Bonga University

College of Agriculture and Natural Resource

Department of plant Science

Postharvest Handling of Horticultural crops

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Course objectives

At the end of the course the students will be able to understand:

- the properties of fruits and vegetables
- the physiological aspects of produce in relation to postharvest
- the major causes of postharvest losses
- proper harvesting and postharvest handling of horticultural crops

Chapter 1

1. Introduction

Fresh horticultural crops are diverse morphological structure (roots, stems, leave, and so on), composition, and general physiological. Thus, commodity requirements and recommendations for maximum postharvest of fruit and vegetable vary among the commodities. All fresh horticultural crops are high in water content and are subject to desiccation and mechanical and physiological injury. They are also susceptibility to attack by bacteria and fungi, with pathological breakdown. Biological (internal and external) causes of deterioration include respiration ,ethylene production and action, rates of compositional changes, mechanical physiological injuries, water stress, sprouting and rooting, physiological disorders, and pathological breakdown. The rate of biological deterioration depends on several environmental (external) factors, including temperature, humidity, air, frost and atmospheric gases composite, and sanitation procedures.

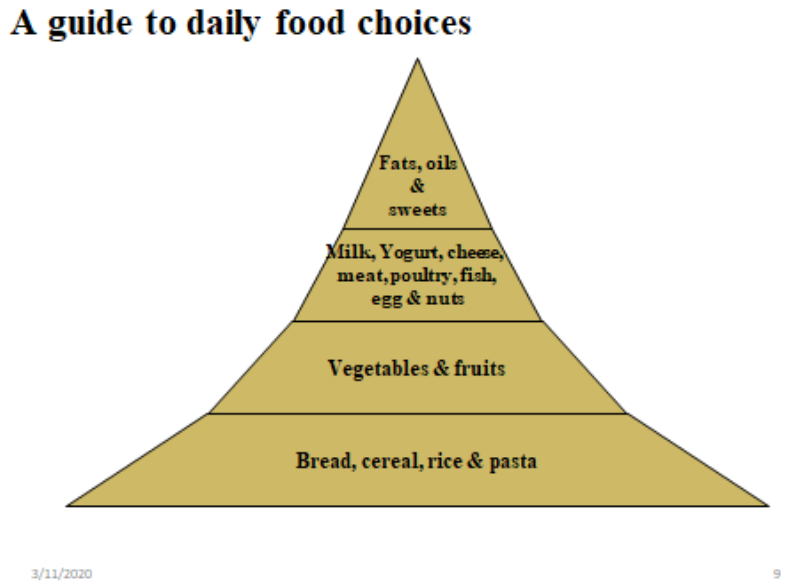
Fresh fruits and vegetables play a very significant role in human nutrition, especially as sources of vitamins minerals, and energy. Other constituents that may lower risk of cancer and other diseases include python nutrients. Postharvest losses in nutritional quality, particularly Vitamin

C content, can be substantial and are enhanced by physical damage, extended storage duration, high temperatures, low humidity, and chilling injury of chilling-sensitive. You have spent months working in the fields, and now have a beautiful fruits and vegetables. You want to ensure that your customers will also enjoy this healthy harvest. How can you best maintain the quality and safety of your produce as it travels from the field in the table? High-quality, disease-free produce with a good shelf life is a result of sound production practices, proper handling during harvest, and appropriate postharvest packaging handling and storage.

1.1. Importance of perishable horticultural crops

- **The postharvest physiology** of fresh fruit and vegetables has in recent times become an important **subdivision** of both plant physiology and horticulture
- The increased attention afforded postharvest horticulture due to
- faulty handling practices after harvest can cause **large losses** of produce

- Food products may be categorized as fresh plant produce, processed plant produce, dairy products, and fresh and processed animal products.
- Fresh fruits & vegetables have been part of human diet for long time
- In the early days, animal products were more valued and only few nations capitalized on fruits and vegetables
- However, recently more attention has been rendered to the later because of more Obesity and coronary heart diseases incidences



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i. Vitamins- C

- fruits & vegetables account 95% of Vitamin C

- Vitamin C (**Ascorbic acid**) is water soluble and antioxidant vitamin and cannot be stored in the body.
- It is excreted from the body regularly, thus it is demand regularly
  - Helps in protecting the body against pollutants.
  - Promoting healthy cell development, normal tissue growth and repair such as healing injuries and burns, and helps in absorption of calcium.
  - Vitamin C is useful for healthy gums to help in protecting against infections.
  - It also strengthens many parts of our body such as blood vessels and muscles.
- The main function of vitamin C is that it helps in the synthesis of **collagen.**
  - **Collagen** is an important component of ligaments, blood vessels and bone.
  - It is a fibrous protein found in skin, bone, and other connective tissues
  - It is found throughout the body, present in cartilage and connective tissues and is used to separate skeletal and smooth muscle cells.

ii. Folic acid:

