POST-HARVEST PHYSIOLOGY
HORT-7126

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Introduction

- **Post harvest horticulture or technology is concerned with all activities between harvest and consumption of fresh crops such as fruits, vegetables and ornamentals.**
- **In developing countries such as Pakistan we have to feed the ever increasing population; there are two ways to feed the population**
  - **To grow more crops/food**
  - **To decrease the post harvest losses**
- **Currently the post harvest losses of fruits and vegetables are 20-40%. If we control or minimize the losses we can fulfill the food requirement and improve the quality of the produce.**
- **By adopting the standard postharvest practices we can export our fruits and vegetables and we can get economic returns.**

- **Due to lack of post harvest system our fruits and vegetables get less prices in international market, for example the mangoes produced by Philippines get 0.86 US $/kg but our mangoes get 0.30 US $/kg. So there is a big gap between prices, and we have to manage this.**

Postharvest Losses

- **Quantitative losses (20-40%)**
- **Qualitative losses (tenderness, nutrients, color, shape)**
- **Economic losses (Low prices in the market)**

Causes of Postharvest losses

- **Loss of moisture from the surface of produce, through transpiration and respiration; loss of moisture from the produce results in shriveling and loss of market value.**
- **When produce is stored at higher temperature than optimum temperature, increased metabolic rate particularly respiration results in the onset of early senescence (aging) and ultimately the death of tissues.**
- **Interruption in normal metabolic activity of the produce, due to either extremely low or high temperature, the produce may show physiological disorder such as chilling injury. It happens in tropical fruits such as banana, mangoes, and avocadoes. At high temperature above 30 ^{o}C the produce get "boiled" in this case the external appearance deteriorates and it spoils quickly.**
- **Invasion of the produce by various pathogens results in fruit rot, injured and senescent tissues are more sensitive to the attack of decay-causing microorganism.**

Physiology and Biochemistry of Fruits and Vegetables

Structure

- **Fruits and vegetables are plant organs made of millions of cells bounded by more or less rigid cell walls.**
- **The cell wall is made up of cellulose, pectic substance and lignin. It is permeable to water and solutes. Each cell consists of cytoplasm and usually one or more vacuoles, fluid reservoirs containing various solutes such as sugars, salts and organic acids.**
- **They are surrounded by a semi permeable membrane known as tonoplast (vacuoles wall). The crispness of the fruits and vegetables is related to the turgidity of the cells comprising it.**
- **Important cell organelles are the plastids, which are involved in energy fixation (chloroplast) colour change (chromoplast) and starch storage (amyloplast).**

Composition

- Fruits and vegetables are composed of water, carbohydrates, proteins, lipids, organic acids, vitamins, minerals and flavoring compounds in volatile form.
- The quantities of these components depends upon the species, or variety of fruits and vegetable, the agro-climatic conditions where they are grown, nutritional factors, stage or maturity, and ripening.

Commodities	Vitamin C (mg/100g)
Guava	200
Broccoli, Brussels sprout	100
Papaya	80
Citrus, Strawberry	40
Cabbage, Lettuce	35
Mango, Carrot	30
Pineapple, Banana, Beans etc.	20
Apple, Peach	10
Onion, Sugar beet	5

Ripening and Respiration

- **After maturation, senescence begins with ripening, which may occur while the fruits or vegetable is attached to the plant or after harvest. The ripening fruit undergoes many physiochemical changes after harvest which determines fruit quality.**
- **Ripening is a complex process with many inter dependents steps, the major metabolic process which take place in the harvested produce is respiration.**
- **It is the oxidative break down of more complex material normally present in the cells such as starch, sugars and organic acids, into simple molecules such as carbon dioxide and water with the concurrent production of energy and molecules which can be used by the cell.**
- **Respiration is of two types aerobic and anaerobic; Anaerobic respiration is known as fermentation and results in the development of off flavors in the produce.**
- **Rate of respiration is good indicator of metabolic activities of fruit tissues and can serve as a commercial indicator of the potential storage life of produce; such information helps in better and scientifically managed/organized marketing.**

During respiration, visible and invisible changes occur in the fruit.

- **Changes of skin color from green to yellow or some other color.**
- **Changes of starch into sugar (development of sweet taste)**
- **Reduction in acids**
- **Softening of pulp (reduction in pectin and lignin substances)**
- **Development of aroma (production of aromatic compounds)**

These changes make the produce edible and acceptable to the consumer but from commercial point of view these processes should be controlled so that the produce have a prolonged storage/shelf life. Flavor is one of the important aspect of quality that develops under normal conditions.

