Postharvest Physiology and Handling of Horticultural Crops
Chapter 1: Introduction

1.1. History of post-harvest technology

➢ Fresh fruits and vegetables (F&V) have been part of human diet since the dawn of the history.

➢ The systematic nutritional value of the some Fruit & Vegetable was recognized in the early 17th century in England.

➢ One example is the ability of the citrus fruit to cure scurvy, a diseases wide spread among naval personnel.

➢ An example of the importance of the field to post-harvest handling is the discovery that ripening of fruit can be delayed, and thus their storage prolonged, by preventing fruit tissue respiration.
Cont…

➢ The knowledge of the fundamental principles and mechanisms of respiration, leading to postharvest storage techniques such as cold storage, gaseous storage, and waxy skin coatings.

➢ Another well known example is the finding that ripening may be brought on by treatment with ethylene.

➢ Fruits and vegetables are being rich in vitamins and minerals, known as protective foods.

➢ Due to their high nutritive valve, ready availability, and being inexpensive they make significantly contributes to human well-being.
1.2. Importance of post-harvest physiology

❖ Post harvest physiology is the scientific study of the physiology of living plant tissues after they have been denied further nutrition by picking/harvest.

❖ The post harvest physiology has a direct application to post harvest handling in establishing storage & transport conditions that prolong storage life and quality.

❖ The goal is to provide the basic biological information needed to understand why fruits, vegetables and cut flowers deteriorate after harvest, and

❖ Then to acquire how to apply appropriate postharvest operation techniques in order to maintain quality and reduce losses.
1.3. Extent of post-harvest losses of horticultural crops

- It is estimated that about one-third of the fresh produce harvested worldwide is lost at some point between harvest and consumption.

- According to the Food and Agriculture Organization (FAO), the annual world production of fruits and vegetables during 2011 was:

  Fruits = 640 million tonnes
  Vegetables = 1 billion tonnes

- Global Quantitative food losses are:
  Fruits, vegetables & tubers = 40-50 %
  (average 45 %)

- Based on this average, the annual loss of:
  Fruits = 288 million tonnes
  Vegetables = 0.45 billion tonnes
1.4. Pre- and post-harvest factors influencing post-harvest quality

• Pre-harvest factors affecting postharvest quality

➢ Several factors before harvest affect quality of horticultural crops after harvest.

➢ Some of these factors are related to the plant, others are related to the environment or to cultural practices.

❖ Cultivars: The quality of the seed or the plant material is an important factor affecting the quality of the fruit produced. Several parameters of quality are controlled genetically.

❖ Cultural practices: All cultural practices have direct effect on the final quality of the horticultural commodities.
Seeding or 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:

✓ Planting density will affect both the quantity and quality of the produce.

✓ High density planting increases competition between plants, reduces light availability, and thus may decrease quality.

✓ Low density plantings usually lead to large size, better colored fruit or vegetable, which may have shorter shelf life.
❖ **Irrigation:**

✓ Irregular watering usually reduces fruit size, increases splitting, physiological disorders, reduces water content in the plant or plant part.

❖ **Fertilization:**

✓ Poor management of fertilizers will increase physiological disorders due to deficiencies of some minerals, wherever, increase of others leading to toxicity.

✓ In both cases quality will be negatively affected.

❖ **Pruning:**

✓ Pruning reduces the load and increases the growth of fruit (increasing size) 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 size and quality.

Pests and Diseases

✓ Pathogens and insects have a very negative effect on quality.
✓ Poor management of plant protection programs can lead to very poor quality and reduced yield and increase pre and postharvest losses.
Environmental factors:

✓ Temperature is the most important environmental factor that affects quality of horticultural crops.

✓ Very low or very high temperatures may injure sensitive crops.

✓ Chilling injury and heat injury respectively, adequate light intensity and light quality is important for the formation of some pigments (colors).

✓ Wind and rain may cause negative effects on some crops.

Chemicals:

✓ Many hormones and growth regulators are used in agriculture and they can affect quality in different ways; positive or negative.
• Causes of losses during harvesting due to:
  ➢ Incorrect stage of maturity
  ➢ Time at harvesting (field heat)
  ➢ Damage due to harvesting devices
  ➢ Exposure to sun
  ➢ Rough handling
Factors causing postharvest losses

- There are many factors involved in postharvest losses, which include:
  - Metabolic
  - Developmental (Development & maturation)
  - Temperature
  - Relative humidity
  - Atmospheric composition
  - Transport
  - Marketing
  - Consumption
❖ **Metabolic**

➢ All fresh horticultural crops are live organs.

