Department of Horticulture

College of Agricultural Engineering Sciences

Salahaddin University -Erbil

Subject: Postharvest Physiology and Technology

Course Book: 4th Year

Lecturer: Prof. Dr. Shabaq M. Nafea Al-Hawezy

Academic Year: 2024-2025

1. Course name	Postharvest Physiology and Technology
2. Lecturer in charge	Dr.Shabaq M.Nafea
3. Department/ College	Horticulture/ Agricultural Engineering Sciences
4. Contact	e-mail: shabaq.hawezy@su.edu.krd
5. Time (in hours) per week	Theory: 2 Practical: 2
6. Office hours	10
7. Course code	
8. Teacher's academic profile	• B.SC: 1979/ Horticulture / College of Agriculture/ University of sulaimani / Kurdistan Region/ Iraq. • M.SC : 1984/ Horticulture/ Pomology / College of Agriculture/University of Salahaddin/ Kurdistan Region/ Iraq • Ph D.: 2008/ Horticulture / Pomology / Viticulture / College of Agriculture/ University of Mosul/ Republic of Iraq.
9. Keywords	Postharvest Fruit Vegetable Ornamental plants Storage

10. Course overview:

1- To develops an appreciation for the factors related to quality deterioration and wastage of horticultural commodities after harvest. These factors include physiological, biochemical, and pathological considerations, as well as compositional and physical changes occurring during maturation and deterioration.

2. To develop an understanding of commercial procedures of harvesting, preparation, packaging, transportation, and storage in relation to biological principles and individual commodity requirements and responses.

11. Course objectives

By the end of the course, students should be able to:

1. Describe the processes/factors that result in quality deterioration and loss of harvested produce
2. Explain technologies/procedures applied to improve quality and reduce losses of harvested produce.
3. Discuss quality attributes and standards required to maintain safety of harvested produce

12. Student's obligation

*Exam policy: Student should engage in 2 exams during the course. From the 3 exams, one will be collected from the weekly quizzes and assignments. Students will have to decide which one to be chosen for correction by the teacher before. There will be no make-up exams for absences students without medical report.

13. Forms of teaching
Teaching methods

1. Lecture
2. Self-study

Teaching media

1. PowerPoint presentations
2. Texts and teaching materials

14. Assessment scheme

We will start most class periods with a short quiz. The quizzes could cover any information presented before that date, but will usually cover information presented in the most recent lectures. The quizzes will be given during the first 5 to 7 minutes of the class period.

Exams will consist of a variety of questions, including multiple choices, true/false, matching, and reasons for, occasionally short answer. **Note:** Number of exams and lectures for each exam did not specify. **Each student attends a report within the course program at the end of the course.**

15. Student learning outcome:

The course will provide students with scientific and technical knowledge on the post-harvest technology of the main horticultural crops to.

1. Understand the post harvest technology of fruits and vegetables
2. Understand cold chain management
3. Understand the work space, tool and equipment design for post harvest technology.

16. Course reading list and references:

1.Gross C Kenneth, Chien Yi Wang, and Mikal Saltveit. (2016).The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. Agricultural ResearchService, USA.

2. Wasim. M. Siddiqui and Asgar Ali. (2017). Postharvest Management of Horticultural Crops. Apple Academic Press. Canada.

3.Paliyath Gopinadha and Jayasankar Subramanian.(2019). Postharvest Biology and Nanotechnology. John Wiley & Sons, Inc.

4.R. Wills et al. (2016). Postharvest of fruit, vegetables & ornamentals; CAB International.

5.Wasim M Siddiqui. (2015). Postharvest Biology and Technology of Horticultural Crops, Principles and Practices for Quality Maintenance. Apple Academic Press, Canada.

6.Yahia M. Elhadi.(2019). Postharvest Physiology and Biochemistry of Fruits andVegetables. Elsevier Inc. All rights reserved.

17. The topics

Week 1: Introduction for Post-harvest Physiology andTechnology knowledge, importance of post them in Horticultural crops.
Week 2: Definition and classification of Horticultural crops and their Perishability nature. Morphology, structure, growth curve and development stages of fruits.
Week 3: The chemical composition of fruit and vegetables.
Week 4: Natural and physiological changes that occur during fruit development.
Week 5: Changes that occur after the harvest of fruit.
Week 6: Respiration - introduction, measurement and its relationship to maturity. Pre-harvest factors affecting post- harvest quality.
Week 7: Ethylene and other plant hormones - role in senescence, Ethylene and fruit ripening.
Week 8: Transpiration and loss of water.
Week 9 : Midterm Exam
Week 10 : Post-harvest for ornamental plants
Week 11: Ripening and packing fruit and vegetables. Compositional changes during maturation and ripening.
Week 12 : Sorting and grading and packing fruit and vegetables. Packaging and Packing house operations
Week 13: Methods of cooling before storage (pre-cooling) and during shipment in refrigerated warehouses.
Week 14: Methods and systems to storage for fresh fruit and vegetables.
Week 15: Nanotechnology in post harvest.
Week 16: Physiological changes that occur during storage of fruits**,** Postharvest disease and insects.

18. Practical

Lecturer's name Azad Hassan Yonis and Kaniaw Najmadin Sharif (2hrs)

19. Examinations:

1. Compositional:

What is the reason of:

1-**In fruit and vegetables enzymes control the reactions associated with ripening.**
biochemical reactions which occur in vegetable cells; control the reactions associated with ripening; after harvest, unless destroyed by heat

2-**Different color of fruit and vegetables**. Different types of pigments.

3-**The storage life of commodities varies inversely with the rate of respiration**.
According to type of fruits.

2. True or false type of exams:

1. Water is the main component of fruits and vegetables .**Yes**
2. Disaccharides are formed by condensation reactions and are broken down by de hydrolysis reactions.
3. Carbohydrates are essential components of nucleic acids as in the case of fructose. **No Glucose**

4. Increase production vertically by raising yields per Acre result of the use of high production, the application of appropriate technological methods. **Yes**

3. Multiple choices:

1- From the fruit, which is off of the main sources of oil:

a- Grape b- Olive c-Date palm (b)

2- Double sigmoid fruit growth curve is in :

a- Strawberry b- Citrus fruit c- Grape (a, c)

20. Extra notes:

Some of the lectures will be presented in PowerPoint lecture will be provided in class. Two textbooks (optional) are recommended for the Postharvest Technology of Horticultural crops of the course.

Postharvest Physiology and Technology

The horticultural produce includes fruits, vegetables, flowers and other ornamental plants, aromatic and medicinal plants and spices. Fresh fruits, vegetables, and flowers are highly perishable because they are alive. Release heat from respiration, and, consequently, lose moisture, which may detract from their appearance, salable weight, and nutritional quality. They can become deteriorate, and die. Dead fresh fruits and vegetables are not marketable.

Fresh fruits, vegetables are living tissues subject to continuous change after harvest. Although some changes are desirable, Postharvest changes in fresh produce cannot be stopped, but they can be slowed within certain limits.

Harvest: It is a specific and single deliberate action to separates the food stuff with or without non edible portion from its growth medium.

"**Post-harvest**" 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, it start at the moment of separation of the edible commodity from the plant. The post-harvest period ends when the crop comes into the possession of the final consumer.

What is postharvest 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 physiology deals with the time period from harvest or removal of the plant from its normal growing environment to the time of ultimate utilization, deterioration, or death.

Detrioration and Death

Approximately 33% of all harvested products worldwide are discarded prior to utilization, due to:

-Senescence

-Stress responses

-Pathogen activity

-Insect attack

-Mechanical damage

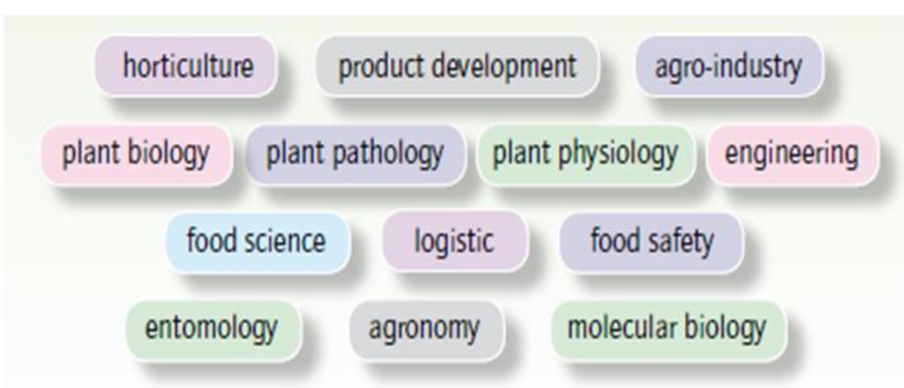
Role of a postharvest physiologist

- To minimize the postharvest loss of horticultural products
- To maintain market, nutritional value and safety of the product by using postharvest technology that mitigate the postharvest deterioration of the product

What is postharvest technology?

Post-harvest technologies constitute an inter-disciplinary science and techniques applied to agricultural commodities after harvest for the purpose of preservation, conservation, quality control/enhancement, processing, packaging, storage, distribution, marketing, and utilization to meet the crop and nutritional requirements of consumers in relation to their needs.

Technical knowledge needed for successful postharvest handling of fruit and vegetable spans many disciplines - chemistry, physiology, biochemistry, pathology, entomology, engineering and molecular biology.



Postharvest technologies have allowed horticultural industries to meet the global demands of local and large-scale production and intercontinental distribution of fresh produce that have high nutritional and sensory quality. Harvested products are metabolically active, undergoing ripening and senescence processes that must be controlled to prolong postharvest quality. Inadequate management of these processes can result in major losses in nutritional and quality attributes, outbreaks of foodborne pathogens and financial loss for all players along the supply chain, from growers to consumers. Optimal postharvest treatments for fresh produce seek to slow down physiological processes of senescence and maturation, reduce/inhibit development of physiological disorders and minimize the risk of microbial growth and contamination. In addition to basic postharvest technologies of temperature management, an array of others have been developed including various physical (heat, irradiation and edible coatings), chemical (antimicrobials, antioxidants and anti-browning) and gaseous treatments.

"**Loss**" means any change in the availability, edibility, or quality of the crops that prevents it from being consumed by people.

Post-harvest losses

Effect on……

1- Quantity
2- Quality
3- Value

Quality:

Is defined as "any of the features that make something what it is" or „**the degree of excellence or superiority"**. The word quality is used in various ways in reference to fresh fruit and vegetable crops **such as** market quality, edible quality, dessert quality, shipping quality, nutritional quality, internal quality and visual quality.

Safety factors include levels of naturally occurring **toxicants** in certain crops (such as glycoalkaloids in potatoes) that vary according to genotypes and are routinely monitored by plant breeders to ensure that they do not exceed their safe levels in new cultivars.

Contaminants, such as chemical residues and heavy metals, on fresh fruits and vegetables ,the harvesting and postharvest handling operations are essential to minimizing microbial contamination. Proper preharvest and postharvest handling procedures must be enforced to reduce the potential for growth and development of mycotoxin-producing fungi.

All fresh horticultural crops have variable shelf life and require different suitable conditions during marketing; **they are high in water content** and are subjected to desiccation (wilting) and **to mechanical injury**. Fruit and vegetable is highly perishable but most important commodity for human due to their **high nutritional value**, **cheapest** and other **source of protective food**.

Horticultural produce is alive and has to stay alive long after harvest. Like other living material it uses up oxygen and gives out carbon dioxide. It also means that it has to receive intensive care.

Losses in quantity and quality affect horticultural crops between harvest and consumption. The magnitude of postharvest losses in fresh fruits and vegetables is an estimated **5 to 25** percent in developed countries and **20 to 50** percent in developing countries, **depending upon the commodity because of :**

•Lack of reliable maturity indices for farmers.

•Poor produce handling.

•Poor transportation and transport without packaging.

•Inappropriate packaging which does not protect the crops.

•Poor temperature and humidity control around the crops.

•Lack of appropriate post-harvest treatments.

•Unsuitable use of pesticides.

•Low prices on the local market which discourage the use of expensive packaging and transport.

To reduce these losses, producers and handlers must understand the biological and environmental factors involved in deterioration and use postharvest techniques that delay senescence and maintain the best possible quality.

The main objectives of applying postharvest technology are:

1. To maintain quality (appearance, texture, flavor and nutritive value).
2. To increase the shelf life of fruit and vegetables.

3.Fruit and vegetable are available in surplus only in certain seasons and availability in different regions. To make the seasonal fruits available throughout the year for storing seeds, such as potatoes and seeds.

4.To facilitate the shipment of fruit for long distances.

5. To protect food safety.

6.To reduce losses between harvest and consumption.

7.To organize the display fruit in the market. To stabilize the prices of the fruit and vegetables in the market.

Postharvest losses can be classified as:

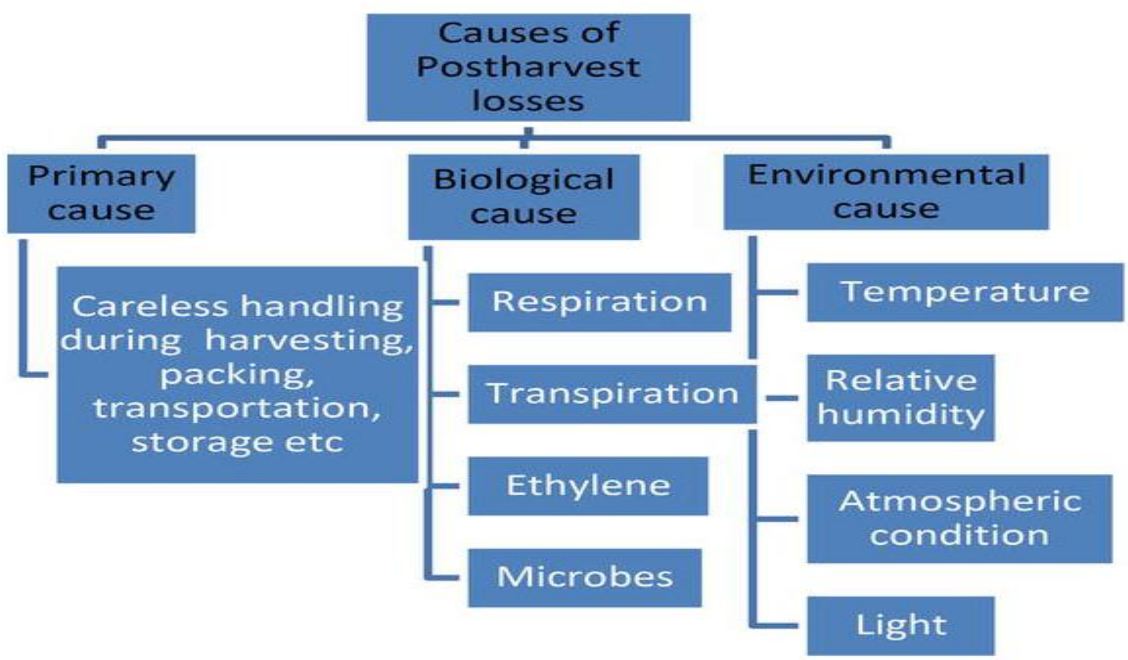
a. **Direct losses** i.e. those caused by waste or consumption by non-human agents, such as insects, birds, fungi, bacteria and others.

b. **Indirect losses** i.e. those due to deterioration in quality or acceptability of the product up to the point of complete rejection by the consumer, eg.changes in its appearance, texture, and color caused by climate, improper handling, transportation, or infrastructure.

c. **Economic losses** i.e. those losses brought about by changes in market conditions and expressed in economic terms, eg. Losses due to changes in demand and supply.

Causes of postharvest losses

The causes of postharvest losses can be divided into different categories:



Important types of postharvest horticultural losses, quality deterioration and food safety problems encountered by produce handlers and marketers.

