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**POSTHARVEST HANDLING**: 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. 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.

Fresh fruits, vegetables, and ornamentals are living tissues subject to continuous change after harvest.

Although some changes are desirable, most -from the consumer's standpoint -are not. Postharvest changes in fresh produce cannot be stopped, but they can be slowed within certain limits. Senescence is the final stage in the development of plant organs during which a series of irreversible events leads to breakdown and death of the plant cells.

**QUALITY AND MATURITY**

**Components of Quality**

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 fruits and vegetables such as market quality, edible quality, dessert quality, shipping quality, nutritional quality, internal quality, and visual quality.

**Components of quality of fresh horticultural crops (1)**

| MAIN FACTORS | COMPONENTS |
|---|---|
| Appearance (visual) | Size: dimensions, weight, volume |
| | Shape and form: diameter/depth ratio, smoothness, compactness |
| | Color: uniformity, intensity |
| | Gloss: wax |
| | Defects: external, internal |
| | Morphological (such as sprouting, rooting, and floret opening) |
| | Physical and mechanical (such as shriveling and bruising) |
| | Physiological (such as blossom end rot of tomatoes) |
| | Pathological (caused by fungi, bacteria, or viruses) |
| | Entomological (caused by insects) |

| | | |
|---|---|---|
| Texture | Firmness, hardness, softness, Crispness, Succulence, juiciness | |
| | Mealiness, grittiness | |
| | Toughness, fibrousness | |
| Flavor (taste and smell) | Sweetness | |
| | Sourness (acidity) | |
| | Astringency | |
| | Bitterness | |
| | Aroma (volatile compounds) | |
| | Off-flavors and off-odors | |
| Nutritive value | Carbohydrates (including dietary fiber) | Proteins |
| | | Lipids |
| | | Vitamins |
| | | Minerals |
| Safety | | Naturally occurring toxicants |
| | | Contaminants (chemical residues, heavy metals,etc.) |
| | | Mycotoxins |
| | | Microbial contamination |

Numerous **defects** can influence appearance quality of horticultural crops. Morphological defects include sprouting of potatoes, onions, and garlic, rooting of onions, and seed germination inside fruits. Physical defects include shriveling (aszalodas)and wilting of all commodities; internal drying of some fruits; and mechanical damage such as punctures, cuts and deep scratches. Temperature-related disorders (freezing, chilling, sunburn, sun-scald), puffiness of tomatoes, blossom-end rot of tomatoes, tipburn of lettuce, internal breakdown of stone fruits, water core of apples, and black heart of potatoes are examples of physiological defects.

**Textural quality** of horticultural crops is not only important for their eating and cooking quality but also for their shipping ability. Soft fruits cannot be shipped long distances without extensive losses owing to physical injuries. This has necessitated harvesting fruits at less than ideal maturity from the flavor quality standpoint in many cases.

**Flavor quality** involves perception of the tastes and aromas of many compounds. Objective analytical determination of critical components must be coupled with subjective evaluations by a taste panel to yield useful and meaningful information about flavor quality of fresh fruits and vegetables. This approach can be used to define a minimum level of acceptability. To find out consumer preferences for flavor of a given commodity, large-scale testing by a representative sample of consumers is required.

Fresh fruits and vegetables play a very significant role in human nutrition, especially as sources of vitamins (vitamin C, vitamin A, vitamin B6, thiamin, niacin), minerals, and dietary fiber. They also contain many phytochemicals (such as antioxidant phenolic compounds and carotenoids) that have been associated with reduced risk of some forms of cancer, heart disease, stroke, and other chronic diseases. Postharvest losses in nutritional quality, particularly vitamin C content, can be substantial and are enhanced by physical damage, extended storage, higher temperature, low relative humidity, and chilling injury of chilling-sensitive commodities.

**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 are also monitored by various agencies to ensure compliance with established maximum tolerance levels. Sanitation procedures throughout 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.

**Quality Standards**

Grade standards are developed to identify the degrees of quality in a given commodity which aid in establishing its usability and value. Such standards are important tools in the marketing of fresh fruits and vegetables because they (1) provide a common language for trading among growers, handlers, processors, and receivers at terminal markets; (2) assist producers and handlers in preparing fresh horticultural commodities for market and labeling goods appropriately; (3) provide a basis for making incentive payment for better quality; (4) serve as the basis for market reporting (prices and supplies quoted if they are based on products of comparable quality); and (5) help settle damage claims and disputes between buyers and sellers.