➢ The natural process of respiration involves the breakdown of food reserves, and the aging of these organs, and thus to food losses. Ethylene is a natural product of plant metabolism.

❖ **Developmental**: *(Development & maturation)*

➢ These include sprouting, rooting, seed germination, change in pigments, phenolic compounds etc. which lead to deterioration in quality and in nutritional value.
Physical Damages

✓ Various types of physical damages (surface injuries, impact bruising, vibration bruising etc.) are contributors of deterioration.

✓ Browning of damaged tissue takes place. Mechanical injury also promotes infections and ethylene production.

Pathological Breakdown

✓ Attack by most organisms follows physical injury or physiological breakdown of the commodity.

✓ Pathogens can infect apparently health tissues and become primary cause of deterioration.
Environmental factors (Temperature, RH, Gasses)

Temperature:
- High temperatures and the lack of refrigeration can lead to significant quantitative and qualitative losses.
- Low temperatures (0-10°C) can cause chilling injury and losses to several chilling sensitive commodities.
- Exposures of produce to sun enhance wilting and decay.

Relative humidity:
- Low relative humidity promotes water loss and shriveling, and increases qualitative and quantitative losses.
Some other Factors

✓ use of inappropriate packages,
✓ inadequate air flow and circulation,
✓ Tight packing and overloading.
✓ Compression damage during stacking,
✓ Vibration damage during transportation,
✓ Heat build up during transportation
❖ **Marketing:**

✓ Losses during marketing can be due to:

- Rough handling
- Exposure to sun and rain
- Poor storage facility and condition
- Mechanical damage in poor packaging results in cracks and cuts cause vegetables lose moisture and become susceptible to microbial attack.

❖ **Consumption:**

✓ Losses during consumption can be due to:

- inadequate preservation methods at home,
- methods of cooking and preparation such as peeling, consumption styles, etc.
2.1. Edible fruit and vegetable parts

Fresh horticultural crops are diverse in morphological structure:-

▪ roots,
▪ stems,
▪ leaves,
▪ flowers,
▪ fruit, etc.
▪ in composition, and general physiology.
2.2. Cellular components & their functions

Cellular Components of a Plant Cell

Intercellular space
Chloroplast
Mitochondrion
Cytoplasm
Amyloplast
Middle lamella
Cell wall
Vacuole
Tonoplast
Chromoplast
Ribosomes
Endoplasmic reticulum
Nucleus
Nucleolus
Plasmalemma
Plasmodesmata

Diagrammatic representation of a plant cell and its constituent organelles
## Cell components their function relevant to postharvest management

<table>
<thead>
<tr>
<th>Components</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I</strong> Cell wall</td>
<td></td>
</tr>
<tr>
<td>A. Primary wall</td>
<td>Includes cellulose (9-25%) hemicelluloses (25-50%) pectin substances and protein (10%). It stretches plastically during cell growth &amp; allows the free passage of water minerals dissolves in water</td>
</tr>
<tr>
<td>B. Sec. wall</td>
<td>Cellulose (45%), hemicelluloses (30%) and lignin (22-28%). Provide structural support to the plants</td>
</tr>
<tr>
<td>C. Middle lamella</td>
<td>A layer of pectin substances forms the middle lamella and acts to bind adjacent cell together</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>II</strong> Protoplast (Content of cell with out cell wall)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A Cytoplasm : (Cytoplasm + nucleolus =Protoplasm)</td>
<td></td>
</tr>
<tr>
<td>PLASTIDS</td>
<td></td>
</tr>
<tr>
<td>i Chloroplast</td>
<td>Chloroplast contains 50% protein and 50-55% lipids and small amount of nucleic acids. These are found in green cells.</td>
</tr>
<tr>
<td>ii Chromoplast</td>
<td>These are developed from mature chloroplasts after degradation of chlorophyll ands responsible for yellow – red pigmentation in the fruits.</td>
</tr>
</tbody>
</table>
Leucoplasts & Amyloplasts