Problems	Examples
Water loss (weight loss)	Shriveling, wilting of fruits and vegetables
Water loss (loss of textural quality)	Softening, limpness, loss of crispiness or juiciness
Mechanical damage	Bruises, cuts, surface abrasions or crushing
Physical losses due to pests	Fungal and bacterial diseases, insect attack
Contamination	Soil, pathogenic bacteria (soil-borne disease) Pesticide and chemical residues
Losses from physiological disorders	Chilling injury, freezing injury, heat injury, sunburn due to temperature
	Calcium deficiency (bitter pit, blossom end rot), due to nutrient imbalances Boron toxicity
	Damage from ethylene (russet spotting, softening, induced due to atmospheric gases browning), low oxygen, high carbon dioxide, or refrigerant gas leaks (ammonia)
Losses due to continued growth	Rooting, sprouting, shoot development, and development after harvest elongation and curvature of asparagus, greening of potatoes, fiber development, seed germination inside fruits, compositional changes (loss of color, flavor, firmness)
Nutritional losses of stored	Carbohydrates, vitamin C

1. Primary causes

Horticultural commodities like fruits and vegetables are when grown and transported to consumers are subjected to various agricultural operations like harvesting, packing, storage etc. The large number of losses may occur when harvesting is not done at adequate moisture content and time of harvesting. Delayed harvesting or too early harvesting may subject the crop severe losses by various factors like attack of birds, rodents, microbes, natural calamities etc.

2. Biological cause

2.1. Respiration

Respiration is a physiochemical process in which stored organic materials like carbohydrate, lipids, fats are catabolized into simple compounds in order to liberate energy essential for metabolic processes. Respiration is an important phenomenon which influences the physiological and biochemical activities of horticultural produces like fruits and vegetables. In other words, the deterioration of horticultural products is directly related to respiration rate. The respiration rate of horticultural produce can be estimated in terms of O_2 consumed or CO_2 evolved in various processes like development, maturation, ripening etc.

2.2. Transpiration

Transpiration is the physiological process which involves loss of water in the form of vapor from living tissues of the plant. The extreme loss of water from harvested produce is the major cause of deterioration which compromises its quality, nutrition, palatability and demand among consumers.

2.3. Microbes

Stored horticultural produce are often subjected to postharvest diseases caused by bacteria, mould, fungi and incidence of insect pest and rodents. The common pathogen that infects the postharvest produce includes *Penicillum sp., Botrytis sp., Fusarium sp., Phytophthora infestans* etc. **Mechanical damages** and bruising during harvesting and other agricultural operations are common point of entry of pathogenic microorganisms which affect the quality and quantity of produce adversely and reduces marketability as well.

2.4. Ethylene

Ethylene is a gaseous hormone which plays an active and important role in postharvest technology of horticultural produce. It is a Ripening hormone which controls ripening process in fruits and vegetables. However, it has also some undesirable effects on fruits like premature ripening, skin damage etc.

3. Developmental

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

4. Parasitic diseases

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

5. Physiological deterioration

Exposure of the commodity to undesirable temperatures can result in physiological disorders.

Freezing injury results when commodities are held below their freezing temperatures.

Chilling injury occurs in some commodities (mainly those of tropical and subtropical origin) held at temperatures above their freezing point and below 5° to 15°C (41°-59°F), depending on the commodity.

The most common symptoms are surface and internal discoloration (browning), pitting, water soaked areas, uneven ripening or failure to ripen, off-flavor development.

Heat injury is induced by exposure to direct sunlight or to excessively high temperatures. Its symptoms include bleaching, surface burning or scalding, uneven ripening, excessive softening, and desiccation.

6. Lack of market demand

Poor planning pr inaccurate production and market information may lead to over production of certain fruits or vegetables which can't be sold in time. This situation occurs most frequently in areas where transportation and storage facilities are inadequate. Produce may lie rotting in production areas, if farmers are unable to transport it to people who need it in distant locations.

7. Consumption

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

increase production can be achieved by:

1-**Increase horizontal**: the expansion of agricultural area by adding new space through the reclamation or improvement of land.

2-**Increase vertical**: by raising yields per Acre result of the use of high production, the application of appropriate technological methods.

Technologies for minimizing the losses

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.

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.

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.

6. 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 and papaya fruit fly.

7. 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. They not only minimize the post harvest losses but also need for energy intensive operations and controlled atmosphere storage.

Pre-harvest factors affecting quality

1. **Cultivar and rootstock genotype:** Cultivar and rootstock genotype have an important role in determining the taste quality, nutrient composition, and postharvest life of fresh commodities. The incidence of and severity of decay, insect damage, and physiological disorders can be reduced by choosing the correct genotype for given environmental conditions.
2. **Mineral nutrition:** Nutritional status is an important factor in quality at harvest and postharvest life of various fruits and vegetables. High nitrogen levels can stimulate vigorous vegetative growth but at the same time cause a reduction in ascorbic acid content, lower sugar content, increase tissue softening, lower acidity, and altered levels of essential amino-acids. In green leafy vegetables such as spinach, lettuce, celery and cabbage, high nitrogen application under low light conditions can result in the accumulation of nitrates in plant tissues to unhealthy levels.
3. **Irrigation and drainage:** A deficiency or excess of water may influence postharvest quality. Extreme water stress reduces yield and quality, mild water stress reduces crop yield but may improve some quality attributes, and no water stress increases yield but may reduce postharvest quality.
4. **Cultivation practices:**
   weed control, pesticides and herbicides, growth regulating chemicals.
5. **Crop rotations:** Is the practice of growing a series of dissimilar/different types of crops in the same area in sequenced seasons. It also helps in reducing soil erosion and

increases soil fertility and crop yield.Growing of different crops in succession on piece of land to avoid exhausting the soil and to control weeds, pests, and diseases.

Characteristics of horticultural crops:

Horticultural commodities are living products and sometimes are still growing. Therefore, they often continue development in ways that sometimes reduce quality.

1- Living tissue after harvest
2- Respiration
3- Transpiration (water loss)
4- Ethylene Production
5- Pathological damage, their susceptibility to fungal diseases
6. Growth and Development:

- Sprouting (onions, tubers, root crops)
- Rooting (onions, root crops)
- Elongation & Curvature (asparagus, gladiolus)
- Seed Germination (lemon, tomato, pepper)

Shelf life

Shelf life is generally defined as **the time** it as takes for a product to become unacceptable for consumption or unsalable. Quantities of shelf life depends on measurement of sensory, instrumental, or microbial deterioration, and the rate is affected by the type of product, processing method, Packing and storage condition.

Fruits and horticultural crops are divided according to their **ability to the store** to the following sections:

1 - Perishable crops:

Leafy greens such as lettuce, spinach and cabbage, crops such as artichokes and figs. These crops are perishable and not more than one- two weeks a period stored.

2 - Moderate crop damage:

These include vegetable fruit crops such as tomatoes, melons, beans and fruits such as grapes, peaches and pears and citrus. And these crops can be stored for a period of 3 weeks to several months.

3 - Slow crop damage (N0n perishable):

They include vegetable crops such as potato tubers and root like sweet potato and turnips and radishes and carrots - bulbs such as onions and garlic - the fruits of dry legumes such as beans and peas, Walnut. These crops and stored for longer than several months to about the year. This division is the most important ways to divide the interest in horticultural crops Postharvest.

Fruit formation

Most commonly develop from the ovary wall.

"True fruits" – fruit derived from ovary only.

"False fruits" - composed of tissues derived from flower parts other than the ovary or from more than one ovary.

- Simple fruits - derived from a single ovary eg. apple and mango
- Aggregate fruit - compound fruits where separate ovaries are joined eg. blackberry
- Multiple fruit or compound fruit - fruit that develop from the ovaries of many flowers growing in a cluster or into a single structure eg. pineapple

Fruit Development

Generally occurs in four phases: 1. fruit set 2. rapid cell division 3. cell expansion 4. ripening/maturation

Fruit set

Transformation of flower to fruit pollination and fertilization begins a new stage is the stage of the fruit and inside the seed, it takes several hours as in the flowers of mango to several days as in tomatoes, this fruits of its composition to the division of cells of the wall of the ovary and this needs tonic hormonal get walls of the ovary of the three known outer wall **Exocarp**, and East **Meso** and internal the **Endocarp** of pollen, growth of the seed had a great effect in the growth of the fruit and increase the size of the fruit where the seed supply.

Definition of the fruit according to:

a- The destination plant

An ovary flower mature either ovary alone or ovarian added to some parts of flowering the other and if it contains or consists of fruit from the ovary of the flower just called the fruit of honest because it does not come installed in any part of the flower is the ovary, but if it enters in the composition of fruit parts other than the ovary, such as **receptacle** for example, in strawberry fruits or calyx and the rules of corolla and stamens, such as apples and pears, they are false fruit.

b-The destination of agricultural physiological science storage

It is a part of an edible, such as citrus fruits - apples - plum - peach - tomatoes - cucumber - and in other cases may not have any contact with fruit such as potatoes in botany is a leg mutated (tubers), as well as onion is an onion and lettuce is a leaf and the potato is root.

Fruit Growth Pattern

In general the rate change in fruit size follows two curve patterns.

1. Simple sigmoid curve

e.g. pea and Tomatoes, Pome fruits, Date palm, the initial growth rate slow in absolute terms, then increasing to steady state and finally decreasing toward maturity.

1- **Cell division**: Predominates after bloom, Smaller fruited crops generally have a shorter period of cell division Extended some by blossom thinning.

2- **Cell Enlargement Stage** : Begins soon after pollination, continues through cell division stage, then at diminishing rate until harvest.

3- **Maturity:** Means the arrival of the fruit to the maximum possible change, size, and the end of the operations of different growth.

Horticultural maturity

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

Physiological maturity

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

Commercial maturity

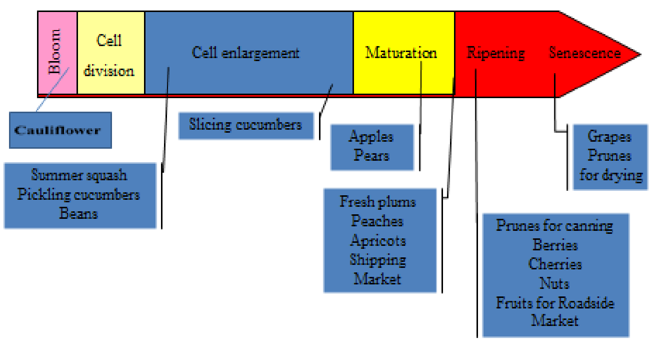
It is the state of plant organ required by a market. It commonly bears little relation to Physiological maturity and may occur at any stage during development stage.

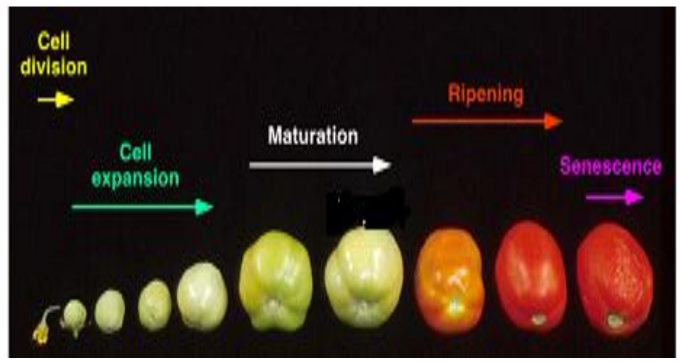
Harvest maturity

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

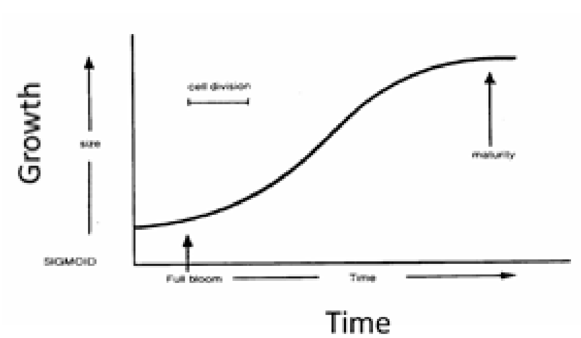
4- **Ripening**: A set of changes that lead to the validity of the fruit for consumption (eating) or manufacturing.

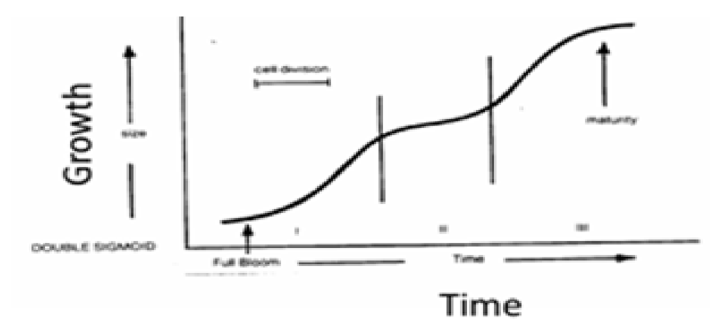
5- **Senecensce** :Related to ripening – but involve catabolic stage where tissue will damage and the organ dead





2. Double sigmoid curve
e.g. Stone fruits, Olive, Grape, Strawberry, Fig, two periods of growth with a period of slow or suspended growth in between.
Pit hardening Lignification of endocarp





Best time is for harvest:

- Early morning:-
  Most fresh produce is at its maximum turgidity and hence best quality.
- Late evening:- Turgidity is down: low turgidity of oil cells in the peel of oranges, hence less damage and susceptibility to fungal infection.
- Mid-day? – **No!!** Physiological activities high.

Environmental conditions affecting fruit development

1. **Water**
   deficient water results in slow growth and small fruit, superfluous water causes fruit drop and less sweet, less aromatic.
2. **Temperature**
   Fruit development is enhanced by greater difference in T between day and night. Without enough light, fruit is smaller, low sugar contents and poor color.
3. **Light**
   Without enough light, fruit is smaller, low sugar contents and poor color.

Vegetable Common Edible Parts

Beans, pod with seeds	Parsley, leaf stems, leaves	Beets, root
Broccoli flower, flower stem	Chard, leaves	Carrot, root
Cauliflower immature flower, flower stem	Onions, bulb and young leaves	
Radish roots, leaves	Celery and Dill leaf stems, leaves	
Tomato and Cucumber fruit with seeds	Turnip roots, leaves	
Eggplant fruit with seeds	Leek, leaves	Potato, tuber stem
Peas seeds, pods vegetable parts.	Okra pods with seeds	Potatoes, tuber root

What are differents between fruit and vegetable?

Chemical Composition of fruit&vegetables

Nutrient is defined as a substance obtained from food and used in the body to promote growth, maintenance, and repair of body tissues, nutrients are classified into two groups, namely macronutrients (also called energy producing nutrients or energy-yielding nutrients) and micronutrients (also called protective).

Nutrients

Macro nutrients

Energy producing

Carbohydrates, Fats and Proteins

Micro nutrients

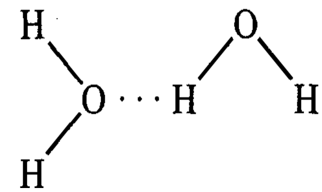
protective

Vitamins minerals

Macronutrient: Nutrient needed in large amounts for normal growth and development.

Micronutrient: Nutrient needed in tiny amounts; a substance that an organism requires for normal growth and development but only in very small quantities, e.g. vitamins or minerals.

1 – Water



Vegetal cells contain important quantities of water.

Water plays a vital role in the evolution and reproduction cycle and

in physiological processes. It has effects on the storage period length and on the consumption of tissue reserve substances. It is one liquid that allows us to live. Vegetables contain generally **90-96%** water while for fruit normal water content is between 80 and 90%., water is present in following forms:

1- Bound water or dilution water which is present in the cell and forms true solutions with mineral or organic substances.
2- Colloidal bound water which is present in the membrane, cytoplasm and nucleus and acts as a swelling agent for these colloidal structure substances; it is very difficult to remove during drying/dehydration processes.
3- Constitution water, directly bound on the chemical component molecules and which is also removed with difficulty.

2- Carbohydrates

After water, carbohydrates are polyhydroxy aldehydes or ketones, or substances that yield such compounds on hydrolysis, they are the main component of fruits and vegetables and represent more than 90% of their dry matter. Carbohydrates are:

- A major source of energy.
- Composed of the elements C, H and O.
- Also called saccharides, which means "sugars."
- Essential components of nucleic acids as in the case of ribose.
- Components of vitamins such as ribose and riboflavin.

Carbohydrates play a major role in biological systems and in foods. They are produced by the process of photosynthesis in green plants.

Carbohydrates can be oxidized to furnish energy, and glucose in the blood is a ready source of energy for the human body. Fermentation of carbohydrates by yeast and other microorganisms can yield carbon dioxide, alcohol, organic acids and other compounds. Carbohydrates include sugars and their polymers.

- Simple Carbohydrates : The six simple carbohydrates include the monosaccharides (glucose, fructose and galactose) and the disaccharides (sucrose, maltose and lactose).

a- Monosaccharides are similar in numbers and kinds of atoms but differ in their arrangement and sweetness, contain a single polyhydroxy aldehyde or ketone unit (*saccharo* is Greek for "sugar") (e.g., glucose, fructose).

