HOR 311 Postharvest Management and Value addition of Fruitsand Vegetables (1+1)

Theory Study Material

COURSE TEACHERS

Dr. M. BHARATHI RAJA, Assistant Professor (HOR)

Dr. B. KARPAGAVALLI, Associate Professor (FSN)

HOR 311 Postharvest management and value addition of fruits and vegetables (1+1)

Theory schedule

1. Scope and importance of postharvest technology of fruits and vegetables
2. Factors responsible for post-harvest losses.
3. Preharvest factors affecting postharvest life of fruits and vegetables
4. Physiological and biochemical changes during maturity and ripening
5. Respiration and ripening and the factors affecting the ripening of fruits and vegetables
6. Role of ethylene in ripening of fruits and vegetables
7. Preharvest operations to extend shelf life of fruits and vegetable crops
8. Postharvest handling of the produce (washing, fungicide treatment, precooling, grading, sorting waxing and nano coating)
9. **Mid -semester examination**
10. Importance of packaging, types of packaging and packaging materials.
11. Methods of storage of fruits and vegetables *viz.* , Zero energy cool chamber, cold storage, controlled atmosphere, modified atmosphere and hypobaric storage and management of cold chain for export of high value fruits and vegetables
12. Principles and methods of preservation of fruits and vegetables
13. Preservation and value addition of fruits viz. , jam, jelly, marmalade, preserve and candy
14. Concepts and standards in fermented and non fermented beverages from fruits and vegetables
15. Drying, dehydration and osmotic dehydration of fruits and vegetables- concepts and methods
16. Canning of fruits and vegetables- concepts-processing of canned products-spoilage and prevention
17. Packaging of products and standards in value addition of fruits and vegetables viz. , GMP, HACCP, FSSAI, Codex alimentrarius and ISO certification.

Lecture 1

Scope and importance of postharvest technology of fruits and vegetables

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, Ramayanaand 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 byfungi and bacteria, whereas physiological losses include changes in respiration, transpiration, pigments, organic acids and flavour.

NATURE AND CAUSES OF POST-HARVEST LOSSES:

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

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

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

- Farmer‘s field (15-20%)
- Packaging (15-20%)
- Transportation (30-40%)
- Marketing (30-40%)

Need for Post harvest technology

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

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

Eg - pre cooling – waxing - cleaning/washing - chemical treatments- trimming/sorting packaging- curing, - transportation- grading - storage, ripening and distribution

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

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

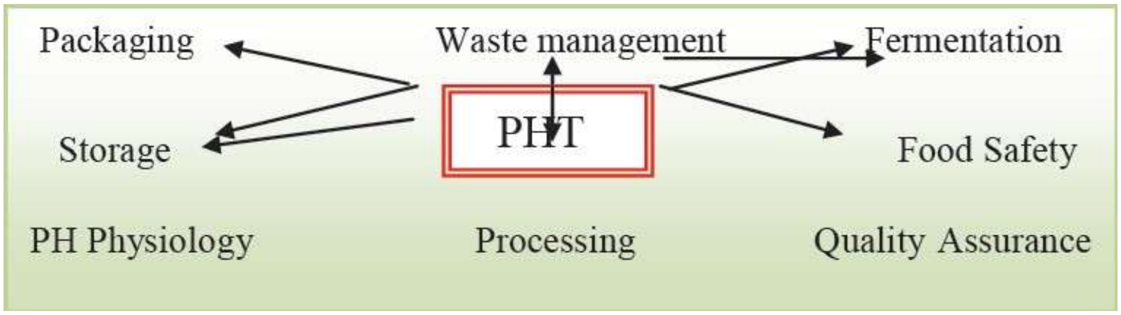
Post harvest Shelf Life - Once harvested, produce are subject to the active process of senescence. Numerous biochemical processes continuously change the original composition of the produce until it becomes unmarketable. The period during which consumption is considered acceptable is defined as the time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

Post harvest shelf life is typically determined by objective methods like

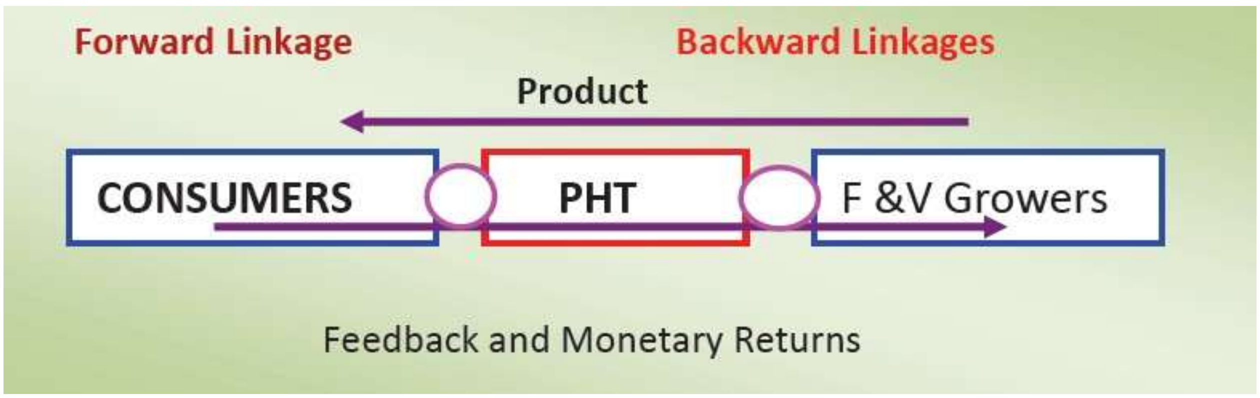
- Overall appearance
- Taste, flavor, and texture of the commodity. These methods usually include a combination of sensory, biochemical, mechanical, and colorimetric (optical) measurements.

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

Postharvest technology and its sub – disciplines



Post harvest technology functioning chain



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

There are many interacting steps involved in any post harvest system. Produce is often handled by many different people, transported and stored repeatedly between harvest and consumption.

PHT – Importance and Role

1. PH Loss reduction

2. Value addition

3. Contribution to the Economy

4. Making availability of fruits and vegetables during off seasons

5. Tools for export earnings

6. Employment generation

7. Adding variety in taste and nutrition

8. Waste utilization

9. Home scale preservation

10. Supply of food to the defense forces

11. Special canned fruits for infants & children"s

12. Food supplier to the Astronauts

1) Reduction in post-harvest losses: Post harvest technology ensures reduction of losses in what has already been produced. So, reduction of post-harvest losses is an alternative way of increasing production of agricultural and horticultural crops.

2) Reduction of cost of production: Post harvest technology reduces cost of production, packaging, storage, transportation, marketing and distribution, lowers the price for the consumer and increases the farmer‘s income.

3) Reducing malnutrition: Proper post-harvest technology ensures availability of sufficient food to all thus reducing malnutrition and ensuring healthy growth of the nation. It also extends the season of availability of a particular commodity.

4) Economic loss reduction: Reduces economic losses at grower level, during marketing and at consumers end.

5) Availability: Had there been no knowledge of post-harvest technology, apples would not have ever reached Kerala and Banana in H.P. or Kashmir today. Today we can get perishable commodities like Banana, tomato etc. throughout the year and in almost every place in the country. Apples can be made available throughout the year although the cropping season is just for 2-3 months. Thanks to the advancement made in the field of post-harvest technology. The increasing exports of fruits and vegetables have become possible only by the interventions made in post-harvest technology.

6) Employment generation: The food processing industry ranks first in terms of employment generation with approximately 15 lakhs persons employed. Employment potential in post-harvest and value addition sector is considered to be very high. Every one crore rupee invested in fruit and vegetable processing in the organized sector generates 140 persons per year of employment as compared to just 1050 person days of employment per year in small scale investment (SSI) units. The SSI unit in food industry employs 4, 80,000 persons, contributing 13% of all SSI units employed.

7) Export earnings: Export of fresh and processed horticultural commodities also attracts valuable foreign exchange.

8) Defense and astronaut's requirements: Defense forces posted in remote border areas as well as astronauts who travel into space have special requirements of ready to eat and high energy low volume food. The requirements are fulfilled by processing industries.

9) Infant and sports preparations: To day special infant and sports drinks and other processed preparations are available for use especially by these people. These preparations are done especially to meet the specific nutritional requirements of their body.

Role of PH Technologist

1. To provide quality, nutritious and safe food

2. To develop new product & technologies - Discoveries - The best example for the highest post harvest life in the nature is the Swiss Apple - *Uttwiler Spatlauber*, is well known for its excellent storability; it can stay fresh looking for up to four months after being harvested. However, it has not been widely cultivated because of its sour taste.

Innovation –biotechnology has been used to extend the storage life in tomato and developed variety called FLAVR SAVR ™,- using technology to reduce the activity of the enzyme endopolygalcturonase, which involved in the cell wall breakdown during ripening and fruit will remain firmer during ripening on and off the plant.

3. To develop new equipment and determine their efficiency.

Lecture 2

Factors responsible for post-harvest losses

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 flavor.

It is well known fact that fruits, vegetables and flowers are living commodities even after harvest and continue to respire, transpire and carryout other biochemical activities. Therefore they are more perishable when compared to other agricultural commodities. The deterioration in harvested fresh produce occurs both quantitatively and qualitatively. The losses that occur from the time of harvesting of fresh produce till they reach the consumer are referred as post-harvest losses.

NATURE AND CAUSES OF POST-HARVEST LOSSES

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

(a) Extend of post-harvest loss: It is evident that the estimation of post-harvest loss is essential to make available more food from the existing level of production. A recent joint study conducted by the management consultancy firm, McKinsey and Co. and (The Confederation of Indian Industry (CII), at least 50% of the production of fruits and vegetab1es in the country is lost due to wastage and value destruction. The wastage cost is estimated to be Rs.23, 000 crores each year. Swaminathan Committee (1980) reported the post-harvest handling accounts for 20-30% of the losses at different stages of storage, grading, packing, transport and finally marketing as a fresh produce or in the processed form. According to Chadha (2009) India loses about 35-

45% of the harvested fruits and vegetables during handling, storage, transportation etc. leading to the loss of Rs. 40,000 crores per year.

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

• Farmer's field (15-20%)

• Packaging (15-20%)

•. Transportation (30-40%)

Marketing (30-40%)

C) Estimated loss of fruits

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

Estimated loss of Vegetables

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

Post harvest losses occur in terms of

1) **Quantitative loss** - referring to the reduction in weight due to moisture loss and loss of dry matter by respiration

2) **Qualitative loss** - referring to freshness deterioration leading to loss of consumer appeal and nutritional loss including loss in vitamins, minerals, sugars, etc.

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

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

I. Biological factors

II. Environmental factors

I. Biological factors

Following biological factors are responsible for deterioration of Horticultural Produce:

1. Respiration rate

2. Ethylene production

3. Compositional changes

4. Growth and development

5. Transpiration

6. Physiological breakdown

7. Physical damage

8. Pathological breakdown

9. Surface area to volume

10. Membrane permeability

1. Respiration rate - Being living entities fruits, vegetables, flowers respire actively after harvest. Increase in respiration leads to quicker ripening and detoriation

2. Ethylene production - Ethylene plays a vital role in postharvest produce and changes the physical and metabolic activities.

3. Compositional changes - Many pigment changes also takes place even after harvest in some commodities.

These changes are:

a. Loss of chlorophyll (green color) – In vegetables

b. Loss of carotenoids (yellow and orange color) – In apricot, peaches, citrus fruits and tomato

c. Loss of anthocyanins (red and blue color) – In apples, cherries and strawberries

d. Change in carbohydrates

i. Starch to sugar conversion – potato

ii. Sugar to starch conversion – peas, sweet corn

e. Breakdown of pectin and other polysaccharides – causes softening of fruit

f. Change in organic acids, proteins, amino acids and lipids. – can influence flavor

g. Loss in vitamins – effects nutritional quality

4. Growth and development

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

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

5. Transpiration

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

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

Factors influence the transpiration rate in various commodities:

Surface of the commodity - commodities having greater surface area in relation to their weight will lose water more rapidly. It is clearly visible in leafy vegetables where the water loss is much faster than a fruit as they have more surface area to volume ratio.

- ✓ Surface injuries - Mechanical damages accelerate the rate of water loss from the harvested produce. Bruising and abrasion injuries will damage the protective surface layer and directly expose the underlying tissues to the atmosphere allowing greater transpiration.
- ✓ Maturity stage - less matured fruits lose more moisture then matured fruits/vegetables
- ✓ Skin texture - Fresh produce having thin skin with many more spores lose water quickly than those having thick skin with fewer spores.
- ✓ Temperature - Water loss is high with increase in storage temperature. The loss will be further enhanced when high temperature is combined with low relative humidity
- ✓ Relative humidity - The rate at which water is lost from fresh produce also depends on the water vapour pressure difference between the produce and the surrounding air. So water loss from fresh produce will be low when the relative humidity i.e. moisture content of the air is high**.** Further, the faster the surrounding air moves over fresh produce the quicker will be the water loss.

Transpiration results in following type of deterioration:

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

6. Physiological breakdown

When produce is exposed to an undesirable temperature physiological breakdown takes place.

Following physiological breakdowns are common in various commodities:

- ✓ Freezing injury - when commodity stored at below their freezing temperature
- ✓ Chilling injury - when commodity stored at below their desired storage temperature

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

7. Physical damage

- Various types of physical damages responsible for deterioration are
- Mechanical injury/cut - during harvesting, handling, storage, transportation *etc*.
- Bruising due to vibration (during transportation), impact (dropping) and compression (overfilling)

8. Pathological breakdown

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

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

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

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

II. Environmental factors

Following environmental factors are responsible for deterioration

1. Temperature

2. Relative humidity

3. Atmospheric gas compositions

4. Ethylene

5. Light

6. Other factors

1. Temperature

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

2. Relative humidity

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

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

3. Atmospheric gas composition

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

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

4. Ethylene

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

5. Light

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

6. Other factors

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

Others

MAJOR PRE AND POST HARVEST DEFECTS

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

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

Sl. No.	**Defects**	**Damage**
1.	Insect pests	Holes and mis-shapen
2.	Microorganisms	Black scurf, canker, Scab, Blight, Blisters, Sooty blotch, Rotten/decay
3.	Nutritional deficiency	Dry circular crevices
4.	Improper cultural practices	Green spot (potato)
5.	Environmental factors	Russeting, water core, discoloration, staining, dried leaves, hail damage, dull/ pale look, shriveling / wrinkling, sunburn, sun scald, superficial sunscald, lanky, torn leaves, black/brown calyx, water core, fresh rooting, splitting, cracks, natural growth cracks, water berry, scales on surface
6.	Birds / animals	Bird damage
7.	Delayed harvesting	Mature /over mature, fibrous, over ripe, seed stem
8.	Handling	Black edges, handling damage, packing damage, pressure damage, shatter or loose berry, damage, soft, bruises and broken
9.	Mechanical means	Healed dark brown marks, chipped, hole, punctured skin, cuts, mechanical damage
10	Improper washing, cleaning, trimming and pruning	Long stalk, dirty outer leaves, secondary roots, wrapper/extra covered leaves, unclean
11.	Physiological disorders	Bitter pit, puffiness, cracking
12.	Improper cold storage	Dried berries, sprouting, hollow heart
13.	Genetic abnormalities	Misshape and double

Impact of post-harvest losses

Postharvest 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.

Technologies for minimizing the losses

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

1. Waxing

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

2. Evaporative cool storage

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

3. Pre-packaging

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

4. Cold storage

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

5. Modified atmosphere packaging (MAP)

These packaging modify the atmosphere composition inside the package by respiration. This technology is successful to extend the shelf life of (Cavendish banana, carrots capsicum, green chilli and tomatoes by 15, 14, 13, 8 and 15 clays as against 5, 7, 8, 4 and 7 days in control respectively, under ambient conditions. Storage of Papaya can be extended 4 weeks when stored at 10 -12 °C under modified atmosphere (MA) conditions by wrapping them in low density polyethylene (LDPE) bag. Using this technique, the fruit can be transported to different markets in refrigerated sea containers with Temperature Sea at 10-12 °C. Fruits ripen within 3-4 days after arrival when placed at ambient temperature. While using optimum low temperature, storage life of Cavendish banana, capsicum, green chili and tomato can be extended to 42,21,28 and 30 days in comparison to 21, 10,21 and 15 days respectively.

6. Controlled Atmosphere (CA) storage

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

7. Cold chain

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

8. Irradiation

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

9. Edible coatings

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

10. Others

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

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

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

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

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

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

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

Lecture 3

Preharvest factors affecting postharvest life of fruits and vegetables

Quality of post-harvest product

Post harvest quality represents market quality, edible quality, transport quality, table quality, nutritional quality, internal quality and appearance quality. Quality means a combination of characteristics, attributes and properties that gives the values to human and enjoyments. Consumers consider good quality in relation to colour, flavour and nutrition. Quality of the produce is the final manifestation of inter-relation between the commodity and its environment. The genetic characteristics and physiological status of the commodity determine the typical post-harvest behavior and quality of the produce and these two are the major bases for the interaction.

Pre-harvest factors viz, environmental factors such as temperature, relative humidity, water potential, light, cultural practices and pest management techniques determined the inherent quality of the produce. However, the ultimate quality is the final manifestation of inter relation between the commodity and its environment.

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

I. Pre Harvest Factors

1. Genetic / variety

2. Light

3. Temperature

4. Humidity

5. Mineral nutrition

6. Water relation/ Irrigation

7. Canopy manipulation

8. Rainfall

9. Seasons / Day and day length

10. Carbon dioxide

11. Use of agrochemicals

12. Planting density

13. Root stock, pruning and crop rotation

14. Pest and diseases

II. Harvest Factors

1. Stage of harvest

2. Time of harvest

3. Methods of harvest

I. PRE – HARVEST FACTORS

1. Genetic / variety

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

2. Light – Light regulates several physiological processes like chlorophyll synthesis, phototropism, respiration and stomatal opening. The duration, intensity and quality of light affect the quality of fruits and vegetables at harvest. Most of the produce needs high light intensity (3000-8000 f.c.). Absorption of red light (625-700 nm) through pigments, phytochrome, is essential for carbohydrates synthesis which determines the shelf life of the produce. The vase life of the carnation and chrysanthemums is longer under high light intensity than low.

Citrus and mango fruits produced in full sun generally had a thinner skin, a lower weight, low juice content and lower acidity but a higher TSS. And citrus fruits grown in the shade may be less susceptible to chilling injury when subsequently stored in cold storage.

In tomatoes, leaf shading of fruits produced a deeper red colour during the ripening than in the case of those exposed to light. The side of the fruit that have been exposed to sun will generally firmer than the non exposed side. In general, the lower the light intensity the lower the ascorbic acid content of plant tissues. In leafy vegetables, leaves are larger and thinner under condition of low light intensity.

3. Temperature – all type of physiological and biochemical process related to plant growth and yield are influenced by the temperature. The higher temperature during field conditions decreases life and quality of the produce. At high temperature, stored carbohydrates of fruits, vegetables and flowers are quickly depleted during respiration and plant respires at the faster rate. The produce which is having higher amount of stored carbohydrates show longer storage/vase life. **For example:** high temperature during fruiting season of tomato leads to quick ripening of fruits on and off the plant.

Orange grown in the tropics tend to have higher sugars and TSS than those grown sub tropics. However, tropical grown oranges tend to be green in colour and peel less easily and it is due to the lower diurnal temperature that occurs in the tropics.

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

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

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

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

Nitrogen - High N fertilization reduces while moderate to high K improves PH life and quality of anthurium, cut flowers and many horticultural produce.

- Applications of K in water melon tend to decrease the PH respiration.
- High levels on N tend to decrease flavor, TSS, firmness and color of the fruit and in stone fruits it increases physiological disorders and decrease fruit colour. Generally, crops that have high levels of nitrogen typically have poorer keeping qualities than those with lower levels as. High nitrogen increases fruit respiration, faster tissue deterioration thereby reducing their storage life.

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

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

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

Physiological disorders of storage organs related to low Ca content of the tissue are

- Bitter pit in apples
- Cork spot in pears
- Blossom end rot in tomato
- Tip burn in lettuce and hallow heart in potato *etc.*
- Red blotch of lemons

Zn is known to act as vehicle for carrying ions across tissue and increase Ca content of the fruit. Adequate supply of Bo improves the mobility of Ca in the leaves and the fruits and subsequently increases fruit firmness, TSS, organic acids and reduce the incidence of the drought spot, bitter pit and cracking disorders and impart diseases resistance. The incorporation of 4% Ca into proto pectin of middle lamella form bond with the cellulose of the cell wall and thus delayed softening in fruits. Infused Ca inhibits the internal browning, retarded respiration, and reduced the metabolism of endogenous substrates. Post climacteric respiration of apple decreased as peel Ca level increased from 400 to 1300 ppm. Ca may reduce the endogenous substrate catabolism by limiting the diffusion of substrate from vacuole to the respiratory enzymes in the cytoplasm (limited membrane permeability).

Application of CaCl2 delayed the accumulation of free sugars, decreased inorganic contents, mold development, softening and development of red colour in strawberry. In pears reduced cork spot, increased flesh firmness, total acidity and juiciness and in apple even after 90 day of storage at ambient condition shown acceptable quality.

5. Water relation and Irrigation – stress due to excessive or inadequate water in the medium reduce the longevity of the produce. Crop like carnation require 850 to 1200 g of water to produce one gram of dry matter. In general, <5 % of water absorbed in the plant system is utilized for the development of different plant components. Moisture stress increases the rate of transpiration over the rate of absorption and irregular irrigation/ moisture regime leads fruits/vegetable cracking (potato and pomegranate cracking). Higher level of moisture stress affects both yield and quality by decreasing cell enlargement.

Crops which have higher moisture content generally have poorer storage characteristics. An example of this is the hybrid onions, which tend to give high yield of bulbs with low dry matter content but which have only a very short storage life. If fully matured banana harvested soon after rainfall or irrigation the fruit can easily split during handling operations, allowing microorganism infection and PH rotting.

If orange is too turgid at harvest (early morning) the flavdeo/oil gland in the skin can be ruptured during harvesting , releasing phenolic compounds and causes Oleocellosis or oil spotting (green spot on the yellow / orange coloured citrus fruit after degreening).

Quailing – ‗harvested produce is kept in the basket for few hours in the field before being transported to pack house, this will allow the produce to loose little moisture'. Some growers have practice of harvesting lettuce in the late in the morning/ early afternoon because when they are too turgid the leaves are soft and more susceptible to bruising.

In green leafy vegetables, too much rain or irrigation can results in the leaves becoming harder and brittle, which can make them more susceptible to damage and decay during handling and transport.

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

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

6. Canopy Manipulation

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

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

Eg.: Grapes, Mango, peaches, kiwifruits

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

7. Season / Day – seasonal fluctuation and time of the day at harvest will greatly affects the postharvest quality of the produce. Synthesis of higher amount of carbohydrates during the day time and its utilization through translocation and respiration in the night is responsible for the variation in the longevity of the cut flowers. Roses and tuberose have been found to show longer keeping quality in the winter season under ambient condition than in the summer seasons.

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

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

8. Carbon dioxide – quality planting material, early flowering, more flowering, increased yield and rapid crop growth and development at higher level of CO2. Production of chrysanthemum under green house at 1000 – 2000 ppm of CO2 showed an increase in stem length, fresh weight, leaf no. and longevity of cut flowers.