<table>
<thead>
<tr>
<th>iii</th>
<th>Leucoplasts &amp; Amyloplasts</th>
<th>Leucoplasts are colour less plastids and contain protein. In the later stages leucoplasts are known as amyloplasts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B. Vacuoles</td>
<td>These are reservoir of cell and occupies about 80-90% of the cell volume. It contains various inorganic ions, sugars, amino acids, organics acids, gums, mucilages, tannins, flavonoids, phenolics, pigments and others nitrogenous compounds</td>
</tr>
<tr>
<td></td>
<td>C. Nucleus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D. Ergastic substances</td>
<td>Crystal like calcium oxalate, tannins, fats. CHO and proteins are stored in various components of the cell.</td>
</tr>
</tbody>
</table>
2.3. Postharvest quality of fruit & vegetables

COMPONENTS OF QUALITY
1. Appearance (size, colour, shape)
2. Condition and absence of defects
3. Texture
4. Flavour
5. Nutritional value

1. APPEARANCE
Maybe the most important quality factor determining market value because, people “buy with their eyes”. People perceive the inner qualities of the products based on the outer appearance.

Size: A criterion that can easily be measured. Many products are graded according to size, especially for fruits and vegetables.

Fruits, like apples, and vegetables, like carrots, can be graded in different size-standards. Larger products often receive an increased prize. Also for packaging uniform size is valued.
Cont...,

**Shape:** products shaped differently than the “normal” are often not well accepted and will often get a lower price.

**Colours:** Especially fruits and vegetables are colorful products that are often valued for their “decoration” of other fruits.

- The consumer also has a very clear perception of which colour the product should have to have a good quality.

- Red tomato = well ripened. This can however be misleading – Ex. Banana that ripens at high temperatures will stay green.
CONTINUATION

CONDITION AND ABSENCE OF DEFECTS

- Condition usually refers to freshness and stage of ripeness or senescence of a product. e.g. Wilted leafy vegetables are not appealing to the customer.

- Absence of defects/appearance is important because if the product has e.g. Skin blemishes such as bruises, scratches, marks, cuts etc., people tend not to buy them.

- Especially for export this point is important. “Normal” appearance (which is different from country to country) is very important to the customer.
TEXTURE

✓ It is the feeling the product gives in the hand by touching or by the mouth when eating.

✓ The cells of the plant have the ability to absorb water through the cell wall and to generate hydrostatic pressure within the cells.

✓ This is called turgor pressure and generate the property of crispness/texture to the product.

✓ Texture is affected by maturity. Texture is also often a grading requirement that can be tested using compression instruments that measure the firmness.
FLAVOUR

- The **flavor** of vegetables may be considered to originate from the basic constituents, such as carbohydrates, particularly the monosaccharides and disaccharides, proteins and fats as well as vitamins and minerals.

**Taste**: The sensation to the tongue – sweet, sour, salty, bitter. Aroma: due to volatile organic compounds.

NUTRITIONAL VALUE

✓ Most essential nutrients can neither be seen nor tasted. Therefore it is seldom a direct quality attribute for the consumer when purchasing a product.

✓ Products such as fruits and vegetables have high value of vitamins and minerals, and through marketing and information consumers can be informed of this and increase their consumption of these products.

✓ So, the nutritional value as a component of quality for the consumer preference is indirect through general knowledge.
Chapter 3: Physiological and biochemical aspects of produce development

FRUIT AND VEGETABLES ARE ALIVE AFTER HARVEST

✓ Horticultural Produce respire by taking up O₂, giving off CO₂ 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 H₂O, 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.
3.1. Growth, maturation, ripening & senescence

I. PHYSIOLOGY OF FRUIT AND VEGETABLES

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

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

These are: Growth ➞ Maturation ➞ Senescence
Cont…,

**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 flavor. Ripening occur during the later stages of maturation and is the first stage of senescence.
# Changes during ripening and storage life

## Difference between climacteric and non-climacteric fruits

<table>
<thead>
<tr>
<th>Climacteric Fruit (CF)</th>
<th>Non-climacteric Fruit (NCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>Normally they ripen after harvest</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>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)</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>Exhibits a peak in respiration</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>More ethylene is produced during ripening</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td>Significant increase in $\text{CO}_2$ production</td>
</tr>
<tr>
<td><strong>6</strong></td>
<td>Significant increase in $\text{CO}_2$ production</td>
</tr>
<tr>
<td></td>
<td>Decrease in internal oxygen concentration</td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>7</td>
<td>Low concentration of ethylene 0.1-1.0 µL/L/day is sufficient to hasten ripening</td>
</tr>
<tr>
<td>9</td>
<td>Eg - Many except in the apposite column</td>
</tr>
</tbody>
</table>
3.3. Internal & external factors regulating respiration