Postharvest Respiration

- **The basic principle in postharvest handling is that horticultural produce such as fruits and vegetable are living, not only when they are on the tree but also after they are detached from the plant.**
- **They continue metabolic reaction and maintain their physiological functions.**
- **They respire through the uptake of oxygen, produce carbon dioxide and heat energy, transpire and lose water.**
- **The major difference between pre-and post harvest stages is that when the fruit is attached to the plant it replaces consumed energy through the flow of cell sap, but after it is harvested, it has to depend entirely on its stored food energy. This is the point where deterioration begins.**
- **In the physiological development of any fruit or vegetable here are three stages, growth, maturation and senescence. Growth involves cell division and enlargement, while maturation begins when growth stops. Both these stages are developmental phases. After maturation senescence starts. This is the stage when a fruit/vegetable should be harvested (before ripening).**
- **In senescence, anabolic biochemical processes give way to catabolic processes, leading to ageing and finally death of tissues.**

Changes that may occur during the ripening of fresh fruits are

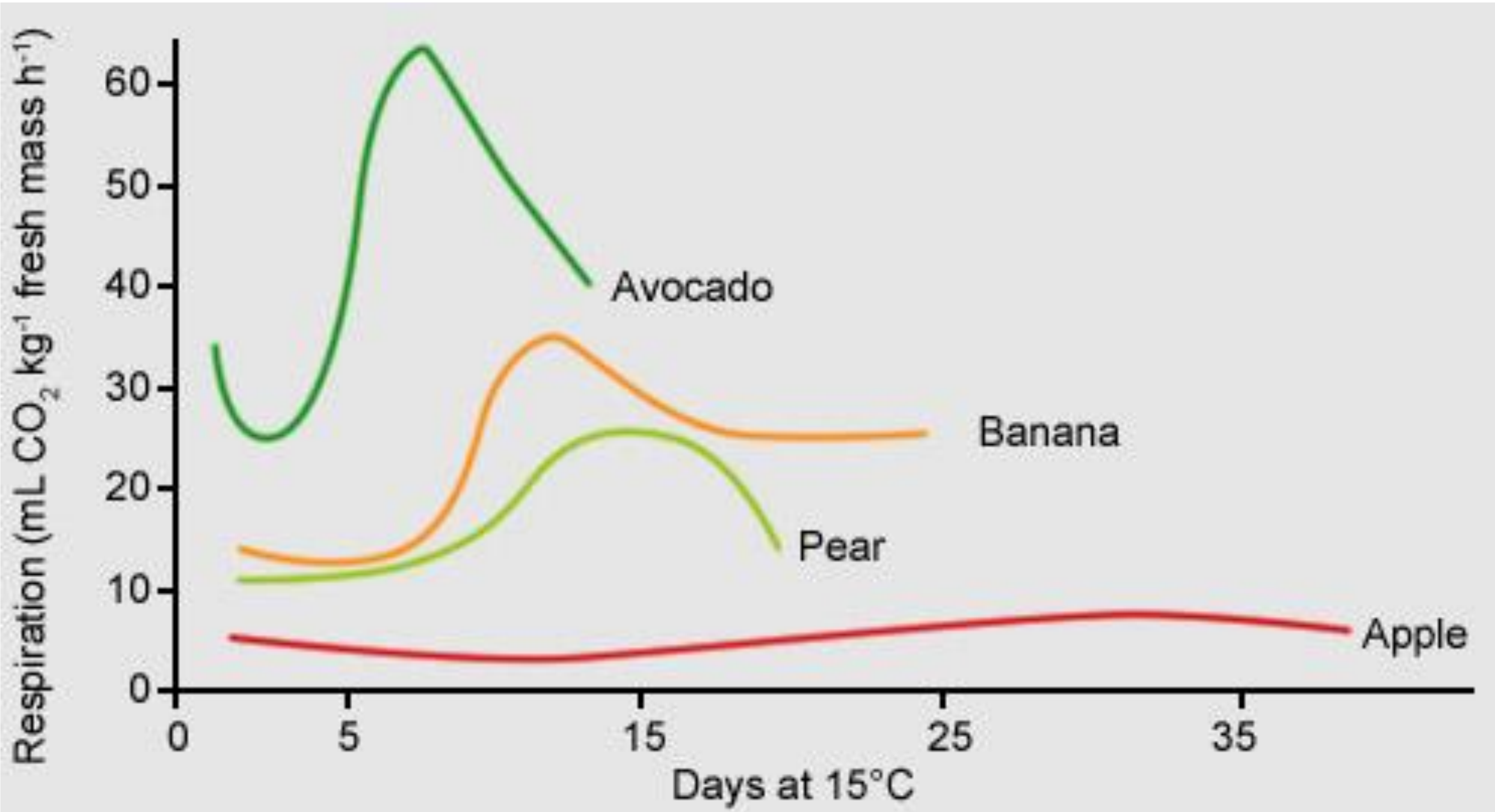
- **Seed maturation**
- **Color changes**
- **Abscission (detachment from the parent plant)**
- **Changes in respiration rate**
- **Change in rate of ethylene production**
- **Change in tissue permeability**
- **Softening (change in pectic substance)**
- **Change in carbohydrate composition**
- **Organic acid changes**
- **Protein changes**
- **Production of flavoring and aromatic compounds**
- **Development of wax on the skin**