9. Use of Agro chemicals – Pre-harvest application of chemicals such as BA, IAA, GA3, growth retardants like B-9, CCC, A-Rest and Phosphon-D have be reported to improve quality and longevity of flowers crops. Application of GA3 @ 50-100 ppm improves PH quality of roses by anthocyanin development. And it stimulate the accumulation of N, K, Mg and S. Pre-harvest spray with Alar(1500ppm), MH(500ppm), and Cycocel (500ppm) increased vase life of Aster.

Beneficial effect of leaf manure, K and GA3 is found to enhance the longevity of tuberose flowers.

Use of chemicals on the plants to prevent the pathogen will have direct impact on extending the postharvest life. Generally, if produce has suffered an infection during development its storage or marketable life may be adversely affected. Banana which suffers a severe infection with diseases such as leaf spot may ripen pre maturely or abnormally after harvest and in mango it is rapid postharvest loss. Pre harvest application chemicals like MH on onion filed prevent them sprouting during storage.

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

Harvest factors

Maturity at harvest: Maturity at harvest is the most important determinant of storage life and final produced quality. Immature produced are high susceptible to shriveling and mechanical damage are of inferior quality. Hence, fruits and vegetables are harvest at proper stage of maturity. Many leafy vegetables and immature fruits-vegetables (such as cucumbers, sweet corn, green beans peas and okras), attain optimum eating-quality prior to reaching to full maturity. This often results in delayed harvest and consequently in producer of low quality.

Harvest time: Quality is depends on timing the harvest correctly for most vegetables. Size, flavor, tenderness, texture and color can all be influenced by harvest timing. Snap bean must reach a certain sieve size, summer squash and cucumbers must be harvested within a narrow size range melon must be reach an acceptable sugar content tomatoes to be shipped must be harvested at ―mature green‖ or as ―breaker‖ but usually no post the ―pink stages‖ tomatoes for direct sales can be harvested when ripe. Cabbage winter squash pumpkin peppers have a wider harvest window.

Harvest methods: The methods of harvesting (hand vs. mechanical) can be significantly impact up on the composition and post-harvest quality of fruits and vegetables. Mechanical injuries (such as brushing, surface abrasions and cuts) can accelerate loss of water and vitamin C resulting in all increased susceptibility to decay-causing pathogens. Most fresh fruits and vegetables an all flowers are harvested by hand. Root crops (such as carrot, onion, potato and sweet potato) and some commodities destined for processing (such as processing tomatoes, European plums and tree nut crops) are mechanically harvested

Pre-harvest factors affecting the quality of fruits and vegetables

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

1. Environmental factors

Sl. No.	Factors	Quality affected
a.	**Temperature**	Maturity, colour, sugar, acidity etc. High temperature reduces the quality, e.g., citrus, radish, spinach, cauliflower, etc., and increased the quality in grapes, melons tomato, etc. Low temperature cause chilling and freezing injury.
b.	**Light**	Essential for anthocyanin formation. Exposed fruit to sun light develop the **lighter weight, thinner peel, lower juice and acids and higher TSS** thanshaded fruits, e.g., citrus, mango, etc. Exposure of potato to light causes **Greening** (solanine formation) which has toxic properties. High sun light intensity causes **Sunscald** in citrus and tomatoes and reduces the **pure white colour** of cauliflower. Low light intensity causes **thin and large leaves** in leafy vegetables.
c.	**Rains**	Causes **cracking** in grapes, dates, litchi, limes, lemon, tomato, sweet potato, etc.It reduces **appearance** and **sweetness**.
d.	**Wind**	Causes **brushing**, **scratching** and **corky scar** (citrus fruits) on the fruit anddamage leafy vegetables.
e.	**Humidity**	High humidity reduces the **colour** and **TSS** and **increases acidity** in citrus, grapes, tomato, etc., but on other hand it is needed for **better quality** of banana,litchi and pineapple.

2. Cultural factors

I. Mineral nutrition		
a.	**Nitrogen**	High nitrogen **reduces the ascorbic acid content**, **TSS/ acid ratio and keeping quality** but increases **thiamine, riboflavin, carotene,** e.g., Citrus and Spinach. Its deficiency reduces **size of fruits**.
b.	**Phosphorous**	High phosphorous **decreases size, weight, vitamin C.** e.g., Citrus. Its deficiencycauses **poor appearance of fruit**.
c.	**Potassium**	Increase **size, weight and vitamin C**, e.g., Citrus. Its deficiency causes unevenripening

d.	**Calcium**	Increases **firmness** of many fruits, e.g., Apple, Mango, Guava, Tomato, etc.
e.	**Magnesium**	Increases **size, weight and vitamin C**, e.g., Citrus fruits
f.	**Zinc**	Increases **size, weight and vitamin C**, e.g., Citrus. Deficiency causes straggled cluster in Grape.
g.	**Boron**	Deficiency causes **flesh browning in fruits**, e.g., Fruits and vegetables become **hard and misshapen**. Cabbage, Turnip andcauliflower are sensitive to boron deficiency.
h.	**Copper**	Deficiency causes **irregular blotch on citrus fruits** and **spoils the appearance**.
	II Growth Regulators	
a.	**Auxins**	Increases **fruit size** in loquat (2, 4, 5-TP), mandarins (NAA) and **TSS** in mango(2, 4,-D).
b.	**Gibberlic acid**	Increases size and weight of grape berries, apricot, and strawberry and causes **parthenocarpic fruits** in fig, guava, grape, tomatoes etc. It reduces **disorder of fruits**, e.g., water spot and corky spot in citrus
c.	**Cytokinin**	Maintain **green colour** of leafy vegetables and causes **parthenocarpic fruits** in fig.
d.	**Ethylene**	Ethephon increases **anthocyanin** (coloured grape, plum, apple, chillies, brinjal), carotenoides (mango, guava, papaya, citrus, tomato etc), **ascorbic acid and TSS** and reduces t**annin** (grapes, dates, etc) and acidity (grape, mango, tomato, etc.)
e.	**Growth retardant**	Alar (B9) increases **colour** in fruits, e.g., apple, cherry, apricot, etc. **Maleic hydrazide** (MH) inhibits s**prouting** in onion bulbs
III	**Root stock**	In citrus Troyer and Carizzo (Citranges) rootstock produce the fruit of **excellent quality** of oranges, mandarins and lemons. In guava *P.pumilum* root stock **increases sugar** and *P.cujavillis* **ascorbic acid** content of fruits.
IV	**Irrigation**	Excess irrigation causes **high acidity** and deficiency of moisture reduces **fruit size,juice content** and increases **thickness of peel**.

V	**Pruning**	It affects the **size, colour, acidity and sugar content** of grape, phalsa, ber, peach,apple etc.
VI	**Thinning**	Thinning in grapes, dates, peaches, plum, etc., increases **size, colour, acidity andsugar** content of fruits.
VII	**Girdling**	In grapes, it increases **size, colour and sugar** content of the berries.
VIII	**Variety**	Varieties differ in **size, shape, colour** and **chemical composition**. **High yield, brightappearance** and good **shipping qualities** are most important characters of the varieties.
IX	**Diseases and pests**	Both are harmful to fruits and vegetables.
X	**Pesticide**	Pesticide spray residues may give rise to flavor taints in the processed product. Excessive use of pesticides may even produce harmful metabolites and toxicity not necessarily destroyed during processing.
XI	**Maturity**	In general vegetables with exception of potato and onion are of higher quality when less mature because they are more tender, succulent, less fibrous or starchy. On the other hand fruits when ripe are of higher quality on account of full size, bright colour, sweetness and less acidic
XII	**Mechanical injury**	Fruits and vegetables should be in no case injured or damaged otherwise injury, such as skin abrasion and tissue bruising will reduce appearance and may be source of infection

Lecture 4

Physiological and biochemical changes during maturity and ripening

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

PHYSIOLOGY OF FRUIT AND VEGETABLES

Fruits and Vegetables are living entities and diverse in structure, composition and physiology. They have the typical plant cell system. The life of fruit and vegetables can be conveniently divided into three major physiological stages following germination.

Growth - involves cell division and subsequent cell enlargement, which accounts for the final size of the produce.

Maturation - usually commences before growth ceases and includes different activities in different commodities. Growth and maturation are often collectively referred to as the development phase.

Senescence - is defined as the period when synthetic (anabolic) biochemical process gives way to degradative (catabolic) process, leading to ageing and finally death of the tissue.

Ripening - is a phase of qualitative change which occurs in fruits particularly, after completion of maturation, during which the fruit becomes acceptable for consumption in terms of taste and flavour. Ripening occur during the later stages of maturation and is the first stage of senescence.

Normally development and maturation processes are completed before harvest. The completion of this stage is referred to as ‗maturity‘. But depending upon the nature of produce and the desired characteristics in a particular fruit or vegetable, the stage of maturity differs. Sometimes in fruits like mango, it has to attain the full stage of maturation to develop the characteristic flavour and taste, while in vegetables like Okra/beans/drumstick it should not mature fully where it becomes fibrous and unpalatable.

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

Principles of harvest maturity

1. Harvested commodity should have its peak acceptable quality when it reaches the consumer.

2. Produce should develop an acceptable flavour or appearance.

3. Produce should have optimum size and shape required by the market.

4. It should not be toxic or un acceptable.

5. Harvest maturity should have adequate shelf life.

Type of Maturity

I. Physiological maturity: Attainment of full development of stage just prior to ripening or ripening in non climacteric fruits.

Eg.: Fruits and vegetables produced for seed production

II. Horticultural /Commercial maturity – stage at which growth and development is optimum for specific use (stage acceptable for consumers/market oriented).

Eg. Fresh vegetables for canning/ dehydration/ IQF – Individual Quick Frozen/ harvesting for local or distant market

Horticulture maturity is classified into 3 different groups

1. Physiological immature – vegetables such as cucumber/peas/beans/carrot/beetroot/okra are harvested when they are tender, crisp and fiber free

2. Firm and mature – Fruits and vegetables which attain characteristic size, shape and maturity are harvested. **E.g.** Apple, Apricot, Annonaceous, Banana, Guava, Mango, Papaya and Tomato

3. Harvest ripe – In non climacteric fruit, maturity is referred as full ripening. Eg. Citrus, grape, pineapple and cherry.

FRUIT RIPENING

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

Climacteric Fruits

Fruits show dramatic increase in the rate of respiration during ripening and well respond to ethylene for ripening. **Eg.** Apple, Banana, Mango, Tomato.

Non - Climacteric Fruits

Fruits do not show dramatic increase in the rate of respiration during ripening and do not respond to ethylene for ripening. **Eg.** Citrus, Grapes, Pineapple & Watermelon

Sl. No.	**Climacteric Fruit (CF)**	**Non-climacteric Fruit(NCF)**
1.	Normally they ripen after harvest	Fruit that does not ripen after harvest. Ripen on the plant itself.
2.	The quality of fruit changes drastically after harvest characterized by softening, change in colour and sweetness. (except in avocado, which will ripen only after detached from the plant)	The quality do not change significantly after harvest except little softening. Do not change to improve their eating characteristics
3.	Exhibits a peak in respiration	Does not exhibit a peak
4.	More ethylene and CO_2 production is produced during ripening	Little / No ethylene and CO_2 production
5.	Decrease in internal oxygen concentration	Increase in internal O_2 production
	Eg. Apple, Apricot, Avocado, Banana, Ber, Cherimoya, Fig, Guava, Kiwifruit, Mango, Melons, Pear, Peach, Plum, Persimmon, Papaya, Tomato, Sapota, Passion fruit.	Carambola, Cherries, Citrus, Grape, Litchi, Loquat, Olive, Pineapple, Pomegranate, Strawberry

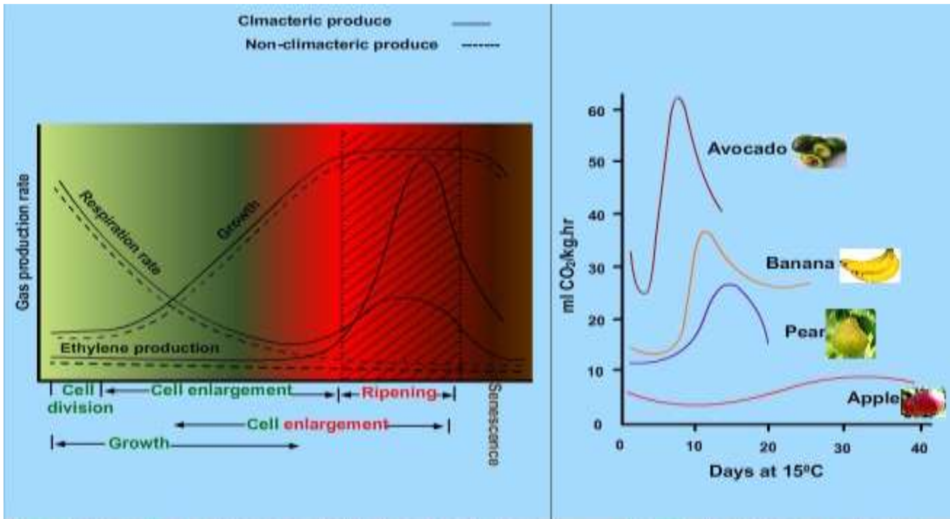


Fig.3.1 Growth, respiration and ethylene production patterns of climacteric and non-climacteric plant organs

Fig.3.2 Respiratory patteren of harvested climacteric fruits

Changes during Fruit Ripening

1. Cell Wall Changes

Cell wall consists of pectic substances and cellulose as the main components along with smal1amounts 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

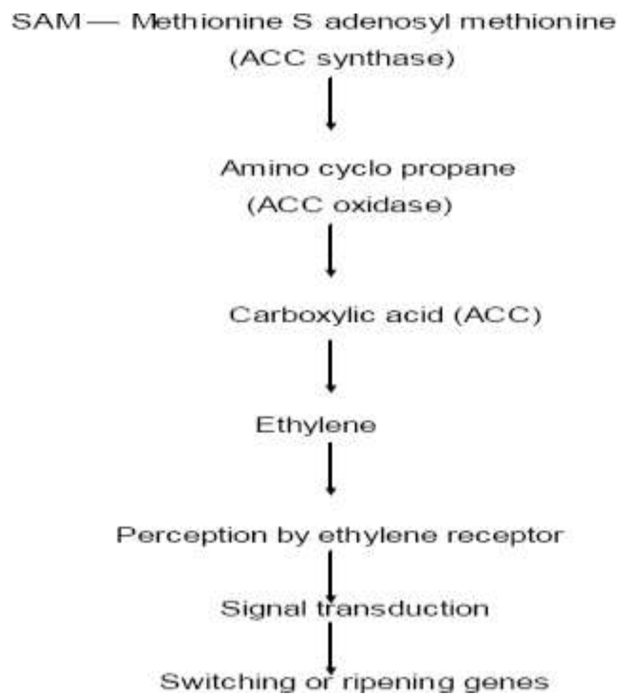
(2) Rise in respiration

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 climacteric 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:

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

Changes in Vegetables

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

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

In edible flower/buds/stems/leaves textures is an often dominant character that determines the both harvest date and quality, as loss of turgor through water loss causes a loss of texture.

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

Events of changes during maturation/ripening of Horticultural produce

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

Lecture 5

Respiration and ripening and the factors affecting ripening of fruits and vegetables

Fruit Respiration

One of the major physiological and biochemical change which occur in fruits and vegetables is a change in the pattern of respiration. The respiration rate of produce is an excellent indicator of the metabolic activity of the tissue and thus is a useful guide to the potential storage life of the produce. If the respiration rate of a fruit or vegetable is measured as their O_2 consumed or CO_2 evolved during the course of the development, maturation, ripening and senescent period, a characteristic respiratory pattern is observed. The respiratory pattern also impacts the pattern of evolution of ethylene. Based on this pattern, fruits can be classified into ‗climacteric' and ‗nonclimacteric'.

Few fruits exhibit the pronounced increase in the respiration (increase in CO_2 and C_2H_4) coincident with the ripening, such increase in the respiration is known as respiratory climacteric, and this group of fruits is called climacteric.

Respiration

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

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

Oxidation of glucose generates an equal amount of CO2 for the O2 consumed, whereas oxidation of malate generates more CO_2 then the O_2 consumed. This ratio between the oxygen consumed and carbondioxide produced is called respiratory quotient. This relationship is important in measuring respiration by gas exchange.

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

Respiration influences the product in following manner

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

- Important for the commodities desire dehydration

The rate of deterioration of horticultural commodities is directly proportion to the respiration rate

On the basis of their respiration rate we can classify different fruit and vegetables in following way:

Classification of horticultural commodities according to their respiration rate

CLASS	Range at 5^o C ($mgCO2Kg$-1 hr^{-1})	COMMODITIES
Very low	< 5	Dates, Dried fruit and vegetables, Nuts, *etc*.
Low	5 - 10	Apple, Beet, Celery, Citrus Fruits, Garlic, Grapes, Kiwi Fruit, Onion, Papaya, Pineapple, Potato (Mature), Sweet Potato, Watermelon *etc*.
Moderate	10 - 20	Apricot, Banana, Cabbage, Carrot (Topped), Cherry, Fig, Lettuce (Head), Mango, Peach, Pear, Plum, Potato (Immature), Radish (Topped), Tomato, Summer squash
High	20 - 40	Avocado. Carrot (with tops), Cauliflower, Leeks, Lettuce (Leaf), Radish (with tops), Raspberry
Very high	40 - 60	Artichoke, Bean Sprouts, Broccoli, Brussels sprouts, Cut flowers, Green Onion, Okra
Extremely high	> 60	Asparagus, Mushroom, Parsley, Peas, Spinach, Sweet corn

Factors responsible for the respiration (external and internal)

1. Temperature

2. RH

3. Gas composition in the ambient and within the cell

4. Moisture content of the tissue

5. Wounding or injury

6. Type of the plant parts

7. Stage of development of tissue

8. Surface area to volume of the produce

9. Pre-harvest treatments and PH methods employed

10. Chemical composition of tissue

11. Size of the produce

12. Presence of natural coating on the surface

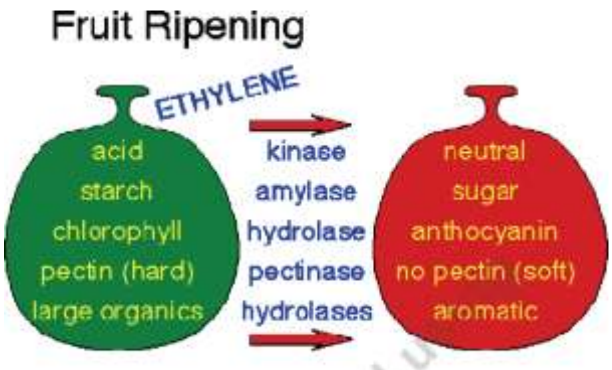
Ripening

Ripening refers to the changes that occur in a mature fruit either before harvest or after harvest. Ripening renders the product edible. Unripe fruits are not edible in most cases. Ripening fruits undergoes many physico chemical changes after harvest that determines the quality of the fruit eventually purchased by the consumer. Ripening is a dramatic event in the life of a fruit – it transforms a physiologically mature but inedible plant organ into a visually attractive olfactory and taste sensation. Ripening marks the completion of the development of a fruit and the commencement of senescence, and it is normally an irreversible event.

Ripening is the result of a complex of changes, many of them probably occurring independently of one another. Some fruits ripen on the tree itself, while others ripen only after harvest. Those, which don‘t normally ripen on the tree, drop off from the tree after attaining maturity if they are not harvested in time. There are two characteristic types of fruit ripening that shows different patterns of respiration.

Non climacteric fruit ripening—refers to those fruits which ripen only while still attached to the parent plant .Their eating quality suffers if they are harvested before they are fully ripe because their sugar and acid content does not increase further. Respiration rate slows gradually during growth and after harvest. Maturation and ripening are a gradual process. Eg. Cherry, cucumber, grape, lemon, pineapple, grape, citrus, straw berry etc.

Climacteric fruit ripening—refers to the fruits that can be harvested when mature but before ripening has begun. These fruits may be ripened artificially. The start of ripening is accompanied by a rapid rise in respiration rate, called the respiratory climacteric. After the climacteric, the respiration slows down as the fruit ripens and develops good eating quality. Eg. apple, banana, mango, sapota melon, papaya, tomato etc.



Changes occurring during ripening

During ripening, changes occur in colour, texture, taste, aroma and chemical constituents. These changes progress till the maximum edibility or taste is attained and there after the degradation or break down of tissues starts, rendering it unfit for eating. These changes are closely associated with the rate of respiration of the fruit.

Colour: Colour change is the most obvious signal; it occurs in many fruits and is often the major criterion used by consumers to determine whether fruits ripe or unripe. Marketability of fruit depends largely on the attractive colour it develops.

The colours arise from carotene, xanthophylls and anthocyanin pigments. Carotene and xanthophylls are yellow in colour and other colours of fruits like red, pink, violet etc are imparted by anthocyanin pigments.

The most common change is the loss of green colour.With a few exceptions, e.g. avocado, kiwifruit and granny smith apple, climacteric fruits show rapid loss of green colour on ripening. Many non-climacteric fruits also exhibit a marked loss of green colour with attainment of optimum eating quality, for example citrus fruit in temperate climates (but not in tropical climates).The green colour is due to the presence of chlorophyll ,which is a magnesium–organic complex. The loss of green colour is due to the degradation of the chlorophyll structure. The disappearance of chlorophyll is often associated with the synthesis of pigments ranging from yellow to red. Many of these pigments are carotenoids, which are unsaturated hydrocarbons.

Carotenoids are stable compounds and remain intact in the tissue even when extensive senescence has occurred.

Carotenoids may be synthesized during the development stages on the plant, but they are masked by the presence of chlorophyll .Following the degradation of chlorophyll, the carotenoid pigments become visisble. With other tissues, carotenoid synthesis occurs concurrently with the chlorophyll degradation.

Banana peel is an example of the former system and tomato of the latter. As the tomato fruit matures, the predominant carotenoid that is synthesized is carotene.

Anthocyanins provide many of the red purple colours of fruit and vegetables and flowers. Anthocyanins are water soluble phenolic glucosides that can be found in the cell vacuoles of fruit and vegetables such as beet root, but are often in the epidermal layers as with apple and grape. They produce strong colours, which often mask carotenoids and chlorophyll. Some fruits like grapes, pomegranate produces anthocyanins when mature. In tomato another pigment accumulates during ripening is lycopene.

The factors that effects fruit colorations are weather, temperature humidity, carbohydrate accumulation, and practices like ringing or girdlings and basketing of fruits. Manuring and irrigation also influence the brightness of colour. Excessive nitrogen tends to delay colour development. Shaded fruits don‘t develop good colour.

Organic acids: Usually organic acids decline during ripening as they are respired or converted to sugars. Acids can be considered as reserve source of energy to the fruit and would therefore, be expected to decline during the greater metabolic activity that occurs on ripening. There are exceptions, such as banana, where the highest level is attained at the full ripe stage, but the level is not high at any stage of development compared to the other produce.

Texture: Terms such as firmness, crispness, mealiness, juiciness and hardiness are all related to the texture of fruits and is controlled by the wall to wall adhesion of cells. Fruits become soft on ripening, mainly due to the dissolution of pectic substances in the cell walls. The softening is due to enzymatic hydrolysis of polysaccharides. The cell wall is made up of cellulose, hemicellulose, calcium pectatae, polyuronoides and glycoproteine. The enzyme pectinase break down pectin between the fruit cells resulting in softening of the fruit.

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

Aroma: Aroma plays an important part in the development of optimal eating quality in most fruit. It is due to synthesis of many volatile organic compounds (often known merely as volatiles) during ripening phase. Together with taste, it constitutes flavour. Aroma usually develops during ripening but occasionally in storage also. During ripening enzymes break down large organic molecules into smaller one that can be volatile (evaporate into the air) and can be detected as an aroma.