- Temperature
- RH
- Gas composition in the ambient and within the cell
- Moisture content of the tissue
- Wounding or injury
- Type of the plant parts
- Stage of development of tissue
- Surface area to volume of the produce
- Pre-harvest treatments and PH methods employed
- Chemical composition of tissue
- Size of the produce
- Presence of natural coating on the surface
Chapter 4: The role of ethylene in postharvest horticulture

Ethylene (C₂H₄)

- The ripening gas
- A simple naturally occurring organic molecule
- A colorless gas at biological temperatures
- Requires oxygen to be synthesized
- Requires oxygen and low levels of CO₂ to be active
Biological Attributes of Ethylene

❖ Readily diffuses from tissue.

❖ Produced from methionine via ACC by a highly regulated metabolic pathway.

❖ Key enzymes are ACC synthase and ACC oxidase.

❖ C$_2$H$_4$ synthesis is inhibited by C$_2$H$_4$ in vegetative and immature reproductive tissue.

❖ C$_2$H$_4$ synthesis is promoted (autocatalytic) by C$_2$H$_4$ in mature reproductive climacteric tissue.

❖ Effective at ppm and ppb concentrations
Ethylene Interactions in Plants

Ethylene stimulates

- Synthesis of $\text{C}_2\text{H}_4$ in ripening climacteric fruit
- Ripening of climacteric and non-climacteric fruit
- Anthocyanin synthesis in ripening fruit
- Chlorophyll destruction and yellowing, e.g. degreening of citrus
- Seed germination and adventitious root formation
- Respiration
- Flower initiation in bromeliads, e.g., pineapple
- Abscission and senescence
Ethylene inhibits

- Ethylene synthesis in vegetative tissue and non-climacteric fruit
- Flowering and flower development in most plants
- Auxin transport
- Shoot and root elongation
Beneficial effects

• Promotes color development in fruit
• Stimulates ripening of climacteric fruit
• Promotes de-greening of citrus
• Stimulates dehiscence in nuts
• Alters sex expression Cucurbitaceae
• Promotes flowering, e.g. pineapple
• Reduces lodging of cereals
Detrimental effects

❖ Accelerates senescence
❖ Enhances excessive softening of fruits
❖ Stimulates chlorophyll loss e.g. yellowing
❖ Stimulates sprouting of potato
❖ Promotes discoloration e.g. browning
❖ Promotes abscission of leaves and flowers
Chapter 5: Major causes of postharvest losses and manipulation of environmental influences

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

Post harvest losses occur in terms of:

1) **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 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
Cont…,

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
5.1. Temperature, atmospheric composition and humidity.

1. Temperature

- Environmental temperature plays a very major role in the deterioration of produce.

- Every increase of 10°C 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 influences the growth rate of fungal spores and other pathogens. It affects the respiration and transpiration rate of produce.
2. Relative humidity

* The rate of loss of water from fruit, vegetables and flowers depends upon the vapor pressure deficit between the surrounding ambient air, which is influenced by temperature and relative humidity.

* The rate of deterioration is a combined factor of temperature and relative humidity and affects the produce in following manner:

✓ Low Temp. & High Relative Humidity -- Low deterioration
✓ Low Temp. & Low Relative Humidity -- Moderate deterioration
✓ High Temperature & High Relative Humidity -- High deterioration
✓ High Temperature & Low Humidity -- Very high deterioration
3. Atmospheric gas composition

♥ Build up of undesirably high carbon dioxide and very low levels of oxygen in the storage facility can lead to many physiological disorders leading to spoilage. Eg. Hollow heart disease in potato is due to faulty oxygen balance in storage or during transportation.

♥ Exposure of fresh fruits and vegetable to O₂ levels below the tolerance limits or to CO₂ 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°C with 1-2%CO₂ and 2-3%O₂, 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 (e.g. 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.
5.2. Mechanical injuries

(Mechanical injuries can be due to impact, harvesting, abrasion, puncturing, bruising etc)

✓ Mechanical injury is a major cause of postharvest losses.

✓ Fresh fruits and vegetables are highly susceptible to mechanical injury due to their soft texture, high moisture content, Poor handling and unsuitable packaging.
Mechanical loss to the fruits is caused by careless handling during
- harvesting,
- packing,
- transportation,
- storage etc.