1- Glucose serves as the essential energy source, is commonly known as blood sugar or dextrose.

2- Fructose is the sweetest, occurs naturally in honey and fruits, and is added to many foods in the form of high-fructose corn syrup.

3- Galactose rarely occurs naturally as a single sugar.

b- Disaccharides are formed by condensation reactions and are broken down by hydrolysis reactions.

1- Condensation reactions link monosaccharide's together.

2- Hydrolysis reactions split molecules and commonly occur during digestion.

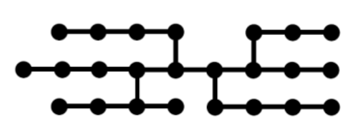
3- Maltose consists of two glucose units. It is produced during the germination of seeds and fermentation.

4- Sucrose is fructose and glucose combined. It is refined from sugarcane and sugar beets, tastes sweet, and is readily available.(Apricot, Peach and pineapple), while cherries, grape and fig have no sucrose.

5- Lactose is galactose and glucose combined. It is found in milk and milk products.

-The Complex Carbohydrates are a few (oligosaccharides) or many (polysaccharides) glucose units bound/linked together in straight or branched chains.

a- Starch



1- Storage form of glucose in plants
2- Found in grains, tubers, and legumes

- **Inulins** are a group of naturally occurring polysaccharides, it is a natural storage carbohydrate produced by many types of plants, including onion, bananas, garlic, asparagus. Inulin is a heterogeneous collection of fructose polymers. For these plants, inulin is used as an energy reserve and for regulating cold resistance. Because it is soluble in water, it is osmotically active. Most plants that synthesize and store inulin do not store other forms of carbohydrate such as starch.

b- Dietary fiber provides structure in plants, is very diverse, and cannot be broken down by human enzymes.

1- Soluble fibers are viscous and can be digested by intestinal bacteria (this property is also known as ferment ability).

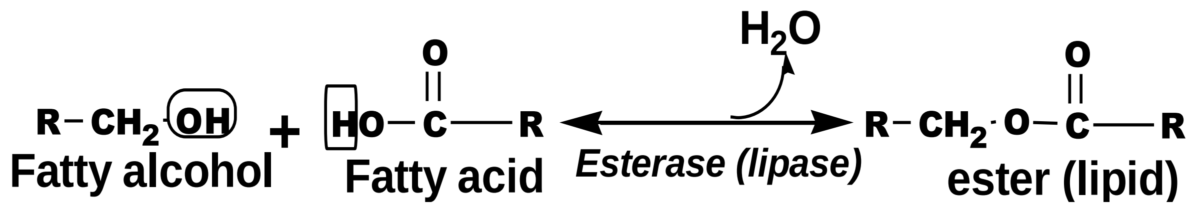
2 -Insoluble fibers are no viscous and are not digested by intestinal bacteria. These fibers are found in grains and vegetables.

3- Lipids

Lipids are organic compounds formed mainly from **alcohol** and **fatty acids** combined together by **ester linkage**. All lipids share one important character;**1-**They have either little or no affinity to water (hydrophobic). **2-** Smaller than other major macromolecules. **3-** Highly varied group in form and function.

Lipids have three important roles as a nutrient:

a- it is a highly concentrated source of energy.
b- it serves as a carrier for fat-soluble vitamins and there are some fatty acids that are essential nutrients that can only be ingested with fat.
c- Fat also serves as a carrier for some of the bioactive compounds present in fruits such as phytoestrogens and carotenoids that are lipophilic Fatty acids are also needed to form cell structures. -Include fats, phospholipids, waxes, some pigments and steroids.



Fat:

-Store large amounts of energy.

-Are constructed from two kinds of smaller molecules: Glycerol and fatty acids. Glycerol is an alcohol with 3 carbons; Fatty acid- has a long carbon skeleton with 16 or 18 carbons and carboxyl group attached at one end.

Saturated fat and fatty acids: have no double bonds between the carbon atoms composing the chain. E.g. Stearic acid. **Unsaturated fat and fatty acids** have double bonds between the carbon atoms composing the chain. E.g. Oleic acid. Generally fruit and vegetables contain very low level of fats. However, significant quantities are found in **nuts** (55%), **apricot seeds** (40%), **grape seeds (**16%), **apple seeds** (20%) and **tomato seeds** (18%).

Waxes are a class of chemical compounds that are plastic (malleable) near ambient temperatures. Characteristically, they melt above 45 °C (113 °F) to give a low viscosity liquid. Waxes are insoluble in water but soluble in organic, nonpolar solvents. All waxes are organic compounds, both synthetic and naturally occurring.

4- **Protein**

Proteins are building blocks of structures called amino acids. Proteins are what your DNA codes to make. A peptide bond forms between amino acids by dehydration synthesis.; Proteins are polymers of some **21 different amino acids joined together by peptide bonds.** Because of the variety of side chains that occur when these amino acids are linked together, the different proteins may have different chemical properties and widely different secondary and tertiary structures. Some of which are essential because the human body cannot synthesize them. From the 21 amino acids that are part of the structure of proteins, almost half of them are considered to be essential, including isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. Proteins are essential for:

- structural components of all cells and are needed by the human body to build and repair tissues.
- for the synthesis of enzymes
- for the synthesis of hormones, and others.

Proteins are made up of a long chain of **amino acids**, sometimes modified by the addition of hem, sugars, or phosphates. Proteins have primary, secondary, tertiary, and quaternary structures, all of which may be essential for the protein to be active. Nitrogenated compounds are present in fruits in low percentages (0.1–1.5%). From a quantitative point of view, fruits are not a good source of proteins; however, in general **berries** are a better source than the rest of the fruits. **Avocado and beans** also present higher levels of it.

5- Organic acids

Fruit contains natural acids, such as **citric acid** in **oranges** and **lemons, malic acid** of **apples**, and **tartaric acid** of **grapes**. These acids give the fruits tartness and slow down bacterial spoilage.

We deliberately ferment some foods with desirable bacteria to produce acids and this give the food flavor and keeping quality. Examples are fermentation of cabbage to produce lactic acid and fermentation of apple juice to produce first alcohol and then acetic acid to obtain vinegar. **Organic acids influence** the color of foods since many plant pigments are natural pH indicators. With respect to bacterial spoilage, a most important contribution of organic acids is in lowering a food's pH.

Acidity and sugars are two main elements which determine the taste of fruit. The **sugar/acid ratio** is very often used in order to give a technological characterisation of fruits and of some vegetables.

Examples of minimum SSC/TA ratio:

grapefruit	6.0
mandarin	8.0
orange	8.0
grape	20.0

Titratable acidity: Titratable acidity (TA) can be determined by titrating a known volume of juice with 0.1N NaOH to end point of pink color as indicated by phenolphethalin indicator. The milliliters of NaOH needed are used to calculate the TA. The TA expressed as per cent malic, citric or tartaric acid can be calculated as follows:

$$TA = \frac{\text{ml NaOH x N (NaOH) x acid meq. Factor* x 100}}{\text{Juice titrated}}$$

* the following acid meq. factor may be used for different fruits

Acid	Acid meq. factor	Commodities
Citric	0.0064	Berries, citrus fruits, pineapple
Malic	0.0067	Apple, pear, peach, tomato
Tartaric	0.0075	Grape

6- Pectin:

A complex, high molecular weight polysaccharide mainly consisting of the partial methyl esters of polygalacturonic acid and their sodium, potassium, and ammonium salts. In some types (amidated pectin) **galacturonamide** units occur in polysaccharide chain. The product is obtained by aqueous extraction of appropriate plant material usually citrus fruits and apples). water-insoluble pectic substance hydrolysed into water-soluble pectin when cooked, form colloidal suspensions which will thicken the juice or pulp of these products. Fruit and vegetables contain a **natural enzyme known as pectin methyl esterase**. Materials such as tomato juice or tomato paste will contain both pectin and pectin methyl esterase.

Pectin content (%):

Potato	2.5	Apple	5 - 7
Tomato	3	Citrus albedo	30 - 35
Carrot	10		

Pectin substances:

Protopectins - highly esterified pectic substances, insoluble in water.

Pectinic acids - Less highly esterified pectic substances. Also known as **pectins**. Form colloidal dispersions or are water soluble.

Pectic acids - Pectic substances with 0% degree esterification.

The amount, structure and chemical composition of pectin differs among plants, within a plant over time, and in various parts of a plant. Pectin is an important cell wall polysaccharide that allows primary cell wall extension and plant growth. During fruit ripening, pectin is broken down by the enzymes **pectinase** and **pectinesterase**, in which process the fruit **becomes softer** as the middle lamellae break down and cells become separated from each other. A similar process of cell separation caused by the breakdown of pectin occurs in the abscission zone of the petioles of deciduous plants at leaf fall.

Fruit sources of pectin include citrus fruits such as **grapefruit**, **oranges** and **lemons**. Other fruit sources include **apples**, **apricots**, **bananas, blackberries, cherries, grapes** and **raspberries**. Pectin is found mostly in fruits, but some vegetable sources do exist. These include **carrots**, **green beans, dried beans or legumes**, **squash** and **sweet potatoes**. Of the pectin-containing vegetables, **carrots** have the highest pectin content.

Some properties of pectin and carbohydrate gums.

- Pectin is common in fruits and vegetables and are gum-like (they are found in and between cell walls) and help hold the plant cells together.
- Pectin in colloidal solution contributes to viscosity of the tomato paste.
- Pectin in solution form gels when sugar and acid are added; this is the basis of jelly manufacture.

7- Mineral substances

Mineral substances are present as salts of organic or inorganic acids or as complex organic combinations (chlorophyll, lecithin, etc.); they are in many cases dissolved in cellular juice. Vegetables are richer in mineral substances as compared with fruits. The mineral substance content is normally between **0.60 and 1.80%** and more than 60 elements are present; the major elements are: K, Na, Ca, Mg, Fe, Mn, Al, P. Cl, and S.

Among the vegetables which are especially rich in mineral substances are: **spinach, carrots, cabbage** and **tomatoes**. Mineral rich fruit includes: **strawberries, cherries, peaches** and **raspberries**. Important quantities of potassium **(K)** and absence of sodium chloride (NaCl) give a high dietetic value to fruit and to their processed products. Phosphorus is supplied mainly by vegetables. Vegetables usually contain more **calcium** than fruit; **green beans, cabbage, onions** and **beans** contain more than 0.1% calcium. The calcium/ phosphorus or **Ca/P** ratio is essential for calcium fixation in the human body; this value is considered normal at 0.7 for adults and at 1.0 for children. Some fruit are important for their Ca/P ratio above 1.0: **pears, lemons, oranges** and some temperate climate mountain fruits and wild berries. Even if its content in the human body is very low, **iron (Fe)** has an important role as a constituent of hemoglobin. Main iron sources are **apples and spinach**.

8- Vitamins

Vitamins are defined as **organic materials** which must be supplied to the human body in small amounts apart from the essential amino-acids or fatty acids. Vitamins function as enzyme systems which facilitate the metabolism of proteins, carbohydrates and fats but there is growing evidence that their roles in maintaining health may extend yet further. The vitamins are conveniently divided into two major groups.

Fat Soluble Vitamins: stored in tissues: A, D, E, K

Water Soluble Vitamins: not stored in tissues, must have constant supply: C, B1, B2, B6 & B12 , Niacin, Folic Acid, C (Sources: citrus fruits, tomatoes, leafy vegetables and potatoes).

Vitamin A

Plants contain no vitamin A but contain its precursor, beta-carotene. Man needs either vitamin A or beta-carotene which he can easily convert to vitamin A. Beta-carotene is found in **the orange and yellow vegetables** as well as the green leafy vegetables, **carrots, squash, sweet potatoes, spinach**.

Vitamin C

Vitamin C is the anti-scurvy vitamin, also known as ascorbic acid, is easily destroyed by oxidation especially at high temperatures and is the vitamin most easily lost during processing, storage and cooking. Excellent sources of vitamin C are **citrus fruits, tomatoes, cabbage and green peppers. Potatoes** also are a fair source; we consume large quantities of potatoes. Lack of it causes fragile capillary walls, easy bleeding of the gums, loosening of teeth and bone joint diseases.

9-Enzymes

A biological catalyst that promotes and speeds up a chemical reaction without itself being altered in the process. Lowers the activation energies of a substance biological catalysts that promote most of the biochemical reactions which occur in vegetable cells; control the reactions associated with ripening; after harvest, unless destroyed by heat, chemicals or some other means, enzymes continue the ripening process, in many cases to the point of spoilage - such as soft melons or overripe bananas.

Structure of an enzyme:

Contains both a **protein** and **a nonprotein.**

Nonprotein is either a coenzyme (usually a vitamin) or a cofactor (usually a mineral).

Some properties of enzymes important in fruit and vegetable technology are the following:

- in living fruit and vegetables enzymes control the reactions associated with ripening;
- after harvest, unless destroyed by heat, chemicals or some other means, enzymes continue the ripening process, in many cases to the point of spoilage - such as soft melons or overripe bananas.
- because enzymes enter into a vast number of biochemical reactions in fruits and vegetable, they may be responsible for changes in flavour, colour, texture and nutritional properties;

- the heating processes in fruit and vegetables manufacturing/processing are designed not only to destroy micro-organisms but also to deactivate enzymes and so improve the fruit and vegetables' storage stability.

Names usually end in –**ase**. Usually named after substrates they act upon e.g. urea --- urease or the resulting type of chemical reaction e.g. hydrolysis --- hydrolases oxidation --- oxidases **This rule does not always apply.** E.g. **ficin** found in figs and **papain** in papayas. In fruit and vegetable storage and processing the most important roles are played by the enzymes classes of hydrolases **(lipase, invertase, tannase, chlorophylase, amylase, cellulase)** and oxidoreductases (peroxidase, tyrosinase, catalase, ascorbinase, polyphenoloxidase).

The major factors useful in controlling enzyme activity are:

1. temperature
2. water activity
3. pH
4. chemicals which can inhibit enzyme action

10- Pigments

Pigments are defined as the set of compounds that have an intense colour and are used in the colouring of other materials. These colouring substances are also called Biological Pigments or the Biochromes, which mainly refers to the true pigments.

- **Chlorophylls**: Is one of the primary pigment found within the plant cells of all green plants. The green colouring of the plant leaves and the tender part of the stem is due to the presence of a pigment called chlorophyll. The chlorophyll pigment is the most significant and essential pigments, as it plays a vital role in the biological process of photosynthesis and responsible for the color of **leafy vegetables** and some fruits. In green leaves, the chlorophyll is broken down during senescence and the green color tends to disappear. In many fruits, chlorophyll is present in the **unripe** state and gradually disappears as the yellow and red carotenoids take over during ripening. In plants, chlorophyll is isolated in the chloroplastids.

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All land plants and green algae possess two forms of this pigment: chlorophyll a and chlorophyll b.

- **Carotenoids:** Are the pigments in the form of orange, red, yellow colours. These compounds are insoluble in water and are attached to the membranes of the cell bodies. These Biomolecules are antioxidants which promote a good eyesight in humans.The most familiar carotenoids are carotene (an orange pigment found in **carrots**), lutein (a yellow pigment found in fruits and vegetables), and lycopene (the red pigment responsible for the color of **tomatoes**).
- **Anthocyanins** are water-soluble flavonoid pigments that appear red to blue, according to pH. They occur in all tissues of higher plants, providing color in leaves, plant stem, roots, flowers, and fruits, though not always in sufficient quantities to be noticeable. **Anthocyanin** is most visible in **the petals of flowers**
- **Flavonoids:**

• Pigments and colour precursors belonging to this class are water-soluble and commonly are present in the juices of fruit and vegetables.

• The flavonoids include the **purple, blue, and red anthocyanins of grapes, berries, plump, eggplant, and cherry**; the yellow anthoxanthins **of light coloured fruit and vegetables such as apple, onion, potato, and cauliflower**, and the colourless **catechins and leucoanthocyanins** which are food **tannins and are found in apples, grapes, tea**, and other plant tissues.

11- Plant hormones

They are chemical compounds synthesized in the cells of stems, leaves, roots, and flowers.

1- Auxins
2- Gibberellins
3- Cytokinins
4- Ethylene:1) promotes fruit ripening 2) stimulates production of cellulose.
5- Plant growth inhibiters (Abscisic Acid).

Properties of plant hormones

1- Active in small amounts.