**Quality factors for selected fresh fruits and vegetables in the U.S. standards for grades**

**Apple:** Maturity, color (color charts), firmness, shape, size; freedom from decay, internal browning, internal breakdown, scald, scab, bitter pit, Jonathan spot, freezing injury, water core, bruises, russeting, scars, insect damage, and other defects.

**Grape** Maturity (as determined by % soluble solids), color, uniformity, firmness,berry size; freedom from shriveling, shattering, sunburn, waterberry, shot berries, dried berries, other defects, and decay. Bunches: fairly well filled but not excessively tight. Stems: not dry and brittle, at least yellowish-green in color.

**Lettuce** Turgidity, color, maturity (firmness), trimming (number of wrapper leaves); freedom from tip burn and other physiological disorders; freedom from mechanical damage, seedstems, other defects, and decay.

**Tomato** Maturity and ripeness stage (color chart), firmness, shape, size; freedom from defects (puffiness, freezing injury, sunscald, scars, catfaces, growth cracks, insect injury, and other defects) and decay.

**Maturity in Relation to Quality**

Although numerous objective indices for maturity are available, only a few are actually used in practice because they are in most cases destructive and difficult to do in the field or orchard. For many vegetables, the optimum eating quality is reached before full maturity (true for leafy vegetables and immature fruits including cucumbers, sweet corn, green beans, and peas). With these crops delayed harvest results in lower quality at harvest and faster deterioration after harvest.

Maturity at harvest is the most important factor that determines storage life and final fruit quality. Immature fruits are more subject to shriveling and mechanical damage and are of inferior quality when ripe. Overripe fruits are likely to become soft and mealy with insipid flavor soon after harvest. Fruits picked either too early or too late in the season are more susceptible to physiological disorders and have a shorter storage life than those picked at the proper maturity.

## BIOLOGICAL FACTORS INVOLVED IN DETERIORATION

### 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 (O2) is used in this process, and carbon dioxide (CO2) is produced. The loss of stored food reserves in the commodity during respiration hastens senescence as the reserves that provide energy to maintain the commodity's living status are exhausted; reduces food value (energy value) for the consumer; causes loss of flavor quality, especially sweetness; and causes loss of salable dry weight (especially important for commodities destined for dehydration). The energy released as heat, known as vital heat, affects postharvest technology considerations such as estimations of refrigeration and ventilation requirement.

Respiration rate is related to deterioration rate of horticultural perishables; the higher the respiration rate, the faster the deterioration rate and shorter the postharvest-life of a given commodity. Respiration rate increases with temperature, exposure to ethylene, and physical and physiological stresses.

**Ethylene Production**

Ethylene, the simplest of the organic compounds affecting the physiological processes of plants, is a natural product of plant metabolism and is produced by all tissues of higher plants and by some microorganisms. As a plant hormone, ethylene regulates many aspects of growth, development, and senescence and is physiologically active in trace amounts (less than 0.1 ppm). It also plays a major role in the abscission of plant organs.

Generally, ethylene production rates increase with maturity at harvest, physical injures, disease incidence, increased temperatures up to 30°C, and water stress. On the other hand, ethylene production rates by fresh horticultural crops are reduced by storage at low temperature, and by reduced O2 (less than 8 percent) or ethylene is competitively inhibited by elevated CO2 (above 1 percent) levels around the commodity.

**Compositional Changes**

Many changes in pigments take place during development and maturation of the commodity on the plant. Some may continue after harvest and can be desirable or undesirable. Loss of chlorophyll (green color) is desirable in fruits but not in vegetables. Development of carotenoids (yellow and orange colors) is desirable in fruits such as apricots, peaches, and citrus; the desired red color development in tomatoes, watermelons, and pink grapefruit is due to a specific carotenoid (lycopene); beta-carotene is provitamin „A" and is important in nutritional quality. Development of anthocyanins (red and blue colors) is desirable in fruits such as apples (red cultivars), pomegranates, cherries, strawberries, cane berries, and red-flesh oranges; these water-soluble pigments are much less stable than carotenoids. Changes in anthocyanins and other phenolic compounds, however, are undesirable because they may result in tissue browning.