The flavouring compounds are found to be different in different types of fruit but all of them are volatile. The aroma of fruit is not due to a single chemical compound but it is a mixture of no. of chemicals, which may be derived from aliphatic compounds, alcohols, acetates, ketones or esters and terpinoides. In most of the fruits, the bioconversion of flavouring compounds increase with the advent of ripening. The process needs specific temperature for difficult types of fruits.

The major volatile formed is ethylene, which accounts for about 50-75% of the total carbon in the volatiles; ethylene does not contribute to typical fruit aromas. The amount of aroma compounds is therefore extremely small. Non-climacteric fruits also produce volatiles during the development of optimum eating quality. The fruits doesn‘t synthesize compounds as aromatic as those in climacteric fruit; nevertheless, the volatiles produced are still important in consumer appreciation.

Abscission: During ripening the pectinase enzyme also unglue the cells of the abscission zone (the layer of cells in the pedicels often called abscission zone). So, the cells in this zone become weak and the weight of the fruit will cause it to fall from the plant.

Development of surface wax: The delicate waxy or powdery substance develops on the surface of certain fruits like grape and berries.

Respiration rate: It is essential for ripening as it provides the energy required to drive many of the reactions and changes. If respiration is inhibited, ripening is also inhibited. Based on respiration characteristics fruits and vegetables can be divided into climacteric and non-climacteric. In non-climacteric fruits relatively low, consistant rate of respiration is maintained during ripening. The fruits often don‘t have large carbohydrate reserves and ripening occurs while attached to the plant.

Cucumber and olive are vegetables that are non-climacteric.

In contrast, in climacteric fruits the respiration declines during the final stages of maturation, as ripening proceeds the respiration rate increases rapidly reaching peak (often referred as climacteric peak) after which there is a subsequent decline in respiration. Tomato and bitter melon exhibit climacteric ripening.

Chemical changes: Starch is hydrolyzed in to sugars (Glucose and fructose), pectin‘s become soluble, acids disappear and tannins responsible for astringency are eliminated by the action of enzymes**.**

Factors influencing ripening

Temperature: Fruits picked up at right time generally ripen at any temperature between two critical limits. In certain cases fruits may require a cold treatment before being placed in the temperature limit for ripening.

Temperature affects the rate of synthesis of specific pigments and their final concentration in the fruit. The optimum and maximum temperature for synthesis of a specific pigment varies between species.

For example lycopene synthesis in tomato is inhibited at $30^{O}C$ where as in watermelon; synthesis is not prevented until the fruit temperature rises above $37^{O}C$.

Carbon- di- oxide: Elevated levels of CO_2 will inhibit ripening due to decrease in respiration.

Oxygen: Reduced levels of oxygen inhibit the ripening of fruits and vegetables. The use of elevated CO_2 and reduced O_2 levels in refrigerated storage is called **―Controlled atmospheric storage‖.**

Oxygen is essential for carotenoid synthesis and increasing the oxygen concentration enhances the synthesis of this pigment.

Radiation: May act as inhibitors or stimulators of ripening. Grapes ripen more quickly under treatment with ‗infrared' radiations. Banana irradiated with ‗X' rays exhibited a decrease in softening but an increase in skin blackening.

Air humidity: The relative humidity and velocity of the air in the vicinity of the fruit influence the maturity, especially in the evolution of flavour. Saturated air hinders the development of good flavour in pears. Apples show blackening of the core.

Volatiles: Non-ethylinic volatiles can stimulate ripening. Air purification with activated carbon, H2SO4 and NaOH slowed down the ripening of pre-climacteric apples in a recirculation system. Carbon (activated) reduces the effect in both the cases.

Growth regulators: These sometimes stimulate ripening of gathered fruits. It seems that the treatment is effective especially when the application is made very early soon after the picking. Stems of bananas immersed in solution containing 1000 ppm sodium 2,4-D, 2,4,5 -T or Para-chloro- phenoxy acetic acid showed that ripening was accelerated.2, 4,5 -T and to some extent 2,4-D when sprayed in a wax emulsion delayed the development of yellow colour in the rind of lemons during storage. The storage life increases.

Application of ethephon promotes degreening and early ripening in grape, tomato, coffee, pear, plum, peach and citrus. Smoking is commercially employed to hasten de-greening and ripening of banana and mango. Calcium carbide release acetylene which on hydrolysis hasten ripening process. ABA at 1ppm, thio- urea at 20%.CCC 4000ppm, ethrel 200-300ppm sprays one week before harvest hastens ripening.

Auxins may slow down (generally) or even sometimes accelerate ripening process. Ethylene formation is inhibited by auxin and therefore auxins have to be broken down by peroxidases (IAA Oxidases) to control fruit ripening. Ripening in accompanied by a rise in auxin degrading enzymes.

Gibberellins also stop colour changes in fruits like banana. Accumulation of abscisic acid (ABA) is also associated with ripening.

The shelf life of fruits like apple, banana and others can be improved by storing the fruit in low oxygen tension (203%) or by absorbing ethylene with a suitable absorbent like alumina or silica gel impregnated with potassium permanganate.

MH,GA (10-6M), IAA (10-6 M) sprays one to two weeks before harvesting and postharvest dip of cycocel, Alar, GA (150ppm), Vit K3, $KMNO_4$,$CaCl_2$,Waxol delays ripening.

Harvest: The extent to which certain fruits are pre-climacteric or post climacteric at the time of harvest is an important factor affecting ripening. The mere act of picking may influence the ripening rate of certain fruits. Detachment accelerates ripening of fruits like avocado and apple. It has been postulated that an inhibitory auxin was contributed by the leaves while the fruit is attached to the tree. In fruits like citrus, apples, bananas and avocados bruising often stimulate ripening. so; careful handling of fruits at the time of harvest is required.

Optimum ripening condition for fruits

Temperature	18-25^{0}C (<18delay ripening, > 25 microbes)
RH	85-90%
Ethylene conc.	10-100 ppm
Duration	12 -72 hours depending on fruit type and stage of maturity
Air circulation	Sufficient to maintain the distribution of ethylene within ripening room
Ventilation	Require adequate air exchange in order to prevent accumulation of O_2 which reduces the effectiveness of ethylene

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

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

Lecture 6

Role of ethylene in ripening of fruits and vegetable crops

Ethylene is a natural plant hormone released by all plant tissues and microorganisms. It is also called ‗Ripening hormone', as it plays an important role in ripening process. Low concentration of 0.1-1.0 microlitres is sufficient to trigger the ripening process in climacteric fruits.

It has autocatalytic activity because of which such small quantities can trigger further release of large quantities of ethylene by the fruit tissue. Very little response is only seen to exogenous application of ethylene in case of non-climacteric fruits.

Effect ethylene on fruit ripening

• Ethylene decides the postharvest life of fruits, vegetables and cut flowers.

• Synthesis of ethylene varies with maturity of fruits, vegetables and flowers.

• Synthesis of ethylene is less in young buds while it is more in opened and senescing fruits, vegetables and flowers.

• Endogenous ethylene production takes place in the style which triggers wilting and senescence of flowers.

• The most accepted pathway for synthesis of ethylene is methionine pathway.

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

Factors governing the activity of ACC synthase

Stage of senescence

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

Auxin level

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

Physical injury

• Physical injury induces the synthesis of ethylene

Chilling injury

• Chilling injury induces the synthesis of ethylene

Action of ethylene

• C2H4 + Receptor (Copper) C_2H_4 - Receptor complex Accelerate senescence

• Ag ++ replaces the copper which delays the senescence

Removal of ethylene

• Eliminate the ethylene sources

• Provide proper ventilation

• KMnO4 oxidizes the ethylene

$$C_2H_4 \xrightarrow{KMnO_4} CO_2 + H_2O$$

• Brominated or activated charcoal absorbs ethylene

Ethylene inhibitors

• Silver chloride ($AgCl_2$) • Silver nitrate ($AgNO_3$)

• Silver Thio Sulphate (STS) • Methyl Cyclo Propane (1- MCP)

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

Regulation of ethylene in storage

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

2. **Controlled atmosphere storage-** The rate of ethylene synthesis is low at high CO_2 and low O_2.

Class	Range at 20^0 C (μ C_2H_4 release $kg^{-1}hr^{-1}$)	Commodities
Very low	< 0.1	Artichoke, Asparagus, Cauliflower, Cherry, Citrus, Grape, Cut Flowers, Leafy Vegetables, Pomegranate, Potato, Root Vegetables, Strawberry
Low	0.1-1.0	Brinjal, Chilli, Cucumber, Green C
Moderate	1.0 -10	Banana, Guava, Fig, Litchi, Melon, Mango, Tomato
High	10-100	Apple, Apricot, Avocado, Kiwi Fruit (ripe), Papaya,Peach, Plum, Pear
Very high	> 100	Sapota, Passion Fruit

Sources of ethylene

1. **Ethylene gas** – pure C2H4 gas enclosed in the can/cylinder is sprayed /injected into chamber. Ethylene portable can which contain 3 g sufficient to ripe 2-6 ton of produce is available commercially.

2. **Ethephon** – Used as spray/ dip, acidic in water releases C_2H_4.

3. **Ethylene mixture -** C_2H_4 + inert gas like CO_2. Inert gas because not enough O2 remains in the chambers to provide an explosive mixture. Eg, Ripe gas contain 6% C_2H_4

4. **Ethylene generators** - Widely used method where in liquid spirit produces C_2H_4 when heated in the presence of catalyst platinised asbestos.

5. **Use of ripe fruits** – cheap and simple, where in ripe fruit with high C_2H_4 producers such as apple, banana, mango, sapota and tomato is used at home to ripe.

De-greening: It is the process of decomposing green pigments in fruits usually by applying ethylene or other similar metabolic inducers to give a fruit its characteristic colour as preferred by the consumer.

It is applicable to banana, mango, citrus and tomato. The time required to degreen a fruit depends upon the degree of natural colour break at maturity.

The higher the green colour and more mature a fruit is, the less time is required to reduce the chlorophyll to a desired level.

De-greening is carried out in special treating rooms with controlled temperature and humidity in which low concentrations ethylene (20ppm) is applied to keep the CO_2 level below 1 % (Low colouring). The ethylene should be supplied from a gas cylinder. These rooms are thoroughly ventilated to keep the carbon-dioxide level below 1%, which does not allow higher colouring. Ethylene accelerates decomposition of chlorophyll without significantly affecting the synthesis of carotenoid pigments. The best degreening temperature is 27oC.Higher temperature delay degreening. The Relative humidity should be 85-90%.Higher humidity levels cause condensation during degreening and are associated with slow degreening and increase in decay. Low humidity though checks decay causes excessive shrinkage, shriveling and peel break down.

Lecture 7

Preharvest operations to extend shelf life of fruits and vegetable crops

Quality of post-harvest product

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

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

A. Pre-harvest factors

a) Related to plants

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

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

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

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

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

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

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

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

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

b) Related to environments

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

c) Related to chemicals

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

B) During harvest factor

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

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

have lost water through transpiration and therefore are less brittle. Cucumber is harvested in the late morning when it to be transported under less than ideal condition because it is less prone to injury when it contains less water.

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

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

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

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 8

Postharvest handling of the produce

(Washing, fungicide treatment, precooling, grading,sorting, waxing and nano coating)

Postharvest handling

Fruits and vegetables are perishable in nature. After harvest, fruits and vegetables are liable to accelerated physiological, chemical and microbial processes that invariably lead to deterioration and loss of wholesomeness. Scientific harvesting and handling are the practical way to reduce the losses due to physical damage and spoilages due to insect damages and microbial growth.

Pre-cooling

Pre-cooling refers to removal of field heat (quick cooling) after harvest. The entire products must be pre-cooled as early as possible to the recommended storage temperature and relative humidity. Pre-cooling is done just above chilling and freezing temperature.

Advantages of pre-cooling:

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

Above factor helps in extends the product shelf life

Currently used pre-cooling methods include room cooling, forced air cooling, water cooling, vacuum cooling and package icing.

a) **Room cooling:** It is relatively a simple method which needs only a refrigerated room with adequate cooling capacity. The produce is packed in containers which are loosely stacked in the cooling room, leaving enough space between containers for each one to be exposed to circulating cold air. The rate of cooling is rather slow compared to other methods of cooling, because the heat inside each container needs to be transferred to the surface of the container by means of conduction before being carried out by the refrigerated air. It may take hours or even days to cool the product depending upon what kind of product it is, the size and nature of container and the temperature and velocity of the circulating air.

All fruits and vegetables like banana ,beans, cabbage, coconut, garlic ,ginger, lemon, onion, orange, lime cucumber, pineapple, potato, pumpkin, radish, sweet potato, tomato watermelon are pre cooled by this method.

b) **Forced air cooling:** It is a more rapid way of air to cool the produce. Cold air is forced to flow through the inside of each container, so that it carries away heat directly from the surface of the produce rather than from the surface of the container. The air flow is produced by creating a pressure difference between the two perforated sides of each container. The containers are stacked inside covered tunnel with an exhaust fan at one end. Highly perishable and high value products such as grapes, straw berries and rasp berries may be cooled in less than an hour using this method.

Fruits and fruit type vegetables like banana, berries, Brussels sprouts ,cucumber, eggplant, fig, ginger, grape, guava ,litchi, mango, kiwi fruit, okra, oranges, papaya, passion fruit, bell pepper, pineapple, pomegranate, sapota, straw berry, tomato, tubers, cauliflower etc are pre cooled by this method.

c) **Water cooling (Hydro cooling):** It is also known as hydro cooling. It is rapid and less expensive method. Produce is exposed to cold water by means of showering or dipping. The required cooling time is often a matter of minutes. However not all kinds of products tolerate hydro cooling.

Hydrocooled products inevitably have a wet surface which may encourage decay in some kinds of produce. Some leafy vegetables, fruits like artichoke, asparagus beet, broccoli, Brussels sprouts, cantaloupe, carrot, cauliflower, celery, Chinese cabbage, cucumber, brinjal, green onion, kiwifruit, leek ,knoll-khol ,orange, parsely, parsnip, peas, pomegranate, radish, spinach, rhubarb, swiss chard, summer squash etc. are pre cooled by this method.

d) **Vacuum cooling:** It is the most efficient method for cooling leafy vegetables, particularly headed ones such as lettuce, cabbage and Chinese cabbage. The produce is placed inside a vacuum tube in which air pressure is reduced. When the pressure is reduced to 4.6mm Hg, water boils of at 0^0C from all over the leaf surface. The boiling effect draws heat for vaporization and hence cools the produce. The cooling time is usually in the order of 20-30 minutes. The equipment needed for vacuum cooling is very expensive, and may not be good choice for small scale.

Some stem, leafy and flower type vegetables like endive, Brussels sprouts, carrot, cauliflower, Chinese cabbage, celery, leek, lima bean, spinach, sweet corn, swiss chard etc. are pre-cooled by this method.

e) **Package-icing or top icing:** It is the simplest way of cooling. Adding crushed ice, flake ice or slurry of ice in containers can cool the produce. However this method is not suitable for produce which is very sensitive to ice cold temperatures .Cooling by ice is also inevitably wets both the produce and the container and generates water which needs to be drained.

Roots, stems, flower type vegetables like endive ,broccoli, Brussels sprouts, carrot, spring, onions ,Chinese cabbage, leek, parsley, snow peace, spinach, swiss chard, sweet corn etc. are pre cooled by this method.

Curing: It is done immediately after harvesting. It strengthens the skin. The process is induced at a relatively higher temperature and humidity involving sterilization 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, garlic are cured prior to storage or marketing.

In Sweet potato this condition is most rapid at 33^0C and relative humidity of 95%. Potato tubers are held at 18OC for 2 days and then at 7^0C-10^0C 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. Maximum safe temperature for onion curing at field is 37.8^0C for 3-5 days. Artificial curing of onions in crates at 40^0C for 16 hours reduces rot losses in storage.

Washing

Fruits and vegetables are usually washed to remove the soil, sticking dirt or deposits of wax on the surface. Washing not only helps in cleaning and making the fruits/vegetables fresh and also improves the appearance. Washing also helps in extending the shelf life of the produce. Washing is done manually under tap water or in a wash tank. Produce should be thoroughly washed with clean water preferably with 100 – 150 ppm hypochlorite/chlorine or calcium hydroxide or sodium metabisulphate as disinfectant. After washing the produce is then wiped with dry muslin cloth or air dried to remove excess surface moisture. Under automated systems, the produce passes under a spray washer on a moving conveyor rollers. Thumb rule is to use 1 to 2 ml of chlorine bleach per liter of water (100-150 ppm of chlorine). pH of the water must be 6.5 to 7.5.

Chemical treatment

Succulent nature of fruits and vegetables make them easily invaded by these organisms. The common pathogens causing rots in fruits and vegetables are fungi such as *Alternaria, Botrytis, Diplodia, Phomopsis, Rhizopus, Pencillium* and *Fusarium* and among bacteria, *Erwinia* and *Pseudomonas* cause extensive damage.

Losses from post-harvest disease in fresh produce can be both quantitative and qualitative. Loss in quantity occurs where deep penetration of decay makes the infected produce unusable. Loss in quality occurs when the disease affects only the surface of produce causing skin blemishes that can lower the commercial value of a crop.

Mode of infection of micro organism

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

Damage by micro organism

It mainly causes physical loss of the edible matter, which may be partial or total. Also affects marketability, particularly where mold growth is obvious on the produce surface. In some cases the superficial infection also make the produce either entirely unmarketable or at least reduce its economic value.

Example: Fungi *Aspergillus flavus* and *A. parasitica* which produce aflatoxin like mycotoxin on ground nut kernels, coconut, dry beans and some leafy foods. The apples juice is also affected by mycotoxin "patulin" produced by *Penicillium patulum* and *P. expansum, P.urticae, Aspergillus clavatus* when stored for too long before being processed. This mycotoxin is carcinogenic and has maximum permitted levels of 50 ppb in fruit juices.

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

Sanitation

Sanitation is essential, both to control the spread of disease from one item to another and to limit spore buildup in wash water. Fungicide may be used as postharvest dip to control diseases and disorder. Excess water should be removed from the produce to avoid rotting. In crops where water dipping is possible, differential floatation could be used to separate rejects. Root and tuber vegetables are often washed to remove adhering soil.

Postharvest treatments with fungicides like Thiobendazole and Benomyl have rendered good control of stem end rot in citrus fruits, anthracnose of banana and mangoes despite the fact that infection occurred long before the treatment was applied. Safer and less toxic chemicals grouped under the category of GRAS (generally regarded as safe) can be used for the control of postharvest diseases of fruit and vegetables. These compounds mostly include weak organic acids, inorganic salts and neutralized compounds. It has been reported that extracts of *Eucalyptus globulus*, *Punica granatum*, *Lawsonia inermis*, *Datura stramonium* and *Ocimum sp*. extracts are effective against various fruits rots. Mustard, castor and paraffin oils have been found effective against *Rhizopus* rot of mango. Disinfection of all handling equipments in pack houses with 1-3% formaldehyde solution, hypochlorite or SOPP (Sodium ortho phenylphenate) will help in prevention of secondary infection.

Methods of Chemical Application

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

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

Eg. Citrus, apples, pineapple, root vegetables.

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

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

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

5. Fumigation / Vapour treatment – Fumigation is to eliminate insects, either adults, eggs, larvae or pupae and pathogen inoculum. Fumigant such as sulphur dioxide (SO2) is used for controlling postharvest disease in grapes. This is achieved by placing the boxes of fruit in a gastight room and introducing the gas from the cylinder to the appropriate concentration. This treatment results in a residue of 5-18 ppm SO2 in the grapes is sufficient to control decay. Its toxicity to *Botrytis cinerea* was found to be proportional to temperature over the range of 0- 30^0C, where the toxicity of SO_2 increased about 1 ½ times for every 10^0C rise in temperature. In general treatment with 0.5- 1% SO2 for 20 min is found to be effective fallowed by ventilation. During storage, periodic (every 7-10 days) fumigations are performed in concentrations of 0.25%.

Disadvantages

a. SO_2 can be corrosive, especially to metals, because it combines with atmospheric moisture to form sulphurous acids. Hence, special sodium met bisulphate impregnated pads are available which can be packed into individual boxes of fruits to gives a slow releases of SO2. Eg.: **Grape guard** used in grapes fruit packing.

b. At higher concentration it has bleaching effects on black grapes.

c. Some people are allergic to SO_2, particularly those who have chronic respiratory problems.

Litchi fruits - SO2 fumigation at 1.2% for 10 min. is used to prevent discolouration of the skins of fresh litchi fruits caused by fungal infection, followed by 2 min. dip in 1 N HCL stabilizes the red colour and reduces the skin browning.

Snap beans - Exposing the beans to SO2 at 0.7% for 30 seconds reduced the broken end discoloration due to mechanical injury.

Other chemicals

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

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

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

6. Cold storage – many insect pests do not tolerate prolonged exposure to low temperature. Storing the produce at <1.60C for 16 days has been shown to be effective for disinfesting fruits against Mediterranean and Queensland fruit fly. But chilling susceptible fruits are not suitable for the this method

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

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

8. Biological control

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

Chemicals used to control spoilage and quality in fruit and vegetables

Item	Chemicals
Apple	Sodium - phenyl phenate
Banana	Thiobendazole, Benomyl
Citrus	Sodium carbonate, Borax, SOPP, Biphenyl, 2,4- D, N Cl3 fumigation
Mango	Hot water, Benomyl
Grapes	SO_2 fumigation
Papaya	Hot water
Pomegranate	Ethyloleate
Potato	Hypochlorite
Carrot & cabbage	Thiobendazole , Benomyl
Onion	Benomyl
Sweet potato & tomato	2,6-dichloro-4-nitroaniline

Dry cleaning: Few fruits and vegetables are just wiped with clean dry cloth . In some cases cleaning is done by dry brushing instead of washing eg. removal of white cottony mealy bugs attached in between the surface holes of custard apple fruits. Few fruits and vegetables are not suitable for washing eg. onion, garlic, okra, grapes, strawberry, mushrooms, etc.

Dressing: Removal, trimming and cutting of all undesirable leaves/ stem/ stalks/ roots/ other nonedible or unmarketable parts is called dressing. Dressing makes vegetables attractive and marketable. Trimming is done especially in vegetables to remove unwanted, discoloured, rotting and insect damaged parts (e.g., cabbage, cauliflower, spinach, lettuce etc.) or parts that may favour deterioration or damage during later handling. In case of grapes, trimming of bunches is done to remove the undersize, immature, dried, split and damaged berries. Trimming and removal of decaying parts are preferably done prior to washing. Trimming enhances visual quality, minimizes water loss and other deteriorative processes. Trimming reduces the spread of diseases, facilitates packaging and handling and reduces damage for other produce.

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

Sorting: Sorting is done mainly to remove the foreign or undesirable items from desirable product.

Grading: Grading is the classification of cleaned product into various quality fractions depending upon various commercial values. It is done according to the weight or dimension. Grading can be done manually or by automatic grading lines. Size grading can be done subjectively (visually) with the use of standard size gauges. Round produce units can be easily graded by using sizing rings. The grading of fruits plays an important role in domestic and export marketing of fruits. Different fruits have different grades on the basis of their size and weight.

Grade designation and quality of fruits:

Minimum requirements are fruits and vegetables should be

- clean and fresh in appearance
- free from damage caused by pests or diseases
- free from any visible foreign matter and foreign smell and/or taste

The grades of different fruits and vegetables suggested by Directorate of Marketing and Inspection (DMI) are as detailed below,

Mangoes:

Grade	Fruit weight(g)	Max. permissible difference between fruits within packages (gm)
A	100-200	50
B	201-350	75
C	351-550	100
D	551-800	125

Waxing

Fruits and vegetables have a natural waxy layer on the whole surface, which is partly removed by washing.