2- Produced in one part of plant & transported to another for action.

3- Action is specific for that site.

Each has a Multiplicity of effects:

- Depending on site of action
- Developmental stage of plant
- Concentration of hormone

Changes that occur before and after the harvest of fruit

Fruit and vegetables, before and after harvest, include changes in carbohydrates, pectin, organic acids, and the effects these have on various quality attributes of the products.

- The courses of change in starch and sugars are markedly influenced by postharvest storage temperatures. Thus potatoes stored below about 10 C° (50 F°) continue to build up high levels of sugars, while the same potatoes stored above 10 C° do not.

- There is decrease in water-insoluble pectic substance and a corresponding increase in water soluble pectin. This contributes to the gradual softening of fruits and vegetables during storage and ripening. Further breakdown of water-soluble pectin by pectin methyl esterase also occurs.
- The organic acids of fruit generally decrease during storage and ripening. This occurs in apples and pears and is especially important in the case of oranges. Oranges have a long ripening period on the tree and time of picking is largely determined by degree of acidity and sugar content which have major effects upon juice quality.

Deterioration factors of fruits and vegetables

1- Enzymic changes: Enzymes which are endogenous to plant tissues can have undesirable or desirable consequences. Examples include:
   a- the post-harvest senescence and spoilage of fruit and vegetables.

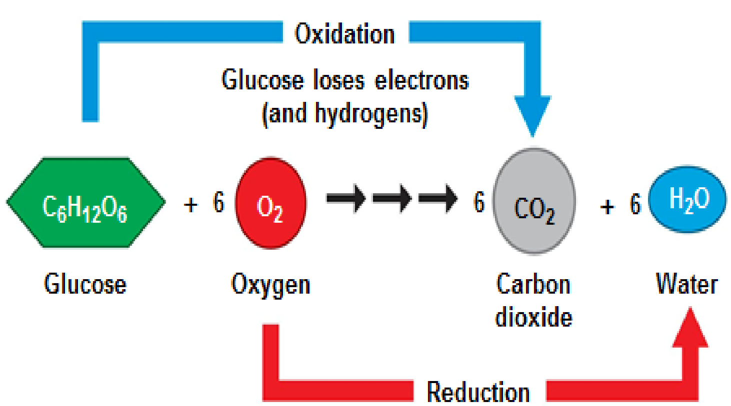
   b- oxidation of phenolic substances in plant tissues by phenolase (leading to browning); sugar - starch conversion in plant tissues by amylases.
   c- Post-harvest demethylation of pectic substances in plant tissues (leading to softening of plant tissues during ripening.

2- Flavour changes: In fruit and vegetables, enzymically generated compounds derived from long-chain fatty acids play an extremely important role in the formation of characteristic flavours. In addition, these types of reactions can lead to significant off-flavours.

Respiration

Respiration is the process by which stored organic materials (carbohydrates, proteins, fats) are broken down into simple end products with a release of energy. Oxygen is used in this process, and carbon dioxide is produced. The losses of stored food reserves in the commodity during respiration means the hastening of senescence as the reserves that provide energy to maintain the commodity's living status are exhausted; reduced food value (energy value) for the consumer, loss of flavour quality, especially sweetness; and loss of salable dry weight, which is especially important for commodities destined for dehydration. The energy released as heat, known as **vital heat**, affects post -harvest technology considerations, such as estimation of refrigeration and ventilation requirements.

It is of the most important of all living things is respiratory metabolism. The process of respiration involves combing O_2 in the air with organic molecules in the tissue (usually a sugar) to form various intermediate compounds and eventually CO_2 and water. The energy produced by the series of reactions comprising respiration can be captured as high energy bonds in compounds used by the cell in subsequent reactions, or lost as heat. The energy and organic molecules produced during respiration are used by other metabolic processes to maintain the health of the commodity. Heat produced during respiration is called **vital** heat and contributes to the refrigeration load that must be considered in designing storage rooms.



What is the chemical equation for cellular respiration?

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

sugar (glucose) + oxygen → carbon dioxide + water + energy

The plants obtain oxygen from their environment and return carbon dioxide and water vapor into it. The biochemical process, which occurs within cells and oxidises food to obtain energy, is known as **cellular respiration**. Various enzymes (biocatalysts) catalyzethis process. The process by which cells obtain energy from complex food molecules depends upon whether or not oxygen is present in their environment and utilised. Respiration is termed **aerobic** when oxygen is utilized and **anaerobic** when oxygen is not utilized. In anaerobic respiration, organic molecules are incompletely broken down and only a small fraction of energy is captured as ATP for use by the cell. In aerobic respiration the reactions of anaerobic respiration are followed by an oxygen requiring process that releases much larger quantity of energy in the form of ATP.

Aerobic respiration:-

Takes place in the presence of air/ oxygen.

Anaerobic respiration: -

Takes place in the absence of air/ oxygen.

Steps in respiration

1. Glycolysis: In cytoplasm of the cell, operates both under aerobic as well anaerobic conditions. Net gain of 8ATP. **Glycolysis (Glyco= sugar, Lysis=breaking).**
2. Oxidation of Pyruvic Acid: In matrix of mitochondria, operates under aerobic conditions only. Net gain of 3 ATP.
3. Kreb Citric Acid Cycle: Tricarboxylic Acid – In matrix of mitochondria, under aerobic condition only. Net gain of 24ATP.
4. Oxidative Phosphorylation: In inner membrane of mitochondria under aerobic conditions only .*NADPH=3ATP

ATP= **A**denosine **t**ri**p**hosphate organic molecule containing high-energy Phosphate bonds.

- The energy released during respiration is not used directly by cells.
- Instead it is used to make a molecule called ATP which stores the energy

What does ATP do?

- ATP supplies energy for all the processes that need it, for example:
  - » movement
  - » chemical reactions
  - » growth.

ADP + Pi -----------------------ATP

The whole process is under the control of enzymes

Aerobic (Aero = Air)	**Anaerobic (Anaero = No air)**
1. Takes place in presence of oxygen. 2. Leads to complete oxidation of organic substrate. 3. It is most common in higher organisms (both plants and animals). 4.Takes place in both cytoplasm and mitochondria of the cell. **$C6H1_2O6 + 6O_2$ ------- $6CO_2$ + 6 H_2O +38ATP**	1. Takes place in complete absence of oxygen. 2. Incomplete oxidation of organic substrate takes place. 3. Takes place in lower organisms such as bacteria, fungi. 4. Takes place only in cytoplasm of the cell. **$C6H1_2O_6$ ---------2Ethyl alcohol +$2CO_2$ +2ATP**

In addition to glucose, cellular respiration can "burn":

- Diverse types of carbohydrates
- Fats
- Proteins

There are various ways of measuring gas exchange, but the three methods used most often are:

1. Static method: a specific gas composition is generated around an object and the gas flow is closed for a specific period of time. Gas composition is measured at the beginning and end of the period.

2. Flowthrough method: a specific gas composition is generated around an object and the gas composition of the inward and outward flow is measured.

3. MA method: using a package with film of known O_2 and CO_2 permeability, the equilibrium concentrations that develop are measured. Gas exchange rates can then be calculated.

Respiratory Quotient:

During aerobic respiration, O_2 is consumed and CO_2 is released. The ratio of the volume of CO_2 evolved to the volume of O_2 consumed in respiration is called the respiratory quotient (RQ) or respiratory ratio. The respiratory quotient depends upon the type of respiratory substrate used during respiration.

When carbohydrates are used as substrate and are completely oxidised, the RQ will be 1, because equal amounts of CO_2 and O_2 are evolved and consumed,

This means that one molecule of sugar reacts with six molecules of oxygen to produce six molecules of carbon dioxide and six molecules of water. **Energy** is released during this process.

$C6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + 686$ kcal/mole

$RQ = 6\ CO_2 / 6\ O_2 = 1$

When fats are used in respiration, the RQ value of proteins and fats is < 1 (0.7 to 0.9)

When organic acids are used in respiration, the RQ is >1(1.3- 4).

RQ value is important in identifying the kind of substrate used in respiration.

RQ value in anaerobic respiration is infinity as oxygen is not used.

Factors Affecting Respiration

1-Temperature: Without a doubt, the most important factor affecting postharvest life is temperature. This is because temperature has a profound affect on the rates of biological reactions, eg., metabolism and respiration.

2-Stage of development: Respiration rates vary among and within commodities. Storage organs such as nuts and tubers have low respiration rates. Tissues with vegetative or floral meristems such as asparagus and broccoli have very high respiration rates. As plant organs mature, their rate of respiration typically declines. This means that commodities harvested during active growth, such as many vegetables and immature fruits, have high respiration rates. Mature fruits, dormant buds and storage organs have relatively low rates.

3- Oxygen

4- Carbon dioxide

5- Light **6-Damage** **7-Water**

Respiration Rates	**Types of Fruits and Vegetables**
Very Low	Dried fruit and nuts
Low	Apples, garlic, grapes, onions, potatoes (mature), sweet potatoes
Moderate	Apricots, cabbages, carrots, figs (fresh), lettuce, nectarines, peaches, pears, peppers, plums, potatoes (immature), tomatoes
High	Artichokes, cut flowers, green onions, snap beans
Extremely High	Asparagus, broccoli, mushrooms, peas

Fermentation

The main source of CO_2 production by plant tissues is respiration. At low O_2 or high CO_2 atmospheres, however, fermentation becomes increasingly important. The main fermentative metabolites found in plant tissues are ethanol, acetaldehyde, and lactic acid.

Ethanol is the most abundant metabolite, especially under prolonged anoxia, resulting in additional CO_2 production (24,25). Ethanol fermentation is the catabolism of pyruvate to ethanol: the combination of glycolysis and fermentation can be expressed as:

Significance of fermentation

Fermentation has a number of industrial applications. It is made use of on a large scale in certain industries. Microorganisms like the different strains of bacteria and yeast are cultured in very large numbers and used for various purposes.

1. In bakeries for preparing bread, cakes and biscuits etc.
2. In breweries for preparing wine and other alcoholic drinks.
3. In producing vinegar and in the tanning and curing of leather.
4. Ethanol is used to make gasohol, a fuel that is used for cars.

Transpiration (Loss of water)

Most fresh produce contains from 65 to 95 percent water when harvested. Within growing plants there is a constant flow of water. Liquid water is absorbed from the soil by the roots, then passed up through the stems and finally is lost from the aerial parts, especially leaves, as water vapour.

- Transpiration is the major mechanism that drives the movement of water through a plant.
- Transpiration is the loss of water from a plant by **evaporation.**
- Water can only evaporate from the plant if the **water potential** is **lower** in the **air** surrounding the plant (Fruit).

Transpiration in fruits

Transpiration is a mass-transfer process in which water vapor moves from the surface of a fruit or vegetable to the surrounding air. Water can only evaporate if the water potential is lower in the air surrounding the plant (Fruit).This process of moisture loss induces wilting, shrinkage, and loss of firmness and crispness of fruits and vegetables, and thus adversely affects the appearance, texture, flavor, and mass of produce.

Loss of water, as vapor, from the product's area exposed to the air, throughout the **cuticle, lenticels, stomas**, etc. freshness is water and water loss is one of the main causes of deterioration, which reduces the marketability of fresh fruits and vegetables. Profitability in fresh fruit, vegetable sales depends on the ability to deliver as much of this water as possible to consumers it depends on:

- **Internal factors:**
  1. Species and variety.
  2. Type of tissue.
  3. Integrity and sanitary product condition.
- **External factors:**
  1. **Relative humidity**: - air inside fruits is saturated (RH=100%).
  2. **Air Movement**: - increase air movement increases the rate of transpiration as it moves the saturated air from around the fruit.

3. **Temperature**: - increase in temperature increases the rate of transpiration as higher temperature
4. **Atmospheric pressure**: - decrease in atmospheric pressure increases the rate of transpiration.
5. **Water supply**: - transpiration rate is lower if there is little water available as transpiration depends on the mesophyll cell walls being wet.

6. **Light intensity**: - greater light intensity increases the rate of transpiration because it causes the stomata to open, so increasing evaporation through the stomata.

Water loss can be reduced by:

1. maintaining high moisture content in the air around the vegetables.
2. precooling;
3. reducing air movement.
4. protective packaging
5. applying a surface coating
6. Curing,

Water loss or transpiration results in the following effects on harvested vegetables:

i. Losses in appearance due to wilting, this results in a loss of snapping quality of yard long beans and okra.
ii. Losses in textural quality: softening, flaccidity, juiciness and nutritional quality. Actual water content is dependent on the availability of water to the tissue at the time of harvest, therefore the water content of the produce will vary during the day if there are diurnal fluctuations in temperature. For most produce, it is desirable to harvest when the maximum possible water content is present as this result in a crisp texture. Hence the time of harvest can be an important consideration, particularly with leafy vegetables, which exhibit large and rapid variations in water content in response to changes in the environment.

Is that the speed of the loss of water at temperature 35 º F and relative 85% more or at temperature 45 º F. and relative humidity 95%, and how to prove it?

T °F	0	1	2	3	4	5
20	**0.103**	**0.108**	**0.113**	**0.119**	**0.124**	**0.130**
30	**0.165**	**0.172**	**0.180**	**0.188**	**0.196**	**0.204**
40	**0.248**	**0.258**	**0.268**	**0.278**	**0.289**	**0.300**
50	**0.363**	**0.376**	**0.391**	**0.405**	**0.420**	**0.436**

$$\textbf{Vapor Pressure Deficit (VPD)} = \frac{100\text{-RH at T}}{100} * \text{VP of Water at T}$$

$$\textbf{VPD 1} = \frac{100-}{100} * \quad =$$

$$\textbf{VPD 2} = \frac{100-}{100} * \quad =$$

VPD1/ VPD2=

Preservation of fruits and vegetables by wax coating

Waxes are a class of organic compounds in both synthetic and naturally occurring. that are plastic (malleable) near ambient temperatures. Characteristically, they melt above 45 °C (113 °F) to give a low viscosity liquid. Waxes are insoluble in water but soluble in organic, nonpolar solvents. . Waxes are the esters formed from a fatty acid and a high molecular weight alcohol.

Is the process of covering fruits (and in some cases vegetables) with **natural and artificial** waxing material. Natural **wax is removed** first, usually by washing.

The natural waxy coat is not adequate to offer protection against water loss and high respiration rate.Waxing of fruits and vegetables is done according to the recommendations.

Food grade waxes are used to replace some of the natural; waxes removed in washing and cleaning operations, and this helps to reduce the water loss during handling and marketing. If produce is waxed, wax is an ester a long chain aliphatic acid chain aliphatic alcohol

Fruits that are waxed: Apple Avocadoes, pepper Lemon, Grapes, Banana Melons, Oranges, Lime, Peaches and Pine apples.

Vegetables: Cucumber, Tomato, Sweet potato and Melon.

Methods of waxing

1. Liquid Paraffin wax method
2. Slab wax method
3. Spray method
4. Dipping or cold wax method

Purpose of waxing

• To reduce the weight loss.
• To replace the natural wax.
• To increase the appearance
• To increase the freshness
• To decrease the rate of transpiration.
• To inhibit mold growth.
• To prevent other physical damage.

Curing:

Curing is conducted immediately after harvesting. It strengthens the skin. The process is induced at **relatively higher temperature and humidity** involving sub erization 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, onion and garlic are cured prior to storage or marketing.

Crop	Temperature (°C)	Relative humidity (%)	Curing time (days)
Potatoes	13-17	Above 85	7-15
Sweet potatoes	27-33	Above 90	5-7
Yam	32-40	Above 90	1-4

Cooling

Cooling is considered one of the most important steps in the postharvest handling chain. Reducing the temperature of fresh produce after harvest greatly reduces respiration rate, extends shelf-life, and protects produce quality, while reducing volume losses by decreasing the rates of water loss and decay. This first cooling step is usually referred to as "precooling" since it is done as soon as possible after harvest and ideally accomplished before produce is placed into cold storage or loaded into refrigerated trucks or marine containers for shipment to market.

Pre- cooling

Pre-cooling is the rapid removal of field heat from fresh produce. It is among the most efficient quality enhancements available to commercial producers and ranks as one of the most essential value-added activities in the horticultural chain.

Pre-cooling methods and techniques to optimise quality

The primary objective in pre-cooling perishable commodities is to remove field heat prior to shipment, storage and display. Proper pre-cooling of freshly harvested commodities can:

i. Suppress enzymatic degradation and respiratory activity (softening).

ii. Slow or inhibit water loss (wilting).

iii. Slow or inhibit the growth of decay-producing microorganisms.

iv. Reduce production of ethylene.

v. Provide market flexibility by making it possible to market at an optimum time.