Changes in carbohydrates include starch-to-sugar conversion (undesirable in potatoes but desirable in apple, banana, kiwifruit, mango, and other fruits), sugar-to-starch conversion (undesirable in peas and sweet corn but desirable in potatoes), and conversion of starch and sugars to CO2 and water through respiration. Breakdown of pectins and other polysaccharides results in softening of fruits and a consequent increase in susceptibility to mechanical injures. Increased lignin content is responsible for toughening of asparagus spears and root vegetables.

Changes in organic acids, proteins, amino acids, and lipids can influence flavor quality of the commodity. Loss in vitamin content, especially ascorbic acid (vitamin „C"), is detrimental to nutritional quality. Production of flavor volatiles associated with ripening of fruits is very important to their eating quality.

**Growth and Development**

Sprouting of potatoes, onions, garlic, and root crops greatly reduces their utilization value and accelerates deterioration. Rooting of onions and root crops is also undesirable. Similar geotropic responses occur in cut gladiolus and snapdragon flowers stored horizontally. Seed germination inside fruits such as tomatoes, peppers, and lemons is an undesirable change.

**Transpiration or Water Loss**

Water loss is a main cause of deterioration because it results not only in direct quantitative losses (loss of salable weight) but also in losses in appearance (wilting and shriveling), textural quality (softening, flaccidity, limpness, loss of crispness and juiciness), and nutritional quality.

Transpiration rate is influenced by internal or commodity factors (morphological and anatomical characteristics, surface-to-volume ratio, surface injuries, and maturity stage) and external or environmental factors (temperature, relative humidity, air movement, and atmospheric pressure). Transpiration (evaporation of water from the plant tissues) is a physical process that can be controlled by applying treatments to the commodity (e.g., waxes and other surface coatings and wrapping with plastic films) or by manipulating the environment (e.g., maintenance of high relative humidity and control of air circulation.

**Physiological Breakdown**

Exposure of the commodity to undesirable temperatures can result in physiological disorders. Freezing injury results when commodities are held below their freezing temperatures. The disruption caused by freezing usually results in immediate collapse of the tissues and total loss. 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. Chilling injury symptoms become more noticeable upon transfer to higher (nonchilling) temperatures. The most common symptoms are surface and internal discoloration (browning), pitting, water soaked areas, uneven ripening or failure to ripen, off-flavor development, and accelerated incidence of surface molds and decay (especially organisms not usually found growing on healthy tissue). 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.

Certain types of physiological disorders originate from preharvest nutritional imbalances. For example, blossom-end rot of tomatoes and bitter pit of apples result from calcium deficiency. Increasing calcium content via preharvest or postharvest treatments can reduce the susceptibility to physiological disorders. Calcium content also influences the textural quality and senescence

rate of fruits and vegetables; increased calcium content has been associated with improved firmness retention, reduced CO2 and ethylene production rates, and decreased decay incidence.

Very low oxygen (less than 1 percent) and high carbon dioxide (greater than 20 percent) atmospheres can cause physiological breakdown (fermentative metabolism) of most fresh horticultural commodities. Ethylene can induce physiological disorders in certain commodities. The interactions among O2, CO2, and ethylene concentrations, temperature, and duration of storage influence the incidence and severity of physiological disorders related to atmospheric composition.

**Physical Damage**

Various types of physical damage (surface injuries, impact bruising, vibration bruising, and so on) are major contributors to deterioration. Browning of damaged tissues results from membrane disruption, which exposes phenolic compounds to the polyphenol oxidase enzyme. Mechanical injuries not only are unsightly but also accelerate water loss, provide sites for fungal infection, and stimulate CO2 and ethylene production by the commodity.

**Pathological Breakdown**

One of the most common and obvious symptoms of deterioration results from the activity of bacteria and fungi. Attack by most organisms follows physical injury or physiological breakdown of the commodity. In a few cases, pathogens can infect apparently healthy tissues and become the primary cause of deterioration. In general, fruits and vegetables exhibit considerable resistance to potential pathogens during most of their postharvest life. The onset of ripening in fruits, and senescence in all commodities, renders them susceptible to infection by pathogens. Stresses such as mechanical injuries, chilling, and sunscald lower the resistance to pathogens.