- It is a supplemental form of a B Complex vitamin called folate that is necessary for
  - Formation of **red blood cells**
  - DNA synthesis and for protein metabolism
  - Folate is found in citrus fruits, green leafy vegetables, and whole grains.
  - Women who may get pregnant need ample amounts of folate every day

iii. Vegetables and fruits prevent a raft of medical conditions

- Appendicitis
- Colonic and rectal cancers
- Constipation
- Diabetes
- Gallstones
- Hemorrhoids
- Varicose veins, etc

- Fruits and vegetables are low in fat and high in dietary fiber thus they are good substitute for animal based food staffs

iv. As for ornamentals

- Mixed with prepared foods

- Principally, they are food for the mind
- Traditionally, they are gown in gardens, interior-scapes, hotels and offices
- Especial occasions
    - Weddings, Funerals/ memorable service, Valentine's day, parades/display and rallies/ public meeting
    - In some countries they are symbol of the state.

1.2. Basic concepts

- In the process of utilization of plants or plant parts by humans there is always a postharvest component
- This is an integral/ essential part of the human food supply chain for
    - Subsistence agriculture and seasonal production
    - Distance between production and urban centers
    - International traders

Postharvest: refers to the time period from harvest to the time of ultimate utilization, deterioration or death.

It is the beginning of the products end

Loss: - any change in the availability, edibility or quantity of the food that prevents it from being consumed by people.

- Hunger and malnutrition can exist in spite of adequate food production.
- These can be the result of uneven distribution, losses, and deterioration of available food resources. Hence, maximum utilization of available food and minimization of postharvest food losses are absolutely essential.
- The loss of foods (both in quality and quantity) in the post-harvest system has always been a problem.
- **To reduce such loss,**
    - one must understand the biological and environmental factors involved in deterioration of the product and
    - Use of post-harvest techniques.
- Post-harvest technology has to be based on a sound knowledge of **postharvest physiology**

Post-harvest physiology: It is the division of plant physiology dealing with functional processes in plant material after it has been harvested.

- Post-harvest physiology is concerned with plants or plant parts that are **handled and marketed in the living state** including seeds, fruits, vegetables, cut flowers, and foliage, nursery products, turf, vegetative propagules and edible fungi.
- Post-harvest period starts with the harvest, but pre harvest factors could also influence the final quality.
- Unless materials /products are consumed immediately after harvest, changes will take place.

  Why we need to study Postharvest Physiology?

✖ Harvested fruits and vegetables are still living organs as they continue to respire and lose water.

✖ Faulty handling practices after harvesting can cause large losses of produce that required large input of labor, material and capital to grow.

✖ This is mainly due to increased expense to prevent deterioration of the produce by proper and safe storage and transportation

- **Postharvest technology (PHT):** is the science which deals with all aspects of
  - Quality maintenance
  - Loss reduction
  - Value enhancement, and
  - By-product utilization of the harvested agricultural produce.

Under the conditions of optimum energy, economic viability and employment potential is high.

✖ The **technique** involved in harvesting, handling, transporting, storing to reduce losses and to keep them fresh is **post-harvest technology**.

✖ The whole chain of movement and operation is **postharvest handling**.

Factors affecting post-harvest handling

+ The nature of plant materials (its physiological processes)
+ The technology used
+ Economic aspects associated with handling, storage, and marketing of plants and plant parts

1.3. Post-harvest losses of Horticulture Products

1.3.1. Nature of postharvest Losses

Post-harvest losses are any change in the quantity or quality of a product after harvest that prevents or alters its intended use or decrease its value.