On the basis of respiratory patterns, horticultural crops can be divided into two major groups

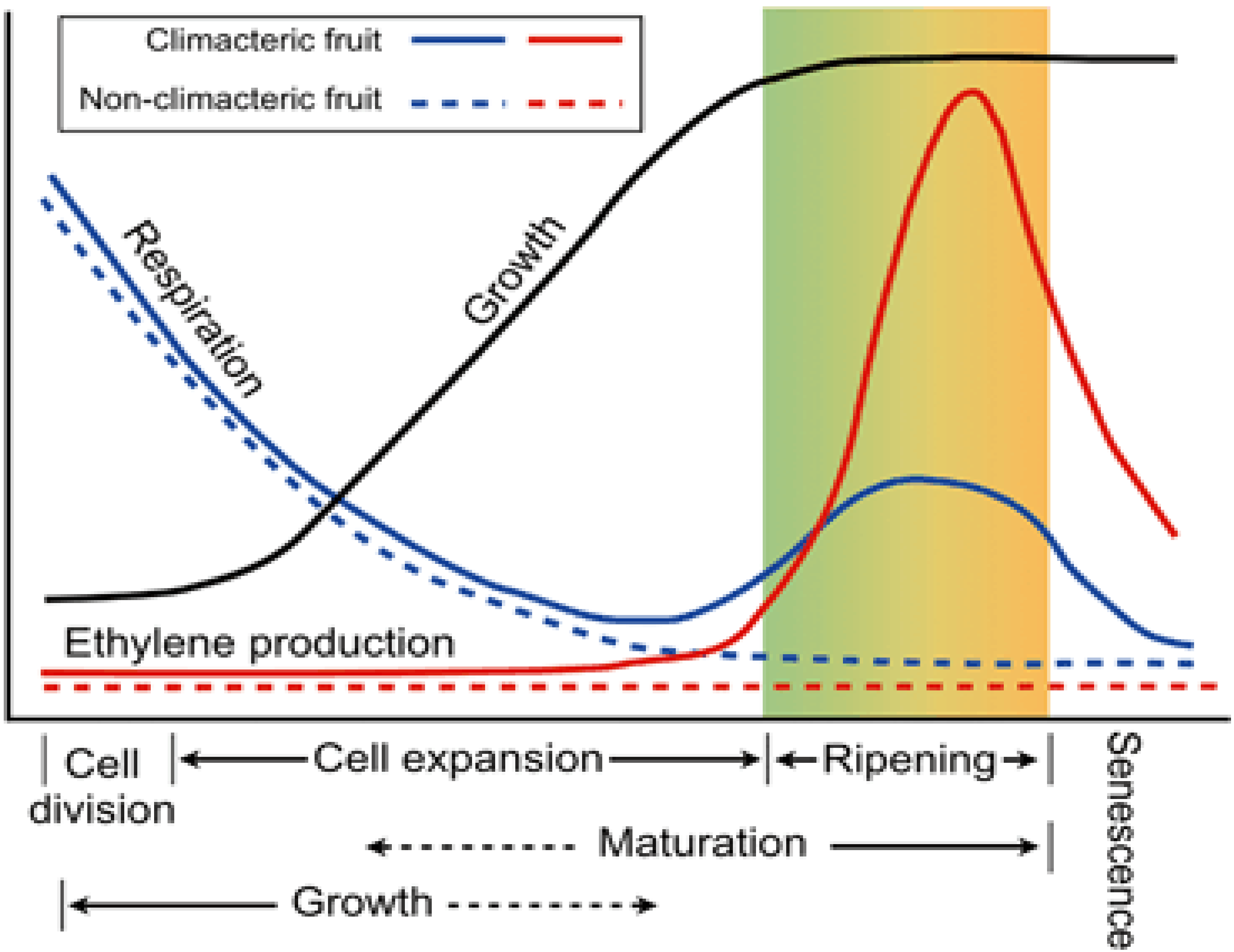
- **Climacteric**
- **Non-climacteric**

Climacteric fruits

- **Climacteric fruits are those fruits in which there is a period in the development of fruit during which a series of biochemical change results in increased respiration, leading to ripening and making the changes from growth to senescence. e .g. Apple, Apricot, Banana, Avocado, Mango, Plum, Peach, Persimmon, Tomato etc.**
- **Non-climacteric fruits: Sweet cherry, Cucumber, Lemon, Pineapple, Mandarin, Sweet orange, Strawberry etc.**