Waxing is especially important if tiny injuries and scratches on the surface of the fruit or vegetable are present and these can be sealed by wax. Waxes are esters of higher fatty acid with monohydric alcohols and hydrocarbons and some free fatty acids.

Waxing generally reduces the respiration and transpiration rates, but other chemicals such as fungicides, growth regulators, preservative can also be incorporated specially for reducing microbial spoilage, sprout inhibition etc. However, it should be remembered that waxing does not improve the quality of any inferior horticulture product but it can be a beneficial in addition to good handling.

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

Waxing is artificial application of a very thin film of wax or oil or other material to the surface of the fruits or vegetables as an addition to or replacement for the natural wax coating.

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

Advantages of wax application are:

- Improved appearance
- Reduced PLW - reduced moisture losses and retards wilting and shriveling during storage
- Reduced weight loss
- Prevents chilling injury and browning
- Protect produce from bruising
- Reducing respiration rate - by creating diffusion barrier between fruit and surrounding as a result of which it reduces the availability of O2 to the tissues.
- Protects fruits from micro-biological infection

- Considered a cost effective substitute in the reduction of spoilage when refrigerated storage is unaffordable.
- Carrier agent - used as carrier for sprout inhibitors, growth regulators and preservatives.
- Increase in the shelf life

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

Disadvantage:

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

How fruit coating works?

Fruit coating results in the restriction of the gas exchange between the fruit and surrounding atmosphere. This causes a builds up of CO2 and a depletion of O2 with in the fruit, thus causing an effect similar to CAS (controlled atmosphere storage).

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

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

Fruits suitable for waxing

1. Immature fruit vegetables - cucumbers and summer squash
2. Mature fruit vegetables - eggplant, peppers and tomato, potato, pumpkin, carrot, snake gourd, coccinia and capsicum

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

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

Types of Waxing

A. Natural waxing

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

B. Artificial waxing

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

List of commercial waxes

Waxes

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

Methods of wax application

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

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

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

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

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

Trade name of some extensively used waxes

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

Use of wax concentration on the fresh produce

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

Cost of wax treatment

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

Colouring waxes - Dyes are sometimes added to waxes for greater consumer appeal, it is being used on red variety of Irish potatoes, sweet potatoes, and other vegetables. They enhance the colour to give the same shade or tint as when the roots were freshly dug. In citrus fruits, dye has been approved for general use. Citrus Red No.2 is 1-2(2,5-dimethoxy phenylazo)2-napththol with an established tolerance of 2 ppm.

Lecture 10

Importance of Packaging, Types of Packaging and PackagingMaterials

Food Packaging:

In today's society, packaging is pervasive and essential. It surrounds, enhances and protects the goods we buy, from processing and manufacturing, through handling and storage, to the final consumer. Without packaging, materials handling would be a messy, inefficient and costly exercise and modem consumer marketing would be virtually impossible. The packaging sector represents about 2% of Gross National Product (GNP) in developed countries and about half of all packaging is used to package food.

Definition of packaging:

Packaging has been defined as a socio scientific discipline which operates in society to ensure delivery of goods to the ultimate consumer of those goods in the best condition intended for their use.

The Packaging Institute International (PII) defines packaging as the enclosure of products, items or packages in a wrapped pouch, bag, box, cup, tray, can, tube, bottle or other container form to perform one or more of the following functions: containment, protection, preservation, communication, utility and performance. If the device or container performs one or more of these functions, it is considered a package.

Other definitions of packaging include a co-ordinated system of preparing goods for transport, distribution, storage, retailing and end-use, a means of ensuring safe delivery to the ultimate consumer in sound condition at optimum cost, and a techno-commercial function aimed at optimizing the costs of delivery while maximizing sales.

Package, Packaging, Packing:

It is important to distinguish between the words "package," "packaging" and "packing." The package is the physical entity that contains the product. Packaging was defined above and in addition, is also a discipline. The verb "packing" can be defined as the enclosing of an individual item (or several items) in a package or container.

Levels of Packaging:

A **primary package** is the one which is in direct contact with the contained product. It provides the initial, and usually the major protective barrier. Example: Metal cans, paperboard cartons, glass bottles and plastic pouches, aerosal spray can, Beverage can, cushioning envelopes, plastic bottles, skin pack.

A **secondary package** contains a number of primary packages. It is outside the primary packaging perhaps used to group primary packages together. It is the physical distribution carrier and is sometimes designed so that it can be used in retail outlets for the display of primary packages. Ex. Corrugated case, Boxes

A **tertiary package** is made up of a number of secondary packages. It is used for bulk handling. Example being a stretch-wrapped pallet of corrugated cases.

A **quaternary package** is frequently used to facilitate the handling of tertiary packages. This is generally a metal container up to 40 m in length which can be transferred to or from ships, trains, and flatbed trucks by giant cranes. Certain containers are also able to have their temperature, humidity and gas atmosphere controlled. This is necessary in particular situations such as the transportation of frozen foods, chilled meats and fresh fruits and vegetables.

Functions of packaging:

Contain

- portion control (profitability)
- consistency
- company reputation
- consumer expectation
- consumer convenience

Protect

- contamination
- maintain quality
- legislation (Codex, local legislation)
- product consistency
- company reputation

Inform (labelling)

- nature of the contents
- legislation, Codex, and other codes
- nutrition
- instructions for use
- elimination of fraud
- storage requirements

Attract

- advertise that this product is satisfying and fun and healthy

Classification of Packages:

Packages can be classified as 1) traditional or natural and 2) fabricated or modern packaging materials based on the availability of the materials.

Traditional or natural packaging materials are – Bamboo basket, fiber or leaf mats, Leather containers of animal skin, clay containers, gunny bags, cloth bags, Arecanut and teak leaves sheath.

Modern packaging materials can be divided into rigid, semi rigid and flexible materials.

- **Rigid containers** are – metal drums, metal barrels, glass bottles, glass jars, wooden boxes, wooden crates, plastic bottles, plastic drums, plastic crates, paper drums, plywood containers.
- **Semi rigid containers** are – aluminium collapsible tube, plastic collapsible tube, composite container, paper based cartons.
- **Flexible container** is plastic bags.

Types of Packaging Materials:

1. Paper based packaging materials
2. Metal packaging materials
3. Glass packaging materials
4. Plastic packaging materials
5. Edible and bio based packaging materials

Paper as Packaging Material:

Paper derives its name from the reedy plant ―papyrus‖, which the ancient Egyptians used to produce the world's first writing material by beating and pressing together thin layers of the plant stem. Paper is widely used as a packaging material because of its stiffness and printability.

The main **advantages of paper as packaging material** are – Good stiffness, good absorbent, good creaseability, good printability, low density, not brittle, biodegradable, low cost.

The main **disadvantages** are – poor tensile strength, poor wet strength, tear easily, no barrier property without coating.

Types of Paper:

- Kraft paper
- Bleached paper
- Greaseproof Paper
- Glassine paper
- Vegetable parchment
- Waxed paper

Paper is divided into two broad categories:

- Fine papers, generally made of bleached pulp, and typically used for writing paper, bond, ledger, book, and cover papers, and

- Coarse papers, generally made of unbleached kraft softwood pulps and used for packaging.

Paperboard Products:

Paper is generally termed board when its grammage exceeds 224 g m^{-2}. Multiply boards are produced by the consolidation of one or more web plies into a single sheet of paperboard, which is then subsequently used to manufacture rigid boxes, folding cartons, beverage cartons and similar products. One advantage of multi-ply forming is the ability to utilize inexpensive and bulky low-grade waste materials (mostly old newspapers and other postconsumer waste papers) in the inner plies of the board where low fiber strength and the presence of extraneous materials (e.g., inks, coatings, etc.) have little effect on board properties. However, multi-ply boards containing postconsumer waste papers are not used for food contact purposes.

Paperboard Grades:

- Linerboard
- Foodboard
- Folding Boxboard (Cartonboard)
- Chipboard
- Folding Cartons
- Beverage Cartons
- Molded pulp containers

Metal packaging materials

Four metals are commonly used for the packaging of foods: steel, aluminium, tin and chromium. Today, materials like tinplate and aluminum have become universally adopted for the manufacture of containers and closures for foods and beverages, largely due to several important qualities of these metals. These include their mechanical strength and resistance to working, low toxicity, superior barrier properties to gases, moisture and light, ability to withstand wide extremes of temperature and ideal surfaces for decoration and lacquering.

Advantages

Metal cans have a number of advantages over other types of container, including the following:

- They provide total protection of the contents
- They are convenient for ambient storage and presentation
- They are tamperproof.

Disadvantages

- The high cost of metal and the high manufacturing costs make cans expensive.
- They are heavier than other materials, except glass, and therefore have higher transport costs

Protective and Decorative Coatings:

- They protect the metal from the contents
- They avoid contamination of the product by metal ions from the container
- They facilitate manufacture
- They provide a basis for decoration and product dentification
- They form a barrier to external corrosion or abrasion

Protective coatings:

For most containers, the enamel is applied to the metal in the flat before fabrication. Many types of internal enamel are available for food containers including oleoresinous, vinyl, vinyl organosol, acrylic, alkyd, polybutadiene, phenolic and epoxyphenolic

Decorative Coatings:

Although the primary purpose in decorating the external surface of a metal container is to improve its appearance and assist its marketability, it also significantly improves the container's external corrosion resistance.

Aluminum foils and containers:

Aluminum foil is a thin-rolled sheet of alloyed aluminum varying in thickness from about 4 to 150 µm. Foil can be produced by two methods: either by passing heated aluminium sheet ingot between rollers in a mill under pressure and then rerolling on sheet and plate mills until the desired gauge is obtained, or continuously casting and cold rolling. Aluminum foil is essentially impermeable to gases and water vapor when it is thicker than 25.4 µm, but it is permeable at lower thicknesses due to the presence of minute pinholes

Glass packaging materials

Glass has been defined by the American Society for Testing and Materials (ASTM) as "an amorphous, inorganic product of fusion that has been cooled to a rigid condition without crystallizing‖. The two main types of glass container used in food packaging are bottles (which have narrow necks) and jars (which have wide openings).

Advantages:

Glass containers have the following advantages:

- They are impervious to moisture, gases, odours and micro-organisms
- They are inert and do not react with or migrate into food products
- They are suitable for heat processing when hermetically sealed

- They are re-useable and recyclable
- They are resealable
- They are transparent to display the contents
- They are rigid, to allow stacking without container damage.

Disadvantages:

- Higher weight which incurs higher transport costs than other types of packaging
- Lower resistance than other materials to fractures, scratches and thermal shock
- More variable dimensions than metal or plastic containers
- Potentially serious hazards from glass splinters or fragments in foods.

Plastic packaging material:

Plastics are organic polymers which are long chain molecules obtained by addition or condensation of one or more monomers. Polymerization of single repeating unit gives homo polymers and addition of more than one monomer results in co-polymer.

Plastics have become a major packaging material, along with paper, metal and glass. Plastics are used mainly for consumer packages in the form or wraps, pouches, cartons, bags, tubes, bottles, jars and boxes. In transport, they are used in the form of sacks, stretch films for wrapping tray-loads, containing unit packs or for entire pallet loads. The advent of snack foods, convenience foods and prepared foods has been possible to a great extent due to the availability of plastic packaging materials.

Advantages:

- Barrier to water vapour and gases
- Light weight
- Good strength
- Design flexibility
- Resistance to breakage
- Machinability-high speed filling using form fill and seal techniques
- Glossy and transparent
- Colouring is possible
- High tensile strength
- High tear strength
- High printability
- High level lamination
- Low cost

Disadvantage:

- The disadvantage of plastic is the disposability i.e. it is difficult to get it disintegrated into soil.

Polyethylene:

It is the polymer of ethylene. It accounts for the biggest proportion of the plastics used in packaging. It is good barrier to water vapour but less to oxygen; has high permeability to volatile oils and swells in contact with fats and oil. It gives very good heat seals and easily coated to other materials and serves as a laminated layer. It is used as bags, liners, bottles

1. Low Density Polyethylene (LDPE):
2. Linear Low Density Polyethylene (LLDPE):
3. High Density Polyethylene (HDPE):

Polypropylene (PP):

Polypropylene is a linear polymer containing little or no unsaturation. PP has low water vapour transmission, medium gas permeability, good resistance to greases and chemicals, good abrasion resistance, high temperature stability, good gloss and high clarity

Polystyrene (PS):

It is produced by the polymerization of styrene. It is transparent, but has low barrier property. The material is used for packing vegetables and fresh meat on trays, yoghurt and other milk products in cups, and for the over wrapping of fruits and vegetables.

Polycarbonate:

It is glass-like, heat resistant, and sterilisable upto 130°C and is available in the form of film, beside the rigid containers, but has very few food packaging applications.

Polyvinyl Chloride (PVC):

There are two types – rigid and plasticized. The rigid form has good moisture and gas barrier properties and resistance to fats. Hence, these are used for packing butter or margarine, and for making transparent bottles for mineral water, edible oils, fruit juices, carbonated beverages and beer, as these bottles can withstand pressure. The plasticised form is used for packing meat, fruits and vegetables and for shrink wrapping. It is also used for the shrink wrapping of pallets.

Polyvinylidene Chloride (PVdC):

PVDC has the lowest water vapour, oxygen and CO2 permeability amongst all commercially used plastic films, besides having resistance to fats and chemicals. PVDC is used as a coating material on polyethylene and other plastics, to improve the gas and moisture barrier properties of the native plastics. It is used for packing dense materials like cheese, poultry etc.

Ethylenevinyl Alcohol (EVOH):

EVOH copolymers offer not only excellent processability but also superior barriers to contaminants such as gases, odors, fragrances and solvents. It is widely used polymer in the manufacture of high barrier containers, as in the manufacture of bulk bags used for aseptic packaging, retort pouches and containers.

Polyethylene Terephthlate (PET):

PET is a linear, transparent thermoplastic polymer. It has low permeability to moisture and gases, but has poor sealing property. Hence, it has to be laminated with PE. PET containers are used widely for packing mineral water, carbonated and non-carbonated beverages, syrups, edible oils and liquors.

Retort Pouch:

The retort pouch is a flexible package, hermetically sealed on three or four sides and made from one or more layers of plastic or foil, each layer having a specific functionality. The advantages include the ease of carrying, reheating and serving, as well as weight and space saving. Finally, disposal of the used pouch is much simpler than for the metal can as it can be easily flattened. Three-layer pouch structure would consist of an outer layer of 12 μm PET for strength and toughness, a middle layer of 7 to 9 μm of aluminium foil as a moisture, light and gas barrier and an inner layer of 70 to 100 μm of CPP for heat sealability, strength and compatibility with all foods. An additional inner layer of 15 to 25 μm of PA is used when a longer shelf life is required.

Edible and bio based packaging materials

Biodegradable polymers are a newly emerging field in food packaging. These are biodegradable, ecofriendly and are produced from natural or renewable resources. Biodegradable polymers (BDPs) or biodegradable plastics refer to polymeric materials that are ‗capable of undergoing decomposition into carbon dioxide, methane, water, inorganic compounds, or biomass in which the predominant mechanism is the enzymatic action of microorganisms, that can be measured by standardized tests, in a specified period of time, reflecting available disposal condition'.

Classification of Biodegradable Polymers

Biopolymers can be classified into two main groups, these two groups being

- The agropolymers obtained by biomass fragmentation processes (polysaccharides, proteins…),
- The biopolyesters obtained
  - by synthesis from bio-derived monomers (polylactic acid – PLA) or

- by extraction from micro-organisms (polyhydroxyalkanoate – PHA) or
- by synthesis from synthetic monomers (polycaprolactone – PCL, aromatic and aliphatic copolyesters – PBAT, PBSA…)

Advantages of Biodegradable Polymers

The principal advantages of plastics are their cost, functionality, durability and weight. The advantages of biodegradable plastic are numerous.

- Biodegradable plastics take less time to break down
- Biodegradable plastics are renewable
- Biodegradable plastics are good for the environment
- Biodegradable plastics require less energy to produce
- Biodegradable plastics are easier to recycle
- Biodegradable plastics are not toxic
- Biodegradable plastics reduce dependence on foreign oil

Controlled atmosphere Packaging:

Controlled atmosphere packaging (CAP) is the enclosure of food in a gas impermeable package inside which the gaseous environment with respect to CO_2, O_2, N_2, water vapor and trace gases has been changed, and is selectively controlled to increase shelf life. In this technology, the storage system consists of airtight storage chambers, O_2 regulatory unit, CO_2 absorbing unit equipment for monitoring as well as controlling the chambers and composition. Liquid N_2 generator is commonly installed to flush and chambers with liquid N_2 as and when required for maintaining optimum level of O_2. For maintaining optimum level of CO_2 in the chambers, air in chambers is circulated through CO_2 scrubber frequently. CO_2 absorbing materials such as hydrated lime, calcium or potassium hydroxides are generally used in scrubber. Refrigeration unit is employed for maintaining storage temperature. The storage life of various fruits and vegetables can be increased by 2 to 4 times the normal life by employing Controlled Atmosphere storage technology.

Modified Atmosphere Packaging:

Modified Atmosphere Packaging (MAP) can be defined as the enclosure of food in a package in which the atmosphere inside the package is modified or altered to provide an optimum atmosphere for increasing shelf life and maintaining quality of the food. Modification of the atmosphere may be achieved either actively or passively. Active modification involves displacing the air with a controlled, desired mixture of gases, a procedure generally referred to as gas flushing. Passive modification occurs as a consequence of the food's respiration or the metabolism of micro-organisms associated with the food; the package structure normally incorporates a polymeric film, and so the permeation of gases through the film (which varies depending on the nature of the film and the storage temperature) influences the composition of the atmosphere that develops.

Advantages:

- Shelf life will be increased by 50 to 400%.
- Reduced economic losses due to longer shelf life.
- Provides a high quality product.
- Centralized packaging and portion control.
- Improved presentation – clear view of product and all –around visibility.
- Little or no need for chemical preservatives.
- Sealed packages are barriers against product recontamination and drip from package.
- Odorless and convenient packages.

Disadvantages:

- Added costs for gases, packaging materials and machinery.
- Temperature control necessary.
- Different gas formulations for each product type.
- Special equipment and training required.
- Increased pack volume adversely affects transport costs and retail display space.
- Loss benefits once the pack is opened or leaks.
- CO_2 dissolving into the food could lead to pack collapse and increased drip.

Gases used in MAP:

The three main gases used in MAP are CO_2, O_2, and N_2, either singly or in combination.

Carbon dioxide: Carbon dioxide is the most important gas in the MAP of foods because of its bacteriostatic and fungistatic properties. It inhibits the growth of any spoilage bacteria, the degree of inhibition increasing with increasing concentration.

Oxygen: Oxygen promotes several types of deteriorative reactions in foods including fat oxidation, browning reactions and pigment oxidation. Most of the common spoilage bacteria and fungi require O_2 for growth. For these reasons, O_2 is either excluded or the level set as low as possible. Exceptions occur where O2 is needed for fruit and vegetable respiration or the retention of color in red meat.

Nitrogen: Nitrogen is an inert gas with no odor or taste. It has a lower density than air and a low solubility in water and other food constituents, making it a useful filler gas in MAP to counteract package collapse caused by CO_2 dissolving in the food. Nitrogen indirectly influences the micro-organisms in perishable foods by retarding the growth of aerobic spoilage microbes but it does not prevent the growth of anaerobic bacteria.

Labelling

Labelling‖ includes any written, printed or graphic matter that is present on the label, accompanies the food, or is displayed near the food, including that for the purpose of promoting its sale or disposal

Nutrition labelling

Nutrition labelling is information found on the labels of prepackaged foods. The legislated information includes:

- The Nutrition Facts table
- The ingredient list
- Some optional nutrition claims

These give information about the nutritional value of a food. The Nutrition Facts table gives information about calories, 13 core nutrients and percentage daily value (% DV) of nutrients. All of the information in the Nutrition Facts table is based on an amount of food. This amount is always found at the top of the nutrition facts table.

Important functions of labelling:

(i) Describe the Product and Specify its Contents:

A label provides complete information regarding the product. It mainly includes ingredients of the product, its usage, and caution in use, cares to be taken while using it, date of manufacturing, batch number, etc.

(ii) Identification of the Product or Brand:

It is easier to identify a particular product among many with the help of labelling.

(iii) Grading of Product:

When a product has different qualities, labelling helps to find out which pack contains what type of quality

(iv) Help in Promotion of Products:

The fourth function of labeling is to promote sales. Sometimes a consumer gets encouraged to buy a product simply due to attractive label. Nowadays labeling is used as an effective sales promoting tool.

(v) Providing information required by Law:

Another important function performed by labeling is to provide statutory warning required by law. To put ‗smoking is injurious to health' on the package of cigarette and ‗Chewing Tobacco is Injurious to Health' on the package of Pan Masala are the examples of statutory warning? Similarly, in case of hazardous or poisonous products, appropriate statutory warning need to be put on the label.

Mandatory Labelling of Prepackaged Foods

The following information shall appear on the label of prepackaged foods

The name of the food

The name shall indicate the true nature of the food and normally be specific and not generic. A –coined‖, –fanciful‖, –brand‖ name, or –trade mark‖ may be used

List of ingredients

Except for single ingredient foods, a list of ingredients shall be declared on the label. The list of ingredients shall be headed or preceded by an appropriate title which consists of or includes the term ‗ingredient'. All ingredients shall be listed in descending order of ingoing weight (m/m) at the time of the manufacture of the food. The following foods and ingredients are known to cause hypersensitivity and shall always be declared:

- Cereals containing gluten; i.e., wheat, rye, barley, oats;
- Crustacea and products of these;
- Eggs and egg products;
- Fish and fish products;
- Peanuts, soybeans and products of these;
- Milk and milk products (lactose included);
- Tree nuts and nut products; and
- Sulphite in concentrations of 10 mg/kg or more.

Net contents and drained weight

The net contents shall be declared in the metric system (–Système International‖ units). The net contents shall be declared in the following manner:

(i) for liquid foods, by volume;

(ii) for solid foods, by weight;

(iii) for semi-solid or viscous foods, either by weight or volume.

Name and address

The name and address of the manufacturer, packer, distributor, importer, exporter or vendor of the food shall be declared.

Country of origin

The country of origin of the food shall be declared if its omission would mislead or deceive the consumer.

Lot identification

Each container shall be embossed or otherwise permanently marked in code or in clear to identify the producing factory and the lot.

Date marking and storage instructions

If not otherwise determined in an individual Codex standard, the following date marking shall apply:

(i) The –date of minimum durability‖ shall be declared.

(ii) This shall consist at least of:

- the day and the month for products with a minimum durability of not more than three months;
- the month and the year for products with a minimum durability of more than three months. If the month is December, it is sufficient to indicate the year.

(iii) The date shall be declared by the words:

- –Best before …‖ where the day is indicated;
- –Best before end …‖ in other cases.

(iv) The words referred to in paragraph (iii) shall be accompanied by:

- either the date itself; or
- a reference to where the date is given.

(v) The day, month and year shall be declared in uncoded numerical sequence except that the month may be indicated by letters in those countries where such use will not confuse the consumer.

