature products in a stable market, but this may change as the cost of these containers becomes more competitive.

Pulp Containers

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

Paper and Mesh Bags

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

Supermarket produce managers like small mesh bags because they make attractive displays that stimulate purchases. However, bags of any type have several serious disadvantages. Large bags do not palletize well and small bags do not efficiently fill the space inside corrugated fiberboard containers. Bags do not offer protection from rough handling. Mesh bags provide little protection from light or contaminants. In addition, produce packed in bags is correctly perceived by the consumer to be less than the best grade. Few consumers are willing to pay premium price for bagged produce.

Plastic Bags

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

In addition to engineered plastic films, various patches and valves have been developed that affix to low-cost ordinary plastic film bags. These devices respond to temperature and control the mix of environmental gases.

Shrink Wrap

One of the newest trends in produce packaging is the shrink wrapping of individual produce items. Shrink wrapping has been used successfully to package potatoes, sweet potatoes, apples, onions, sweet corn, cucumbers and a variety of tropical fruit. Shrink wrapping with an engineered plastic wrap can reduce shrinkage, protect the produce from disease, reduce mechanical damage and provide a good surface for stick-on labels.

Rigid Plastic Packages

Packages with a top and bottom that are heat formed from one or two pieces of plastic are known as clamshells. Clamshells are gaining in popularity because they are inexpensive, versatile, provide excellent protection to the produce, and present a very pleasing consumer package. Clamshells are most often used with consumer packs of high value produce items like small fruit, berries, mushrooms, etc., or items that are easily damaged by crushing. Clamshells are used extensively with precut produce and prepared salads. Molded polystyrene and corrugated polystyrene containers have been test marketed as a substitute for waxed corrugated fiberboard. At present they are not generally cost competitive, but as environmental pressures grow, they may be more common. Heavy-molded polystyrene pallet bins have been adopted by a number of growers as a substitute for wooden pallet bins. Although at present their cost is over double that of wooden bins, they have a longer service life, are easier to clean, are recyclable, do not decay when wet, do not harbor disease, and may be nested and made collapsible.

As environmental pressures continue to grow, the disposal and recyclability of packaging material of all kinds will become a very important issue. Common polyethylene may take from 200 to 400 years to breakdown in a landfill. The addition of 6 percent starch will reduce the time to 20 years or less. packaging material companies are developing starch-based polyethylene substitutes that will break down in a landfill as fast as ordinary paper. The move to biodegradable or recyclable plastic packaging materials may be driven by cost in the long term, but by legislation in the near term. Some authorities have proposed a total ban on plastics . In this case, the supermarket of the early 21st century may resemble the grocery markets of the early 20th century.

Standardization of Packaging

Produce package standardization is interpreted differently by different groups. The wide variety of package sizes and material combinations is a result of the market responding to demands from many different segments of the produce industry. For example, many of the large-volume buyers of fresh produce are those most concerned with the environment. They demand less packaging and the use of more recyclable and biodegradable materials, yet would also like to have many different sizes of packages for convenience. packers want to limit the variety of packages they must carry in stock, yet they have driven the trend toward preprinted, individualized containers. Shippers and trucking companies want to standardize sizes so the packages may be better palletized and handled.

Produce buyers are not a homogeneous group. Buyers for grocery chains have different needs than buyers for food service. For grocery items normally sold in bulk, processors want largest size packages that they can handle efficiently - to minimize unpacking time and reduce the cost of handling or disposing of the used containers. Produce managers, on the other hand, want individualized, high quality graphics to entice retail buyers with in-store displays.

Selecting the right container for fresh produce is seldom a matter of personal choice for the packer. For each commodity, the market has unofficial, but nevertheless rigid standards for packaging; therefore it is very risky to use a nonstandard package. Packaging technology, market acceptability, and disposal regulations are constantly changing. When choosing a package for fresh fruits and vegetables, packers must consult the market, and in some markets, standard packages may be required by law

Packaging materials in use

A great variety of materials are used for the packing of perishable commodities. They include wood, bamboo, rigid and foam plastic, solid cardboard and corrugated fibre board. The kind of material or structure adopted depends on the method of perforation, the distance to its destination, the value of the product and the requirement of the market.