Respiratory pattern of some climacteric fruits store at 15-20°C



Climacteric fruit
Non-climacteric fruit
Respiration
Growth
Ethylene production
Cell division
Cell expansion
Ripening
Senescence
Maturation
Growth

Postharvest Technology Procedures

Temperature management procedure

- Temperature management is the most effective tool for extending the shelf life of fresh horticultural commodities. It begins with the rapid removal of field heat by using one of the following methods
  - Hydro cooling
  - Top icing
  - Evaporative cooling
  - Room cooling
  - Forced air cooling
  - Vacuum cooling

- **Cold storage facilities should be well engineered and adequately equipped.**
- **They should have good construction and insulation, strong floors, adequate and well positioned doors for loading and unloading, effective distribution of the refrigerated air, and sensitive and properly located controls.**
- **Storage rooms should not be loaded beyond their limits for proper cooling.**
- **In monitoring temperatures, commodity temperature should be measured rather than air temperature.**
- **Transit vehicles must be cooled before loading the commodity. Delay between cooling after harvest and loading in transit vehicles should be avoided, and proper temperature maintenance should be ensured through out the handling system.**

Control of Relative Humidity/ Management Procedure

- **Relative humidity can influence water loss, decay development, incidence of some physiological disorders, and uniformity of fruit ripening.**
- **Proper relative humidity is 90-98% for vegetable except (70-75%) dry onion and pumpkins, and 80-85% for fruits.**
- **Relative humidity can be controlled by adding moisture (water mist) to air by humidifier.**
- **Regulating air movement and ventilation in relation to the produce load in the cold storage room.**
- **By providing moisture barriers that insulate rooms and transit vehicle walls.**
- **By wetting floors in storage room.**
- **Adding crushed ice in shipping containers if commodity is not damaged.**
- **Sprinkling produce with water during retail marketing.**

Recent Trends in Perishable Commodities Handling

Selection of cultivars

- For many commodities producers are using cultivars with superior quality and long shelf life. Plant breeders in public and private institutions are using molecular biology methods along with plant breeding procedures to produce new genotypes that taste better, maintain firmness and are disease resistant.

Packing and Packaging

- The produce industry is increasingly using plastic containers that can be reused and recycled in order to reduce waste disposal problems.
- There is increase in the use of modified atmosphere and controlled atmosphere packaging (MAP & CAP) systems at pallet, shipping containers, and consumer package level.
- The use of absorbers of C_2H_4, CO_2,O_2, and water vapors as a part of MAP and CAP is increasing.

Cooling and Storage

- The current trends is towards increased precision in temperature and relative humidity management to provide the optimal environment for fresh fruits and vegetables during cooling and storage.
- Precision temperature management (PTM) tools are becoming more common in storage facilities.
- Operators can ensure that all produce shipment leave the cooling facility within 0.5ºC of the optimal storage temperature.

Postharvest Integrated Pest Management

- Calcium treatment have shown to reduce decay incidence and severity, wound healing following physical injury has been observed in some fruits and has reduced their susceptibility to decay.
- Biological control agents are being used alone or in combination with reduced concentrations of postharvest fungicides, heat treatment etc.
- Chemical fumigants especially methyl bromide are still the primary methods used for insect control in harvested fruits when such treatment is required by quarantine authorities in importing countries.
- Many studies are underway to develop alternative methods of inset control that are effective, not phyto-toxic to fruits and present no health hazard to the consumer. The alternatives include cold treatment, hot water or hot air treatment, ionizing radiations (0.15-0.30 kilo gray) and exposure to reduce O_2 (0.5%) or elevated CO_2 (40-60%) atmosphere.

Food Security

Food security exist when all people, at all the times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.