The rate fresh produce cools depends on several factors:

1. the rate of heat transfer from the produce to the air or water used to cool it.
2. the difference in temperature between the commodity and the cooling medium, i.e. the greater the difference between the two the faster the product cools.
3. the nature of the cooling medium, i.e. cold water has a greater capacity to absorb heat than cold air.
4. the nature of the commodity which influences the rate heat is lost, i.e. leafy vegetables have a greater thermal conductivity than root crops and so cools faster.
5. Social factors – In low-income areas and in areas that lack electricity or cooling infrastructure, the use of simple and appropriate, inexpensive cooling methods makes sense.
6. Package design – Package ventilation (i.e. number and size of holes) and palletization design can greatly impact on the rate of cooling of produce.

Please note that the rate a commodity cools is not constant. It starts cooling rapidly and then quickly slows down. As the difference in temperature between the product and the cooling medium falls the rate of cooling slows down. So it takes longer for the product to cool the last 5^0C than the first 5^0C.

Methods of pre-cooling

1. Room cooling
2. Forced-air cooling
3. Hydro-cooling
4. Use of ice
5. Liquid icing
6. Vacuum cooling

1- **Room cooling**

Room cooling is a relatively low cost but very slow method of pre-cooling. Produce is simply loaded into a cold room, and cold air is circulated around the cartons, sacks, or bins. This cooling method is best suited to less perishable commodities such as potatoes, onions, apples, sweet potatoes and citrus fruits, since more highly perishable crops will deteriorate before being adequately cooled. Room cooling may be well suited to chilling sensitive crops that are cooled from relatively cool early morning harvest temperatures to storage temperatures of 10–13ºC (50–55 ºF). It is important to leave adequate space between stacks of boxes inside the refrigerated room in order for product cool more quickly.

2- **Forced-air cooling**

FA cooling pulls or pushes air through produce containers, greatly speeding the cooling rate of any type of produce.

Many types of forced-air coolers can be designed to move cold air past the commodities. Examples include a fixed unit, where a fan is housed inside the wall of a cold room, or a portable fan unit that can be moved around inside the cold room as needed .When utilizing a tunnel-type forced-air cooler, the canvas sheets must be well sealed over the top of the load, and pallet openings blocked for the cooler to function properly. Package vents must be aligned between boxes to allow the air to flow across a pallet of boxes.

3-**Use of ice**

Ice can be used either directly as package ice, to cool water for use in a hydro-cooler, or as an ice bank for a small forced-air or room cooling system. Ice can be manufactured using simple solar PV systems, where flat plate solar collectors are used to generate power to make ice, which is then used to cool produce.

4-**Vacuum Cooling**

Produce is placed in a chamber and a vacuum is applied. The vacuum reduces the water vapor pressure in the produce, which evaporates moisture and cools the produce. The water loss is objectionable for some produce. A system called Hydro Vacuum cooling was designed to add water during the cooling cycle. Vacuum cooling works well with vegetables that have a high surface-to-mass ratio, such as head lettuce or greens. Precooling but is best suited for medium to large produce operations and **must be economically feasible** to install. The electrical needs of the system must be sized according to the refrigeration system required.

Half-Cooling Time

A common concept used to characterize the hydrocooling. Process is the half-cooling time. **The half-cooling time is the time required to reduce the temperature difference between the commodity and the cooling medium by one-half.** This is also equivalent to the time required to reduce the fractional unaccomplished temperature difference, by one-half.

The half-cooling time is independent of the initial temperature, and remains constant throughout the cooling period provided the cooling medium temperature remains constant. Therefore, once the half-cooling time has been determined for a given commodity, the prediction of hydrocooling time is possible, regardless of the initial temperature of the commodity or the temperature of the cooling medium.

Advantage of half-cooling time:

How to be the heat of the crop after 4 hours if the temperature of the crop 60º F. and heat the center of cooling 32 º F. and half cooling time of the crop is 2 hours?

What is postharvest life of flowers or ornamental plants ?

Period of time from harvest until the flower or plant has lost its decorative value.

Symptoms of poor keeping quality

- bud drop / drying
- flower abscission / senescence
- petal abscission
- leaf abscission / senescence
- leaf yellowing

Factors affecting the postharvest life of ornamentals

1. Temperature and atmosphere
2. Water and food supply
3. Ethylene (effects and control of responses)
4. Light
5. Mechanical damages
6. Disease

Quality in flowers and ornamentals

Quality in horticultural products is assessed by the relative values of several characteristics which, considered together, will determine the acceptability of the product to the buyer and the ultimate consumer. There are several definitions for quality in floricultural crops, only the most important being quoted here:

Different products require different criteria for an assessment of their quality. Apart from quantitative (net weight, length of stalk, number of leaves, leaf and flower size) and qualitative (freedom from diseases, mechanical damage and condition of flower), hidden and sensory characteristics (appearance, colour and size) also determine the ultimate quality of floral products. For example, the criteria of cut carnations set forth by the Society of American Florists are as follows:

Flower: size condition maturity shape longevity

Stem: size shape

The three major components of quality at the time of purchase are:

(1) appearance

(2) chemical

(3) anatomical.

Appearance **includes size, shape (form), surface cleanliness, colour and condition (freshness). Optimum size** of a product changes with time, depending upon the purchasing ability of the consumer. In recent years, there has been an increased demand for medium to small (miniature) types of flowers and potted plants. The mode of utilization of a commodity also influences its size, e.g. long-stemmed or large flowers and foliage plants may not be useful for flower arrangements or as house plants.

The form or shape relates to consumers' preconceived notions regarding how the floral crops should look. Whereas in the USA, roses are preferred in their bud-harvested stages, and carnations and chrysanthemums are generally accepted fully open, in Europe, bud-harvested floral crops are considered of high quality.

Physical blemishes due to **insects, diseases, and pests, and/or certain physiological disorders present on the surface of flowers** and ornamental plants markedly reduce their quality. High quality products must be clean and free of insects, pathogens, and residues of pesticides and other chemicals used to preserve their quality.

Colour has a major influence on consumer acceptability, more even than flavour does in most edible horticultural commodities, like fruits and vegetables. **Significant amounts of sprays and tints are employed in the floricultural industry to protect flower colours and to fulfill specific consumer needs.** Intangible quality characteristics, like freshness and absence of damage, refer to the subjective evaluation of term "condition" of the product and cover those factors or components of floral quality not included under the heading of size, form, surface, cleanliness and colour. Very few floral crops were grown for their odour or fragrance and this chemical factor influencing flower quality had become less important in the recent past. Breeders, in fact, even tried to eliminate the fragrance factor in lieu of more desirable quality traits. However, **fragrance** is regaining importance in the floricultural industry.

Anatomical or physical characteristics of flowers such as **crispness, toughness** etc. are related to the texture of the product and have direct bearing on their keeping quality. While normally turgidity aids the freshness of cut flowers, sometimes slight wilting may actually improve their longevity and postharvest quality.

Allowing standard chrysanthemums to wilt slightly during their last 2 to 3 weeks' period prior to harvest increases their keeping quality . However, foliage and flowering potted plants should not be allowed to wilt, especially at the consumer level, because it may result in severe damage due to soluble salts accumulation.

Several pre-harvest, harvest and postharvest factors including **genetic**, **climatic** or **environmental** (light, temperature, relative humidity, pressure and composition of air) and **management** (soil condition, nutrition, fertilization, irrigation, plant protection etc.) factors, influence the postharvest quality and longevity of cut flowers and other ornamental plants.

Postharvest losses and problems of handling in flowers and ornamentals owing **to higher moisture content, ornamentals are highly perishable** and, as such, are difficult to dry and preserve as dehydrated products. Furthermore, dried floral products are often not accepted by the consumers. Flowers and ornamentals are more susceptible to **mechanical and physical damage and infection by diseases and pests during and after harvest.** Even after being detached from the mother plant, the cut flowers are metabolically active and carryon all life processes at the expense of stored reserve food in the form of carbohydrates, proteins and fats, limiting their longevity to less than a few days. Certain flowers are inherently short-lived after harvest and pose unique problems in handling and marketing.

Recent developments in loss reduction **biotechnologies** in flowers and ornamentals improved postharvest handling of floral crops and potted ornamental plants to maintain the high quality of the produce during transit has increased the international movement of these products in the recent years. The following loss reduction technologies to reduce shrinkage losses in cut flowers and other foliage plants.

1. Selection of quality species and cultivars.

2. Standardization of harvest standards.

3. Pre shipping chemical treatments.

4. Packaging techniques.

5. Regulation of storage environment

a. Temperature: 1. Precooling 2. Mechanical refrigeration

b. Atmospheric composition and pressure:

1. Controlled atmosphere

2. Modified atmosphere

3. Hypobaric storage: Is a form of controlled atmosphere storage in which the produce in a partial vacuum . The vacuum chamber is vented continuously with water saturated air to maintain oxygen levels and to minimize water loss. ripening is restarted by hypobaric storage due to the reduction is partial pressure of oxygen and also due to the reduction in ethylene level. A reduction of air pressure of air to 10 kilopascal (0.1 atmosphere) is equivalent to reducing oxygen concentration to about 2.1 at normal atmospheric pressure .Hypobaric storage are expensive to construction because of the low internal pressure required and this high cost of application appears to limit hypobaric storage to high value production such as cut flower.

6. Use of floral preservatives and bud-opening solutions.

7. Mode of transportation.

Senescence of flowers and ornamentals

Basic Principles and Considerations

Definition and terminology senescence is one of the least well-defined steps in biological development. The gross change of a series of changes leading finally to death of an organism has been referred to as senescence, defined **as the final phase in the ontogeny of the organ in which a series of normally irreversible events is initiated that leads to cellular breakdown and death of the organ.** Senescence of higher plants is classified into three major types:

1. Population senescence (e.g. annual plants)
2. Organism or individual plant senescence
3. Determinate organ senescence (e.g. leaves, fruits, flowers, petals etc.).

senescence as the deteriorative processes that are the natural causes of death; ageing, by contrast, refers to processes accruing maturity with the passage of time. Ageing thus includes a much wider span of physiological processes, which may either weaken the organism or be neutral with respect to the capability of the biological organism or be neutral with respect to the capability of the biological organism to survive. Senescence, in contrast, refers to the changes providing for the endogenous regulation of death."Longevity", a correlate of ageing and senescence, is linked to flowering and fruiting, as is evident in the case of annual plants.

Longevity: The period for which flowers or foliage remain in presentable form without loosing its grade and quality is known as longevity, vase life, display life or shelf life.

Biochemical changes

Respiration and enzymatic hydrolysis of cellular components are the two major biochemical and metabolic events occurring in the senescing flowers and petals of tulip and orchid, carnation,rose and chrysanthemum . The enhanced peroxidase activity was associated with an increse in the level of peroxides and free radicals, which reacted with cellular constituents , and are probably involved in promotion of senescence and in the production of ethylene. A delay in the senescence of carnation flowers was demonstrated by treating them with free radical scavengers such as sodium benzoate . Significant increases in the activities of ribonuclease, deoxyribonuclease, and hydro lases of cell wall polysaccharides of Ipomoea and of ribonuclease in roses were reported.

The marked development of senescence in flowers was associated with a variety of changes, such as bluing of red petals, decrease in protein content, and increase in ribonuclease activity. Since senescence of cut flowers is closely related to depletion of energy required for synthetic reactions, an exogenous supply of sugar has been recommended as the most efficient means of delaying the onset of senescence. Glucose supply prevents a sharp decrease in the amount of soluble proteins in petals.

The principal effect of applied sugars is to maintain the structure and function of mitochondria. The rapid decline in the rate of water uptake and the relatively sustained rate of transpiration when cut flowers are placed in water also leads to loss of turgor. This has been attributed to vascular blockage at the stem base reducing water uptake by the stem.

Metabolic changes

Internal metabolic changes in respiration of cut flowers have been reported by several workers. The rate of respiration in many cut flowers reaches its **peak at the time of opening of** flowers, and **decreases as the flowers mature and senesce**. Later, there is a second dramatic increase in respiration over a relatively short period, followed by a **final decline.** The second peak in the respiration drift signifies the last phase of senescence. It has been considered to be an analogue to the climateric rise in respiration of many fruits.

Changes in pigments

Discolouration or fading of colour is a common sympton of many senescing flowers. The carotenoids and anthocyanins, two major classes of pigments responsible for different colour in flowers, change significantly during the development and maturation of plant organs. Differential changes in the anthocyanin content of senescing flowers have been noted. While its level stays stable in certain flowers, in others it decline significantly, whereas in orchids anthocyanines are synthesized continuously.

Postharvest quality requirements

Stem length and physical condition of the flower are the two major postharvest considerations in handling cut carnations. Most of the grades presently followed in different countries are mainly based on these two parameters. The Society of American Florists (SAF) suggested the following inspection standards for cut carnations:

1. Bright, clean, firm flowers and leaves.
2. Fairly tight petals near the center of the flowers that are tight and unopened.
3. Symmetrical flower shape and size characteristic of the variety.
4. No buds or suckers.
5. No decay or damage.
6. Straight stem and normal growth.

Rose

Roses, owing to their wide variety in flower colour, form, growth habit and plant size, have widespread consumer acceptance. Cut roses are generally preferred to carnations and chrysanthemums when they are fresh. Furthermore cut roses are commonly used for many religious and social events such as marriages, birthdays, and social gatherings and are regularly exchanged between loved ones. Two kinds of roses are commercially grown for cut flowers.

The following quality components for rose:

1. Straight strong stem capable of holding the flower in upright position.
2. Uniform stem length-flowers with different stem length should not be mixed.
3. Size of flower representative of cultivar.
4. Uniform stage of development.
5. Flowers should be free from bruising injuries, petal discolouration and diseases and pests.

6. Good, healthy, normal foliage, the size representative of variety. There are no uniform grades that are adopted universally. The purpose or market outlet, the country and the grower influence the grading procedure.

Vase Life evaluation in roses

In the past, the number of days a flower remains fresh or in acceptable condition was taken as a criterion for describing the keeping quality of flowers. These methods were used to evaluate the effectiveness of a given preservative in extending vase life. Other factors, like net water uptake in relation to vase life, have also been used by some researchers to determine the quality of flowers. All these methods provide subjective data for the evaluation of floral preservatives.

Ripening

The composite of the processes that occur from the latter stages of growth and development through the early stages of senescence and that results in characteristic aesthetic and/or food quality, as evidenced by changes in composition, color, texture, or other sensory attributes.

Fruit ripening:

- Increase in membrane permeability
- Increase in protein (enzyme) synthesis
- Changes in color, flavor, and texture that give rise to the best eating quality of the fruit.

Management of ripening of fresh fruits

1. Stages of fruit development
2. Fruits that must ripen on the plant
3. Fruits that can ripen on or off the plant
4. Role of ethylene in fruit ripening

On the basis of ripening behavior, fruits are classified as climacteric and non-climacteric fruits.

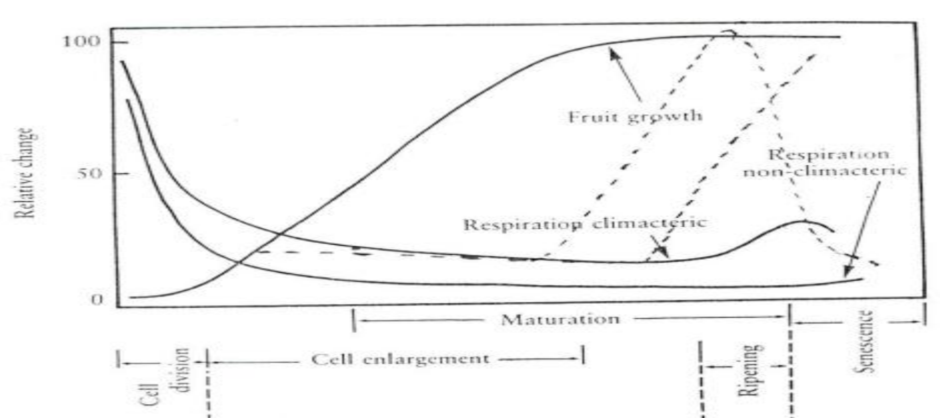
Climacteric: Climacteric fruits are defined **as fruits that enter 'climacteric phase' after harvest *i.e.* they continue to ripen. During the ripening process the fruits emit ethylene**

along with increased rate of respiration. Ripe fruits are soft and delicate, these fruits are harvested hard and green, but fully mature and are ripened near consumption areas. Small dose of ethylene is used to induce ripening process under controlled conditions of temperature and humidity.