1. CFB Boxes

Corrugated fiberboard is the most widely used material for fruit & vegetable packages because of the following characteristics:

1. Light in weight
2. Reasonably strong
3. Flexibility of shape and size
4. Easy to store and use
5. Good pointing capability
6. Economical

2. Wooden Boxes

Materials used for manufacture of wooden boxes include natural wood and industrially manufactured, wood based sheet materials.

3. Sacks

Sacks are traditionally made of jute fibre or similar natural materials. Most jute sacks are provided in a plain weave. For one tonne transportation of vegetables, materials of 250 grams per square meter or less are used. Natural fibre sacks have in many cases been replaced by sacks made of synthetic materials and paper due to cost factors, appearance, mechanical properties and risk of infestation and spreading of insects. Sacks made of polypropylene of type plain weave are extensively used for root vegetables. The most common fabric weight is 70-80 grams per square meter.

Palletisation

Pallets are widely used for the transport of fruit & vegetable packages, in all developed countries. The advantages of handling packages on pallets are:

o Labour cost in handling is greatly reduced.
o Transport cost may be reduced.
o Goods are protected and damage reduced.
o Mechanized handling can be very rapid.
o Through high stacking, storage space can be more efficiently used.
o Pallets encourage the introduction of standard package sizes.

In designing export packages, their handling on pallets for shipping or for transport and storage within the importing country, is an important factor. The most common pallet size is 1200 mmx1100 mm.

Ventilation of Packages

Reduction of moisture loss from the product is a principal requirement of limited permeability packaging materials. A solution to moisture loss problems from produce appeared with the development and wide distribution of semi permeable plastic films. Airflow through the ventilation holes allows hot fruit or vegetable to slowly cool and avoid the buildup of heat produced by the commodity in respiration. Holes are also important in cooling the fruit when the packages are placed in a cold storage, especially with forced air-cooling. Ventilation holes improve the dispersal of ethylene produced.

Cushioning Materials

The function of cushioning materials is to fix the commodities inside the packages and prevent them from mixing about in relation to each other and the package itself, when there is a vibration or impact. Some cushioning materials can also provide packages with additional stacking strength. The cushioning materials used vary with the commodity and may be made of wrapping papers, Fibreboard (single or double wall), Moulded paper pulp trays, Moulded foam polystyrene trays, Moulded plastic trays, Foam plastic sheet, Plastic bubble pads, Fine shredded wood, Plastic film liners or bags.

Controlled and Modified Atmospheric Packaging (CAP and MAP)

The normal composition of air is 78% Nitrogen, 21% Oxygen, 0.03% Carbon dioxide and trees of the noble gases. Modified atmosphere packaging is the method for extending the shelflife
of perishable and semi-perishable food products by altering the relative proportions of atmospheric gases that surround the produce. Although the terms controlled atmosphere (CA)

and modified atmosphere (MA) are often used interchangeably a precise difference exists between these two terms.

Controlled atmosphere (CA)

This refers to a storage atmosphere that is different from the normal atmosphere in its composition, wherein the component gases are precisely adjusted to specific concentrations and maintained throughout the storage and distribution of the perishable foods. Controlled atmosphere relies on the continuous measurement of the composition of the storage atmosphere and injection of the appropriate gases or gas mixtures into it, if and when needed. Hence, the system requires sophisticated instruments to monitor the gas levels and is therefore practical only for refrigerated bulk storage or shipment of commodities in large containers. If the composition of atmosphere in CA system is not closely controlled or if the storage atmosphere is accidentally modified, potential benefit can turn into actual disaster. The degree of susceptibility to injury and the specific symptoms vary, not only between cultivars, but even between growing areas for the same cultivars and between years for a given location. With tomatoes, excessively low O_2 or high CO_2 prevents proper ripening even after removal of the fruit to air, and CA enhances the danger of chilling injury.

Modified atmospheric packaging (MAP)

Unlike CAPs, there is no means to control precisely the atmospheric components at a specific concentration in MAP once a package has been hermetically sealed. Modified atmosphere conditions are created inside the packages by the commodity itself and / or by active modification. Commodity – generated or passive MA is evolved as a consequence of the commodity‘s respiration. Active modification involves creating a slight vacuum inside the package and replacing it with a desired mixture of gases, so as to establish desired EMA quickly composed to a passively generated EMA.