Food Safety Assurance

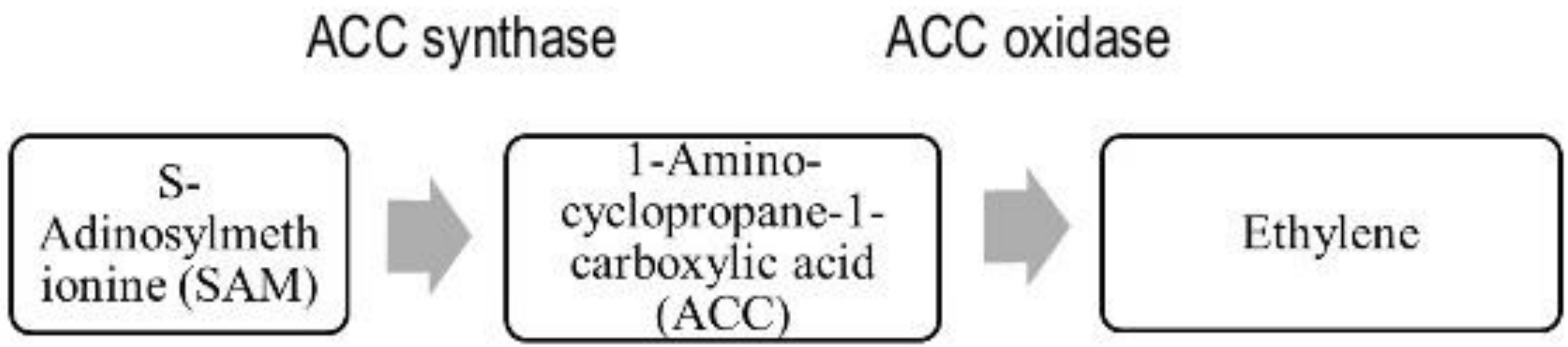
- During the past few years, food safety became and continues to be the number one concern of the fresh produce industry. Various international organizations related to fruits and vegetables business have developed the guidelines to minimize microbial food safety hazards of fresh fruits and vegetables. The guide is based upon following principles
- Prevention of microbial contamination of fresh produce is favored over reliance on corrective action once contamination has occurred.
- Producers, growers, packers or shipper should use good agricultural practices to control contamination.

- Fresh produce may be contaminated at any point from farm to table food chain. The major source of microbial contamination of produce is associated with human and animal faeces.
- When water come in contact with produce, the quality of water is important.
- Practices using animal manure or municipal based bio-solid wastes should managed closely to minimize the potential for microbial contamination of fresh produce.
- The workers hygiene and sanitation practices during production, harvesting, sorting, packing and transport play a critical role in minimizing the potential for microbial contamination of fresh produce.