Lecture 11
Methods of storage of fruits and vegetables

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

Goals of storage

- Slow down biological activity
- Reduce product drying and moisture loss
- Reduce pathogenic infection
- Avoid physiological disorders
- Reduce physical damage
- Factors affecting storage

Storage life of fresh horticultural produce is affected by many factors like

i) Pre harvest factors

ii) Maturity at harvest

iii) Harvesting and handling practices

iv) Pre-storage treatments

v) Temperature and humidity in storage room

Overall hygiene

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

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

Principles of storage

1. Control of respiration

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

2. Control of transpiration

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

Hence, this process can be controlled by storing the produce at low temperatures and high relative humidity.

3. Prolonging the Dormancy period/Control of sprouting and rooting

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

4. Control of spoilage

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

Traditional storage

A. Traditional / Low Cost Storage Technologies

In situ/ On site/ Natural or field storage

In Situ means delaying the harvest until the crop is required and is employed for the root, tuber and rhizomes crops. Crops should be left in the soil until preparation for the market. The land where crop is grown remains occupied and new crop cannot be planted there. This is similar to how citrus and some other fruits are left on the tree. Eg.: Roots (carrots, sweet potato, and cassava) tubers (potato) and rhizomes (Ginger). Disadvantages: In case of cassava, delayed harvest results in reduced acceptability and starch content and pre harvest losses. The crops should be protected from pest and disease attack, chilling and freezing injuries.

Sand and Coir

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

Bulk storage of dried bulb crops

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

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

Clamp storage of root and tuber crops

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

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

Storage using evaporative coolers/ Evaporative cooling

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

Zero Energy Cool Chambers (ZECC)

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

Design and Construction

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

Operation: After construction, the whole structure is made wet by sprinkling water once in evening till it is saturated to maintain a lower temperature and higher humidity in it. Direct contact of water with fruits and vegetables should be avoided. Fruits and vegetables should be placed in crates or in suitable baskets and then in the chamber. Maximum and minimum thermometer and a wet and dry thermometer are placed in the chamber to note temperature and relative humidity in the cool chamber. Storage life-Storage life of different commodities can be increased by 2 to 3 times as compared to ambient conditions especially during summer.

Natural ventilation

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

Improved storage methods

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

Low temperature storage (Refrigeration/cold storage)

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

Why cold storage is necessary?

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

Product quality: Fresh horticultural produce intended for storage should be free from physical damage, of optimum maturity and free from infections.

Temperature: Low temperature storage is recommended for perishables as it retards respiration and metabolic activity, aging due to ripening, softening and textural and colour changes, moisture loss, spoilage due to diseases and undesirable growth (sprouting/ cooling). Maintenance of uniform temperature constantly, continuously and also adoption of optimum low temperature for each specific produce are very essential.

Relative Humidity: The relative humidity of the air in storage rooms directly affects the keeping quality of the produce held in them. If it is too low, wilting or shrivelling is likely to occur, if it is too high, it may favour the development of decay. An RH of 85-90% is recommended for most perishables.

Air circulation and package spacing: Air must be circulated to keep a cold storage room at an even temperature throughout the storage. This is required to remove respiratory heat. Entry of outside air and proper spacing of containers on pellets are also important.

Respiration rates, heat evolution and refrigeration: When the storage of fresh produce is considered, it should be remembered that these commodities are alive and carry on all activities of living tissues, the most important being respiration. During this process, energy is released in the form of heat which varies with the commodity and the temperature. This `vital heat' expressed in BTU (British thermal units) is of paramount importance in calculating the refrigeration load of the commodity.

Low Pressure Storage / Hypobaric Storage

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

Mechanism

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

The storage of fruits and vegetables in CA Storage is one of the most advanced methods of storage. It was first suggested by W.R. Philips of Canada. From the construction point of view, controlled atmosphere facilities are similar to refrigeration facilities.However, they should be airtight to allow creation of an atmosphere different from normal. The Oxygen consumption and its replacement by carbon dioxide by respiration, create the atmosphere. When the appropriate combination has been reached, a limited intake of oxygen is required to satisfy the reduced rate of respiration. Accumulation of carbon dioxide is removed by means of different methods.

CA Storage

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

Essential features of CA Storage

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

Benefits of CA storage

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

Limitations of CA storage

1. Causes certain physiological disorders such as black heart in potatoes, brown stain of lettuce.
2. Irregular ripening of produce such as banana, pear, tomato etc.
3. Development of off flavours and off odours at very low O_2 concentrations.

4. Timely non availability of gas

5. Costly and technical knowhow is required

Modified Atmosphere storage (MAS)

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

Biochemical and Physiological Basis of MA

The rate of respiration and metabolism doubles for every 10°C rise in temperature. Respiration can be therefore reduced by decreasing the temperature, O_2 level and/or increasing the CO_2 level in the storage atmosphere. Both O_2 and CO_2 levels exert independent effects on respiration. The net effect may be additive or synergistic. When O_2 concentration is reduced below 10%, respiration rate is decreased. However, when O_2 concentration falls below 2%, anaerobic respiration may set in, thereby leading to the accumulation of ethanol and acetaldehyde.

The desirable effect of MA on plant tissues is also attributed to lower pH, due to dissolution of CO_2 in tissues. Ethylene action and biosynthesis are also effected besides water loss and chilling injury

Environmental factors affecting MA storage

a. Temperature and relative humidity

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

b. Light

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

c. Sanitation Factors

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

Differences between CA and MA Storage

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

Lecture – 12

Principles and methods of preservation of fruits and vegetables

Preservation

Preservation are the measures employed to prevent (or) minimize all such undesirablechanges takes place due to spoilage which caused by both internal and external organisms.

Need for preservation of foods

Freshly harvested or prepared products are highly attractive in appearance and possess good taste and aroma, but deteriorate rapidly if kept for some time. This is due to (1) Fermentation caused by moulds, yeasts and bacteria (2) Enzymes present in the products may affect the colour and flavour adversely (3) Chemicals present in the processed food react withone another and spoil its taste and aroma (4) Air coming in contact with the product, may react with the glucosidal materials present in it and render the product bitter (5) Traces of metal from the equipment may get into the product and spoil its taste and aroma.

Importance / advantages of food preservation

1. Prevention of colossal wastage of fresh produce
2. To extend the shelf life of the produce.
3. To develop value added products.
4. Self-employment opportunities.
5. Provides convenient and preferable forms to the consumer (jam, jellies, RTS, squash,etc.,)
6. Foreign exchange earnings from the export of processed foods and it will improve ournational economy.
7. Available in the form of ready to serve and hence (fuel consumption) energy is saved.In the preservation of foods by various methods the following principles are involved.

1. Preservation or delay of microbial decomposition and
2. Preservation or delay of self - decomposition of the food

I. PREVENTION OR DELAY OF MICROBIAL DECOMPOSITION

1. Asepsis (Absence of infection)

Asepsis means preventing the entry of microorganisms. The inner tissues of healthy plants and animals usually are free from microorganisms and if any microorganisms are present, they are unlikely to initiate spoilage. If there is a protective covering about the food, microbial decomposition is delayed or prevented. Examples of such coverings are the shells of nuts, the skins of fruits and vegetables, the husks of ear corn, the shells of egg and the skin, membranes (or) fat on meat (or) fish. It is only when the protective covering has been damaged (or) decomposition has spread from the outer surface that the inner tissues are subjected to decomposition of microorganisms.

Maintaining of general cleanliness while harvesting, handling, grading, packing and transporting of fruits and vegetables increase their keeping quality and the products prepared form them will be of superior quality.

Washing (or) wiping of fruits and vegetables before processing should be strictly followed as dust and soil particles adhering to the raw materials contain microorganisms and by doing so the number of organisms can be reduced considerably.

Packaging of foods is a widely used application of asepsis. The covering may range from a loose carton (or) wrapping, which prevents primarily contamination during handling, to the hermetically seale3d container of canned foods, which, if tight, protects the processed contents from contamination by microorganisms.

2) Preservation by high temperature

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.

High temperature preservation are usually used for: (1) Pasteurization temperature – below 100^0C (2) Heating at about 100^0C and (3) Sterilization temperature above 100^0C

a) Pasteurization – below 100^0C

Pasteurization is a heat treatment that kills part but not all the microorganisms present and the temperature applied is below 100^0C. 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 (i) refrigeration eg. of milk (2) keeping out microorganisms usually by packaging the product in s 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.

Methods of pasteurization

HTST method - High temperature and short time (above 70^0C)

LTH method - Low temperature and higher time (or) Holding method (60 - 70^0C)

b) Heating at about 100^0C

A temperature of approximately 100^0C is obtained by boiling a liquid food, by immersion of the container of food in boiling water or by exposure to flowing steam. Some very acid foods, e.g., sauerkraut may be preheated to a temperature somewhat below 1000C, packaged hot, and not further heat processed. Blanching fresh vegetables before freezing or drying involves heating briefly at about 1000C.,

c) Sterilization above 100^0C

By this method all microorganisms are completely destroyed due to high temperature. The time and temperature, necessary for sterilization vary with the type of food. Temperatures above 100^0C can only be obtained by using steam pressure sterilizers such as pressure cookers and autoclaves.

Fruits and tomato products should be noted at 1000C for 30 min. so that the spore forming bacteria which are sensitive to high acidity may be completely killed. 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. Continuous heating for 30 – 90 min at 116^0C is essential fro their sterilization. Empty cans and bottles should also be sterilized for about 30min. by placing them in boiling water.

Difference between pasteurization and sterilization

1.	Partial destruction of microorganism	Complete destruction of microorganism
2.	Temperature below 100^0C	Temperature 1000C and above
3.	Normally used for fruits	Normally used for vegetables

Aseptic canning

It is a technique in which food is sterilized outside the can and then aseptically placed in previously sterilized cans which are subsequently sealed in an aseptic environment.

Hot Pack (or) Hot fill

Filling of previously pasteurized or sterilized foods, while still hot, into clean but not necessarily sterile containers, under clean but not necessarily aseptic conditions.

3. Preservation by low temperature

Microbial growth and enzyme reactions are retarded in foods stored at low temperature. The lower the temperature, the greater the retardation. Low temperature can be produced by

1. **Cellar storage (about 15^0C):** The temperature in cellar (underground rooms) where surplus food is stored in many villages is usually not much below that of the outside air and is seldom lower than 15^0C. It is not enough to prevent the action of many spoilage organisms of platn enzymes. Root crops, potatoes, cabbage, apples, onions and similar foods can be stored for limited periods during the winter months.
2. **Refrigerated (or) chilling (0 to 5^0C):** Chilling temperature are obtained and maintained by means of ice or mechanical refrigeration. It may be used as the main preservative method for foods or for temporary preservation until some other preservative process is applied. Most perishable foods, including eggs, dairy products, meats, sea foods, vegetables and fruits may be held in chilling storage for a limited time with little change from their original condition. Enzymatic and microbial changes in the foods are not prevented but are reduced considerably. Factors to be considered in connection with

chilling storage include the temperature of chilling, the relative humidity, air velocity and composition of the atmosphere in the store room, and the possible use of ultra violet rays or other radiations.

3. **Freezing – 18 to 40^{0}C :** At temperature below the freezing point of H_2O, growth of microorganisms and enzyme activity are reduced to minimum. Most perishable foods can be preserved for several months. Fruits, vegetables, juices and fleshy foods 9meat, poultry, fish and sea foods) can be preserved in this method.

4. Preservation by chemicals

many chemicals will kill or inhibit the growth of microorganisms but most of these are not permitted in foods. A few that are permitted in prescribed low levels in certain foods include are as follows:

1.	Sodium benzoate and potassium metabisulfite	-	Fruits and vegetables products.
2.	Sorbic acid	-	Milk and milk products, sweets, cheese, wines and pickles, halwa, baked goods, beverages, syrups (fat containing food stuffs)
3.	Ethyl formate, Ethyl oxide and Propylene oxide	-	Act as fumigant against microorganisms in spices, nuts, dried fruits, dried eggs, gelatin, cereals and dried yeasts.

5. Preservation by drying

Microorganisms need moisture to grow so when the concentration of water in the food is brought down below a certain level they are unable to grow. Moisture can be removed by the application of heat as in sun-drying or by mechanical drying (dehydration). Sun-drying is the most popular and oldest method of preservation. In these days, mechanical drying has replaced by sun drying. This is a more rapid process as artificial heat under controlled conditions of temperature, humidity and air flow is provided and fruits and vegetables e.g., green peas, cauliflower, mango etc., are dried to such an extent that the microorganisms present in them fail to survive.

In this method, juices are preserved in the form of powder. The juice is sprayed as a very fine moist into an evaporating chamber through which hot air is passed. The temperature of the chamber and the flow of air are so regulated that dried juice falls to the floor of the chamber in the form of a dry powder. The powder is collected and packed in dry containers which are then closed airtight. The powder when dissolved in water makes a fruit drink almost similar to the original fresh juice.

6. Preservation by filtration

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

7. Preservation of carbonation

Carbonation is the process of dissolving sufficient CO_2 in water or beverage so that the product when served gives off the gas as fine bubbles and has a characteristic taste. Carbonation adds to the life of a beverage and contributes in some measure to its tang. Fruit juice beverages are generally bottled with CO_2 content varying from 1 to 8g /per litre. Though this concentration is much lower than that required for complete inhibition of microbial activity (14.6g/litre). It is sufficient for supplementing the effect of acidity on pathogenic bacteria. Another advantage of carbonation is the removal of air thus creating an anaerobic condition, which reduce the oxidation of ascorbic acid and prevents browning.

Moulds and yeasts require O_2 for their growth and become inactive in the presence of CO_2. In ordinary carbonated drinks, the O_2 which is normally present in solution in water in sufficient amount to bring about fermentation, is displaced by CO_2. Although carbonated beverage contain sugar much below 66%the absence of air and the presence of CO_2 in them help to prevent the growth of moulds and yeasts.

High carbonation should, however, be avoided as it usually destroys the flavour of the juice. The keeping quality of carbonated fruit beverages is enhanced by adding about 0.005%

sodium benzoate. The level of carbonation required varies according to the type of fruit juice and type of flavour.

8. Preservation by sugar

Syrups contain 66% or more of sugar does not ferment. Sugar absorbs most of the available water with the result that there is very little water for the growth of microorganisms hence their multiplication is inhibited, and even those already present die out gradually. Dry sugar does not ferment.

Thus sugar acts as a preservative by osmosis and not as a true poison for microorganisms. Fruit syrup, jam, jelly, marmalade, preserve, candy, crystallized fruit and glazed fruit are preserved by sugar.

9. Preservation by fermentation

Decomposition of carbohydrates of microorganisms or enzymes is called fermentation. This is one of the oldest methods of preservation. By this method, foods are preserved by the alcohol or organic acid formed by microbial action. The keeping quality of alcoholic beverages, vinegars and fermented pickles depends upon the presence of alcohol, acetic acid and lactic acid respectively. Wines, beers, vinegar, fermented drinks, fermented pickles etc., are prepared by these processes.

Fourteen percent alcohol acts as a preservative in wines because yeasts, etc., cannot grow at that concentration. About 2% acetic acid prevents spoilage in many products.

10. Preservation by salt

Salt at a concentration of 15 – 25%, is sufficient to preserve most products. It inhibits enzymatic browning and discoloration and also acts as an antioxidant, salt in the form of brine is used for canning and pickling of vegetables and curing of meat. Salt has been reported to have the following effects: (a) it causes high osmotic pressure and hence plasmolysis of cells (b) it dehydrates foods by drawing out and tying up moisture as it dehydrates microbial cells. (c) it ionizes to yield the chloride ion, which is harmful to organisms (d) it reduces the solubility of O2 in the moisture (e) it sensitizes the cell against CO_2 and (f) it interferes with action of proteolytic enzymes.

11. Preservation by acids

Acid conditions inhibit the growth of many microorganisms hence organic acids are added to or allowed to form in foods to preserve them. Acetic (vinegar), citric (lime juice) and lactic acids are commonly used for preservation. About 2% acetic acid prevents spoilage of many products. Onions are bottled in vinegar with a little salt. Vinegar is also added to pickles, chutneys, sauces and ketchups. Citric acid is added to many fruit squashes, jams and jellies to increase the acidity and prevent mould growth.

12. Preservation by oil and spices

A layer of oil on the surface of any food produces anaerobic conditions which prevent the growth of moulds and yeasts. Thus pickles in which enough oil is added to form a layer at the top can be preserved for long periods. Spices like turmeric, pepper and asafetida have little bacteriostatic effect and their ability to prevent growth of other microorganisms is questionable. Different lots of spice vary in effectiveness, depending on the source, the freshness and whether they have been stored whole or ground up. Their primary function is to impact their characteristics flavour to the food.

13. Preservation by Antibiotics

Certain metabolic products of microorganisms have been found to have germicidal effect and are termed as antibiotics.

Nisin is an antibiotic produced by *Streptococcus lactis,* an organism commonly found in milk, curd, cheese and other fermented milk products. It is non-toxic and has no adverse effect on the sensory qualities of food. It is widely used in the food industry especially for preservation of acid foods in which it is more stable. It is commonly used in canning of mushrooms, tomatoes and milk products. *Nisin* suppresses the growth of spoilage organisms, mainly the gas – producing, spore – forming bacteria and toxin – producing *clostridium botulinum.*

Subtilin an antibiotic obtained from certain strains of *Bacillus subtilis* is used in preservation of asparagus, corn and peas. It is most effective against gram-positive bacteria and spore – forming organisms. Canned peas and tomatoes containing 10 and 20 ppm of subtilin respectively were found to be free of microorganisms.

Pimaricin an antifungal antibiotic can be used for treating fruits and fruit juices. At present the above three antibiotics are permitted only in such foods as are cooked prior to use and in the process of cooking the residual antibiotic is expected to be destroyed. Use of antibiotics along with other sterilizing agents including heat and radiation offer good promise.

14. Preservation by irradiation

Sterilization of food by ionizing radiations is a recently developed method of preservation which has not yet gained general acceptance. The unacceptable flavour of some irradiated foods and the fear that radioactivity might be induced in such food has come in the way of its greater use.

When gamma rays (or) electron beams pass through foods there are collisions between the ionizing radiation and food particles at atomic and molecular levels, resulting in the production of ion pairs and free radicals. The reactions of these products among themselves and with other molecules results in physical and chemical phenomena which inactivate microorganisms in the food. Thus irradiation of food can be considered to be a method of ‗Cold sterilization' i.e. food is free of microorganisms without high temperature treatment. Radiation dose of upto 1 Mrad is not hazardous.

Ionizing radiations can be used for sterilization of foods in hermetically sealed packs, reduction of the spoilage organisms in the perishable foods delays ripening of fruits, inhibits sprouting of root vegetables and controls infestation (insects) in stored cereals.

15. Preservation by modified atmospheric packaging

To control organisms that require it, air is removed. Increasing the level of CO2 concentration in the sealed container helps to prevent the activity of microorganism. Wax coating of cheeses or oxygen impermeable skin tight plastic films can be quite effective.

II. PRESERVATION (OR) DELAY OF SELF DECOMPOSITION OF THE FOOD

1) By destruction (or) inactivation of food enzymes 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 min. followed by cooling. The extent of blanching varies with the food.

Advantages

i) Inactivates enzymes which cause toughness, discolouration, mustiness, off-flavour, softening and loss of nutritive value.

ii) Reduces the area of leaf vegetables such as spinach by shrinkage or wilting, making their packing easier.

iii) Removes tissue gases which reduce sulphides.

iv) Reduces the number of microorganisms

v) Remove saponin (toxin) in peas.

vi) Removes undesirable acids and astringent taste of the peel, and thus improves flavour.

vii) Remove the skin of vegetables such as beetroot and tomatoes which helps in their peeling.

2. Preservation by antioxidants

An antioxidant is a substance which when added to fats and fat containing foods prevents their oxidation and thus prolongs their shelf-life, wholesomeness and palatability, without them fatty foods (e.g. potato chips, salted nuts, fat-containing dehydrated foods) cannot be stored for any length of time without becoming rancid. Antioxidants used in foods are butylated hydroxyanisole (BHA), butylated hydroxyl toluene (BHT), propyl gallate, thiodiproponic acid, stannous chloride, tocopherol, vitamin E, SO_2 and ascorbic acid.

Lecture - 13

Preservation and value addition of fruits

JAM

Jam is made using pulp from a single fruit or from a mixture of fruits. The combination of high acidity (pH around 3.0) and high sugar content (68-72%), prevents mould growth after opening the jar. Jellies are crystal-clear jams that are made using filtered juice instead of fruit pulp and marmalades are produced from clear citrus juices (lime, orange, grapefruit, lemon or orange) that have fine shreds of peel suspended in the gel. Ginger may also be used alone or mixed with the citrus fruits.

There are two important points to remember when making jams, jellies or marmalades:

1) There must be the correct proportions of juice, sugar, acid and pectin in order to form a good gel. In general, slightly under-ripe fruits contain more acid and pectin than do over- ripe fruits, but there are differences in the amounts of acid and pectin in different types of fruit

2) Water must be boiled off quickly to concentrate the mixture before it darkens. If whole fruit is used, there are two heating stages:

a.) The fruit is heated slowly to soften it and to extract pectin; then the mixture is boiled rapidly until the sugar content reaches 68-72%. This change in heat output requires a large and easily controllable burner.

b.) At a small scale, a Stainless steel pan and a gas burner can be used but the mixture should be constantly stirred to prevent it burning onto the base of the pan, particularly towards the end of boiling when it thickens. At higher production rates, a double-jacketed pan is better because it gives more even and faster heating and does not risk burning the product.

Jam is a product made by boiling fruit pulp with sufficient quantity of sugar to a reasonable thick consistency, firm enough to hold the fruit tissues in position. Apple, sapota, papaya, plums, mango, grapes, jack, pine apple, banana, guava and pears are used for the preparation of jam. It can be prepared from one kind of fruit or from two or more kind of fruits. In its preparation about 45% of fruit pulp should be used for every 55% of sugar. The FPO or FSSAI specification of jam is 68.5% TSS, 45% of fruit pulp and 0.5 – 0.6% acid (citric acid) per 100g of prepared product.

Preparation of jam

- Select matured and ripened fruits.
- To remove the dust and dirt.
- Remove the skins from the flush of the fruits.
- Cut the peeled fruits into small portions.
- Make it into pulp either by use of hand pulper (or) by mixie.
- Take the pulp and sugar (required amount) in a vessel and heat it over fire by stirring continuously, till the final TSS reaches 68.5◦ bx.
- Remove from the fire and allow cooling to room temperature.
- Pack it in a sterilized bottle and cover it with airtight cover.
- Label it with correct information.

Sheet or flake test

The end point of the jam is judged by sheet (or) flake test. A small portion of jam is taken out during boiling in a spoon (or) wooden ladle and cooled slightly. It is then allowed to drop. If the product falls off in the form of a sheet (or) flakes instead of flowing in a continuous stream (or) syrup, it means that the end point has been reached and the product is ready. Otherwise, boiling is continued till the sheet test is positive.

Problems in jam production

Crystallization

If the percentage of invert sugar is less than 30 % cane sugar may crystallize out on storage and if it is more than 50% the jam will become a honey like mass duo to formation of small crystals of glucose. Corn syrup or glucose may be added along with cane sugar to avoid crystallization.

Sticky or gummy jam

Because of higher percentage of TSS, Jams tend to become gummy or sticky. This problem can be solved by addition of pectin or citric acid or both.

Premature setting

This is due to low TSS and high pectin content in the jam and can be prevented by adding more sugar.

Surface graining and shrinkage

This is caused by evaporation of moisture during storage of jam. Storing in cool place can reduce it.

Microbial spoilage

Moulds may spoil the jam during storage. It is also advisable to add 40 ppm of SO_2 in the form of KMS or 200 ppm of benzoic acid.