Some insects and birds are also responsible for the mechanical injury in fruits and vegetables.
The high moisture content and soft texture of horticultural commodities make them susceptible to mechanical injury, which can occur at any stage from production to retail marketing because of:

➢ poor harvesting practices;

➢ unsuitable field or marketing containers and crates;

➢ over packing or under packing of field or marketing containers;

➢ careless handling, such as dropping or throwing or walking on produce.
Mechanical injuries caused can take many forms:

- splitting of fruits or roots and tubers from the impact when they are dropped;
- internal bruising caused by impact;
- superficial scratches affecting the skins and outer layer of cells;
- Crushing of leafy vegetables and other soft produce.
Injuries cutting through or scraping away the outer skin of produce will:

- provide entry points for moulds and bacteria causing decay;
- increase water loss from the damaged area;
- Cause an increase in respiration rate and thus heat production.

Bruising injuries, which leave the skin intact and may not be visible externally causes:

- increased respiration rate and heat production;
- internal discoloration because of damaged tissues;
- Off-flavours because of abnormal physiological reactions in damaged parts.
5.3. Physiological disorders

- Physiological disorders can occur before or after harvest.
- Several physiological disorders are initiated before harvest and commonly appeared after harvest, especially during storage.
- The causes of Physiological disorders are:
  - Temperature (low or high),
  - mineral imbalance/ nutrition deficiency,
  - chemicals including ethylene, and some agricultural practices.
Freezing injury:

Temperature below freezing point, either before or after harvest, can cause freezing injury which causes the collapsing of the tissue.

Freezing injury causes degradation of tissue structure and losses of several components including vitamins.

Freezing injury occur at below 0°C, depending on the soluble solids content of the tissue.

Products with higher soluble solids content will freeze at a lower temperature.

The ranges of temperatures at which some fruits and vegetables freeze are 2.2 to -1.7°C (1.8 to -1.7°C in potatoes -0.9 to -0.8°C in cucumber and 0.6 to -0.3°C in lettuce).
Many subtropical and tropical crops are chilling sensitive.

Chilling injury is cumulative and usually appears after about two days at room temperature following low temperature storage.

Several factors affect chilling injury including:

- Maturity (ripe fruits are less sensitive),
- Atmosphere modification (high concentrations of CO$_2$ ameliorate chilling injury),
- High temperatures (reduce chilling injury incidence),
- Calcium applications (reduce symptoms).
Chilling injury is prevented with the use of optimum (above critical) temperatures.

**Chilling injury symptoms**

- Failure of the fruit to ripen, a good example is mature green tomato when kept in refrigeration for few days.
- Softening of the fruit, common in all sensitive crops.
- Loss of flavor and aroma, most easily observed in guava maintained at 8°C or less for few days.
- Increased decay in all sensitive crops
- Browning of the skin (such as in banana).
- Off-flavor production in several fruits and vegetables.
Some examples of chilling-sensitive produce

- Asparagus (*Asparagus officinallis*, L.)
- Avocados (*Persea Americana*, Mill)
- Beans (*Phaseolus spp.*),
- Bananas, Various species of citrus
- Cucumbers (*Cucumis sativus*, L.),
- Eggplants (*Solanum melongena*, L.),
Heat/ High temperature injury

- Exposure of horticultural crops to high temperatures (such as during exposure to direct sunlight, or during non-refrigerated storage or transport) can increase their temperature very significantly and can cause major qualitative and quantitative losses.

- Temperatures higher than optimum will increase the activity of the metabolism and will shorten the life of the fruit.

- Several fruits will fail to ripen after exposure to 35-40°C (due to inhibition of ethylene synthesis).

- Higher temperatures will cause the death of the tissue.
Transpiration/Water Loss

- Fresh fruits and vegetables contain from 80 to 95% water, depending on the product.

- Transpiration is a mass-transfer process in which water vapor moves from the surface of a horticultural commodities to the surrounding air.

- This process of moisture loss induces wilting, shrinkage, and loss of firmness and crispness of commodities, and thus adversely affects the appearance, texture, flavor, and mass of produce.
Most horticultural commodities lose their freshness after 3 to 10% mass loss.

Transpiration is considered to be the primary cause of postharvest losses and poor quality in leafy vegetables, such as lettuce, chard, spinach, cabbage, and green onion, and is considered the major cause of commercial and physiological deterioration in citrus fruits.
Methods and technologies for reducing water loss

➢ Control of water loss is very important to reduce quality deterioration and losses of horticultural crops.