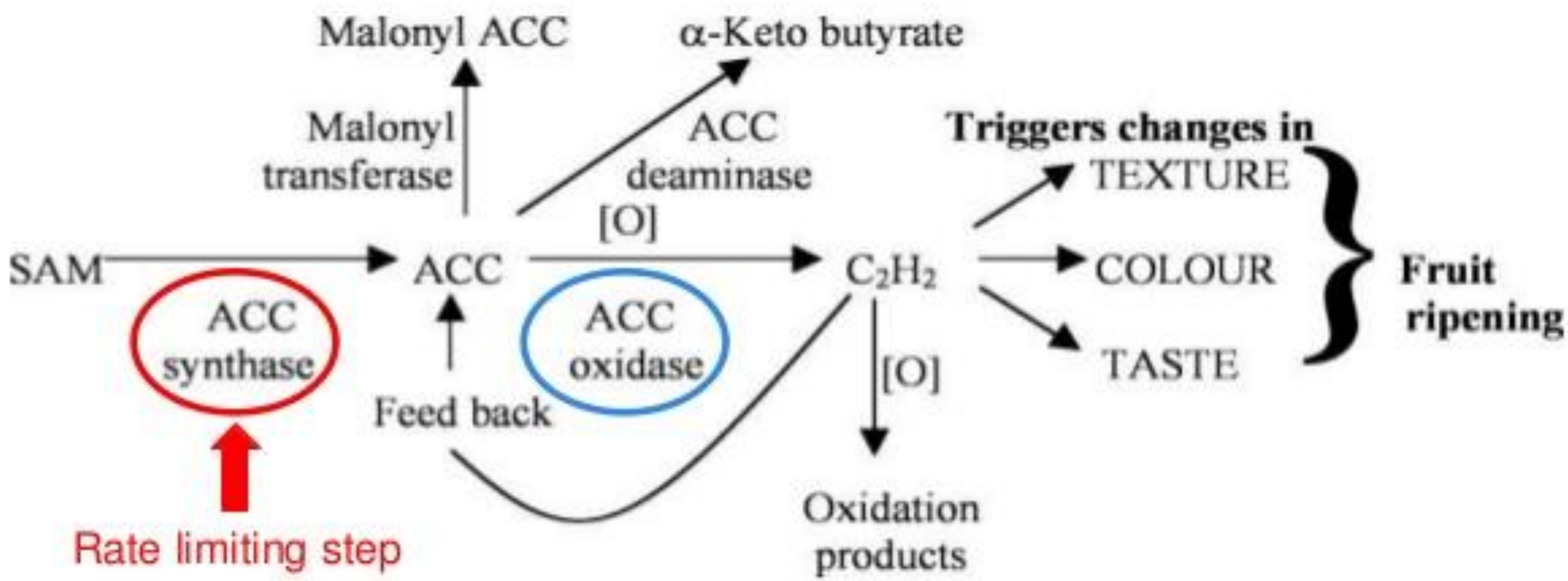
Ethylene Biosynthesis/Production

- **Ethylene is the simplest organic compound, it is a natural product of plant metabolism and is produced by all tissues of higher plants.**
- **As a plant hormone ethylene regulates many aspects of growth, development and senescence and is physiologically active in trace amount (less than 0.1ppm).**
- **It also play important role in abscission of plant organs.**
- **There is no consistent relationship between the ethylene production capacity of a commodity and its perishability, however exposures of most commodities to ethylene accelerate their senescence.**
- **Generally ethylene production rates increases with maturity at harvest and with physical injuries, disease incidence, increased temperature up to 30 ^{o}C and water stress.**
- **On the other hand ethylene production rates of fresh horticultural crop are reduced by storing at low temperature, reduced oxygen levels (less than 8%) and elevated carbon dioxide levels over 2% around the commodities.**
- **ACC synthase, which convert SAM to ACC is the main site of control of ethylene biosynthesis.**