JELLY

Jelly is prepared by boiling the fruit with or without water, straining, mixing the strained and clear juice extract with sugar and boiling the mixture to a stage at which it will set to a clear gel. 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 should keep its shape when removed from the mould. When cut, it should retain its shape and show a clean-cut surface. It should be tender enough to quiver, but not flow.

The FPO or FSSAI specification for jelly is 65% TSS, 45% of fruit extract and 0.5 – 0.75% acid (citric acid) per 100g of prepared product. Guava, sour apple, plum, karonda, wood apple, papaya and jack fruit are rich in pectin and generally used for the preparation of jelly.

Determination of pectin content

The pectin content of the strained extract is usually determined by one the following two methods:

Alcohol test

One teaspoonful of strained extract is taken in a beaker and 3 teaspoonful of methylated spirit are poured gently down the side of the beaker, which is rotated for mixing and allowed to stand for a few minutes. Observations are

a. If extract is rich in pectin, a single transparent lump or clot will form. An equal amount of sugar is to be added to the extract for preparation of jelly.
b. If extract contains moderate amount of pectin, the clot will be less firm and fragmented. Three-fourth, amount of sugar is to be added.
c. If extract is poor in pectin, numerous small granular clots will be seen. Half the amount of sugar is added.

Jelmeter test

The jelmeter is held in the left hand with the thumb and forefinger. The bottom of the jelmeter tube is closed with the little finger. The strained extract is poured into the jelmeter with a spoon, held in the right hand, till it is filled to the brim. While still holding the jelmeter, the little finger is removed from the bottom end and is exactly allowed to flow or drip for one minute, at the end of which the finger is replaced. The reading of the level of extract in the jelmeter is noted. This figure indicates how many parts of sugar are to be added to one part of juice.

Preparation of jelly

- Select sound fully matured ripe fruit (not over ripened or under ripened).
- Wash thoroughly with water to remove any adhering dirt.
- Peel the skin and make it into pulp and add water at the rate of 1½ times and boil it for 30 min. with citric acid.
- Filter the boiled pulp through the muslin cloth.
- Check the pectin strength of the extracted pectin by using alcohol test method.
- Add required sugar to the extract and cook by stirring continuously till it reaches the TSS of 65^{o} bx.
- Remove from the fire and cool, it to room temperature.
- Pack it in a sterilized bottle and cover it airtight.
- Label with correct information.

Judging of end point

Boiling of jelly should not be prolonged, because excessive boiling results in a greater inversion of sugar and destruction of pectin. The important point to remember is that it is the fruit extract which requires boiling and not the added sugar. If a jelly is cooked for a prolonged period, it may become gummy, sticky, syrup and deteriorate in colour and flavour. The end point of boiling can be judged in the following ways:

1. **Sheet (or) Flake test**: As described under jam.

2. **Drop test**: A drop of the concentrated mass is poured into a glass containing water. Settling down of the drop without disintegration denotes the end point.

3. **Temperature test**: A solution containing 65% TSS boils at 1050C. Heating of the jelly to this temperature would automatically bring the concentration of solids to 65%. This is the easiest way to ascertain the end point.

Problems in Jelly Making

Failure to set

This may be due to addition of too much sugar, lack of acid or pectin, cooking below or beyond end point, prolonged cooking

Cloudy or foggy jellies

This is due to the following reasons use of non-clarified juice or extract, use of immature fruits, over cooking, over cooling, non-removal of scum.

Formation of crystals

It is due to excess of sugar

Syneresis or weeping of jelly

The phenomenon of spontaneous exudation of fluid from a gel is called syneresis or weeping. This may due to excess of fluid, too low concentration of sugar, insufficient pectin, premature gelation and fermentation.

MARMALADE

Marmalade 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. The FPO or FSSAI specification for marmalade is TSS – 65%, and fruit juice – 45 % of the prepared product. Citrus marmalades are classified into

- Jelly marmalade – It is prepared from the clarified pectin extract.
- Jam marmalade - The pectin extract is not clarified and whole pulp is used.

Preparation of marmalade

- Select ripe fruits
- Washing and peeling outer portion
- Cutting the peel in to fine shreds and boiled for 10 -15 mins
- Cutting the thick slices of peeled fruit or crushing into pulp
- Boiling (2-3 times its weight of water for 40 – 60 min)
- Straining extract

- Test for pectin content (alcohol test)
- Addition of sugar
- Cooking to 103 -1 05 ^{o} C
- Addition of prepared shreds
- Boiling till jellying point (test for end point - sheet / drop /temperature test)
- Cooling and add flavour
- Fill in sterilized bottles, seal and store at ambient temperature**.**

Problems in marmalade making

Browning during storage is very common which can be prevented by addition of 0.09gm of KMS per kg of marmalade and not using tin containers. KMS dissolved in a small quantity of water is added to the marmalade while it is cooling. KMS also eliminates the possibility of spoilage due to moulds.

CANDY

A fruit / vegetable 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 anola, 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 our 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.

Problems in preparation of preserves and candied fruits:

i. **Fermentation:** It is due to low concentration of sugar used in the initial stages of preparation of preserves. Sometimes fermentation also occurs during storage due to low concentration of sugar and insufficient cooking. This can be prevented by boiling the product at suitable intervals, by adding the required quantity of sugar and by storage in a cool and dry place.

ii. **Floating of fruits in jar:** It is mainly due to filling the preserve without cooling and can be avoided by cooling the preserve prior to filling.

iii. **Toughening of fruit skin or peel:** It may be due to inadequate blanching or cooking of fruits hence blanching till tender is necessary. Toughness may develop when cooking is done in a large shallow pan with only a small quantity of syrup.

iv. **Fruit shrinkage:** Cooking of fruits in heavy syrup greatly reduces absorption of sugar and causes shrinkage. Therefore, fruits should be blanched first or cooked in low-sugar syrup.

v. **Stickiness:** It may develop after drying or during storage due to insufficient consistency of the syrup, poor quality packing and damp storage conditions.

If candied and crystallized fruits are stored under humid conditions, they lose some of their sugar due to absorption of moisture from the air. Further, they become mouldy if they are not sufficiently dried and are packed in wet containers.

There is considerable scope for exporting preserves and candies. Since these products are hygroscopic, water-proof packaging like metal and glass containers which are impermeable to water vapour should be used. Newer flexible plastic films would be cheap and highly effective. There is need for exploring the possibilities of utilizing various types of plastics for packaging of such products.

PRESERVE

A mature fruit / vegetable or its pieces impregnated with heavy sugar syrup till it becomes tender and transparent is known as a preserve. Aonla, bael, apple, pear, mango, cherry, karonda, strawberry, pineapple, papaya, etc. can be used for making preserves.

Intermediate-moisture foods or semi-moist foods, in one form or another, have been important items of diet for a very long time. Generally, they contain moderate levels of moisture, of the order of 20-50% by weight, which is less than is normally present in natural fruits and vegetables, but more than is left in conventionally dehydrated products. In addition, intermediate-moisture foods contain sufficient dissolved solutes to decrease water activity below that required to support microbial growth. As a consequence, intermediate-moisture foods do not require refrigeration to prevent microbial deterioration. There are various kinds of intermediate-moisture foods: natural products such as honey; manufactured confectionery product high in sugar, jellies, jams, and bakery items such as fruit cakes; and partially dried products including figs, dates, etc. In all of these products, preservation is partially from high osmotic pressure associated with the high concentration of solutes; in some, additional preservative effect is contributed by salt, acid and other specific solutes.

A mature fruit / vegetable or its pieces impregnated with heavy sugar syrup till it becomes tender and transparent is known as a preserve. Aonla, bael, apple, pear, mango, cherry, karonda, strawberry, pineapple, papaya, etc. can be used for making preserves.

General considerations:

Cooking of fruit in syrup is difficult because the syrup has to be maintained at a proper consistency so that it can permeate the whole fruit without causing it to shrink or toughen.

Cooking directly in syrup causes shrinking of fruit and reduces absorption of sugar. Therefore, the fruit should be blanched first to make it soft enough to absorb water, before steeping in syrup. However, highly juicy fruits may be cooked directly.

i. **Rapid process:** Fruits are cooked in a low-sugar syrup. Boiling is continued with gentle heating until the syrup becomes sufficiently thick. Soft fruits such as strawberries and raspberries, which require very little boiling for softening, unlike hard fruits like apples, pears and peaches, which require prolonged heating, can be safely cooked in heavy syrup. Rapid boiling should, however, be avoided as it makes the fruit tough, especially when heating is done in a large shallow pan with only a small quantity of syrup. The final concentration of sugar should not be less than 68 per cent which corresponds to a boiling point of 106°C. This is a simple and cheap process but the flavour and colour of the product are lost considerably during boiling.

ii. **Slow process:** The fruit is blanched until it becomes tender. Sugar, equal to the weight of fruit, is then added to the fruit in alternate layers and the mixture allowed to stand for 24 hours. During this period, the fruit gives out water and the sugar goes into solution, resulting in a syrup containing 37-38 per cent total soluble solids. Next day the syrup is boiled after removal of fruits to raise its strength to about 60 per cent total soluble solids. A small quantity of citric or tartaric acid (1 to 1.5 g per kg sugar) is also added to invert a portion of the cane sugar and thus prevent crystallization. The whole mass is then boiled for 4-5 minutes and kept for 24 hours. On the third day, the strength of syrup is raised to about 65 per cent total soluble solids by boiling. The fruit is then left in the syrup for a day. Finally, the strength of the syrup is raised to 70 per cent total soluble solids and the fruits are left in it for a week. The preserve is now ready and is packed in containers. In practice, the number of steps may be varied.

iii. **Vacuum process :** The fruit is first softened by boiling and then placed in the syrup which should have 30-35 per cent total soluble solids. The fruit syrup blend is then transferred to a vacuum pan and concentrated under reduced pressure to 70 per cent total soluble solids. Preserves made by this process retain the flavour and colour of the fruit better than by the other two methods.

In all these processes, the fruit is kept covered with syrup during cooking as well as afterwards otherwise it will dry up and the quality of the product would be affected.

The product should be cooled quickly after the final boiling to prevent discolouration during storage.

The fruits are drained free of syrup and filled in dry containers or glass jars. Freshly prepared boiling syrup containing 68 per cent total soluble solids is then poured into the jars / containers which are then sealed airtight. In commercial scale production, however, it is better to sterilize the cans to eliminate any possibility of spoilage of product during storage.

Process

Mature fruits → Washing → Preparation of fruit for sugar treatment → Keeping fruit and sugar in alternate layers (1.0 kg Fruit: 1 kg Sugar) (or) steeping fruit in syrup of 40% TSS for a day → Removal of fruit → Increasing consistency of syrup to 60% TSS by boiling Steeping ofruit for a day →Repeating the process and raising strength of syrup by 5% TSS to 70% on alternate days – Steeping in 70% TSS for a week → Preserve – Draining – Filling in jar (or) container → Covering fruit with freshly prepared sugar syrup of 68% TSS Sealing (airtight) – Storage.

FRUIT BARS

Fruits are generally liked by majority of the people from all age groups. But fruits are available only during specific season. There are many ways of preserving fruits and making fruit bars is one such method. Consumption of fruits is very important as they are nutritious and supply vitamins and minerals. Pulpy fruits like banana, mango, guava, apple etc. are best suited for making fruit bars.

Processing of Mango Bar

Mangos are one of the most important and most widely cultivated fruit in India. India produces around 1000 variety of mango fruits. Though variety of mango products are available in Indian market one of the important product manufactured in India is mango bar or ―thandra‖.

In the preparation of a fruit bar the pulp or puree of a fruit is usually used along with other ingredients. Sugar is used to enhance the taste. The fruit pulp with the added ingredients is dried in the form of a thin layer in stainless steel trays loaded in the solar dryer. During solar drying water is removed from the product under clean & hygienic conditions

Main raw material quantities to prepare approximately 100 kg of fruit bars are as follows:

Type of fruit	Fruit required in Kg	Pulp obtained in Kg	Sugar required in Kg	Yield (% of fresh fruit) approx.
Mango	720	360	33	14
Banana	600	360	30	17
Guava	406	325	60	25
Mango + banana	540 + 150	360	35	15
Papaya + banana	500 + 140	336	54	23

Ingredients

Thothapuri Mango Pulp -9.30 (Kg)

Sugar +Glucose -3.45 (Kg)

Citric Acid - 18.0(g)

Pectin - 9.0 (g)

Potassium Meta Bi sulphite - 15.0(g)

Method

- Canned mango pulp from Thotapuri or similar variety is best suited for making mango bar.
- Prepare Sugar syrup by adding 400 ml water & glucose.
- Add Citric acid & Pectin.
- Cool the syrup & mix the fruit pulps.
- Add potassium Meta bi sulphite.
- Using electrical hand mixer blend the pulp mix thoroughly
- Pour 900ml of fruit pulp mix in stainless steel trays & spread evenly.
- Carefully load the trays in Solar dryer for drying to make the first layer (Day 1), (at 40º-60º C)

- Repeat the above procedure on the second day & spread the mix on the dried up first layer to make the second layer (Day 2).
- Repeat the above procedure on the third day by spreading the mix on the dried up second layer to make third layer (Day 3).
- After the third layer is well set, cut intobars or small slabs of 3‖x4‖ size / 100g / 150g / toffees of required size.
- Pack in polypropylene sachets & seal airtight.

Mixed Fruit Bar – Composition & Process

Mango mixed fruit bars in combination with different were developed. Fruit bars were processed with varying proportions of fruit pulps of Thotapuri, Guava, Sapota & pineapple juice. Soft seed variety of Guava fruits, Kalipatti variety of Sapota fruits & locally available big size pineapples are best for making pulp.

Making mixed fruit bar:

Ingredients

Thothapuri Pulp - 3.72kg

Guava pulp - 1.86 kg

Sapota pulp - 1.86 kg

Pineapple juice - 1.86kg

Sugar+ Glucose - 3.600kg

Citric acid - 18g

Pectin - 9g

Potassium Meta Bi - sulphite - 15g

Method

- Weigh different fruit pulps separately
- Prepare Sugar syrup & add citric acid & pectin
- Cool the syrup & mix the fruit pulps
- Add potassium meta bi sulphite
- Pour 900ml of mixed fruit pulp in stainless steel trays & spread evenly
- Carefully load the trays in Solar dryer for drying to make the first layer (Day 1) (40-65°C).

- Repeat the above procedure on the second day & spread the mix on the dried up dried up first layer to make the second layer (Day 2) (40-65 °C)
- Repeat the above procedure on the third day by spreading the mix on the dried up second layer to make the third layer (Day 3) (40-65 °C)
- After the third layer is well set & dried cut into bars or small slabs of 3‖x 4‖ size 100g /150g / toffees of required size.
- Pack in polythene sachets & seal airtight

Lecture - 14

Fermented and non fermented beverages from fruits andvegetables

FERMENTED BEVERAGES

Fermentation

Decomposition of carbohydrates by microorganisms or enzymes is called fermentation. Fermentation of food results in the production of organic acids, alcohol, etc., which not only help in preserving the food but may also produce distinctive new food products.

The term fermentation refers to breakdown of carbohydrate and carbohydrate like materials under either *anaerobic* or *aerobic* conditions. Conversion of lactose to lactic acid by *Streptococcus lactis* bacteria is favoured by anaerobic conditions and is true fermentation; conversion of ethyl alcohol to acetic acid by *Acetobacter aceti* bacteria is favoured by aerobic conditions and is more correctly termed an oxidation rather than fermentation. But the word fermentation also is used in a still broader and less precise manner.

Acetic, lactic and alcoholic are the three important kinds of fermentation involved in fruit and vegetable preservation. The keeping quality of vinegar, fermented pickles and alcoholic beverages depends upon the presence of acetic acid, lactic acid and alcohol, respectively. Care should be taken to exclude air from the fermented products to avoid further unwanted or secondary fermentation. Wines, cider, vinegar, fermented pickles and other fermented beverage, etc., are prepared by these processes.

Vinegar

Vinegar is perhaps the oldest known product or fermentation. The word is *derived* from French 'vinaigre' meaning sour wine *(vin* = wine, aigre= sour). Vinegar is a liquid obtained by alcoholic and acetic fermentation of suitable materials containing sugar and starch (at least 10 per cent fermentable sugar). It contains about 5 per cent acetic acid and has germicidal and antiseptic properties. In the trade, vinegar is labelled according to the material used in its manufacture, e.g., malt vinegar (from malt) and cider *vinegar* (from apple juice). The amount of acid in vinegar is expressed as 'grain strength' which is ten times the percentage of the acetic acid present in it, e.g., *vinegar having* 5 per cent acetic acid is termed as vinegar of '50 grain strength'.

Types of vinegar

Vinegars are of two types- (A) Brewed *vinegars,* and (B) Artificial *vinegars*

(A) Brewed vinegars : Brewed *vinegars* are made from *various* fruits, starchy materials (potato) and sugar containing substances (molasses, honey) by alcoholic and subsequent acetic fermentation.

***(1)* Fruit vinegar:** Generally apple, grape, orange, jamun, peach, pear, pineapple, apricot and banana are used. Vinegar made from apple juice is known as cider or apple cider vinegar, while that from grapes as wine or grape *vinegar.*

(2) Potato vinegar: In this case starch is extracted from potato and hydrolyzed by the enzyme diastase before fermentation.

(3) Malt vinegar: Malt *vinegar* is *derived* wholly from malted barley, with or without the addition of the cereal grain, malted or otherwise, the starch of which is saccharified by the diastase of the malt before fermentation. Distilled malt *vinegar* is prepared by distilling the malt *vinegar.* The product merely contains the volatile constituents of the vinegar from which it is de*rived.* It is colourless and is generally used in the manufacture of pickled onions.

(4) Molasses vinegar: In this case molasses is diluted to 16 per cent total soluble solids, neutralized with citric acid and then fermented.

(5) Honey vinegar: It is prepared from low grade honey.

(6) Spirit vinegar: Spirit vinegar is the product prepared by acetous fermentation of a distilled alcoholic fluid which in turn is produced by fermentation. It is usually made by alcoholic fermentation of molasses and then distilled prior to acetic fermentation. It is also called as grain vinegar. distilled vinegar, white vinegar or alcohol vinegar.

(7) Spiced vinegar: Spiced vinegars are prepared by steeping the leaves or spices in an ordinary vinegar.

(B) Artificial vinegars: Artificial vinegars are prepared by diluting synthetic acetic acid or glacial acetic acid to a legal standard of 4 per cent and are coloured with caramel. Artificial vinegars are also called as synthetic vinegar or non-brewed vinegar.

Steps involved in vinegar production

Two distinct steps are involved in its preparation.

(i) Conversion of the sugar in fruits, etc., into alcohol by yeast (alcoholic fermentation):

The most efficient yeasts for fermentation of sugary substances and fruit juices into alcohol are *Saccharomyces ellipsoideus,* S. *malei* and S. *cerevisiae.* For starchy substances. S. *cerevisiae* is the best. In order to obtain quality vinegar, it is essential to first destroy wild (naturally occurring) yeasts and other microorganisms by pasteurization, and then to inoculate pure yeast. The nutrients for the growth of yeast such as phosphates, ammonium and potassium salts and suq. .rs are naturally present in fruit juices and in honey and molasses. The most favourable temperature for the growth of yeast is 25-27°C. Fermentation becomes abnormal at 38°C and ceases altogether at 41°C and below 7.^{0}C.

(ii) Conversion of alcohol into vinegar by acetic acid bacteria (acetification) Acetic acid fermentation is brought about by acetic acid bacteria *(Acetobacter* spp.) which are strongly aerobic but whose activity is greatly reduced by light. Acetic acid fermentation should, therefore, be carried out in the dark. The nutrients required for bacterial growth are generally present in the alcoholic liquor itself, but in the case or distilled alcohol, malt sprouts phosphoric acid, potassium carbonate, trisodium phosphate and ammonium hydroxide are added as nutrients. For acetic acid fermentation, the alcohol content of the fermented mash is adjusted to 7-8 per cent by dilution with water, because acetic acid bacteria do not grow well at higher concentration! of alcohol. After this adjustment, mother vinegar containing acetic acid bacteria is added at the rate of one part to ten parts of fermented mash in order to check the growth of undesirable microorganisms and to hasten the fermentation process.

Preparation of vinegar

Vinegar is prepared by the following methods:

(A) Slow process

(B) Orleans slow process

(C) Quick process (Generator or German process)

(A) Slow process

This process is generally used in India. The fruit juice or sugar solution, filled in earthen pots or wooden barrels, is kept for at least 5-6 months in a warm, damp room to undergo spontaneous alcoholic and acetic fermentations. No special care is taken, but the mouth of the container is covered with cloth to keep out insects, dirt, etc. The main defects of this method are:

(i) Incomplete alcoholic fermentation;

(ii) Slow acetic fermentation;

(iii) Low yield; and

(iv) Inferior quality of vinegar.

(B) Orleans slow process

The vinegar prepared by this process is clear and of superior quality. The steps of the process are:

1. Selection of fruit: Grapes, apples, oranges, mangoes, dates, jamun, or any other sweet fruit of third grade having about 10 per cent sugar in the juice are taken. Cores and peels of certain fruits discarded during canning and jam making can also be used.

2 Extraction of juice : The fruits or vegetables are cut into small pieces and then crushed or pressed through a thick muslin cloth. Fruits which do not yield juice readily are heated with a small quantity of water before pressing.

3. Adjustment of sugar: Only juice containing low percentage of sugar is suitable for the growth of yeast. The concentration of sugar is determined by means of a hand refractometer and adjusted to about 10 per cent either by diluting the juice with water (if the sugar content is high) or by adding additional sugar.

4. Fermentation: The juice is heated (pasteurized) to destroy the microorganisms and then filled in glass carboys, earthen pots or wooden barrels (Fig.A) to threefourths of their capacity. The two important steps in the preparation of vinegar are:

a. Alcoholic fermentation

b. Vinegar fermentation.

a. ***Alcoholic fermentation:*** Pure wine yeast, obtained from a winery or a chemist's shop, is well powdered and dissolved in a little warm juice and then added at the rate of 1.5 g per litre to the whole lot of juice with frequent stirring. The mouth of the carboy or barrel is loosely plugged with cotton wool to allow carbon dioxide gas to escape. The gas should be completely removed otherwise it hinders the yeast fermentation. Initially there is continuous frothing which indicates the progress of fermentation, but it ceases after 3 weeks when the fermentation is complete. All the sugar is converted into alcohol as can be seen by testing with a hand refractometer which indicates 0-1 per cent total soluble solids.

During the fermentation the temperature is maintained at 22 to 27°C as fermentation ceases above 41°C and below 7°C. The fermented juice is stored for 1 to 2 weeks for sedimentation and then strained through a cloth, or the clear supernatant is syphoned off into a clean container which is filled up to three-fourths its capacity :Fig. B).

Vinegar fermentation should be taken up only after ascertaining that the alcoholic fermentation is complete, otherwise yeast will retard the fermentation. For vinegar fermentation the alcohol content of the fermented liquid is adjusted to 7-8 per cent by dilution with water, because acetic acid bacteria do not grow at a higher concentration of alcohol.

b.Vinegar (acetic) fermentation: This is brought about by acetic acid bacteria. Unpasteurized vinegar or "mother" vinegar is added to the product of alcoholic fermentation in the ratio of 1: 10, and mixed well. Thereafter the liquid should not be disturbed otherwise the firm of vinegar bacteria will break and sink to the bottom and consume the nutrients in the liquid without producing vinegar. The mouth of the container is closed with a cork having two holes for proper aeration. The temperature of this liquid is maintained at 21 to *2rC* and the fermentation is completed in 10 to 15 weeks when the acetic acid content reaches a maximum.