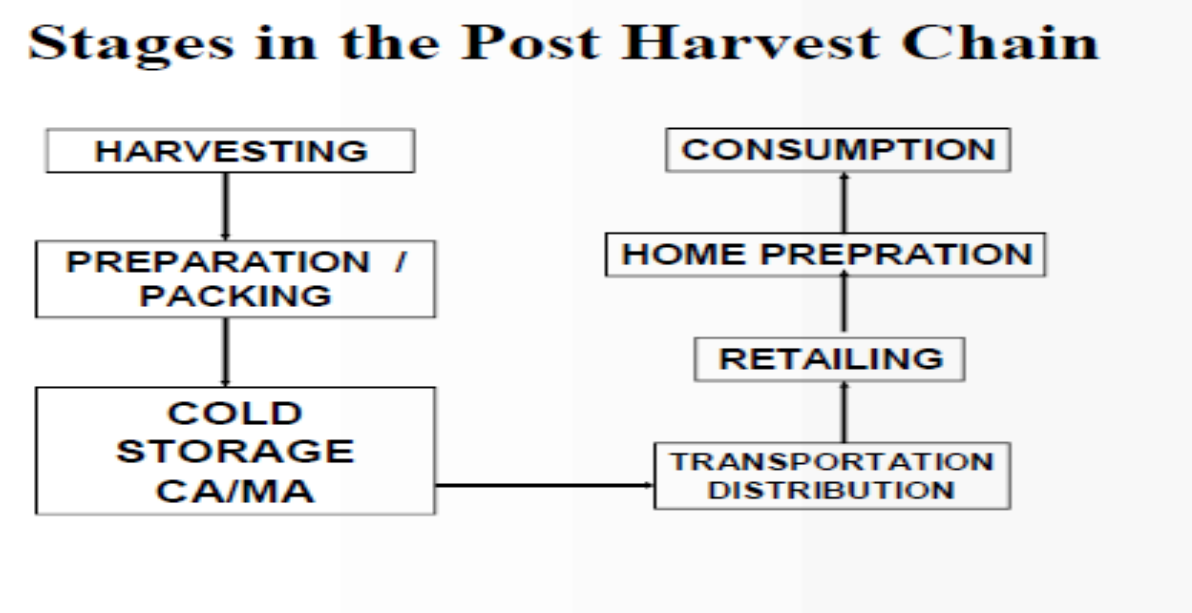
Losses can be

- Quantitative loss or
- Qualitative loss
    - Nutritional value (changes in composition)
    - Sensory quality
    - Texture….. hard or soft
    - Flavor and aroma
    - Color
    - Freshness, turgidity, crispness, firmness
- Economic loss

GROUP	EXAMPLES	PRINCIPAL CAUSES OF POSTHARVEST LOSSES AND POOR QUALITY (IN ORDER OF IMPORTANCE)
Root vegetables	Carrots Beets Onions Garlic Potato Sweet Potato	Mechanical injuries
		Improper curing
		Sprouting and rooting
		Water loss (shriveling)
		Decay
		Chilling injury (subtropical and tropical root crops)
Leafy vegetables	Lettuce Chard Spinach Cabbage Green onions	Water loss (wilting)
		Loss of green color (yellowing)
		Mechanical injuries
		Relatively high respiration rates
		Decay
Flower vegetables	Artichokes Broccoli Cauliflower	Mechanical injuries
		Yellowing and other discolorations
		Abscission of florets
		Decay
Immature-fruit vegetables	Cucumbers Squash Eggplant Peppers Okra Snap beans	Over-maturity at harvest
		Water loss (shriveling)
		Bruising and other mechanical injuries
		Chilling injury
		Decay
Mature-fruit vegetables and fruits	Tomato Melons Citrus Bananas Mangoes Apples Grapes Stone fruits	Bruising
		Over-ripeness and excessive softening at harvest
		Water loss
		Chilling injury (chilling sensitive fruits)
		Compositional changes
		Decay

1.3.2. Importance or magnitude of postharvest losses

- Accurate estimate of losses are simply not available
- It is also difficult to identify the actual step in the post-harvest chain where the loss has occurred.



The extent of loss is highly variable depending on a number of factors:

- Nature of the product (its perishability)
    - There is a very wide range in the degree of perishability between plants.
    - Difference in post-harvest perishability

Post-harvest technology stimulates agricultural productions by;

- ✖ Prevent post-harvest losses
- ✖ Improves nutrition
- ✖ Adds value to agricultural products
- ✖ Opens new marketing opportunities
- ✖ Generates new job

The three main objectives of app post-harvest technologies to harvested fruits and vegetables are:

1. To maintain quality(appreance, texture, flavor and nutritive value)
2. To protect food safety and
3. To reduce losses between harvest and consumption

The difference between Durable (Agronomic crops) and Perishable (Horticultural crops)

Durables (Agronomic crops)

- **Low moisture (10-15%)**
- **Small unit size (<1kg)**
- **Very low respiration rate with very small heat generation**
- **Hard texture, not easily damaged**
- **Stable, natural shelf life of several years**
- **Loss mainly caused by external agents, e.g. Molds, insect & rodents**

Perishables (horticultural crops)

- **High moisture (50-90%)**
- **Large unit size (5g-5kg 0r more)**
- **High to very high respiration rate, with high heat production**
- **Soft texture, easily damaged**
- **Perishable, natural shelf life few days at best several months**
- **Loss caused partly by external agents e.g. rotting, bacteria & fungi and partly by endogenous factors, respiration, senescence and sprouting**

Estimates of post-harvest losses

- Food grain : 25% (from mishandling ,spoilage and pest infection)
- Fresh horticultural produce: 25-100% of the produce

II. Specific time and place (Season and location)

- Post-harvest losses in less developed countries are generally considered to be higher than in developed countries
  - storage, packing, transport and
  - handling of technologies are particularly nonexistent,
- The pattern of loss also varies widely from country to country.

In developed countries, losses may be fairly high during harvesting because:

- Mechanical harvesting leaves some of the commodities in the field
- Mechanical damage
- Considerable quantity of food may be discarded at the point of harvesting because they are the wrong size, shape and color. These are planed losses.