Ethylene biosynthesis



Pathway for ethylene biosynthesis

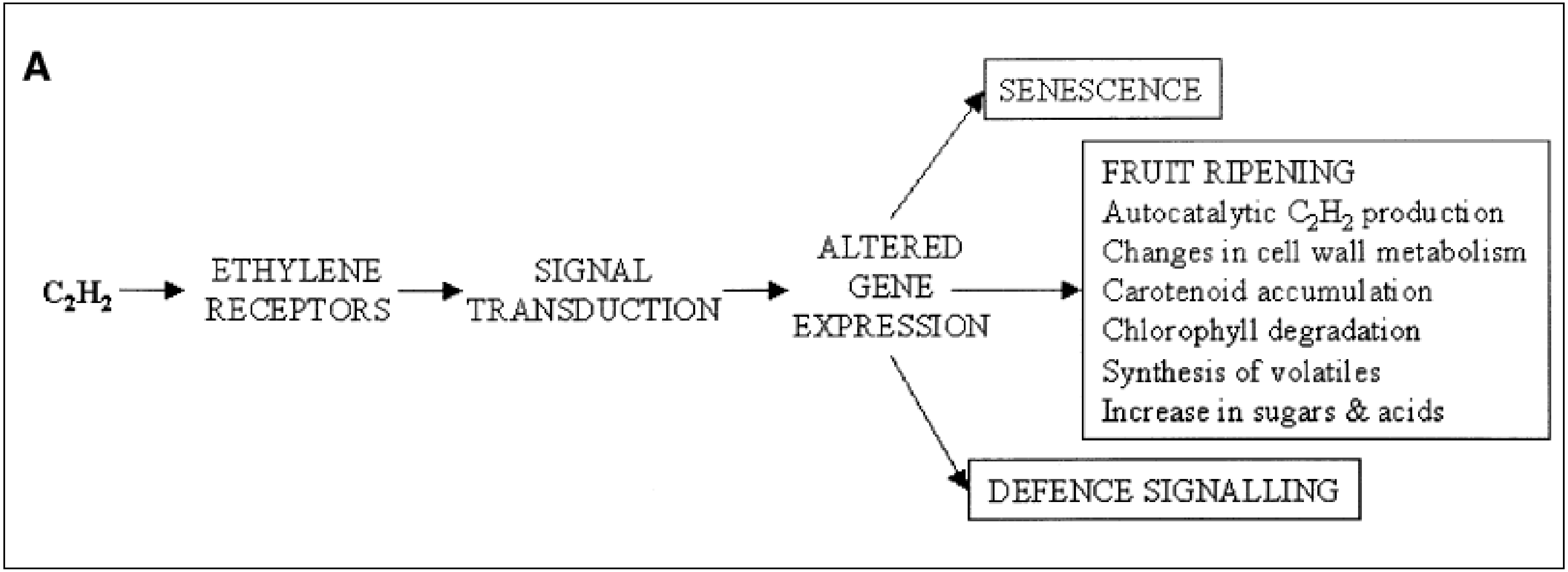


Critical Reviews in Food Science and Nutrition, 47:1–19 ,2007

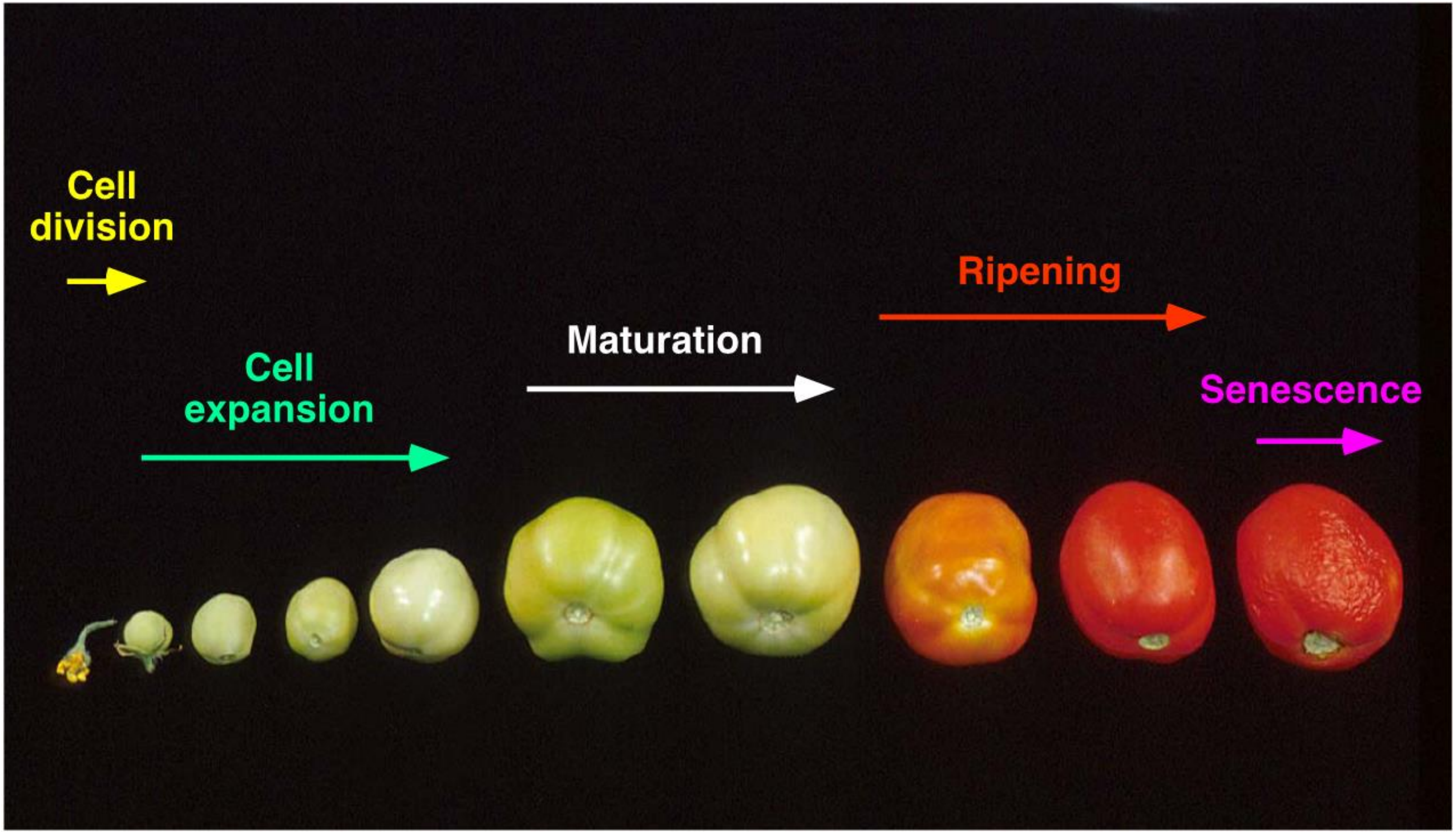
Methionine is a Sulphur containing amino acid found in protein, synthesized in plastids from cysteine.

Assimilation

Incorporation of mineral nutrients into organic substances, such as pigments, enzyme cofactor, lipids, nucleic acid, and amino acids is termed as nutrient assimilation.