**ENVIRONMENTAL FACTORS INFLUENCING DETERIORATION**

**Temperature**

Temperature is the environmental factor that most influences the deterioration rate of harvested commodities. For each increase of 10°C (18°F) above optimum, the rate of deterioration increases twofold to fourfold. Exposure to undesirable temperatures results in many physiological disorders (as previously mentioned). Temperature also influences the effects of ethylene and controlled atmospheres (reduced oxygen and elevated carbon dioxide concentrations). Spore germination and growth rate of pathogens are greatly influenced by temperature; for instance, cooling commodities below 5°C (41°F) immediately after harvest can greatly reduce the incidence of Rhizopus rot.

**Relative Humidity**

The rate of water loss from fruits and vegetables depends on the vapor pressure deficit between the commodity and the surrounding ambient air, which is influenced by temperature and relative humidity. At a given temperature and rate of air movement, the rate of water loss from the commodity depends on the relative humidity. At a given relative humidity, water loss increases with the increase in temperature.

**Atmospheric Composition**

Reduction of oxygen and elevation of carbon dioxide, whether intentional (modified or controlled atmosphere storage) or unintentional (restricted ventilation within a shipping container, a transport vehicle, or both), can either delay or accelerate deterioration of fresh horticultural crops. The magnitude of these effects depends on commodity, cultivar, physiological age, O2 and CO2 levels, temperature, and duration of holding.

**Ethylene**

The effects of ethylene on harvested horticultural commodities can be desirable or undesirable, so it is a major concern to all produce handlers. Ethylene can be used to promote faster and more uniform ripening of fruits picked at the mature-green stage. On the other hand, exposure to ethylene can be detrimental(hatranyos)to the quality of most nonfruit vegetables and ornamentals.

**Light**

Exposure of potatoes to light should be avoided because it results in formation of chlorophyll (greening) and solanine (toxic to humans). Light-induced greening of Belgian endive, garlic, and onion is also undesirable.

**FOOD SAFETY**

Over the past few years, food safety has become and continues to be the number one concern of the fresh produce industry. To Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables is based on the following

**principles:**

(1) Prevention of microbial contamination of fresh produce is favored over reliance on corrective actions once contamination has occurred;

(2) In order to minimize microbial food safety hazards in fresh produce, growers, packers, or shippers should use good agricultural and management practices in those areas over which they have control;

(3) Fresh produce can become microbiologically contaminated at any point along the farm-to-table food chain. The major source of microbial contamination with fresh produce is associated with human or animal feces;

(4) Whenever water comes in contact with produce, its quality dictates the potential for contamination. The potential of microbial contamination from water used with fresh fruits and vegetables must be minimized;

(5) The use of animal manure or municipal biosolid wastes as fertilizers should be closely managed in order to minimize the potential for microbial contamination of fresh produce; and

(6) Worker hygiene and sanitation practices during production, harvest, sorting, packing, and transport play a critical role in minimizing the potential for microbial contamination of fresh produce.

**HARVESTING**

**Harvest Methods**

Fresh vegetables, fruits, and flowers are still harvested by hand. Only humans have the unique combination of eyes, brain, and hands that permits the rapid harvest of delicate and perishable crops with minimal loss and bruising. Harvesters can also be trained to select only those fruits or vegetables of the correct maturity, thus greatly reducing the amount of material that must be removed on the grading line in the packing shed. In fact, some crops can be harvested directly into shipping containers without further sizing or grading.

Mechanical harvesters are usually sophisticated and have a very high unit cost. They may require a smaller but more skilled labor force. Savings may be realized because the harvest can be accomplished in less time. Crops are often damaged or poorer grade, and more susceptible to decay when mechanically harvested. Mechanically harvested commodities often are fit only for processing.

**Management of Harvesting Operations**

Management of harvesting and delivery to the packinghouse operations to maintain the commodity's quality may involve some or all of the following aspects:

1. Organization, training, supervision, and motivation of the harvesting crew to achieve maximum efficiency while maintaining effective quality control (selection of proper maturity, discarding unmarketable units, and avoiding physical damage).

2. Scheduling harvesting during the cooler part of the day, protecting the harvested commodity from the sun, and expediting transport to the packinghouse to reduce losses in quality due to high temperatures.

3. Reducing physical injuries during harvesting and transport to the packinghouse by ensuring that buckets, field boxes, bins, and gondolas used are clean and have smooth surfaces; by grading roads to eliminate potholes and bumps; and by restricting speed of transport vehicle to a level that will avoid free movement of the commodity.