In less develop countries, harvest losses are lower Because:

- Most of the crop is handpicked.
- The material rejected here is also lower because of the expectation of quality and uniformity
- But in developed countries loss during

- handling, storage, transportation and processing is low because of the
  - efficiency of the equipment,
  - good quality storage condition (facility) and
  - Close control of critical variable by highly trained personnel.

Time:

The longer the time the produce is stored, the greater is deterioration and the greater is the chance of damage and loss.

Hence storage time is critical factor in the loss of commodities, especially which has a short natural shelf life.

1.3.3. Causes of post-harvest Losses

What do you think are the main causes of post-harvest losses?

Primary causes

- **Chemical and biochemical**-(undesirable reactions between chemical compounds present in the food such as browning, rancidity, enzymatic changes, etc.)
- **Mechanical-(**Spillages and damages caused by abrasion/cut, bruising/yellowing, crushing, puncturing, etc.)
- **Biological and microbiological** (Diseases and pest)-consumption or damage by insects, pests, animals and microorganisms, i.e. molds and bacteria
- Fresh produce can become infected before or after harvest.
- These organisms directly consume small amounts of the produce but they damage it to the point that it becomes unacceptable because of rotting and other defects.
- They produce toxic substance
- **Physical-improper environmental and storage conditions** (T0, relative humidity, air speed, etc.)
- **Psychological**- human aversion or refusal due to personal or religious reasons
- **Physiological-**sprouting, senescence, other respiratory and transpiratory changes
  - All horticultural crops are living parts containing 65-95% water and they continue their living process after harvest.
  - That is, they are metabolically active and they respire and transpire.

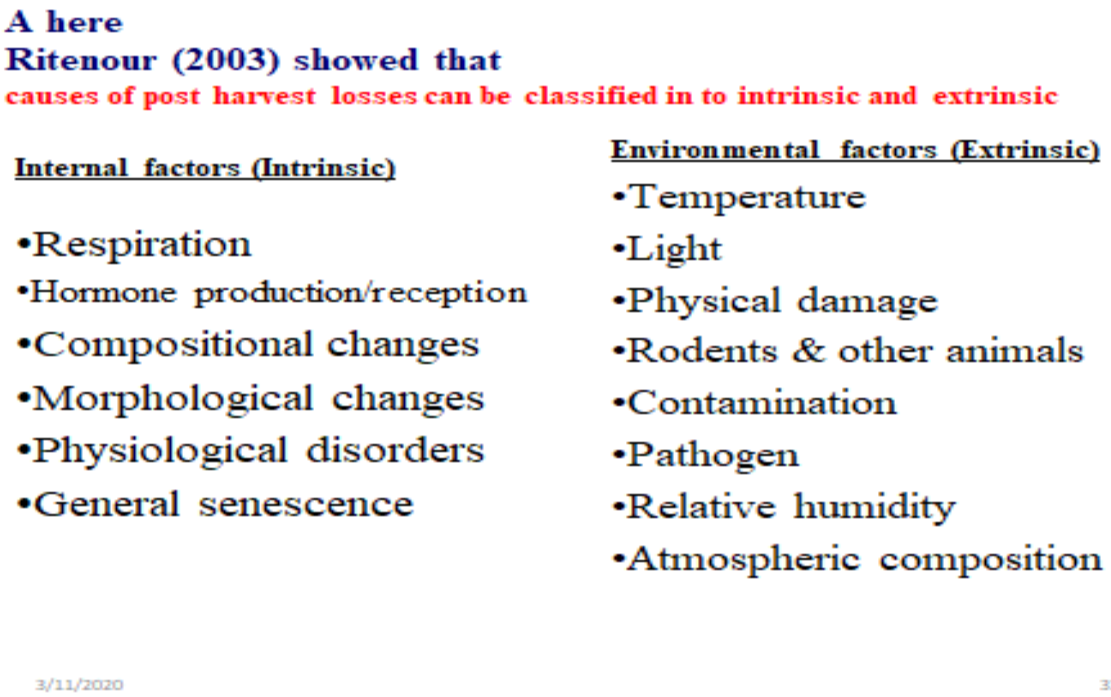
+ There may be an increase in the rate of loss because of normal physiological changes
  - Ripening

- Color changes
- Dormancy

  - These are desirable changes to some extent but may lead to:

+ **Over maturity**
  - Off flavor, sprouting and undesirable color changes
+ Increased susceptibility of the commodity to mechanical damage or infection by pathogens
+ Abnormal physiological deterioration also occurs when fresh produce is subjected to extremes of temperature, atmospheric humidity or because of contamination leading to undesirable compositional changes.
+ **Interaction :**
  - Disease and pest damage ---- Increase respiration
  - Mechanical damage---------increase ethylene production and respiration
  - Ripening:----------increased infection
+ **<u>Secondary causes</u>**
  - **Improper harvesting and handling and**
  - **Inadequate storage facilities, transportation, packaging and marketing systems**