These fruit in fully ripe state are too delicate to withstand transportation over long distances and should preferably be ripened near the consumption area. Mango, Banana, Papaya, Guava, Apple, Pear, Kiwi, Tomato.

Non-Climacteric: Non-climacteric fruits once harvested do not ripen further. Non-climacteric fruits produce very small amount of ethylene and do not respond to ethylene treatment. There is no characteristic increased rate of respiration or production of carbon dioxide. Citrus, Grape, Strawberry, Pomegranate.

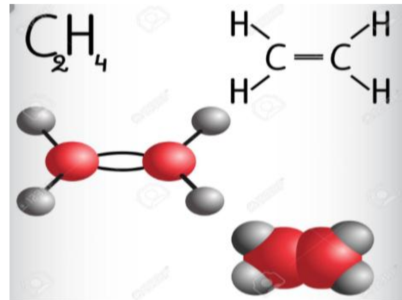
Climacteric fruit	**Non-climacteric fruit**
1- Increased respiration at ripening 2- Ripen faster 3- Ethylene •Produce more •Higher internal level •Level increases at ripening 4- Applied Ethylene Respond to applied ethylene in non-rate dependent	1- No increase in respiration 2- Ripen slower 3- Ethylene • Produce less • Lower internal levels • No increase at ripening 4- Applied ethylene rate dependent response



Growth and rispiration patterns during fruit developing

Fruit Changes during Ripening:

- Texture
- Color
- Flavor
- Ethylene
- Susceptibility to stress



Ethylene

(C_2H_4) **$H_2C=CH_2$**

During the nineteenth, when coal gas was used for street illumination, it was observed that trees in the vicinity of streetlamps defoliated more extensively than other trees. Eventually it became apparent that coal gas and air pollutants affect plant growth and development, and ethylene was identified as the active component of coal gas. In 1901, Dimitry Neljubov, a graduate student at the Botanical Institute of St. Petersburg in Russia, observed that dark-grown pea seedlings growing in the laboratory exhibited symptoms that were later termed the *triple response*: reduced stem elongation, increased lateral growth (swelling), and abnormal, horizontal growth. When the plants were allowed to grow in fresh air, they regained their normal morphology and rate of growth. Neljubov identified ethylene, which was present in the laboratory air from coal gas, as the molecule causing the response. The first indication that ethylene is a natural product of plant tissues was published by H. H. Cousins in 1910. Cousins reported that "emanations" from oranges stored in a chamber caused the premature ripening of bananas when these gases were passed through a chamber containing the fruit. However, given that oranges synthesize relatively little ethylene compared to other fruits, such as apples, it is likely that the oranges used by Cousins were infected with the fungus *Penicillium*, which produces copious amounts of ethylene. In 1934, R. Gane and others identified ethylene chemically as a natural product of plant metabolism, and because of its dramatic effects on the plant it was classified as a hormone. For 25 years ethylene was not recognized as an important plant hormone, mainly because many physiologists believed that the effects of ethylene were due to auxin, the first plant hormone to be discovered. Auxin was thought to be the main plant hormone, and ethylene was rediscovered and its physiological significance as a plant growth regulator was recognized was considered to play only an insignificant and indirect physiological role. Work on ethylene was also hampered by the lack of chemical techniques for its quantification. However, after gas chromatography was introduced in ethylene research in 1959, the importance of ethylene.

Is gaseous plant growth substance which is involved in the regulation of many aspects of:

- Growth and development
- Fruit ripening
- Senescence

It is physiologically active at levels as low as less than 0.1 ppm. Therefore, the regulation of ethylene biosynthesis and **action is very important in agriculture today.**

Ethylene is a small hydrocarbon colorless gas. It is naturally occurring, but it can also occur as a result of combustion and other processes. You can't see or smell it. Some fruit will produce ethylene as ripening begins. Apples and pears are examples of fruit that produce ethylene with ripening. Ethylene is responsible for the changes in texture, softening, color, and other processes involved in ripening. Fruits such as cherries and blueberries do not produce much ethylene and it doesn't influence their ripening.

Ethylene is thought of **as the aging** hormone in plants. In addition to causing fruit to ripen, it can cause plants to die. It can be produced when plants are injured, either mechanically or by disease. Ethylene will cause a wide range of effects in plants, depending on the age of the plant and how sensitive the plant is to ethylene. Ethylene effects include fruit ripening, loss of chlorophyll, abortion of plant parts, stem shortening, abscission of plant parts. Ethylene can be either good or bad, depending on what commodity you work with. It is used in a positive manner in fruit ripening, for example. It can also cause damage in crops. Examples of damage might include yellowing of vegetables, bud damage in dormant nursery stock, or abscission in ornamentals (leaves, flowers drop off).

Often **two of the important items** to know are:

1. if a crop naturally produces a lot of ethylene
2. if it is responsive to ethylene.

Responsiveness will **depend on**:

1. the crop
2. the stage of plant development

3. the temperature
4. the concentration of ethylene
5. the duration of exposure.

Ethylene gas is used commercially to ripen **tomatoes, bananas, pears**, and a few other fruits postharvest. Ethylene can be explosive if it reaches high concentrations, so it has to be used cautiously. Several commercial liquid products release ethylene (ethephon, trade name Ethrel). These are only used preharvest.

There are three main ways to produce ethylene:

1. Gas from a cylinder
2. Catalytic generator
3. Ethephon.

Other sources of ethylene include ripening fruit, exhaust from internal combustion engines/heaters, smoke (including cigarettes), welding, rotting vegetation, natural gas leaks, and manufacturing plants of some kinds.

There are several anti-ethylene chemicals. Silver thiosulfate (STS) is used on flowers. Aminoethoxyvinyl-glycine (AVG, trade name ReTain) blocks ethylene synthesis. It is applied preharvest. The fruit (plant) will not produce much ethylene, so there is not an ethylene response. The ethylene blocker 1-methylcyclopropene (1-MCP, trade name EthylBloc) blocks ethylene by binding to its receptor. It is applied postharvest. The fruit (plant) may still produce some ethylene, but there is no response to the ethylene.

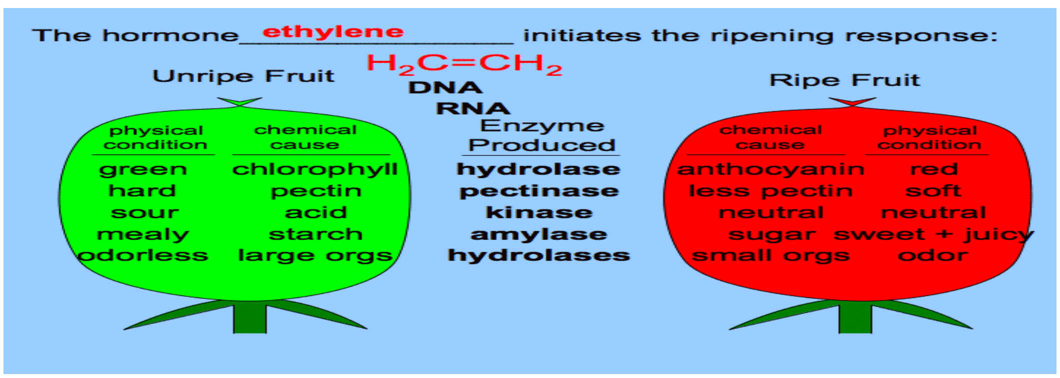
There are several ways to measure ethylene:

1. Gas chromatography (best but expensive)
2. Kitagawa tubes, or equivalent
3. Other types of chemical sensors
4. Another plant that is sensitive to ethylene.

Effects of Ethylene in ripening

- Conversion of starch to sugars.
- Cell wall degradation and tissue softening
- Synthesis of pigments
- Synthesis of flavors

Fruits and vegetables may be classified depending on their response to ethylene. Climacteric species produce ethylene as they ripen, and the harvested produce is capable of ripening during the postharvest period. These commodities, such as bananas, apples, and peaches, tend to get sweeter and softer after harvest. Non-climacteric plants, such as leafy vegetables, do not continue to ripen after harvest; they will soften and rot, but this is due to moisture loss, decay, and tissue deterioration.



Sources of ethylene

• endogenous (synthesised in plants)

• exogenous (common air pollutant):

– stressed, oxidized or combusted organic materials

– car and aircraft exhaust

– cigarette smoke

– rubber materials exposed to heat or UV light

– virus infected plants

– ripening fruits

De-greening 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 consumers. It is applicable to banana, mango, citrus, and tomato. The time required to degree a fruit depends upon the degree of natural colour break and 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.

Pigment changes

- Chlorophyll (Green color) - a loss of chlorophyll in tomatoes is good but a loss in chlorophyll in broccoli is bad.
- Carotenoids (Yellow, Orange and Red colors) - Carotenoids are desirable in fruits such as apricots, peaches and citrus giving them their yellow and orange color. In tomatoes and pink grapefruit a specific carotenoid called lycopene gives them their red color
- Anthocyanin (Red and Blue colors) - Anthocyanin give red and blue color to apples, berries, cherries etc.
- Phenolic compounds - Are responsible for tissue browning.

Carbohydrate changes

1-Conversion of starch to sugar-Not desirable in potato but very desirable in apples,bananas.

2-Conversion of sugar to starch - Not desirable in sweet corn but very desirable in potato

3-Conversion of starch and sugars to CO_2 and water during respiration - Not desirable because it leads to a reduction in quality.

Other changes

- Organic acids (affects sweetness)
- Proteins (affects texture)
- Amino acids (affects flavor)
- Lipids (affects flavor)

Factors that increase ethylene

- Maturity at harvest
- Physical injuries
- Disease
- High or low temperature
- Water stress

Control of ethylene production

- Reducing the storage temperature
- Reducing O_2 levels to less than 8%
- Treating with enzyme inhibitors of ACC synthase and ACC oxidase
- Genetic engineering (using antisense technology to prevent enzyme expression).

Impacts of ethylene on postharvest quality of fruits and vegetables

1-Russet spotting of lettuce (dark brown spotting on the mid-ribs of lettuce leaves).

2-Yellowing or loss of green color (for example, in cucumber, broccoli, spinach).

3-Increased toughness in turnips and asparagus spears sprouting in potatoes.

4-Softening, pitting, and development of off-flavor in peppers, summer squash, and watermelons.

5-Browning and discoloration in eggplant pulp and seed.

6-Discoloration and off-flavor in sweet potatoes.

7-Development of bitter taste in carrots.

Steps to reduce ethylene exposure during storage

- Do not store or transport green leafy vegetables in containers holding ripening fruit (apples, pears, mangoes, tomatoes, bananas).
- If possible, use electric powered equipment in storage areas versus gas powered.
- Remove overripe or rotting fruit from storage loads (these produce higher amounts of ethylene).
- Avoid storing ethylene sensitive products with products that produce high levels of ethylene.
- Increase the ventilation rate of the storage area, assuming that the outside air is ethylene free.
- Use ethylene scrubbers in storage areas to remove ethylene in the air.

Ethylene production is enhanced by wounding during processing and the accumulation of this gas within the packages of fresh fruits can be detrimental to their quality and shelf-life. These effects can be reduced by:

1. Exclusion and/or removal of ethylene from packages.
2. Treatment with 1-methylcycloprene (1-MCP) to block ethylene action.

Packinghouse (purpose, operations, design)

A packing house is a facility where fruit is received and processed prior to distribution to market. Following harvest, most crops must be cleaned, sorted, sized, and packaged if they are to be sold in the fresh produce market. These procedures are normally done in packinghouses which could be a small shelter located in the field or an automated packing line located in a centralised area.

Purpose of packinghouses: They serve as a sheltered working site for the produce and the packers, and should create an orderly assembly and flow of produce which can be well managed and centrally supervised. They can also serve as a storage point for packing equipment and materials and, if large enough, can house office and communication facilities. For export of fresh commodities, packinghouses are an essential part of the operation where selection, grading, and quality control must be implemented and monitored.
Operations of packinghouses: These include some or all of the following:

i- Receival area: Here the commodities, upon arrival at the packinghouse, are counted, weighed and, in some cases, sampled for quality and labelled to identify the date and source.

ii- Packing lines:

Packing lines differ greatly according to the type and quantity of the crop load. Thus a packing line may consist of simple sloping tables where the commodities are trimmed, cleaned, sized and packed. This is suitable for a small-scale facility. For large-scale operations a packinghouse with full mechanisation is necessary to include one or more packing lines. The packing line may include the following features:

a. Receiver bet:

   Where the commodities are carefully transferred from the harvesting container. To reduce physical damages such as bruising, compression and abrasions to commodities it is essential to have the conveyor belt on the receiver line well padded to minimise the negative impact of drop heights. The receiver belt must never be overloaded. At this point commodities must also be subjected to an initial sorting procedure to eliminate those that are unmarketable due to defects such as decay, insect damage, physical damage, undersize, and heat injuries etc.

b. Cleaning:

   Wash commodities in chlorinated water (100-250 ppm). The soft rotating brushes located inside the washer (Figure 2) are used to remove surface debris and other unwanted contaminants. Commodities are then allowed to dry naturally after washing or dried artificially using air blowers which are sometimes heated.

c. Special treatments:

   After washing some crops receive special treatments to extend their storage and market life, or to make them more attractive to the consumer. Postharvest treatments may include waxing to reduce shrivelling and improve appearance or bactericidal or fungicidal dips to control pathogens.

d. Sorting and grading:
   Almost all commodities are sorted, graded and sized in the packinghouse to meet the quality and size standards of the markets being served. Sorting to remove substandard commodities and grading into different classes could be done manually. Sizing according to weight, length or diameter is more often a mechanised procedure which can be done with sizing equipment attached to the packing line.
e. Packing and packaging:
   Packing stations may supply commodities to different buyers and markets, each having different quality and packaging requirements. Flexibility in packing methods and materials employed should therefore be built into the system, even though standardisation of the commodities should lead to a reduction of the number of different packages.

Storage

The term "storage", **as now applied to fresh produce, is almost automatically assumed to mean the holding of fresh fruit and vegetables under controlled conditions.**

The main goals of storage are to

1. Slow the biological activity of fruits and vegetables without chilling injury;
2. Slow the growth of microorganisms,
3. Reduce transpiration losses.

Proper marketing of perishable commodities such as fruits and vegetables often requires some storage to balance day-to-day fluctuations between harvest and sale or for long-term storage to extend marketing beyond the end of harvest season. Many horticultural crops are highly perishable and can only be stored for a few days but some produce may be stored for much longer periods. The main reasons for storing products are primarily related to marketing:

1. because there is no immediate buyer.
2. because transportation or some other essential facility is not available.
3. to extend the marketing period and so increase the volume of sales.
4. to wait for a price increase.

In temperate countries the production of fruits and vegetables is largely confined to relatively short growing seasons and thus storage is important to enable sales of produce outside of the harvest season. With the modern greenhouse cultivation methods, as well as other improved technologies, the production season may be extended but storage is still often desirable to enable an extended supply for the consumer.

Storage adds to the cost of a product and the more elaborate the storage method, the higher the added cost. Short-term storage is used to provide flexibility in marketing but it is not usually worthwhile storing fresh produce if the price increase that results from the storage does not exceed the costs of storage. Storage will reduce quality and shelf life. It is costly and, in most instances, when the produce is withdrawn from storage it has to compete in the market against freshly arrived produce.

Principles of storage Storage operations may be classified as either **natural** or **artificial**.

The natural storage operation keeps the produce without any treatment, whereas artificial storage may be further classified into four types:

- Mechanical or structural
- Controlled atmosphere
- Chemical
- Radiation

In case of natural storage, the main purpose is to let the fruits or vegetables mature and ripen on plants as long as possible.

1. Natural storage

Vegetables such as potato, sweet potato, and garlic are kept underground for several months. They are harvested prior to the rainy season for a better market price. This harvesting does not involve extra expenditure and building for storage.

2. Artificial storage

Pits or trenches are dug underground for storing beets, potatoes, onions, carrots, cabbages, and sweet potatoes where they are covered with straw and soil until there is a market demand.