Another active modification technique is the use of carbon dioxide or ethyl absorbers (scavengers) within the package to prevent the build-up of the particular gas within the package. This method is called active packaging. Compounds like hydrated lime, activated charcoal, magnesium oxide are known to absorb carbon dioxide while iron powder is known to absorb carbon dioxide. Potassium permanganate, squakna and phenyl methyl silicone can be used to absorb ethylene within the packages. These scavengers can be held in small sachets within the packages or impregnated in the wrappers or into porous materials like vermiculite. With activity respiring commodities like fruits and vegetables, the package atmosphere should contain oxygen and carbon dioxide at levels optimum to the particular commodity. In general, MA containing between 2-5% Oxygen and 3.8% carbon dioxide have been shown to extend the shelf life of a wide variety of fruits and vegetables.

If the shelf life of a commodity at 20-25°C is 1, by employing MAP, it will be doubled, whereas refrigeration can extend the shelf life to 3, and refrigeration combined with MAP can increase it to 4. Few types of films are routinely used for MAP, the important ones are polyvinyl chloride, (PVC), polystyrene, (PS), polyethylene (PE) and polypropylene (PP). The recent developments in co-extrusion technology have made it possible to manufacture films with designed transmission rates of oxygen.

Vacuum packaging

Vacuum packaging offers an extensive barrier against corrosion, oxidation, moisture, drying out, dirt, attraction of dust by electric charge, ultra violet rays and mechanical damages, fungus growth or perishability etc. This technology has commendable relevance for tropical countries with high atmosphere humidity. In vacuum packaging the product to be packed is put in a vacuum bag (made of special, hermetic fills) that is then evacuated in a vacuum chamber and then sealed hermetically in order to provide a total barrier against air and moisture. If some of the product cannot bear the atmosphere pressure due to vacuum inside the package then the packages are flushed with inert gases like Nitrogen and CO_2 after evacuation.

Edible packaging

An edible film or coating is simply defined as a thin continuous layer of edible material formed on, placed on, or between the foods or food components. The package is an integral part of the food, which can be eaten as a part of the whole food product. Selection of material for use in edible packaging is based on its properties to act as barrier to moisture and gases, mechanical strength, physical properties, and resistance to microbial growth. The types of materials used for edible packaging include lipids, proteins and polysaccharides or a combination of any two or all of these. Many lipid compounds, such as animal and vegetable fats, acetoglycerides have been used in the formulation of edible packaging for fresh produces because of their excellent moisture barrier properties. Lipid coatings on fresh fruits and vegetables reduce weight losses due to dehydration during storage by 40-70 per cent.
Research and development effort is required to develop edible films and coatings that have good packaging performance besides being economical.

DEFINES:

Food Preservation

When the availability of food is more than the present use it is preserved for future consumption.

Heat Processing

The temperature and time used in heat processing a food will depend upon what effect heat has on the food and what other preservative methods are to be employed.

Pasteurisation

Pasteurisation is a heat treatment that kills part but not all the microorganisms present and usually involves the application of temperatures below 100 .

Canning

Canning involves the application of temperatures (to food) that are high enough to destroy all microorganisms present in sterilized containers to prevent recontamination and to preserve the food.

Preservatives

Preservatives are defined as "chemical agents, which serve to retard, hinder or mask undesirable change in food".

Dehydration

The word dehydration usually complies the use of controlled conditions of heating, with the forced circulation of air or artificial drying as compared with the use of

Osmotic dehydration

The moisture is drawn out from all cell tissues.

Spray drying

Thin fruit juices like pine apple, citrus are dried to a powder in spray driers in which the liquid is atomized and sprayed into a hot air stream for almost instant drying.

Freeze drying

Freeze drying is a method of drying involving freezing and then the sublimates of the ice under vacuum. Removal of water from a product while it is frozen by sublimation is called freeze drying.

What is the difference between jam and jelly?

Jams are prepared using the fruit pulp, while jelly is prepared using fruit extract only and hence jelly will be somewhat transparent or translucent type.