Causes of post-harvest losses can be classified in to intrinsic and extrinsic



Physical damage/Mechanical damage/ injury

- ❖ Includes cuts, punctures (penetrate), cracks and splits.
    - Careless handling during harvesting, packaging, transportation and storage will reduce storage life
        - Internal bruising which results in physiological damage
        - Skin breakage indirectly provides opportunities for entry of pathogens
        - Wounding, physical pressure, breakage, bruises and trimming result in the increased production of ethylene and thus accelerate the rate of senescence of the tissue

Based on the nature of biological or environmental factors

Biological factors

- Respiration
- Ethylene production
- Compositional changes
- Growth and development
- Transpiration
- Physiological breakdown-freezing injury or frost damage. Heat injury vs chilling injury

1.4. Significance or importance of Post-harvest physiology

- **Significance levels of post-harvest losses**
- The farmer can't recover his costs and make a profit and this might causes for poverty
- Less food to people who are malnutrition/starvation
- Health aspects: The production of horticultural crops is **seasonal.** There is thus a need to store produce to meet requirements during the **off season**. Otherwise, there will be deficiency disease as a result of there their absence.
- **Reduction** of post-harvest losses means reduction of:
- Wastage of produce, labor, materials and capital used in the process of production

- In order to deliver perishable produce with best quality to consumer;
- An understanding of the physiology of the produce
- The nature and cause of deterioration should be well understood.
- This leads to the development of appropriate post-harvest handling practice and technology by which deterioration of the produce is reduced.

Then by using proper post-harvest technology on handling, packaging, transportation and storage reduces the post-harvest losses of fruit and vegetables. Processing and preservation technology helps to save excess fruit and vegetable for the glut season (off season). The technology has become a necessity to improve the food safety and strengthen nation's food security. The technology helps to boost export of agricultural commodities in the form of preserved and value added products. Presently, citrus, grapes, tomatoes, peas, are being processed on a large scale in Ethiopia.

Advantages of reducing PHL

- Nutritional advantages
- Economic Advantages
- Feedback incentive to the growers
- Cost effective
- Environmentally friendly
- Consumer satisfaction

How can we reduce post-harvest losses?

We can do it if we

1 **.** Understand the causes of postharvest losses
2 . Determine factors which affect them and how
3 . Effectively use conditions which control the factors and minimize the spoilage

Chapter: 2

2. Structure, Composition & Nutritional Value of Horticultural Crops

2.1. Structure

Fruit and vegetables have many similarities with respect to their

- Compositions
- Methods of cultivation and harvesting, storage properties and processing.

- In fact, many vegetables may be considered as fruit in the true botanical sense.
- Botanically, fruits are those portions of the plant which house seeds.
- Therefore, such items are tomatoes, cucumbers, eggplant, peppers, and others would be classified as fruits on this basis.
- The important distinction between fruit and vegetables has come to be made on usage basis.
- Those plant items that are generally eaten with the main course of a meal are considered to be vegetables.
- Those that are commonly eaten as dessert (a sweet course eaten at the end of a meal)are considered fruits.
- That is the distinction made by the food processor.
- Vegetables are derived from various parts of plants and it is sometimes useful to associate different vegetables with the parts of the plant they represent since this provides clues to some of the characteristics we may expect in these items.
- Fruit as a dessert item, is the mature ovaries of plants with their seeds.
- The edible portion of most fruit is the fleshy part of the pericarp or vessel surrounding the seeds.
- Fruit in general is acidic and sugary.

Category	**Examples**
Earth vegetables roots	Sweet potatoes, carrots
Modified stems tubers	potatoes
Modified buds bulbs	onions, garlic
Herbage vegetables	
Leaves	cabbage, spinach, lettuce
Petioles (leaf stalk)	celery, rhubarb

Flower buds	cauliflower, artichokes
Sprouts, shoots (young stems)	asparagus, bamboo shoots
Fruit vegetables	
Legumes	peas, green beans
Cereals	sweet corn
Vine fruits	squash, cucumber
Berry fruits	tomato, egg plant
Tree fruits	avocado, breadfruit

2.2. Composition and nutritional value

- Most fresh vegetables and fruit are high in water content, low in **protein and fat**.
- In these cases water contents will generally be greater than **70%** and frequently greater than **85%.**
- Commonly protein content will not be greater than 3.5% fat content greater than 0.5 **%.**
- Exceptions exist in the case of **dates** and **raisins** which are substantially lower in moisture but cannot be considered fresh in the same sense as other fruit.
- Legumes such as peas and certain beans are higher in protein; a few vegetables such as **sweet corn** which are slightly higher **in fat** and **avocados** which are substantially higher in **fat.**

- Water
- Mineral substances
- Carbohydrates
- Fats
- Organic acids
- Nitrogen containing substances
- Vitamins
- enzymes
- pigments

1. **Water**

- Vegetable cells contain important quantities of water. Water plays a vital role in physiological processes.
- It has effects on the storage period length and on the consumption of tissue **reserve substances.**

➢ In vegetable cells, water is present in following forms:-

- **Bound water or dilution water** which is present in the **cell** and forms true solutions with **mineral** or **organic substances**;
- **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;
- **Constitution water**, directly bound on the chemical component molecules and which is also removed with difficulty.