➢ Some of the important techniques and methods commonly used include:

✓ Refrigeration.

- Low temperature and high relative humidity in cold stores are the most effective means for reducing water loss.

✓ Packaging:

- The use of different packages, especially of ventilated plastic, can serve as vapor barrier and can reduce water loss.
✓ **Waxing:**

- Several fruits and vegetables are waxed to increase the resistance of water diffusion and to reduce water loss.
- Waxing can also modify the internal atmosphere of the commodity.

✓ **Curing:**

- Some crops such as potatoes and sweet potatoes are cured to increase the synthesis of suberized cells on the surface, and therefore to increase water diffusion and decrease water loss.
Means for reducing postharvest losses

➢ Harvest products at optimum maturity, and adequate (cool) time.
➢ Protect the product from exposure to the sun after harvest.
➢ Avoid mechanical injury during harvesting.
➢ Use of pre-cooling and refrigeration.
➢ Use of appropriate high relative humidity during storage and transport.
➢ Avoid infestation with diseases and insects, and use adequate control measures.
➢ Use appropriate packing and packaging systems.

➢ Transport products adequately.

➢ Store the product properly at the appropriate conditions.

➢ Adequate handling (avoid rough handling) of the produce during all the postharvest chain.
5.4. Postharvest diseases

✓ The attack by fungi, bacteria, insects and other organisms is a major cause of postharvest losses in horticultural crops.

✓ Microorganisms readily attack fresh produce and spread rapidly, due to the lack of natural defense mechanisms in the tissues of fresh produce, and the abundance of nutrients and moisture which supports their growth.

✓ Control of postharvest decay is increasingly becoming a difficult task, since the number of pesticides available is rapidly declining as consumer concern for food safety is increasing.
MAJOR MICROORGANISMS

- Major post-harvest losses of fruits/vegetables are caused by species of fungi like:-
  - Alternaria, Botrytis, Diplodia, Monilinia, Penicillium, Phomopsis, Rhizopus and Sclerotinia
  - And Bacteria like:- Erwinia and Pseudomonas.

Most of these organisms are weak pathogens in that they can only invade damaged produce.
Often the relationship between the host (fruit/vegetable) and the pathogen is reasonably specific, for example, Penicillium digitatum rots only citrus and P. expansum rots apple & pear, but not citrus.

The appearance of many commodities may be marred by surface lesions caused by pathogenic organisms without the internal tissues being affected.
INFECTION PROCESS

- Microorganisms can infect the produce at any of the following stages:-
- While still attached to the plant.
- During harvesting
- Subsequent handling
- Storage
- Marketing

Infection at any stage is facilitated by mechanical injuries, physiological conditions, temperature, humidity, formation of periderm.
Chapter 6: Postharvest handling technologies

❖ Post-harvest Handling

✓ The objective: To extend the shelf life of fresh horticultural commodities.

✓ Use Post-harvest technology procedures which will delay senescence and maintain the best possible quality of horticultural commodities.

❖ The main purpose of applying postharvest technology to harvested horticultural commodities are:

➢ To diminish losses between harvest and utilization
➢ To maintain best possible quality (appearance, texture, flavor and nutritive value)
➢ To ensure food product safety
Postharvest operations

➢ Some postharvest operations are include:

✓ Harvesting

✓ Washing/sorting/grading

✓ Packaging

✓ Cooling

✓ Storage

✓ Transport to retail market
6.1. Harvesting and preparation for market

✓ Most of the fruits are harvested at proper maturity stage but quite earlier than the ripening stage.

✓ They are ripened artificially later on as per the market demands.

✓ Harvesting of fruits and vegetables should be done at cooler parts of the day and the produce should be shifted to the packing shade as early as possible.

✓ Harvesting during hot period raises the field heat of the produce and consequently wilting and shriveling may occur.

✓ Harvesting of vegetables during or immediately after the rains should not be carried out as it creates conditions most favorable for the multiplication of micro-organisms.
✓ Manual harvesting using **knife and spade clippers** for fruit picking is still in trend.

✓ While harvesting vegetables, care should be taken to avoid mechanical injury.

✓ For large scale harvesting of tuber crops such as **potato or the underground vegetables**, mechanical diggers like potato digger can be safely used.

✓ The large size of fruit trees poses a great problem in **manual harvesting**, resulting in more damage to the fruits.