Then the vinegar is syphoned off or strained through a thick cloth leaving at the bottom of the container a turbid liquid, which is used as "mother" vinegar for fresh fermentation.

5. Aging: Vinegar prepared by the above method is turbid and does not possess a good taste. It is stored in containers for 4 to 8 months during which the vinegar develops a good aroma and flavour and becomes mellow.

6. Clarification: The dear aged liquid should be syphoned out and filtered.

7. Colouring: Caramel colour is added for colouring.

8. Pasteurization: The vinegar is poured into previously sterilized bottles, corked airtight and the bottles heated (pasteurized) in hot water at 71 to 77°C for 15 to 20 minutes, so that further growth of bacteria is stopped and the strength of vinegar maintained during storage.

Note: An *ideal vinegar should contain only about 0.3 per cent sugar.* A *higher percentage denotes incomplete fermentation* due, *to* excess *of* acetic acid *during yeast fermentation.*

(C) Quick process (Generator or German process)

In this process additional oxygen is supplied for the growth of bacteria and the surface of the bacterial culture is also increased resulting in rapid fermentation. The equipment, used known as "Upright Generator", is a cylinder of height 3.66 to 4.2 m and diameter 1.2 to 1.5 m which is divided into three compartments:

(i) Distributing (ii) Central, and (iii) Receiving.

(i) Distributing compartment: This is the upper compartment and is about 30 cm above the central one. It is separated from the central compartment by a partition having small perforations. In the distributing compartment then! is fitted a W-shaped tilting trough or revolving sprinkler which distributes the liquid by trickling slowly over the material filled in the central compartment.

(il) Central compartment: This is filled with pumice stone, straw, corn cobs, rattan or beech wood shavings to increase the surface area. Beech wood shavings are preferred as they remain tightly coiled even when wet with vinegar. This compartment is fitted with an adjustable opening near the bottom for admission of air.

(iii) Receiving compartment: This is the lowest compartment of the generator and

Fermented fruit beverage

These have been known to mankind from time immemorial. But the development of biochemical principles of fermentation was originated by Lavoisier in France in 1789 by way of analyzing the chemical composition of sugar and its fermentation products such as ethanol, carbon dioxide and a trace of acetic acid. Much later in 1860, the fellow countryman Louis Pasteur carefully analyzed the fermentation products and showed that in addition to ethanol and carbon dioxide, other compounds such as glycerol and succinic acids are also produced. Fermentation process in beverage preparation is mediated through yeast and in the process it produces a range of products such as organic acids, alcohols, esters and sulphurous compounds. Grape wine is the oldest example of a fermented beverage.

(1) Wine

Wine is defined differently in the laws of different countries, e.g., in China wine is considered to be an alcoholic beverage and the Chinese word for it may be translated as *appetite* wine. In California, it is defined as the fermented juice of various fruits. But wine generally denotes the product produced by fermentation of grape juice. The most satisfactory definition seems to be "wine is a beverage resulting from the fermentation by yeasts of the grape juice with proper processing and addition." In other words, wine strictly signifies the fermented alcoholic beverage produced from grape juice without distillation. Grapes have been historically associated with wine-making because of following advantages:

(i) Juice Is extremely rich in natural sugar.

(ii) Natural association of fermentative yeasts with berries.

(iii) High content of nitrogenous matters in promoting growth of yeast-and hence fermentation.

(iv) High acidity of juice favouring yeasts and protecting against other bacterial fermentation.

(v) High alcohol and acid content in the fermented wine keep it stable and safe for prolonged storage.

The varieties of wines are endless and they differ in so many attributes that it is difficult to classify them. According to colour, there are two types, *red* and *white.* In making *red* wines, the grapes are crushed and stemmed but the skin and seeds are left in the must. *White* wines are made from white or greenish grapes or from the juice of grapes from which the skin have been removed.

Grape wines are of two kinds, *dry* and *sweet. Dry wines* are those which contain very little or no sugar that can be detected by testing. In *sweet wines,* the sugar content is high enough to be detected by taste. The alcohol content of these two kinds of wines ranges from 7 to 20 per cent. Wines with 7 to 9 per cent alcohol are known as *"light"*, those with 9 to 16 per cent "medium", and those with 16 to 21 per cent *"strong"*. Sparkling wine contains Co2. They are made effervescent by secondary fermentation in closed containers, generally in the bottle itself. *Still wines* are those which do not contain carbon dioxide. *Fortified wines* contain added alcohol in the form of brandy. Generally wines with more than 12 per cent alcohol are fortified with fruit brandy (alcohol) prepared by distilling grape wine.

Equipments used for wine making

(i) For crushing and pressing: Roller crusher or basket press.

(ii) Primary fermentation vessel : Open-ended cylindrical vessels of suitable size made of plastic or wood.

(iii) Secondary fermentation vessel : Narrow mouthed containers of wood, plastic or glass.

Thermometer, hydrometer, hand refractometer. measuringcylinder. Siphon tube, filter, bottles. Crown corks and corking machine. etc., are also required.

(i) Selection of fruit: The grape berries should be ripe and fresh. White wine is produced from varieties having greenish or yellowish skin. Red wines derive their colour from red pigment present in the skin or flesh of coloured varieties.

(ii) Crushing: It is done with the help of a basket press. Before crushing the grapes their stems and stalks are removed. Crushed material (must) is put in jars which should not be filled more than three-fourths.

(iii) Addition of sugar : Cane sugar is added to maintain at least 20 per cent total soluble.solids but not more than 24 per cent. If the grapes are sour, 70 g of sugar are added for each kg of grapes. at the rate of 1.5 g for every 10 kg of grapes, mixed and allow to stand for 2 to 4 hours. KMS inhibits growth of wild yeasts and spoilage organisms.

(vi) Addition of wine yeast: Wine yeast. e.g., *Saccharomyces ellipsoideus* inoculum is added at the rate of 20 ml for every 5 kg of grapes, about an hour after the addition of preservative. If the yeast is not available then potassium metabisulphite is not added.

The yeast present in the skin of grapes can also ferment and produce wine but it is not of good quality.

(vii) Fermentation : Grapes are allowed to ferment for two days in a cool place, i.e., at 22 to 28°C. The mouth of the jar is covered with cloth during fermentation.

(viii) Filtration: The contents are filtered through a thin muslin cloth or a filter aid on the third day and the filtrate again allowed to ferment in a cool place for another ten days without any disturbance. During this period yeast cells and other solids settle at the bottom.

(ix) Racking: Syphoning off the fermented wine to separate it from the solid deposits is Known as racking.

(x) Fining and Filtration: The newly prepared wine is sometimes not clear and requires fining and filtration. A suitable fining agent, e.g., bentonite, is added. All the colloidal material settles down along with bentonite. The clear wine is syphoned off and filtered if necessary. Alternatively, the wine is stored in a refrigerator for about two weeks and thereafter the clear wine is syphoned off.

(xi) Aging (Maturation) : The clear wine which is syphoned off is filled into bottles or barrels. These should be filled completely and sealed airtight. The wine is allowed to mature for 6 to 8 months in a cool place. Sometimes fermentation continues in the bottle with the result that the cork flies off or bottle cracks. Wine loses its flavour during aging because of which barrels of oak wood are generally used for storing it. The wood imparts a fine aroma to the wine.

(xii) Packing: The volatile acid content of wine, mainly acetic acid, should be low. High content of volatile acids (0.09-0.20 g/100 ml in terms of acetic acid) indicates that acetic acid bacteria are active during fermentation. It is often desirable to pasteurize the wine to destroy spoilage organisms and coagulate the colloids that cause cloudiness. Generally wines are pasteurized at 82 to 88°C for 1-2 minutes and then bottled. The bottles are closed with crown corks of good quality, pasteurized at 65°C for about 20 minutes, then cooled and stored.

The following' are the well-known wines produced in various countries:

(1) Champaigne

It is a sparkling wine, made chiefly in France, from certain varieties of grapes such as Chardonay and Pinot Noir. It is made in other countries as well. The fermentation is allowed to proceed to completion in bottles which are specially made to withstand high pressure of gas produced during fermentation.

(2) Port

It is a fortified, sweet red wine made originally in Portugal, but now in other countries also.

(3) Sherry

Spanish wine, matured by placing the barrels for 3 to 4 months in sunlight, where the temperature is as high as 54 to 60°C.

(4) Tokay

This is a very famous fortified wine made in Hungary.

(5) Muscat

It is prepared from Muscat grapes in Italy, California. Spain and Australia.

(6) Perry

Wine made from pears is known as *perry*. Its method of preparation is similar to that of apple cider. Wastes, culled fruits and trimmings left over from canning may also be used for making perry.

(7) Orange wine

Orange juice is sweetened by adding sugar and then allowed to ferment. The method of preparation is similar to that of grape wine. Orange oil should not be added to the juice as it hinders and sometimes stops fermentation.

(8) Berry wine

Wines prepared from berries like strawberry, blackberry are known as 'Berry wines'. These products are generally popular in other countries but are not common in India.

(9) Nira

It is prepared from the juice of the palm tree.

(10) Feni

This is a fermented wine made from cashew apple in Goa.

(11) Cider

It is mostly prepared by fermentation of special grade of apples which have a high tannin content of 0.1-0.3 per cent. However, a great deal of confusion exists as far as the apple cider is concerned. In the U.S.A., apple cider means non-clarified apple juice, whereas apple juice is the clarified and treated sparkling juice. On the contrary in the Europe and in India. apple cider partially fermented apple juice. In the U.K., special varieties of apples known as cider apples are used. For cider preparation apples may be graded on the basis of tannin and organic acid contents as 'bitter-sweet', 'bitter-sharp', 'sweet' and 'sharp'. Nearly 60 per cent of full-flavoured cider is prepared using bitter-sweet and bitter sharp apple. Cider apples are so chosen that their juice contain higher percentage of sugar (i.e., 12.5 per cent) than normal apple juice (10.5 per cent) with higher proportion of sugar in the form of fructose. In India, cider apples are not available in sufficient quantity, hence dessert varieties which are easily available, are used. There are two types of apple cider, dry and sweet. Fruits such as bael, jamun, phalsa and aonla can also be used for preparation of cider.

NON FERMENTED BEVERAGES

SQUASH

Squash is a type of fruit beverage .The FPO or FSSAI specification for squash is fruit juice 25 per cent, TSS 45^{o} brix, acidity 1.0 per cent, preservative 350 ppm of SO_2 (or) 700 ppm of potassium metabisulphite or 600 ppm of sodium benzoate. The dilution is 1:4. Lime, mango, orange and pine apple are used for making squash commercially using KMS as preservative or fruits viz. jamun, passion fruit, raspberry, strawberry, grape fruit with sodium benzoate as preservative.

Preparation of squash

- Select ripe and firm fruits
- Washing and Peeling of outer skin
- Cut into small pieces
- Extraction of juice by crushing
- Strain the juice and Juice measuring
- Preparation of sugar syrup (Sugar + water + acid heating to dissolve)

- Strain and Cool the syrup
- Mix with juice
- Addition of preservative
- Bottling and Capping

READY-TO-SERVE (RTS)

This is a type of fruit beverage which contains atleast 10% fruit juice and 10% total soluble solids besides about 0.3 per cent acid. It is not diluted before serving hence it is known as ready to serve. Commercially RTS beverages (with 13% TSS and 0.3 % acid) can be prepared by using SO2 -70 ppm or benzoic acid 120 ppm.

Preparation of RTS

- Select ripe and firm fruits
- Washing and Peeling of outer skin
- Cut into small pieces
- Extraction of juice by crushing
- Strain the juice and Juice measuring
- Preparation of sugar syrup (Sugar + water + acid heating to dissolve)
- Strain and Cool the syrup
- Mix with juice
- Bottling
- Crown corking
- Pasteurization (about 90^{o}C for 25 min)
- Cooling
- Storage

NECTAR

This type of fruit beverage which contains atleast 20% fruit juice/pulp and 25% total soluble solids besides about 0.3 per cent acid. It is not diluted before serving.

S. No.	Fruit	Juice / Pulp (%)	Quantity of water required (litre)
1.	Mango	20	Quantity of finished product (litre) – Quantity of (juice (litre) + sugar (kg) + acid (kg) used
2.	Papaya	20	
3.	Guava	20	

4.	Bael	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.

Lecture 15

Drying, dehydration and osmotic dehydration of fruits andvegetables

Dehydration preserves foods

Foods can be spoiled by food microorganisms or through enzymatic reactions within the food. Bacteria, yeast, and molds must have a sufficient amount of moisture around them to grow and cause spoilage. Reducing the moisture content of food prevents the growth of these spoilage-causing microorganisms and slows down enzymatic reactions that take place within food. The combination of these events helps to prevent spoilage in dried food.

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. If the food is dried at a temperature that is too high, the outer surface will harden, preventing moisture from escaping from the center of the slice, this is called **case hardening**.

Various factors that affect the rate of drying of horticulture produce

a) Composition of raw material

b) Size, shape and arrangement of stacking of produce

c) Temperature, humidity and velocity of air

d) Pressure (barometric or under vacuum)

e) Heat transfer to surface (conductive, convective / irradiative)

Several types of driers and drying methods, each method better suited for a particular situation, are commonly used to remove moisture from a wide variety of food products including fruit and vegetables. Sun drying is followed in certain crops such as prunes, figs, apricots, grapes and dates.

The basics of food dehydration

Three things are needed to successfully dry food at home:

Heat - hot enough to force out moisture (140°F), but not hot enough to cook the food;

Dry air - to absorb the released moisture;

Air movement - to carry the moisture away.

Difference between drying and dehydration

Sl. No.	Drying	Dehydration
1.	It is a natural process and the sun drying is at the mercy of the elements.	It is an artificial process and the removal of water by mechanical driers. The air is used as a drying medium.
2.	Cheap, easy to preserve foods, no need to spend capital money.	High unit processing costs, especially for freeze dried foods.
3.	Moisture temperature and velocity of air are not to be controlled.	Temperature moisture and velocity of air are controllable depending upon the foods to be dried.
4.	The quality of the products obtained is not good.	The quality of the products is better.
5.	More land is required for drying.	Less area is required.
6.	Colour development of the sundried fruits is good.	This is not occurring during dehydration.
7.	Cooking quality of the dried products is not food.	Cooking quality of the dehydrated foods is superior.
8.	Sanitary conditions are not controllable and in open field contamination from dusts, insects, birds and rodents are major problems.	Sanitary conditions are controllable within a dehydration plant.
9.	It is a slow process and the time consumption is more.	It is a continuous and fast process and the product obtained within a shorter period.
10.	Labour requirements are more.	Minimum.
11.	Sundrying is done during favourable hot climatic conditions.	Dehydration of foods are to be practiced an all the seasons.
12.	Here the shelf life of the product obtained is lower.	Prolonged shelf life.

Methods of drying

There are four basic methods of drying. They are as follows:

Air and contact drying under atmospheric pressure

In this case, the heat is transferred through the food either from heated air or heated surfaces, and the resulting water vapour is removed with the air current. Solar drying, sun drying, drum and spray drying all use this technique.

Vacuum drying

Since evaporation of water takes place more readily at lower pressures, drying under vacuum is faster. This method is more expensive than air-drying and is reserved for specialized products.

Freeze-drying

Water is removed by sublimation from frozen foods. Although the food structure is better conserved, the equipment and its maintenance are costly.

Solar Drying/Sun Drying

Sun drying and solar drying are obvious alternatives for this region due to the abundance of natural sunlight. Although the two terms are sometimes used interchangeably, for the purpose of this manual, sun drying refers to the removal of moisture by merely placing the commodity in the sun e.g., on a barbecue, rack, etc. The advantages of solar drying over sun drying include:

- Faster drying rates as higher air temperatures are generated.
  - Lower final moisture content of the finished product.
  - Greater protection of the product from rain, dust, pests.
  - Low insect and mould infestation due to higher temperatures.

Advantages of Drying

- Long Shelf Life
- Reduced Weight
- Convenience
- Concentration of nutrients
- No refrigeration is required for dried products

Disadvantages of Drying

Disadvantages of drying are few, and mainly relate to oxidation, which usually accompanies drying. This results in losses of micronutrients such as carotene and ascorbic acid, and minimal loss in protein as a result of browning reactions. Reduced consumer appeal is often linked with the latter. There might also be changes in flavour and texture if drying is not properly controlled, particularly with regard to maximum temperatures.

Pretreatments

Blanching

Exposing fruit and vegetable to hot or boiling water as a pre-treatment before drying has the following advantages

* It helps clean the material and reduce the amount of microorganisms present on the surface
* It preserves the natural colour in the dried products; for example, the carotenoid (orange and yellow) pigments dissolve in small intracellular oil drops during blanching and in this way they are protected from oxidative breakdown during drying;
* It shortens the soaking and/or cooking time during reconstitution.

During hot water blanching, some soluble constituents are leached out; water-soluble flavours; vitamins (vitamin C) and sugars.

Use of preservatives

Preservatives are used to improve the colour and keeping qualities of the final product for some fruits and vegetables. Preservatives include items such as sulphur dioxide, ascorbic acid, citric acid, salt and sugar and can either be simple or compound solutions.

Sulphuring

Sulphur dioxide fumes act as a disinfectant and prevent the oxidation and darkening of fruits on exposure and thus improves their colour. Sulphur fumes also act as a preservative, check the growth of moulds, etc. and prevent cut fruit pieces from fermenting while drying in the sun. Vitamins in sulphured fruits are protected but not in unsulphured ones. Vegetables are not generally sulphured.–Sulphur box‖ is a closed airtight chamber of galvanized iron sheet.

Sweating

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

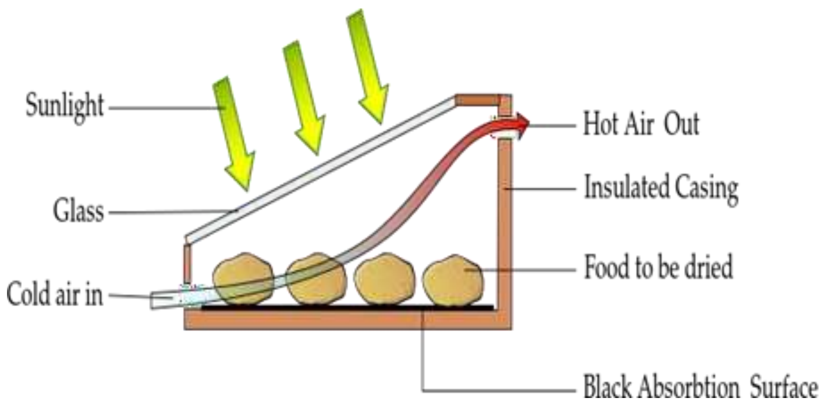
TYPES OF DRYERS

Solar dryer

Essentially, there are two types of solar dryers – direct and indirect.

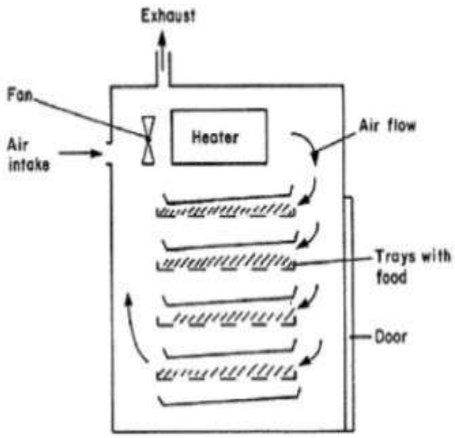
Regardless of which type is used, it is important to have information on the seasonal and daily variation of sunshine, humidity, temperature, wind speed and direction during drying.

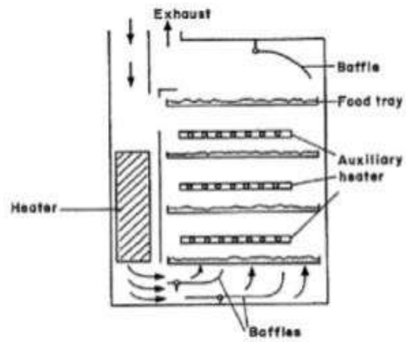
- When the direct solar dryer is used, air is heated in the drying chamber, which acts both as the solar collector and drier.
- The indirect dryer on the other hand comprises of two parts – a solar collector, and a drying chamber for the crop. Air enters the collector where it is heated and its humidity decreases.



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.



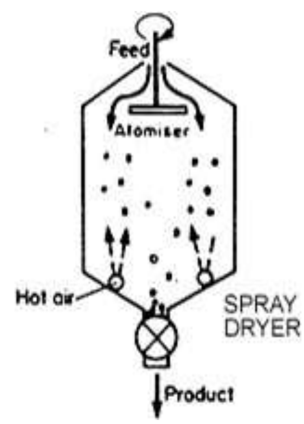


Drying cabinet with auxiliary heaters.

Spray driers

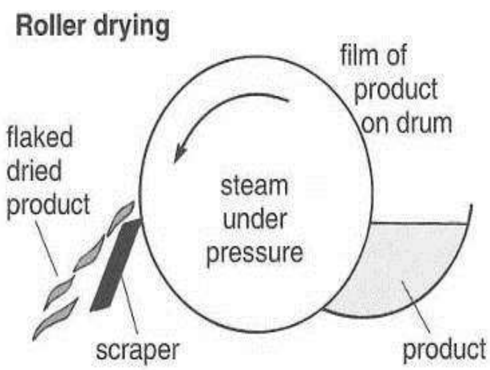
The most important kind of air convection drier is the spray drier. Spray driers turn out a greater tonnage of dehydrated food products than all other kinds of driers combined, and there are various types of spray driers designed for specific food products.

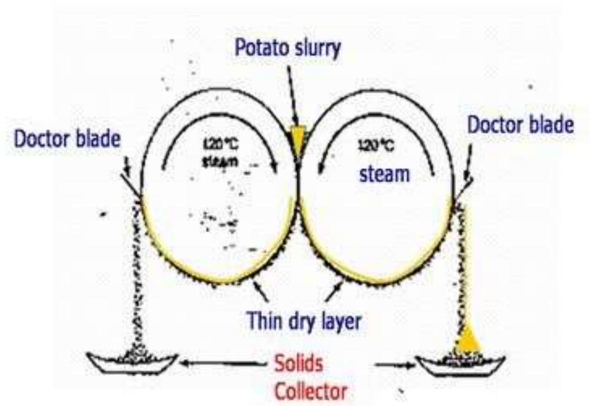
Spray driers are limited to foods that can be atomized, such as liquids and low viscosity pastes or purees. Atomization into minute droplets results in drying in a matter of seconds with common inset air temperatures of about 200^{o}C. Since evaporative cooling seldom permits particles to reach above about 80^{o}C (180^{o}C) and properly designed systems quickly remove the dried particles from heated zones, this method of dehydration can produce exceptionally high quality with many highly heat sensitive materials, including milk, eggs and coffee.



Drum (or) Roller driers

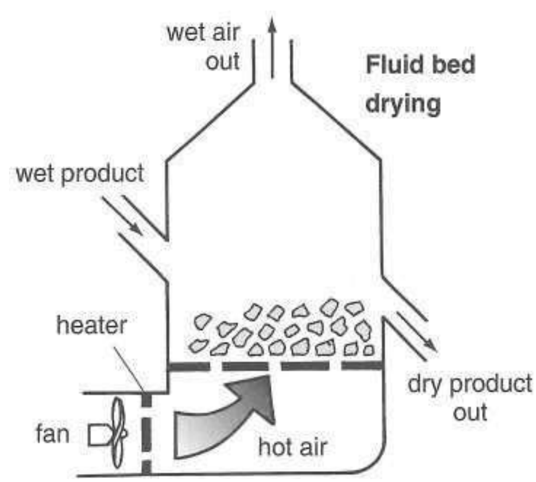
In drum or roller drying, liquid foods, purees, pastes are applied in a thin film onto the surface of steam heated, revolving drums. The drum generally is heated from within by steam. Drier may have a single drum or a pair of drums. The food may be applied between the nip where two drums come together, 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. The thin layer of food loses moisture and dries up. This layer is scraped off with the help of a blade attached to the drum which also is referred to as a doctor blade.. Using steam under pressure in the drum, the temperature of the drum surface may be well above 100° C and is often held at about 150° C. With a food layer of thickness less than 2 mm, drying can be achieved in one min or less, depending upon the food material. Drum dried foods generally, have a more cooked flavour than the spray dried counterparts.