1. **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, 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.**
- Iron (Fe) has an important role as a constituent of **hemoglobin.**
- Main iron sources are **apples and spinach**.

2. **Carbohydrates**

Carbohydrates are the main component of fruit and vegetables and represent more than 90% of their dry matter. From energy point of view carbohydrates represent the most valuable of the food components; daily adult intake should contain about 500g carbohydrates. Carbohydrates can be oxidized to furnish energy/glucose. Glucose in the blood is a ready source o**f energy for the human body.**

Carbohydrate compounds can be classified in to three groups:

- Monosaccharaides: unbranched groups of carbohydrate compound. Eg: **Glucose, fructose, galactose …**
- Oligosaccharides: Monosaccharide units (2 to 10) join glycosidic linkage to form oligosaccharide. Eg:
    - Sucrose (Glucose + Fructose)
    - Maltose (Glucose + Glucose)
    - Lactose (Glucose + Galactode)
- Polysaccharides: Long linear or branched chains of monosaccharaides. Eg:
    - Storage: Starch
    - Structural: Cellulose, hemicelluloses

Some properties of sugars

- Sugars such as glucose, fructose, maltose and sucrose all share the following characteristics in varying degrees, related to fruit and vegetable technology:
    - They supply energy for nutrition;
    - They are readily fermented by micro-organisms;
    - In high concentrations they prevent the growth of micro-organisms, so they may be used as a preservative;
    - On heating they darken in color or caramelize;
    - Some of them combine with proteins to give dark colors known as the browning reaction.

Some properties of starches:

- They provide a reserve energy source in plants and supply energy in nutrition;
- They occur in seeds and tubers as characteristic starch granules.

Some properties of celluloses and hemicelluloses:

- They are abundant in the plant kingdom and act primarily as supporting structures in the plant tissues;
- They are insoluble in cold and hot water;
- They are not digested by man and so do not yield energy for nutrition;
- The fiber in food which produces necessary roughage is largely cellulose.

Some properties of pectin and carbohydrate gums

- Pectin's are 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 contribute to viscosity of the tomato paste;
- It form gels when **sugar and acid** are added; this is the basis of jelly manufacture.

3. Fats

Generally fruit and vegetables contain very low level of fats, below 0.5%. However, significant quantities are found in nuts (55%), apricot kernel (40%), grapes seeds (16%), apple seeds (20%) and tomato seeds (18%).

4. 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.** 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. Under **anaerobic** conditions and slightly above a pH of 4.6, *Clostridium botulinum* can grow and produce **lethal toxins.** This hazard is absent from foods high in **organic acids** resulting in a pH of 4.6 and less

5. Nitrogen-containing substances

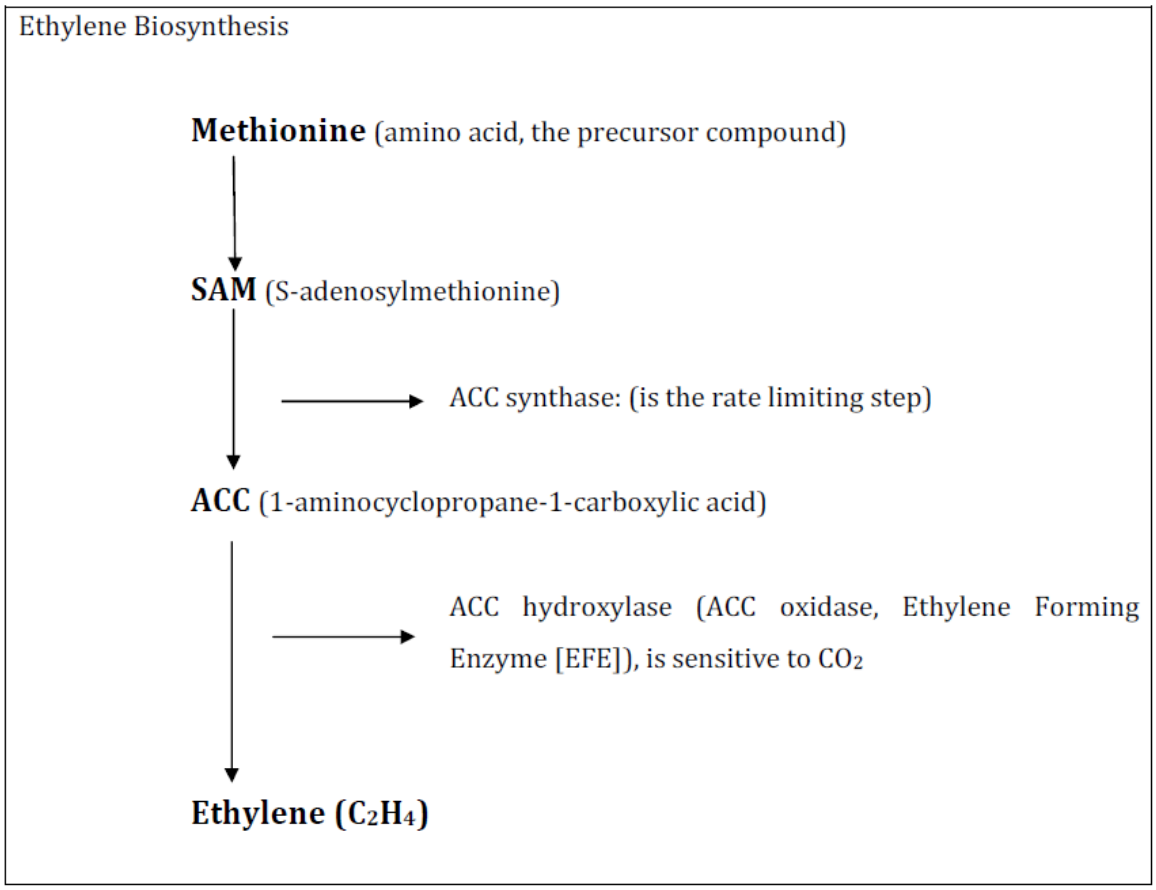
These substances are found in plants as different combinations: proteins, amino acids, amides, amines, nitrates, etc. Vegetables contain between 1.0 and 5.5% while in fruit nitrogen-containing substances are less than 1% in most cases. From a biological point of view vegetal proteins are less valuable than animal ones because in their composition all essential amino-acids are not present.