✓ However, **manual harvesting** is easier and more efficient in the case of **high density orchards** where fruit trees planted are dwarf.
The following points should be kept in mind as harvesting the crop:

- Gentle picking and harvesting will help reduce crop losses.
- Wearing cotton gloves, trimming finger nails, and removing jewellary such as rings and bracelets can help reduce mechanical damage during harvest.
- Produce should be harvested during coolest part of the day.
- Empty picking containers with care.
- Keep produce cool after harvest (provide shade).
6.2. Cold chain management of harvested produces

- **Cold chain** is a logistic system that provides a series of facilities for maintaining ideal storage conditions for perishables from the point of origin to the point of consumption.

- It extend and ensure the shelf life of products such as fresh agricultural produce, seafood, frozen food, chemicals and pharmaceutical drugs. Minimize deterioration

- Cold chain retains the longevity of product characteristics, active ingredients, freshness, nutritive value.

- Keeps fruits and vegetables in good condition until they are consumed
Key activities

- **Procurement**: Involves activities such as aggregation, grading, sorting, pre-cooling, packaging farms or manufacturers.

- **Transportation**: It includes all activities related to transportation of produce to the market from farms or manufacturing location.

Objective of cold supply chain

- Reduce costs
- Improve product integrity
- Increase customer satisfaction
- Reduce wastage and returns of expired stock.
Industries using cold supply chain

- Fruits & vegetables
- Floriculture
- Meat & marine products
- Pharmaceutical Products
- Dairy products
- Ice cream sector & confectionery
Cold Supply Logistic Process

Diagram:
- Farm
- Packing House
- Precooling
- Cold Storage
- Refrigerated Transport
- Market
Cold supply chain logistic process

- Cold supply chain logistic process
- Pre-cooling facilities
- Cold Storages
- Refrigerated Carriers
- Packaging
- Warehousing
- Information Management systems (Traceability and Tracking etc.)
6.3. Packaging

➢ In some commodities, crushed or flaked ice is packed along with produce for fast cooling.

➢ However, as the ice comes in contact with the produce, it melts, and the cooling rate slows considerably.

➢ The ice keeps a high relative humidity around the product.

➢ Package ice may be finely crushed ice, flake ice or slurry of ice.

➢ This method is not suitable for produce which is very sensitive to ice-cold temperatures.
Liquid icing distributes the ice throughout the container, achieving better contact with the product.

Packaged icing can be used only with water tolerant, non-chilling sensitive products and with water tolerant packages (waxed fiberboard, plastic or wood crates).
6.4. Storage

**Storage** is the art of keeping the quality of agricultural materials and preventing them from deterioration for specific period of time, beyond their normal shelf life.

Objective of Fresh Fruit and Vegetable Storage

- Minimize deterioration

- Extend the life span of the fruit and vegetables

- Keep fruits and vegetables in good condition until they are consumed
Why is temperature very critical during storage?

- One of the most important functions of refrigeration is to control the crop's respiration rate.

- The higher the storage temperature, the higher the respiration rate will be.

- For refrigeration to be effective in postponing deterioration, it is important that the temperature in cold storage rooms be kept as constant as possible.

- Storage rooms should be well insulated and adequately refrigerated, and should allow for air circulation to prevent temperature variation.
While temperature is the primary concern in the storage of fruits and vegetables, relative humidity is also important:

- directly influences water loss in produce

- Most fruit and vegetable crops retain better quality at high relative humidity (80 to 95%), but at this humidity, disease growth is encouraged.
Storage is essential for the following reasons:

- Perishable nature of agric. & bio-materials
- Provision of food materials all year round
- Pilling/provision for large scale processing
- Preservation of nutritional quality
- Price control and regulation
- Optimization of farmers’ gain / financial empowerment of farmers
- Opportunity for export market, etc
6.5. Preservation and processing

♥ The ability to preserve food is one of the discoveries that have changed the development of the human species.

♥ There is evidence that even the primitive man learned that heated food remained edible for longer than raw food and that meat and grain could be preserved by drying.

♥ Later the ability to preserve large stocks of grain between harvest represented a significant advance, which quickly extended to fruit.

♥ The discovery that salt, saltpeter and acids enhanced this ability was a later discovery.

♥ In the last 100 years there has been a scientific understanding of the reasons for food spoilage, and a modern preservation technology has established.
Reasons for Preservation and Processing

a) To increase the post-harvest life / To preserve the product, to prevent spoilage due to attacks by micro-organisms or enzymatic activities.