Schematic representation of the role that ethylene plays during tomato fruit ripening



Cell division
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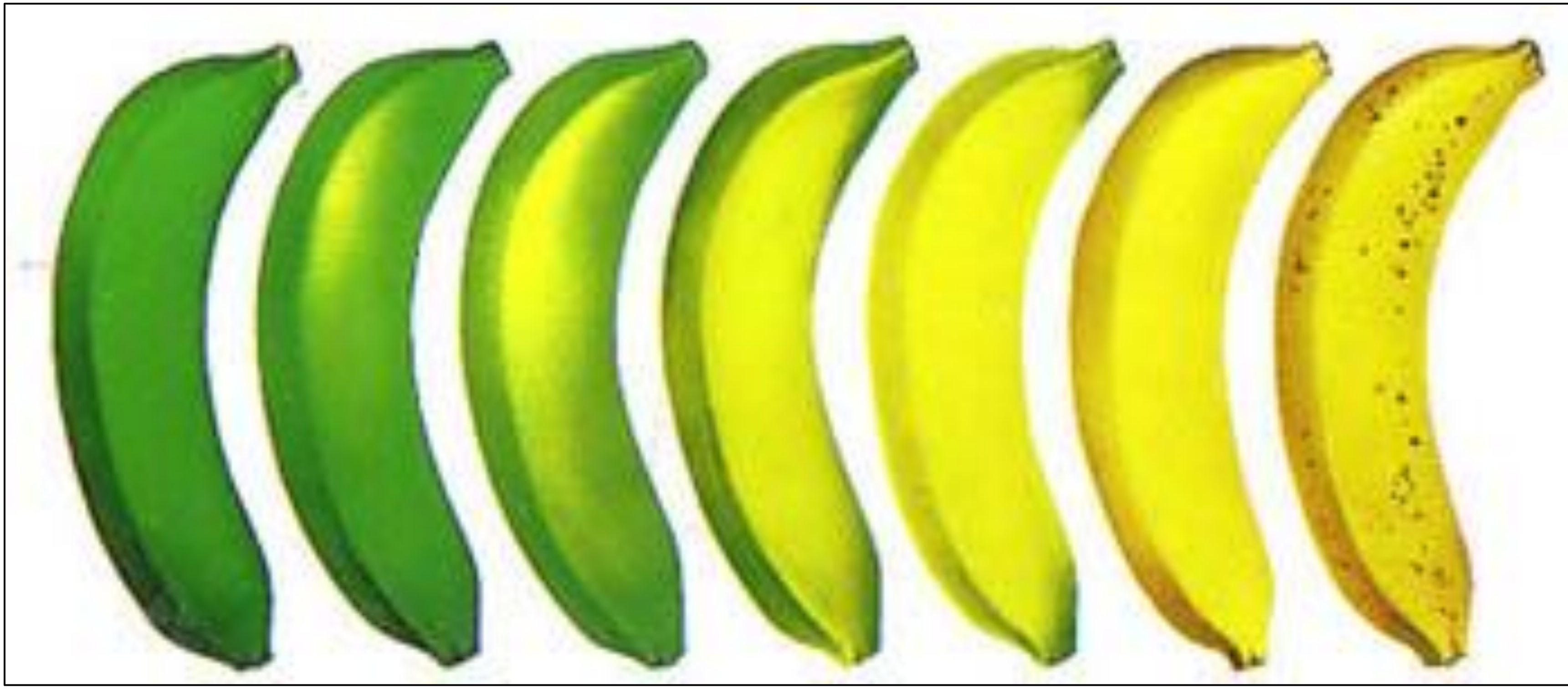
Maturation
Ripening
Senescence



Blocking of Ethylene Biosynthesis and Action

Inhibitors of ethylene biosynthesis

- Aminoethoxy-vinyl-glycine (AVG) and Aminooxyacetic acid (AOA) block conversion of SAM to ACC.
- Cobalt ions (Co^{2+}) block conversion of ACC to ethylene.

Inhibitors of ethylene action

- Silver ions (Ag+) applied as silver nitrate ($AgNO_3$) or silver thiosulphate [Ag $(S_2O_3)_2^{3-}$] are potential inhibitors of ethylene action. Inhibition cannot be induced by other metal ion, only silver is specific.
- CO_2 at higher concentrations (5-10%) also inhibit many effects of ethylene such as fruit ripening, CO_2 is less efficient than silver ions. CO_2 acts as ethylene antagonist.

Volatile Compounds

- Trans-cyclooctene is a strong competitive inhibitor of ethylene binding.
- 1-Methyl-cyclopropene (1-MCP) is novel inhibitor that binds to ethylene receptor irreversibly.

Ethylene Measurement

Gas chromatography can detect little amount

- **Flame ionization detector: 5 part per billion (5ppb) or 1 pL/L (1 pL = 10^{-12})**

Accurate method

Commonly used method

- **Another more sensitive but less common method uses laser-driven photo acoustic detector**

50 part per trillion (50 ppt = 0.05 pL/L)

Thank You

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