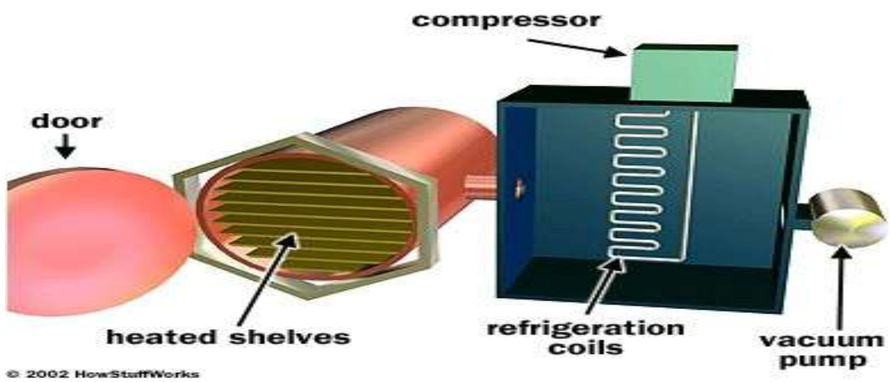
Fluidized bed drier

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.



Freeze dryer

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.

Lecture 16

Preservation through canning

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 and vegetables

(1) Fruits and vegetables should be absolutely fresh.

(2) Fruits should be ripe, but firm, and uniformly mature.

(3) Over-ripe fruits should be rejected because they are infected with microorganisms and give a poor quality product.

(4) Unripe fruits should be rejected because they generally shrivel and toughen on canning.

(5) All vegetables except tomatoes should be tender.

(6) Tomatoes should be firm, fully ripe and of deep red colour.

(7) Fruits and vegetables should be free from dirt.

(8) They should be free from blemishes, insect damage or mechanical injury.

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.

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.

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.

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.

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:

- Inactivates most of the plant enzymes which cause toughness, discolouration (polyphenol oxidase), mustiness, off-flavour (peroxidase), softening and loss of nutritive value.

- Reduces the area of leafy vegetables such as spinach by shrinkage or wilting, making their packing easier.
- Removes tissue gases which reduce sulphides.
- Reduces the number of microorganisms by as much as 99%.
- Enhances the green colour of vegetables such as peas, broccoli and spinach.
- Removes saponin in peas.
- Removes undesirable acids and astringent taste of the peel, and thus improves flavour.
- Removes the skin of vegetable such as beetroot and tomatoes which helps in their peeling.

Disadvantages

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

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

Filing: Before filling cans are washed with hot H_2O 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. After filling covering with syrup or brine in done and this process is called syruping or brining.

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 55^o 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.

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.

Exhausting: The process of removal of air from cans is known as exhausting. After filling and lidding / clinching, exhausting is essential.

Advantages of exhausting is

a) Corrosion of tinplate and pin-holing during storage is avoided

b) Minimizes discolouration by preventing oxidation.

c) Retention of vitamin-C

d) Reduces chemical reaction between the container and the contents

e) Prevents development of excessive pressure

Sealing: Immediately after exhausting the cans are sealed airtight by means of can sealer. In case of glass jars a rubber ring should be placed between the month of the jar and the lid, so that it can be sealed airtight, during sealing the temperature should not fall below 74°C.

Processing: Heating of foods for preserving is known as processing. In canning technology processing means heating or cooling of canned foods to inactivate bacteria. Many bacterial spores can be filled by either high or low temperature. Processing time and temperature should be adequate to eliminate all bacterial growth. Almost all fruit and acid vegetable can be processed satisfactorily at a temperature of 100°C *i.e.* in boiling water.

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

a) Dipping or immersing the hot cans in tanks containing cold water

b) Letting cold water in to pressure cooker specially in case of vegetable

c) Spraying cans with jets of cold water

d) Exposing the cans to air

Storage: After labeling the cans, they should be packed in strong wooden cases or corrugated cardboard cartons and stored in a cool and dry place. Storage of cans at high temperature should be avoided as it shortens the shelf-life of the product.

Containers for Packing of Canned Products

Both tin and glass containers are used in the canning industry, but tin containers are preferred.

Tin containers: Tin cans are made of thin steel plate of low carbon content, lightly coated on both sides with tin metal. It is difficult to coat the steel plate uniformly and during the process of manufacture small microscopic spots are always left uncoated, although the coating may appear perfect to the eye. The contents of the can may react with these uncoated spots resulting in discolouration of the product or corrosion of the tin plate. When the corrosion is severe, black stains of iron sulphide are produced. It is necessary, therefore, to coat the inside of the can with some material (lacquer) which prevents discolouration but does not affect the flavour or wholesomeness of the contents. This process is known as "lacquering". Two types of lacquers are used:

Acid-resistant: Acid-resistant lacquer is golden coloured enamel and cans coated with it are called Renamel or A.R cans. These cans are used for packing acid fruits which are of two kinds: (a) those whose colouring matter is insoluble in water, e.g., peach, pineapple, apricot, grapefruit, and (b) those in which it is water-soluble, e.g., raspberry, strawberry, red plum and coloured grape. Fruits of group (a) are packed in plain cans and those of group (b) in lacquered cans.

Sulphur-resistant: This lacquer is also of a golden colour and cans coated with it are called C-enamel or S.R. cans. They are meant for non-acid foods only and should not be used for any highly acid product as acid eats into the lacquer. These cans are used for pea, corn, lima bean, red kidney bean, etc. Recently, a midget can has become highly popular for fruit juices, mango nectar, etc.

Size of cans: The sizes of cans in general use are given below:

Trade name of can	Size (mm)
Al	68 x 102
1-lb Jam	78x 90
AJ-T	78 x 119
A2	87 x 114
1-lb Butter	103 x 70
A 2-lb Jam	103 x 102
A 21/2	103 x 119
7-lb Jam	157 x 148
A 10	157 x 178

It holds about 165 ml of beverage and is a very popular picnic pack. Tin containers are preferred to glass containers because of certain advantages:

- Ease of fabrication,

- Strength to withstand processing,
- light weight,
- Ease in handling,
- Cheapness, and
- Can be handled by high speed machines.

SPOILAGE IN CANNED FOODS AND ITS PREVENTION

Spoilage of canned products

Spoilage is due to two reasons

A) Physical and chemical changes

B) Micro-organisms

A) Spoilage is due to physical and chemical changes

1) Swell: The swell / bulge is due to the positive internal pressure of gases formed by microbial or chemical action.

a) **Hydrogen swell:** This is due to the H gas produced by the action of food acids on the metal of the can.

b) **Flipper:** The can will appears normal, but when struck against a table top one or both ends becomes convex and springs or flips out, but it can be pushed back to normal condition by little pressure. Such can is termed as ‗flipper'.

c) **Springer:** A mild swell at one or both ends of a can is called ‗Springer'. It is due to insufficient exhausting or overfilling of the can. The bulged ends can be pressed back to the original position, but again it will become bulge.

d) **Soft swell:** At a more advanced stage swell develops at both ends of the can it can e pressed and returned to normal position, but springs back when the pressure is removed

e) **Hard swell:** This is the final stage of well, the bulged ends cannot be pressed back to normal position and the cans ultimately burst.

Precautions are necessary to prevent formation of H swell

- Good quality tin plate should be used
- Plain cans are less susceptible
- Lacquering is more essential
- Addition of 0.5% citric acid to syrup will lower the acidity
- Before placing the lid maintain proper head space (0.6-0.9 cms)

- The lid should placed firmly or clinched before exhausting to ensure a high vacuum in the can.
- Can should be exhausted for a fairly long time, but without affecting the quantity of product.
- The sealing temperature should not be below 74°C
- At high storage temperature hydrogen formation will be more, hence canned products should be stored under cool and dry condition.

2) Overfilling: During retorting, over filled cans become strained due to expansion of the contents, and in the absence of vacuum in them swelling takes place.

3) Faulty retort operation

When the steam pressure is reduced rapidly at the end of processing, high pressure develops inside the cans resulting in their distortion and the cans when cooled look like swells.

4) Under exhausting: Can are exhausted to remove most of the air present in the product. This helps in proper filling of fruit and vegetables and also creates a good vacuum.

5) Paneling: Generally seen in large sized cans that the body is pushed inward due to high vacuum inside.

6) Rust: rust formation can be checked if the cans are extremely lacquered.

7) Foreign flavours: During preparation, filling, storage or even transportation, condition may become unhygienic and the products develops foreign flavour.

8) Damage: Cans show signs of leakage or revere distortion they must be rejected.

9) Undesirable texture: Texture is another important characteristic like flavour and colour.

10) Corrosion of cans: Cans become corrode or perforate due to the acidity of the contents.

11) Leakage: It is due to defective seaming / sealing, nail holes, excessive internal pressure due to microbial spoilage sufficient to burst the can, internal or external corrosion, mechanical damage during handling.

12) Breathing: There may be very tiny leak in the can through which air can pass in destroy the vacuum.

13) Bursting: It is caused by the excess pressure of gases produced by decomposition of the food by micro organisms.

14) Buckling: Due to improper cooling, it resembles like swell.

15) Discolouration: It can be detected by visual examination of the can and its contents. Discolouration is due to biological causes like enzymatic and non enzymatic browning or metallic contamination (Iron and copper salts).

16) Stack burning: If processed cans are not allowed to cool down sufficiently before storing, the contents remain hot for a long time. This is known as stack burning.

B) Microorganisms / microbial spoilage

1) Pre-processing spoilage

This spoilage is due to time gap between filling and heat processing of the containers. Processing checks the growth of organisms the gas already present in the can causes swelling and flipping. Hence, delay between filling and processing must be avoided.

2) Under-processing spoilage

Under-processing of canned foods result in their spoilage by thermophilic bacteria and mesophilic organisms and this is termed as _under processed spoilage'.

a) Thermophilic bacteria

These bacteria can thrive at a high temperature of 100° C. If cans are stored without adequate cooling. Some thermophiles produce hydrogen and some other hydrogen sulphide gas which blackens the contents. The only way to avoid bacterial contamination is to clean and wash the raw material thoroughly before canning.

Three types of spoilage are caused by

Thermophiles

i.Flat sour:

This occurs mostly in non-acid foods like vegetable and is caused by thermophilic spp. Of Bacillus such as *B. coagulans, B. Sterothermophilus* which produce acid without formation of gas. The product has a sour odour and its acidity is much higher than that of normal
product. It is not fit for consumption.

ii. Thermophilic acid (TA) spoilage;

The case of TA spoilage, the cans swell due to production of CO_2 and H_2. Spoilage mostly occur in low and medium acid foods, and develops in cans stored in hot condition.

iii. Sulphide spoilage*:* It develops in low-acid foods.

(b) Mesophilic organisms

Spoilage by mesophilic organisms such as some species of Clostridium, Bacillus, yeast and fungi, is also indicative of under-processing.

Clostridium butyricum and C.pasteurianum cause a butyric acid type of fermentation in foods with swelling of the container due to the formation of carbon dioxide and hydrogen. Other species of Clostridum produce hydrogen sulphide and other undesirable gases. These putrefactive anaerobes generally grow in low-acid material such as vegetables, etc., but sometimes in medium-acid foods also.

Some gas-forming bacilli such as Bacillus polymyxa and B. macerans are also reported to cause spoilage of canned peas, spinach, peach and tomato.

The presence of non-spore forming bacteria in canned food indicates a leak or under-processing. Organisms which are thermoduric include enterococci and Streptococcus thermophilus. These heterofermentatives produce carbon dioxide which swells the can. Some other non-gas forming, non-spore forming bacteria which cause spoilage are species of Pseudomonas, Micrococcus and Proteus.

Moulds and yeasts and their spores are destroyed at pasteurization temperature. Their presence in canned food indicates gross under-processing or leakage. Spoilage of canned products by yeasts results in carbon dioxide production and swelling of the cans. Film yeasts and fungi grow on the surface of the products and cause degradation. In the case of some fruits such as plums, sometimes the fruit breaks down and becomes pulpy in can due to the action of Byssochlamysfulva.

3) After processing

A large number of cans after processing show signs of microbial spoilage due to leakage of can seams. Cans which are water cooled are more likely to leak than air cooled ones. For reducing this type of spoilage the bacterial level of the cooling water should be low and the cans should be properly exhausted to reduce the seam strain.

Lecture -17

Standards in value addition of fruits and vegetables

Every country needs laws to encourage the production of safe and wholesome foods, and to prohibit the sale of foods that are unsafe or fraudulent.

Hazard Analysis Critical Control Point (HACCP):

The Hazard Analysis Critical Control Point (HACCP) is a scientific, rational and systematic approach to identify, assess and control hazards during production, processing, manufacturing and use of food. It ensures safety of the food. A systematic approach to the identification, evaluation, and control of food safety hazards based on seven principles.

History of HACCP:

The application of HACCP to food production was pioneered by the Pillsbury Company with the cooperation and participation of the National Aeronautic and Space Administration (NASA), Natick Laboratories of the US Army, and the US Air Force Space Laboratory Project Group. In the Indian food industry, HACCP is not compulsory practice but due to increase in the cases of food poisoning in the country, HACCP has been recognized internationally as a science-based logical tool for management of food safety. India as signatory to WTO, TBT & SPS agreements along with TQM and ISO is committed to follow WTO regulations whose priority is to protect health of consumer. Our food industry thus needs to install HACCP to avoid any rejection of foods shipped to international market.

Seven principles of HACCP

1. **Conduct hazard analysis**: In this first step, the team assesses hazards associated with growing, harvesting, raw materials and ingredients, processing, manufacturing, distribution, marketing, preparation, and consumption of the food. They identify all significant hazards (biological, chemical, and physical) that need to be controlled to assure food safety throughout each step in the process.

2. **Determine critical control points:** After identifying the significant hazards, the team establishes preventative measures to control the identified hazards. The team identifies areas or points in the flow of a food product (flow chart) with their critical limits that must be met to control the identified hazards. These are called critical control points (CCPs). A Critical Control Point (CCP) is a point, step, or procedure in a food process at which control can be applied and as a result, a food safety hazard can be prevented, eliminated, or reduced to an acceptable level.

3. **Establishment of specification for critical limits**: At each CCP, teams define boundaries or limits of safety to assure that the CCP is in control. They establish upper limits for CCPs. CCP limits are usually based on time, temperature, pH, and moisture content of a food.

4. **Development of monitoring and testing system to control critical point:** CCP and CCP limits are only effective if they are monitored during food processing. Monitoring ensures that the process is in control. Testing procedures have to be developed to ensure that each critical control point is consistently monitored and the process is under control.

5. **Establishment of corrective actions when particular CCP is not under control:** Whenever food companies note a deviation in the critical limits for a CCP, they must correct the deviation. Corrective action may include changing the process, reprocessing, or discarding the product. Corrective actions are intended to ensure that no product injurious to health.

6. **Establish record keeping procedures**: Food companies must keep records of the results of monitoring critical control points. These records are the only proof for a company that process is in control and that they are complying with the HACCP plan. Depending on the commodity, records should be accessible for one to three years. Thus, a system must establish documentation of procedures and records for all aspects of the HACCP programme and give evidence of its functioning base on all data obtained from testing and analysis, deviation or correction actions.

7. **Verification of HACCP system to confirm efficacy:** The procedure need to be established to verify and confirms that operating HACCP system is working effectively. Verification ensures that HACCP plan is adequate and verification includes such activities as review of HACCP plans. They may request an internal or external food safety audit to verify that the HACCP plan is working.

Benefits of HACCP: There are numerous benefits for the food industry while applying HACCP system as a management tool for food safety control. Some of the important benefits are as follows:

1) Application of the HACCP concept is the cost effective approach to food safety.

2) Application of the HACCP concept is enough flexible.

3) Helps to maintain the global food quality and safety standards.

4) The HACCP approach is a systematic approach for all aspects of food safety and can be applied to all stages of the food chain, including raw materials, growth, harvesting, purchase, production, distribution, and storage to final product use.

5) Provides scientifically sound base for protections of a hazard from reaching the end consumer products.

6) HACCP systems can promote international trade by increasing confidence in food safety.

7) HACCP system can facilitate the design and construction of new foodprocessing facilities and equipment.

8) The HACCP system can be readily integrated in to quality management systems like (Total Quality Management) TQM and ISO 9000 etc.

9) HACCP system focuses resources mainly on those parts of the process which are critical for assuring safe products.

10) HACCP system can reduce product losses due to spoilage.

Food Safety and Standard Act 2006(FSSA)

The Food Safety and Standards Authority of India (FSSAI) has been established under Food Safety and Standards act, 2006 which consolidates various acts & orders that have hitherto handled food related issues in various Ministries and Departments.

FSSAI has been created for laying down science based standards for articles of food and to regulate their manufacture, storage, distribution, sale and import to ensure availability of safe and wholesome food for human consumption.

Highlights of the Food Safety and Standard Act, 2006

- Various central Acts like Prevention of Food Adulteration Act (1954), Fruit Products Order (1955), Meat Food Products Order (1973), Vegetable Oil Products (Control) Order,(1947), Edible Oils Packaging (Regulation) Order (1988), Solvent Extracted Oil, De- Oiled Meal and Edible Flour (Control) Order (1967), Milk and Milk Products Order, (1992) was repealed after commencement of FSS Act, 2006.
- The Act also aims to establish a single reference point for all matters relating to food safety and standards, by moving from multi- level, multi- departmental control to a single line of command.

Salient Features of FSSAI Act, 2006

Some of the salient features of the Act are:

- FSSAI as a **single reference point** for all matters relating to Food Safety and Standards, Regulations and Enforcement.

- Integrated **response to strategic issues** like Novel foods, Health Foods, Nutraceuticals, GM foods, international trade etc.
- Adequate **information dissemination** on food to enable consumer to make informed choices.
- **Graded penalty** depending upon the gravity of offences.
- Adequate **representation of government**, industry organizations, consumers, farmers, technical experts, retailers etc.
- **Enforcement of the legislation** by the State Governments/ UTs through the state Commissioner for Food Safety, his officers and Panchayati Raj/Municipal bodies.

Establishment of the Authority

Ministry of Health & Family Welfare, Government of India is the Administrative Ministry for the implementation of FSSAI. The Chairperson and Chief Executive Officer of Food Safety and Standards Authority of India (FSSAI) have already been appointed by Government of India. The Chairperson is in the rank of Secretary to Government of India.

Functions performed by FSSAI

- Framing of Regulations to lay down the Standards and guidelines in relation to articles of food and specifying appropriate system of enforcing various standards thus notified.
- Laying down mechanisms and guidelines for accreditation of certification bodies engaged in certification of food safety management system for food businesses.
- Laying down procedure and guidelines for accreditation of laboratories and notification of the accredited laboratories.
- To provide scientific advice and technical support to Central Government and State Governments in the matters of framing the policy and rules in areas which have a direct or indirect bearing of food safety and nutrition.
- Collect and collate data regarding food consumption, incidence and prevalence of biological risk, contaminants in food, residues of various, contaminants in foods products, identification of emerging risks and introduction of rapid alert system.
- Creating an information network across the country so that the public, consumers, Panchayats etc receive rapid, reliable and objective information about food safety and issues of concern.

- Provide training programmes for persons who are involved or intend to get involved in food businesses.
- Contribute to the development of international technical standards for food, sanitary and phyto-sanitary standards.
- Promote general awareness about food safety and food standards.

Codex Alimentarius Commission (CAC)

The term Codex Alimentarius is taken from Latin and means food code. The Codex Alimentarius Commission develops food standards, guidelines and related texts such as codes of practice under the Joint FAO / WHO Food Standards Programme. About 170 countries were member of the commission.

Purpose of Codex Alimentarius Commission

- It is to protect the health of consumers and to ensure fair practice in the food trade
- To promote coordination of all food standards work undertaken by international governmental and non-governmental organizations
- To determine priorities and initiate and guide the preparation of draft standards through and with the aid of appropriate organizations
- To finalize standards and after acceptance by Governments, publish them in a Codex Alimentarius either regional or worldwide standards

It brings together all the interested parties viz. scientists, technical experts, governments, consumers and industry representatives to help develop standards for food manufacturing and trade. These standards, guidelines and recommendations are recognized worldwide for their vital role in protecting the consumer and facilitating international trade. As Codex Alimentarius represent a consensus of food and trade experts from around the world, these standards are more and more being used in international trade negotiations and also for setting of disputes by WTO. The Codex contract Point in India is the Directorate General of Health Services (DGHS) in the Ministry of Health; however, the Ministry of Food processing Industries is closely associated with the activities of Codex Alimentarius.

Codex can be divided in to three main groups

- The commodity standards committee work vertically dealing with food products such as processed fruits and vegetables , fats and oil, fresh fruit and vegetables, natural mineral water, cocoa products and chocolates, fish and fishery products, sugar, milk, products, cereal and meat products.

- The general subject committees work horizontally on standards such veterinary drug residues, food additives and contaminants, pesticide residues, hygiene, labeling, inspection and certification systems, analysis and sampling, nutrition and foods for special dietary uses.
- The six regional coordinating committees are based in Africa, Asia, Europe, Latin America and Caribbean, North America and South West Pacific and the near East.

Salient Features of Codex Alimentarius:

- Protecting health of the consumers and ensuring fair trade practices
- Promoting coordination of all food standards work undertaken by international governmental and non-governmental organizations
- Determining priorities and initiating and guiding the preparation of draft standards.
- Finalizing standards
- Amending published standards
- Submission of a proposal for a standard
- A decision by the Commission or the executive committee
- Preparation of a proposed draft standard by subsidiary body
- Adoption of standard by the Commission
- Addition of Codex Standard in the Codex Alimentarius

International Standards Organization (ISO): The product sell based on the product quality as perceived by the customer is the major factor for sustained what makes a sales of a product. The method of quality control consisted largely of physical inspection of the end product against the product specification. However, technical specifications may not by themselves guarantee, that a customer's requirements will be met, if there happens to be any deficiency in the specifications or in the organizational system, to design and produce the products, or service. Consequently, this has led to the development of quality system standards and guidelines that complement relevant product, or service, requirements given in the technical specifications.

ISO 22000: 2005: It specifies requirements for a food safety management system where an organization in the food chain needs to demonstrate it stability to control food safety hazards in order to ensure that food is safe at\ the time of human consumption.

ISO 22000:2005 specifies following requirements to enable an organization:

- To plan, implement, operate, maintain and update a food safety management system aimed at providing products that, according to their intended use, are safe for the consumer
- To demonstrate compliance with applicable statutory and regulatory food safety requirements
- To evaluate and assess customer requirements and demonstrate conformity with those mutually agreed customer requirements that relate to food safety, in order to enhance customer satisfaction
- To effectively communicate food safety issues to their suppliers, customers and relevant interested parties in the food chain
- To ensure that the organization conforms to its stated food safety policy
  To demonstrate such conformity to relevant interested parties and
- To seek certification or registration of its food safety management system by an external organization, or make a self-assessment or self-declaration of conformity to ISO 22000:2005.