6. Vitamins

Vitamins function as enzyme systems which facilitate the metabolism of **proteins, carbohydrates and fats.** The vitamins are conveniently divided into two major groups, those that are **fat-soluble** and those that are **water-soluble**. Fat-soluble vitamins are A, D, E and K. Water-soluble vitamins include vitamin C and several members of the vitamin B complex.

7. Enzymes

- Enzymes are biological catalysts that promote most of the biochemical reactions which occur in vegetable cells.
- 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;
  - They may be responsible for changes in flavor, color, 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.



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).

8. Pigments

- In addition to a great range of textures, much of the interest that fruits and vegetables add to our diets is due to their delightful and variable colors.
- The pigments and color precursors of fruit and vegetables occur for the most part in the cellular plastic inclusions such as the chloroplasts and other chromo lasts, and to a lesser extent dissolved in fat droplets or water within the cell protoplast and vacuoles.
- These pigments are classified into four major groups which include the:
  - Chlorophylls,
  - carotenoids,
  - Anthocyanins,
  - Anthoxanthins

Flavonoids

Chlorophyll

- The chlorophylls are contained mainly within the chloroplasts
- The bright green color of leaves and other parts of plants is largely due to the **oil soluble chlorophylls**, which in nature are bound **to protein molecules** in highly organized complexes.
- When the plant cells are killed by ageing, processing, or cooking, the protein of these complexes is denatured and the **chlorophyll may be released.**
- Such chlorophyll is highly **unstable** and rapidly changes in color to **olive green and brown.**
- This color change is believed to be due to the conversion of **chlorophyll to the compound Pheophytin.**
- Conversion to pheophytin is favored by acid **pH but** does not occur readily under **alkaline conditions**.

- For these reason peas, beans, spinach, and other green vegetables which tend to lose their bright green color on heating can be largely protected against such color changes by the addition of **sodium bicarbonate or other alkali to the cooking or canning water.**

Carotenoids

- Pigments belonging to this group are fat-soluble and range in **color from yellow through orange to red.**
- They often occur along with the chlorophylls in the chloroplasts, but also are present in other chloroplasts and may occur **free in fat droplets.**
- Important carotenoids include:
    - The orange carotenes of carrot, maize, apricot, peach, citrus fruits, and squash;
    - The red lycopene of tomato, watermelon, and apricot;
    - The yellow-orange xanthophyll of maize, peach, paprika and squash.

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 colored fruit and vegetables such as apple, onion, potato, and cauliflower, and the colorless catechins and
    - leucoanthocyanins which are food tannins and are found in apples, grapes, tea, and other plant tissues.

Chapter 3

3.1. Physiological and biochemical aspects of produce development

3.1.1. Metabolic changes during maturity, ripening & senescence

Stages of fruit and vegetable development

- Plant development defined as a series of process from ---initiation of growth ----death of a plant or plant part.

Basic stages occur during the development are:

I. Growth:

- The irreversible increase in physical attributes of a developing plant or plant parts.

II. Maturity:

- Maturity is the stage of development leading to the attainment(achievement) of physiological or horticultural/commercial maturity

III. Ripening:

a sequence of changes in texture, color and flavor as a result of physiological and biochemical change --------- and that makes the fruit ready for consumption.