Storage methods and structures

There are various different forms of storage and choice mostly depends on its cost and the produce to be stored. However, other factors must also be taken into account. The maximum storage life of a harvested crop depends on its production history and its quality and maturity at harvest. The actual storage life that can be achieved in practice may be quite different and depends upon harvesting and handling procedures and the storage environment. Not all fresh produce can be **simply stored** and some produce may require **specific** post-harvest treatments such as "curing" or "waxing" prior to storage. The market structure or availability of product might also create constraints whereby stored produce competes at a disadvantage alongside freshly harvested produce. Consideration of each of these factors will **depend largely on storage economics.**

- **Mechanical refrigeration**

Refrigerated storage makes possible the marketing of perishable fruits and vegetables beyond their harvest season. In developed countries, most of the fruits and vegetables are available year-round to consumers. This is due to the refrigerated storage. Most storage facilities use mechanical refrigeration to control the desired temperature. This system utilizes the fact that a **liquid absorbs heat as it changes to gas.**

A common mechanical refrigeration system uses a refrigerant such as ammonia or Freon where vapor can be easily recaptured by a compressor.

Heat exchange methods of heat transfer play an important part in the refrigeration of fruits and vegetables in maintaining the desired temperature in a refrigerator or a refrigerated warehouse.

Controlled and modified atmosphere storages

Controlled atmosphere (**CA**) storage involves altering and maintaining an atmospheric composition that is different from air composition (about 78% N_2, 21% O_2, and 0.03% CO_2); generally, O_2 below 8% and CO_2 above 1% are used. Atmospheric modification should be considered as a supplement to maintenance of optimum ranges of temperature and RH for each commodity in preserving quality and safety of fresh fruits, ornamentals, vegetables, and their products throughout postharvest handling.

Modified Atmospheres - Advantages

Slows down respiration and other metabolic processes (ripening & senescence).

- Reduces sensitivity to ethylene (at < 8% O_2 or >1% CO_2.
- Reduces development of some physiological disorders (chilling injury).
- May inhibit pathogen development.
- Can be used to kill insects.

Disadvantages

- Can cause or exacerbate some physiological disorders (black heart in potatoes).
- Can cause irregular ripening.
- Can result in off-flavors or odors if anaerobic respiration occurs.
- Any MA or CA related injuries stimulate pathogen development.
- May delay periderm development and stimulate sprouting in root or tuber crops.

The choice of the correct storage technique is governed by:

1- The type of produce, including the type and variety its temperature from harvest, its respiration rate and quality

2- The storage temperature and humidity best suited to the produce for the intended storage life and not creating additional problems due to chill damage or unnecessary microbial spoilage

3- Market requirements

4- The economics of the whole operation

There are many basic principles that must be correctly applied for successful refrigeration of perishable crops:

1. Select only healthy products. Refrigeration does not destroy pathogens responsible for product deterioration but only slows their activity. It does not improve product quality but only maintains it.

2. Timely cooling: Since refrigeration slows the development of micro-organisms and the physiological changes responsible for deterioration of perishable crops, it is obvious that cooling should be applied as soon as possible after harvest. The technique of pre-cooling was developed to fill this need by cooling produce soon after harvesting down to a temperature appropriate to that product.

3. Uninterrupted cooling: Refrigeration should be applied from the point of harvest through to the point of consumption and where maximum post-harvest life with high product quality is justified. This is the **"cold chain".**

Refrigerated stores are important components of the marketing process for fresh fruits and vegetables. They also demand careful planning in their design, construction, management and day-to-day operation if the substantial capital invested in them is to be protected and if they are to serve their function in marketing. When designing and constructing a cold store it is important to determine **both the requirements of the cold store and the prevailing environmental conditions.** The products to be stored, their types, quantities and periods of production also have to be weighed against the storage conditions demanded by the produce and the market place. Inherent factors, such as the availability of labour and its skills and experiences also have to be considered.The size of the store will be determined by economic and technical factors. Small rooms are more expensive per unit volume for building and operation than large ones, but stock control and management of large cold stores is more complex and difficult. The volume of the cold store will depend upon the stacking patterns necessary for air circulation and heat dissipation, and the height of the rooms will depend on the **handling and stacking methods to be used, 2.5 to 3 meters for manual handling**, and **6 or even 9 meters if mechanical handling and pallet boxes are used.**

Once all the above factors are accounted for then calculation of the refrigeration load can be made and hence the required refrigeration capacity and room insulation determined. These calculations are based on assessment of:

The heat gain/loss through the walls

- The heat gain/loss by air removal and replacement

- The heat of respiration of the products
- The rate of refrigeration/removal of field heat;
- The heat gain from electric fans, lights, labour, etc.

Good management of cold stores needs knowledge and experience of:

- The storage conditions of the commodities
- Directions for loading of the rooms and maintaining a clean and hygienic state
- Management, control and maintenance of refrigeration equipment
- Staff training in store operation

The loading of a room should be as rapid as possible if there is no pre-cooling process but should be monitored carefully so as not to over-load the refrigeration plant, otherwise the cooling of the produce will take much longer and lead to reduced storage life.

Temperate and subtropical produce are best stored at an optimum storage temperature close to 0°C, whereas tropical produce is best stored at temperatures above 10°C. A high but not recommended temperature and RH conditions for the storage of some produce items. RH affects water loss, uniformity of fruit ripening, decay development and the incidence of some physiological disorders. saturated RH (85 to 95 percent) is optimal for most types of fresh produce.

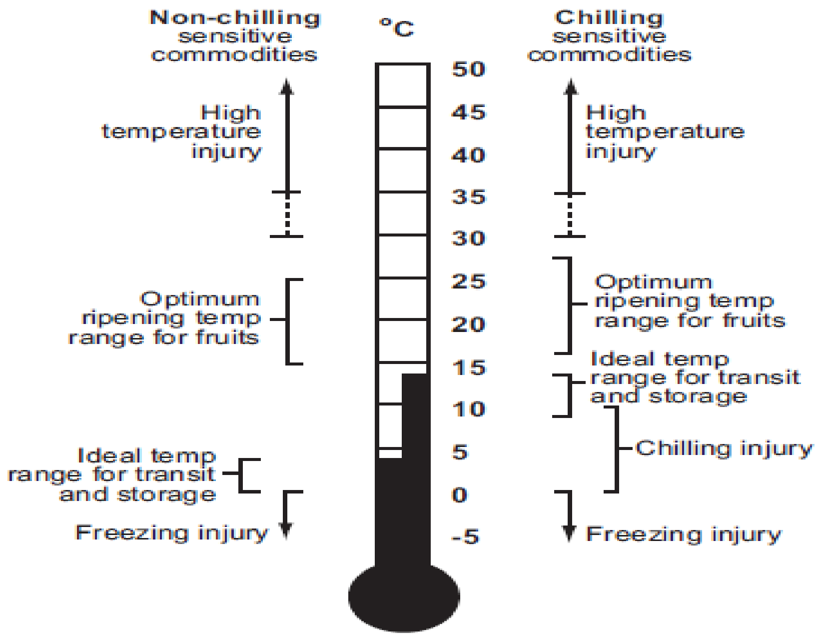
A tissue damage or breakdown which not related to pathogens, insects or mechanical damage.

1- Temperatures
   - Chilling injury, freezing injury or High temperature injury.
2- Altered atmospheric gas concentrations.
   - Low O_2 or Elevated CO_2.
3- Nutrition
   - As calcium deficiency or boron toxicity.

Disorders resulting from poor temperature management

Chilling Injury: Many fruits, vegetables, and ornamentals of tropical or subtropical origin are sensitive to low temperatures. These crops are injured after a period of exposure to chilling temperatures below 10 to 15 °C (50 to 59 °F) but above their freezing points.

Fruits and vegetables classified according to sensitivity to chillinginjury



Group I			Group 2	
Fruits	**Vegetables**		**Fruits**	**Vegetables**
Apple	Artichoke	Asparagus	Avocado	Beans
Apricot	Beet	Broccoli	Banana	Cucumber
Cherry	Cabbage	Carrot	Citrus	Eggplant
Date	Cauliflower	Celery	Guava	Okra
Fig	Corn	Garlic	Mango	Peppers
Grape	Lettuce	Mushrooms	Olive	Potato
Kiwifruit	Onion	Parsley	Papaya	Pumpkin
Loquat	Parsnip		Pineapple	Squash
Nectarine	Peas		Pomegranate	Sweet potato
Peach	Radish			Tomato
Pear	Spinach			Watermelon
Persimmon	Turnip			
Plum				
Strawberry				

Certain horticultural crops of temperate origin are also susceptible to chilling injury. Those temperate crops, in general, have lower threshold temperatures, < 5 °C (41 °F). At these chilling temperatures, the tissues weaken because they are unable to carry on normal metabolic processes. Various physiological and biochemical alterations and cellular dysfunctions occur in chilling-sensitive species in response to chilling stress. When chilling stress is prolonged, these alterations and dysfunctions will lead to the development of a variety of chilling injury symptoms such as surface lesions, internal discoloration, water-soaking of the tissue, and failure to ripen normally, products that are chilled will still look sound when remaining in low temperatures. However, symptoms of chilling injury become evident in a short time after they are removed to warmer temperatures. Fruits and vegetables that have been chilled may be particularly susceptible to decay. Weak pathogens such as *Alternaria spp*. that do not grow readily on healthy tissues can attack tissues which have been weakened by low temperature exposure.

Both temperature and duration of exposure are involved in the development of chilling injury. Damage may occur in a short time if temperatures are considerably below the threshold level, but a product may be able to withstand temperatures a few degrees in the critical zone for a longer time before injury becomes irreversible. Maturity at harvest and degree of ripeness are important factors in determining chilling sensitivity in some fruits like avocados.

Treatments which have been shown to alleviate chilling injury include: intermittent warming; high or low temperature preconditioning;

1- CA storage

2- pretreatments with ethylene

3- abscisic acid

4- other natural compounds; calcium or other chemical applications;

5- hypobaric storage

6- waxing

7- film packaging

8- and genetic manipulation.

What is Hypobaric Storage

During hypobaric storage the produced is ventilated with air at pressures lower than the atmospheric pressure.

Postharvest pathology

Losses caused by postharvest diseases are greater than generally realized because the value of fresh fruits and vegetables increases several-fold while passing from the field to the consumer. Postharvest losses are estimated to range from 10 to 30% per year despite the use of modern storage facilities and techniques.

Postharvest diseases affect a wide variety of crops particularly in developing countries which lack postharvest storage facilities. Infection by fungi and bacteria may occur during the growing season, at harvest time, during handling, storage, transport and marketing, or even after purchase by the consumer.

Specific causes of postharvest losses of fruits and vegetables may be classed as parasitic, nonparasitic, or physical.

Preharvest factors that influence postharvest pathology:

Postharvest losses vary each year. Prevailing weather while the crop is growing and at harvest contributes greatly to the possibility of decay. Certain cultivars are more prone to decay than are others to specific pathogens. In a recent study, it was found that resistance of major apple cultivars to the fungi that cause blue mold, gray mold, bull's-eye rot, and Mucor rot was dependent on cultivar .Condition of the crop, as determined by fertilizer and soil factors, are very important in susceptibility of the crop to disease. Maturity of the crop at harvest, handling and type of storage has a great deal of influence on how long the crop can be stored without decay. Examples are given below that demonstrate how these preharvest factors lead to disease in specific crops.

Weather: Weather affects many factors related to plant diseases, from the amount of inoculum that overwinters successfully to the amount of pesticide residue that remains on the crop at harvest. Abundant inoculum and favorable conditions for infection during the season often result in heavy infection by the time the produce is harvested. For example, conidia of the fungus that causes bull's-eye rot are rain dispersed from cankers and infected bark to fruit especially if rainfall is prolonged near harvest time, causing rotten fruit in cold storage several months later.

Pinpoint or storage scab of apple caused by the same fungus that causes apple scab, and gray mold caused by the fungus *Botrytis cinerea*, are also very much influenced by the weather.

Storage scab only occurs in years with unusually wet summers and early fall, when the fruit remain wet for a day or more.

Flowers and fruit are infected by *Botrytis cinerea* most effectively when it is wet. For example, in grapes infection occurs at 15 to 20 ºC (59 to 68 ºF) in the presence of free water after approximately 15 h. In wet seasons strawberries and raspberry crops may be harvested in apparently sound condition, only to decay during transit and marketing.

Postharvest decay involves further development of pre-harvest infections together with new infections arising from germination of spores on the fruit surface. From these examples it is apparent that decay often has a weather component making thorough weather records an important source of information for predicting possible decay in storage.

Physiological Condition*:* Condition of produce at harvest determines how long the crop can be safely stored. For example, apples are picked slightly immature to ensure that they can be stored safely for several months. The onset of ripening and senescence in various fruit and vegetables renders them more susceptible to infection by pathogens .On the other hand, fruit and vegetables can be made less prone to decay by management of crop nutrition. For example, calcium has been more closely related to disease resistance than any other action associated with the cell wall.

Postharvest factors that influence decay:

Packing Sanitation: It is important to maintain sanitary conditions in all areas where produce is packed. Organic matter (culls, extraneous plant parts, soil) can act as substrates for decay-causing pathogens. For example, in apple and pear packinghouses, the flumes and dump tank accumulate spores and may act as sources of contamination if steps are not taken to destroy or remove them.

Type of pathogen involved in the decay.

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

Selected based on these conditions and fall into either chemical or biological categories listed below.

- **Fungicide treatments***:* Several fungicides are presently used as postharvest treatments for control of a wide spectrum of decay-causing microorganisms. However, when compared to preharvest pest control products the number is very small. Many former products that were used after harvest are no longer permitted because of concerns with residues and possible toxic effects, the most notable being products that contained benomyl. Other products have been lost as effective controls due to development of resistance by the target pathogen. For example, intensive and continuous use of fungicides for control of blue and green mold on citrus has led to resistance by the causal pathogens of these diseases.

- **Irradiation for Postharvest Decay Control:** Although ultraviolet light has a lethal effect on bacteria and fungi that are exposed to the direct rays, there is no evidence that it reduces decay of packaged fruits and vegetables .More recently, low doses of ultraviolet light (254 nm UV-C) irradiation reduced postharvest brown rot of peaches. In this case, the low dose ultraviolet light treatments had two effects on brown rot development; reduction in the inoculum of the pathogen and induced resistance in the host. However, it has not become a practical postharvest treatment as yet and requires more research.

- **Temperature and RH***:* Proper management of temperature is so critical to postharvest disease control that all other treatments can be considered as supplements to refrigeration. Fruit rot fungi generally grow optimally at 20 to 25 ºC (68 to 77 °F) and can be conveniently divided into those with a growth minimum of 5 to 10 ºC (41 to 50 °F) , or -6 to 0 ºC (21.2 to 32 °F). Fungi with a minimum growth temperature below -2 ºC (28.4 °F) cannot be completely stopped by refrigeration without freezing fruit. However, temperatures as low as possible are desirable because they significantly slow growth and thus reduce decay. High temperature may be used to control postharvest decay on crops that are injured by low temperatures such as mango, papaya, pepper, and tomato. Although hot water generally is more effective, hot air has been used to control decay in crops that are injured by hot water.

- **Modified or Controlled Atmospheres***:* Alterations in O_2 and CO_2 concentrations are sometimes provided around fruit and vegetables. With close control of these gases, the synthetic atmosphere is commonly called a controlled atmosphere; the term modified atmosphere is used when there is little possibility of adjusting gas composition during storage or transportation. Because the pathogen respires as does produce, lowering the O_2 or raising the CO_2 above 5% can suppress pathogenic growth in the host. In crops such as stone fruits, a direct suppression occurs when fungal respiration and growth are reduced by the high CO_2 of the modified atmosphere.

Postharvest diseases of fruits:

Fruit crops are attacked by a wide range of microorganisms in the postharvest phase. Actual disease only occurs when the attacking pathogen starts to actively grow in the host. Diseases are loosely classified according to their signs and symptoms. Signs are visible growths of the causal agents, and symptoms the discernible responses produced by the host. In many diseases there is local discoloration and disruption of tissue, with the formation of obvious lesions. Postharvest diseases are caused primarily by microscopic bacteria and fungi, with fungi the most important causal agent in fruit crops. Fungi are further subdivided into classes and are described as lower fungi, characterized by the production of sporangia which give rise to numerous sporangiospores, or higher fungi, described as ascomycetes, deuteromycetes, and basidiomycetes. Ascomycetes are exemplified by fruiting bodies that release sexual spores when mature. Deuteromycetes, a form of ascomycete, only release asexual spores. They are more common than the sexual ascomycete stage in postharvest crops. Deuteromycetes are further subdivided into hyphomycetes and coelomycetes based on spore and structural characteristics. The agonomycetes contain important soil pathogens that form survival structures known as sclerotia that allow them to survive in the absence of the host. These fungi and the rust and smut fungi are examples of basidiomycetes.