❖ The production of many crops is seasonal, making them available only during short periods of the year.

❖ Often in this short time the products are normally produced in greater quantity than the market can absorb.

❖ The surplus can then be processed and preserved to avoid wastage and loss of income to the farmer.

❖ As opposed to storage (which preserves the product), processing kills the product to avoid deterioration due to micro-organisms and enzymatic activities (like respiration).
b) To render the products edible

- The application of heat – cooking, baking or frying – is the most common form of processing.

- Especially for vegetables and also for grain (making bread etc), this is a way of making the products edible. For grains grinding the products into flour is also necessary.

c) To reduce the content of plant toxins

- Plant produce a variety of toxins, many of them as a defense against insect predators. They also produce chemicals that are a part of the plant chemistry, but that are toxic to man.

- The level of toxins in edible plants have however been reduced by plant breeding.
Many of the toxic compounds are destroyed by especially heat processing. One example is sulfur compounds that occur in Brassicas (cabbage etc.) which can cause goitre (enlargement of the thyroid gland).

In green potatoes a group of enzyme inhibitors, anticholinesterases, that are resistant to heat processing can be found. They are detected by their bitter taste and peeled potatoes usually cause no problem.

d) To add value to the product

- By processing the food value can be added to the food by, usually, a secondary producer.
- This can be a bakery, restaurant, factory for producing dried soups, dried fruits etc, canning industry and so on.
- The consumer pay a much higher price than the initial cost of the product from the farmer. The cost of processing the product will be added into the price.
6.6. Transportation

- The goal of every person concerned with transport should be that the produce be kept in the best possible condition during transport and that the haulage of produce be quick and efficient.

- To this end, produce should be properly packaged and properly loaded on a suitable vehicle.

- The damage and loss incurred during non-refrigerated transport are caused primarily by mechanical damage and by overheating
Cont…, 

- Mechanical damage careless handling of packed produce during:-
  - loading and unloading
  - vibration (shaking) of the vehicle, especially on bad roads;
  - fast driving and poor condition of the vehicle;
  - poor stowage, which allows packages in transit to sway;
  - the stow may collapse; packages stacked too high;
  - the movement of produce within a package increases in relation to its height in the stack
6.7. Food hygiene and safety

➢ Food is a potential source of infection and is liable to contamination by microorganisms, at any point during its journey from the producer to the consumer.

➢ Food can become contaminated at any point during slaughtering or harvesting, processing, storage, distribution, transportation and preparation.

➢ **Food hygiene** are the conditions and measures necessary to ensure the safety of food from production to consumption.

➢ Food hygiene in its widest sense, implies hygiene in the production, handling, distribution, and serving of all types of food.

➢ Lack of adequate food hygiene can lead to foodborne diseases and death of the consumer.
WHO,

• “All conditions and measures that are necessary during the production, processing, storage, distribution and preparation to ensure that it is safe, sound and wholesome and fit for human consumption”.

• Primary aim is to prevent food poisoning and other food borne illnesses

• “Illness due to contaminated food is perhaps the most widespread health problem in the contemporary world and an important cause of reduced economic productivity.” (FAO & WHO, 1983).
As per reports of WHO:

- First ever estimates of the global burden of food borne diseases show almost 1 in 10 people fall ill every year from eating contaminated food and 420,000 die as a result.
- Children under 5 years of age are at particularly high risk, with 125,000 children dying from food borne diseases every year.
- WHO African and South-East Asia Regions have the highest burden of food borne diseases.
Almost one third (30%) of all deaths from food borne diseases are in children under the age of 5 years, despite the fact that they make up only 9% of the global population.

This is among the findings of WHO's "Estimates of the global burden of foodborne diseases" – the most comprehensive report to date on the impact of contaminated food on health and well-being.
Causes of Food Born Illness

Foodborne illness

- Improper cooking or reheating
- Poor personal hygiene
- Cross-contamination
- Improper food handling
- Unclean equipment
- Use of unsound, unwholesome or
- Unsafe holding temperatures that

- Chemicals in food
- Insects and rodents
- Infected food handlers
Cont…,

- Food safety is non negotiable and can not be compromised.

- All preventive measures have to be taken during production, processing, storage, distribution to ensure that the food is safe.

- An unsafe food besides causing health problems results in reduced working efficiency and may cause even death.