At present days artificial ripening can also be practiced by introducing ethylene or acetylene gas (calcium carbide) Eg: Banana, mango and avocado.

At the process of ripening there might be

- Loss of chlorophyll (undesirable in vegetable)
- Production of carotenoids and ant ocianines.
- Starches conversion into sugars.
- Changes in organic acids, proteins and fats.
- Reduction in **tannins** and **fungi static** compounds.

IV. Senescence:

- Senescence is the last stage of development during which degradation of biological components occurs.

Metabolic changes during maturity, ripening & senescence

- **During ripening**

Several biodegradation processes can take place **inside the fruits** such as:

- Depolymerization
- Substrate utilization
- Loss of chloroplasts and
- Pigment distraction

Mainly due to the action of **hydrolytic enzymes (esterases, dehydrogenases, oxidases, phosphatases and ribonucleases)**

a. Water

During storage ripening of fruit and vegetable will lose its water content as a result of:

Respiration

Transpiration and

Exchange of gas

This is depends upon the RH, temperature, structure of the plant and the rate of the process (transpiration and respiration).

When the loss is more than 5-10% fruit and vegetable start shrivel and become unusable.

b. Color

The most common changes in fruit during ripening **are loss of green color**.

It is due to degradation of chlorophyll structure.

The disappearance of chlorophyll is associated with the synthesis of pigments ranges from **yellow to red.**

c. Flavoring compounds

- ✓ **Aroma** plays an important part in the development of optimal

Eating quality of fruit and vegetables

This is due to the synthesis of many **volatile organic compounds** during the ripening phase.

D. Carbohydrates

One of the changes that occur in fresh fruits during ripening is change of carbohydrates composition mainly due

To substrate utilization and

Action of hydrolytic enzymes

Starch is completely hydrolyzed into

Simple sugar (Glucose, fructose and sucrose)

Structural carbohydrates (starch) are decreased slightly.

In some fruits approximately equal quantities of glucose and fructose are formed due to hydrolysis of starch.

However, as storage time advances, especially in fruit, the content of all three free sugars (sucrose, glucose and fructose) declines.

During storage of fruit and vegetables, free sugars show a general initial increase (as result of breakdown of polysaccharides) followed by a decrease.

- Several factors contribute towards the excessive decline of sugars during storage, such as:
  - Fruit maturity
  - Storage temperature
  - Concentration of O2, ethylene and CO2.
  - Higher temperature favors faster utilization of sugars as substrate in the respiration process.

e. Organic acids

- Common acids found in fruit include **citric, malic and ascorbic acid.**
- During ripening, **organic acids** are among the major cellular constituents undergoing changes.
- The titratable acidity decreases with storage time, especially at higher temperatures.

- Many of the chemical and physical effects that occur during ripening of fruits are attributed to **enzyme action.**
- The **biochemical changes** are responsible for development of:
  - Off-flavors
  - Discoloration and
  - Loss of firmness as a result of enzymes.
- **The most important enzymes related to food quality include**
  - ✓ lipolytic acyl hydrolase
  - ✓ lipoxygenase
  - ✓ peroxidase
  - ✓ catalase
  - ✓ Protease

  For the changes in Flavor
  - ✓ Polyphenol oxidase ----- Change in color
  - ✓ Amylase (starch---to--- simple sugar)---------- Change in softness
  - ✓ pectin methylesterase (**it makes strong structure**)
  - ✓ Polygalacturonase

  Loss of texture
  - ✓ Ascorbic acid oxidase and Thiaminase

  Loss of nutritional quality

Maturity

Physiological maturity: The stage of development when a plant part will continue development even if detached; mature fruits

Horticultural maturity: The stage of development when a plant part possesses the necessary characteristics for use by consumers

Maturity Indices

<u>Non-climacteric fruits</u>

(Fruits with no starch reserves)

- ✓ **Pineapple**
- ✓ **Strawberry**
- ✓ **Citrus**

<u>Climacteric fruits</u>

(Fruits with starch reserves)

- ✓ **Apples**
- ✓ **Mango**
- ✓ **Banana**

What is a good maturity index?

- ❖ Simple, easy to carry out
- ❖ Objective (free of biases or prejudice caused by personal) vs subjective indicators
- ❖ Related to quality
- ❖ Related to storage life
- ❖ Represents a progressive change with maturity
- ❖ Permits prediction of maturity from year to year
- ❖ Inexpensive

Predicting Maturity

- Days from planting to harvest
- Progressive changes in size, composition of the product
- **Difficult to do;** need new tools and methods
  - ✓ Nondestructive firmness measurement: fruits
  - ✓ Chlorophyll fluorescence, broccoli: green tissues
  - ✓ NIR spectroscopy: sugar concentration in melon
  - ✓ Imaging constituents: internal defects