Postharvest diseases of vegetables:

Postharvest diseases of vegetables are caused by microscopic fungi and bacteria. Bacteria are more common as pathogens of vegetables than fruit because in general vegetables are less acidic than fruit. They are visible under the light microscope as mostly single-celled rods. Bacteria are capable of very rapid multiplication under the right conditions of pH, temperature, and nutrition. They are classified according to their size, shape, reaction to certain stains, and behavior on various growth media.

Integrated control of postharvest diseases:

1. Effective and consistent control of storage diseases is dependent upon integration of the following practices:
2. Select disease resistant cultivars where possible.

3. Maintain correct crop nutrition by use of leaf and soil analysis.
4. Irrigate based on crop requirements and avoid overhead irrigation.
5. Apply pre-harvest treatments to control insects and diseases.
6. Harvest the crop at the correct maturity for storage.
7. Apply postharvest treatments to disinfest and control diseases and disorders on produce.
8. Maintain good sanitation in packing areas and keep dump water free of contamination.
9. Store produce under conditions least conducive to growth of pathogens.

Microbial losses:

Like any other food, vegetables are prone to microbial spoilage caused by fungi, bacteria, yeasts and moulds. A significant portion of losses of vegetables during post harvest is attributing to disease caused by fungi and bacteria. Succulent natures of the vegetables make them easily invadable by the organism. Besides attacking fresh vegetables, the organism also caused damaged to canned and processed products. Many serious post-harvest diseases of fresh vegetables occur rapidly and cause extensive breakdown of the commodity sometimes spoilage the entire package. It is estimated that 36% of the vegetable decay is caused by soft rot bacteria.

Obviously, the source of infection is soil in the field, water used for cleaning and surface contact with equipment and storage environment. The most common pathogens causing rots in vegetables are fungi such as Alternaria , Botrytis, Diplodia, Monilinia, Phomopsis, Pencillium , Rhizphus, and Fusarium and Bacteria, Erwinia, Ceratocystis , and Pseudomonas. While, most of the pathogens can invade only the damaged tissue, a few such as Colletotrichum are able to penetrate the skin of healthy tissue. Initially, only a few pathogens can invade and breakdown the tissue followed by attack of several weak pathogens. High temperature and relative humidity favour the development of post harvest decay organisms. More acidic tissue is generally attacked by bacteria, e.g. bacterial soft rot of potato by Erwinia spp and dry rot by Fusarium spp. Black rot of Sweet Potato by Ceratocystis

Fimbriata, Water Soft rot of Carrot by Sclerotina Sclerotioorum , and leaf vegetables soft rot by Erwina carotovora and dry rot by *Fusarium spp*.

1- Same of fruit disease causal agent fungal class/type

Scab *Sphaceloma persae* Coleomycete

Stem-end rots *B. theobromae,*

Banana Anthracnose *Colletotrichum musae* Coelomycete

Crown rot *C. musae,,*

Pitting disease *Pyricularia grisea* Hyphomycete

Berries Gray mold *Botrytis cinerea* Hyphomycete

Citrus Alternaria rot *Alternaria* spp. Hyphomycete

Bacterial canker *Xanthomonas campestris* Bacterium

Black pit *Pseudomonas syringae* Bacterium

Green mold *P. digitatum* Hyphomycete

Sour rot *Geotrichum candidum* Hyphomycete

Kiwi fruit Gray mold *B. cinerea* Hyphomycete

Grape Aspergillus rot *Aspergillus niger* Hyphomycete

Gray mold *B. cinerea* Hyphomycete

Stem-end rots *B. theobromae,*

Black rot *Phoma caricae-papayae* Coelomycete

Stem-end rot *B. theobromae,*

Pineapple Black rot *Thielaviopsis paradoxa* Hyphomycete

Pome fruit Bitter rot *C. gloeosporioides* Coelomycete

(apple, pear) Black rot *Sphaeropsis malorum* Coelomycete

Blue mold *Penicillium expansum,*

Brown rot *Monilinia* spp. Hyphomycete

Gray mold *B. cinerea* Hyphomycete

Stone fruit Alternaria rot *A. alternata* Hyphomycete

2- Same vegetable disease causal agent fungal class/type

Bulbs Bacterial soft rot *Erwinia caratovora* Bacterium

(Onion, garlic) Black rot *Aspergillus niger* Hyphomycete

Blue mold rot *Penicillium* spp. Hyphomycete

Fusarium basal rot *Fusarium oxysporum* Hyphomycete

Smudge *Colletotrichum circinans* Coelomycete

Crucifers Alternaria leaf spot *Alternaria* spp. Hyphomycete

(Cabbage, etc.) Bacterial soft rot *E. caratovora* Bacterium

Black rot *Xanthomonas campestris* Bacterium

Virus deases Cauliflower mosaic virus

Turnip mosaic virus Virus

Watery soft rot *Sclerotinia* spp. Discomycete

Cucurbits Anthracnose *Colletotrichum* spp. Coelomycete

(Cucumber etc.) Bacterial soft rot *Erwinia* spp. Bacterium

Black rot *Didymella bryoniae* Loculoascomycete

Botryodiplodia rot *Botryodiplodia theobromae* Coelomycete

Charcoal rot *Macrophomina phaseolina* Coelomycete

Fusarium rot *Fusarium* spp. Hyphomycete

Leak *Pythium* spp. Oomycete

Soil rot *R. solani* Agonomycete

Legumes Alternaria blight *A. alternata* Hyphomycete

(Peas, beans) Anthracnose *Colletotrichum* spp. Coelomycete

Ascochyta pod spot *Ascochyta* spp. Coelomycetes

Bacterial blight *Pseudomonas* spp.

White mold *Sclerotinia* spp. Discomycete

Roots/Tubers Bacterial soft rot *Erwinia* spp.

Carrots *Pseudomonas* spp. Bacteria

Gray mold rot *B. cinerea* Hyphomycete

Watery soft rot *Sclerotinia* spp. Discomycete

Roots/Tubers Bacterial soft rot *Erwinia* spp. Bacteria

-Potatoes Blight *Phytophthora infestans* Oomycete

Common scab *Streptomyces scabies* Actinomycete

Use of chemicals

A number of chemicals may be applied to horticultural products in order to obtain a desirable post-harvest effect. Most of these are applied after harvest, but a few are applied in the field in order to obtain a specific post-harvest response. For example, the sprouting of onions in storage can be delayed by spraying the onions with maleic hydrazide (MH) in the field while the tops are still green. Chemicals used pre harvest whose sole propose is to achieve a postharvest effect should be included in the list of post-harvest chemical treatments.

Post-harvest chemicals are classified into groups. Many of these are not used commercially and are of research interest only:

a. Fungicides which prevent or delay the appearance of rot and molds in the product. Examples are, sodium orthophenylphenate (SOPP), benomyl, thiabendazole (TBZ), sodium hypochlorite, and sulphur dioxide (SO_2). Methyl formate (Erinol), ethyl formate and (in some countries) ethylene oxide are frequently applied to dried fruits to kill infestations of insects and molds. Sulphur dioxide and benzoic acid are frequently, and propionic acid, ascorbic acid or sorbic acid sometimes, added to processed fruit products, especially juices, to inhibit the growth of yeasts and molds.

b. Chemicals that delay ripening or senescence. Examples are: the kinins and kinetins that delay chlorophyll degradation and senescence in leafy vegetables, gibberellins that retard the ripening of tomatoes and hold citrus fruits on the tree beyond normal maturity, and auxins that delay physiochemical deterioration of oranges and green beans.

c. Growth retardants that inhibit sprouting and growth. Examples are maleic hydrazide which is applied pre-harvest and inhibits sprouting in a number of stored commodities, e.g., onions and potatoes. A number of chemicals are applied postharvest to potatoes to control sprouting, for example, CIPC, TCNB and MENA. Daminozide (Alar) give a increased fruit firmness, bettor colour and early maturation in apples.

d. Chemicals that hasten ripening and senescence. Examples are ethylene and compounds such as Ephephon that release ethylene, abscisin, ascorbic acid, ß hydroxyethyl hydrazine (BOH), acetylene and substances that release acetylene such as calcium carbide, and certain alcohols and fatty acids.

e. Chemicals that may hasten or delay ripening and senescence depending on the dose and the commodity on which they are used. Examples are 2, 4-D; 2, 4, 5-T; indoleacetic acid (IAA) and naphthalene acetic acid (NAA).

f. Metabolic inhibitors that block certain biochemical reactions that normally occur. Examples are cycloheximide, actinomycin D, vitamin K, maleic acid, ethylene oxide, and carbon monoxide.

g. Ethylene absorbants. These delay ripening and senescence because they remove the ethylene produced by the fruit. They are usually placed in close proximity to the commodity and leave no residue on it. An example is potassium permanganateimpregnated alumina or vermiculite (fur fir).

h. Fumigants to control insects or sometimes molds. Ethylene dibromide and methyl bromide are the most commonly used fumigants.

i. Colouring:The use of artificial colours is sometimes permitted in order to improve the appearance of a fruit. For example, fresh grange from Florida (in USA) may have artificial colour added to the akin for cosmetic purposes. Since most people do not eat orange skins other than for marmalade it is considered to be a harmless addition.
In warm climates ethylene is used to degreen lemons, oranges and tangerines imparting a brighter colour to the skin. Ethylene is a naturally occurring metabolite of ripening fruits.

j. Food additives: A number of compounds are permitted to be added to processed horticultural products for preservative or functional effect.

Nanotechnology

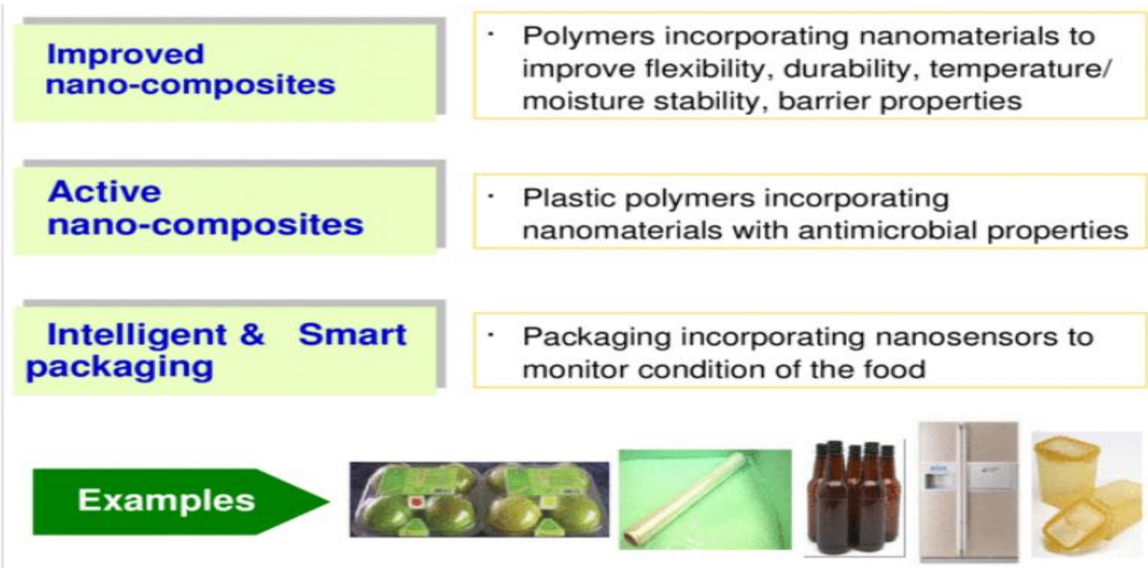
Horticulture science has been defined as science and art of cultivating and handling of fruits, vegetables, flowers, and ornamental plants. Human population is increasing rapidly, so providing sufficient and healthy food is becoming a very important problem in the near future. Now, increasing production efficiency and decreasing post harvest wastage with using the findings of novel scientific researches such as biotechnology and nanotechnology in products, could be counted as the best solution to this problem.

Nanotechnology using particular characteristics of nano-particles can be a very useful technology in all science and industry branches. Nowadays, a lot of usages of nanotechnology in agricultural sciences have been established. In relation with extension of horticultural products shelf life, nanotechnology can help us in some grounds, e.g. controlling growth and development of micro organisms, introducing a new generation of packaging coverage's (Films) and controlling influence of gases and the harmful rays (UV), increasing strength, quality and packaging beauty, and using the multiple chips (Nanobiosensors) for labeling products that considered as fundamental step to automated control of storages.

Anotechnology is a new emerging approach that refers to understanding, controlling and mastering the properties of matter at the nanometer scale. Now a day, nanoparticle science is becoming one of the most imperative tools in modern agro-horticulture pre harvest and post-harvest production sectors. Various biological agents such as microbes (Bacillus spp. Pseudomonas spp. Fusarium spp. Chlorella spp. etc.) and plants/plant extracts (Garlic, aloe, tea etc.) have emerged as economical and efficient candidates for the synthesis of nanoparticles by green synthesis approaches. Due to higher solubility, stability and ecofriendly biodegradable nature of nanoparticles, it finds immense application in sustainable agro-horticulture food chain.

In coming year, findings of novel scientific approach such as biotechnology and nanotechnology could lead to the increase in production efficiency, minimizing post harvest decaying wastage with improving longevity and resistance of horticulture crops products. In relation with post harvest management and shelf life extension of horticultural crops and its products, nanoparticle science can help us in some important areas, e.g. In food safety and quality, for controlling post-harvest crop fungal pathogens and other pathogenic micro organisms, nanopolymer based antimicrobial packaging for storage of fresh horticulture produce, introducing a new generation of packaging films and controlling influence of gases and the harmful rays (UV), developing nanobiosensors for detection food borne pathogens and other contaminants, developing new plastic for food packaging industry and enhancing strength and quality of packaging material. Beside this, nanotechnology promises to accelerate the development of agro-horticulture waste/processed biomass to biofuels production technologies.

Packaging applications



- To convert temperatures in degrees Fahrenheit to Celsius, subtract 32 and multiply by .5556 (or 5/9).

• Example: (50°F - 32) x .5556 = 10°C

- To convert temperatures in degrees Celsius to Fahrenheit, multiply by 1.8 (or 9/5) and add 32.

Example: 30°C x 1.8 + 32 = 86°F

Metric Conversion Chart

Mass

1.0 avoirdupois pound (lb) = 0.454 kilogram (kg) = 454 grams (g)

1.0 kilogram (kg) = 2.2 pounds (lb) = 35.2 avoirdupois ounces (oz) = 32.15 troy ounces

1.0 avoirdupois ounce (oz) = 0.9115 troy ounce = 0.0284 kilogram (kg) = 28.4 grams (g)

1 short ton (T) = 2,000 pounds (lb) = 907.2 kilograms (kg) = 0.893 long ton = 0.907 metric tonne

Length

1 inch (in) = 2.54 centimeters (cm)

1 centimeter (cm) = 0.394 inch (in)

1 foot (ft) = 30.48 centimeters (cm)

1 yard (yd) = 91.44 centimeters (cm) or 0.9144 meter (m)

1 meter (m) = 3.28 feet (ft) = 1.0936 yards (yd)

1 mile (mi) = 1.61 kilometers (km)   1 kilometer (km) = 0.621 mile (mi)

Volume

1 quart (qt) = 0.946 liter (L)   1 liter (L) = 1.057 quarts (qt)

1 cup (c) = 0.24 liter (L)   1 pint (pt) = 0.47 liter (L)

1 quart (qt) = 0.95 liter (L)   1 U.S. bushel (bu) = 35.24 liters (L)

1 liter (L) = 0.2838 bushel (bu)   1 U.S. gallon (gal) = 3.785 liters (L)

1 liter (L) = 0.2642 gallon (gal)   1 cubic foot (ft^3) = 28.32 liters (L)

1 cubic yard (yd^3) = 0.76 cubic meter (m^3)   1 liter (L) = 61.02 cubic inches (in^3)

Area

1 acre = 0.4047 hectare   1 hectare = 2.47 acres

1 square meter (m^2) = 1550 square inches (in^2) = 1.196 square yards (yd^2) = 10.76 square feet (ft^2)

1 square inch (in^2) = 6.45 square centimeters (cm^2)

1 square foot (ft^2) = 0.0929 square meter (m^2)