POSTHARVEST HANDLING
FRESH PRODUCE

IS ALIVE

BREATHES

RELEASES HEAT

LOSES MOISTURE

CAN GET SICK

CAN EVEN DIE
Quality and Maturity

Components of Quality

Quality Standards

Maturity in Relation to Quality
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Controlled and Modified Atmospheres
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)

<table>
<thead>
<tr>
<th>MAIN FACTORS</th>
<th>COMPONENTS</th>
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<tr>
<td>Appearance (visual)</td>
<td>Size: dimensions, weight, volume</td>
</tr>
<tr>
<td></td>
<td>Shape and form: diameter/depth ratio, smoothness, compactness</td>
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<tr>
<td></td>
<td>Color: uniformity, intensity</td>
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<td></td>
<td>Gloss: wax</td>
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<td></td>
<td>Defects: external, internal</td>
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<tr>
<td></td>
<td>Morphological (such as sprouting, rooting, and floret opening)</td>
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<tr>
<td></td>
<td>Physical and mechanical (such as shriveling and bruising)</td>
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<tr>
<td></td>
<td>Physiological (such as blossom end rot of tomatoes)</td>
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<td></td>
<td>Pathological (caused by fungi, bacteria, or viruses)</td>
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<td></td>
<td>Entomological (caused by insects)</td>
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<tr>
<td>Texture</td>
<td>Firmness, hardness, softness</td>
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<tr>
<td></td>
<td>Crispness</td>
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<tr>
<td></td>
<td>Succulence, juiciness</td>
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<tr>
<td></td>
<td>Mealiness, grittiness</td>
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<td></td>
<td>Toughness, fibrousness</td>
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<tr>
<td>Components of quality of fresh horticultural crops (2)</td>
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<td>------------------------------------------------------</td>
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<tr>
<td><strong>Flavor (taste and smell)</strong></td>
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<tr>
<td>Sweetness</td>
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<tr>
<td>Sourness (acidity)</td>
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<tr>
<td>Astringency</td>
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<tr>
<td>Bitterness</td>
<td></td>
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<tr>
<td>Aroma (volatile compounds)</td>
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<tr>
<td>Off-flavors and off-odors</td>
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<tr>
<td><strong>Nutritive value</strong></td>
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</tr>
<tr>
<td>Carbohydrates (including dietary fiber)</td>
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<tr>
<td>Proteins</td>
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<tr>
<td>Lipids</td>
<td></td>
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<tr>
<td>Vitamins</td>
<td></td>
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<tr>
<td>Minerals</td>
<td></td>
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<tr>
<td><strong>Safety</strong></td>
<td></td>
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<tr>
<td>Naturally occurring toxicants</td>
<td></td>
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<tr>
<td>Contaminants (chemical residues, heavy metals, etc.)</td>
<td></td>
</tr>
<tr>
<td>Mycotoxins</td>
<td></td>
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<tr>
<td>Microbial contamination</td>
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</tbody>
</table>
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 (aszalódás) 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

<table>
<thead>
<tr>
<th>Commodity</th>
<th>QUALITY FACTORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>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.</td>
</tr>
<tr>
<td>Grape</td>
<td>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.</td>
</tr>
<tr>
<td>Lettuce</td>
<td>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.</td>
</tr>
<tr>
<td>Tomato</td>
<td>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.</td>
</tr>
</tbody>
</table>
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.
<table>
<thead>
<tr>
<th>INDEX</th>
<th>EXAMPLES</th>
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<td>Elapsed days from full bloom to harvest</td>
<td>Apples, pears</td>
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<tr>
<td>Mean heat units during fruit development</td>
<td>Peas, sweet corn</td>
</tr>
<tr>
<td>Development of abscission layer</td>
<td>Muskmelon</td>
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<tr>
<td>Surface morphology and structure</td>
<td>Cuticle formation on grapes and tomatoes</td>
</tr>
<tr>
<td></td>
<td>Gloss of some fruits</td>
</tr>
<tr>
<td></td>
<td>(development of wax)</td>
</tr>
<tr>
<td>Size</td>
<td>All fruits and many vegetables</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>Cherries, watermelons, potatoes</td>
</tr>
<tr>
<td>Shape</td>
<td>Angularity of banana fingers</td>
</tr>
<tr>
<td></td>
<td>Compactness of broccoli and cauliflower</td>
</tr>
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### Maturity indices for selected fruits and vegetables (2)

<table>
<thead>
<tr>
<th>INDEX</th>
<th>EXAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solidity</strong></td>
<td>Lettuce, cabbage, Brussels sprouts</td>
</tr>
<tr>
<td>Textural properties</td>
<td></td>
</tr>
<tr>
<td>- Firmness</td>
<td>Apples, pears, stone fruits</td>
</tr>
<tr>
<td>- Tenderness</td>
<td>Peas</td>
</tr>
<tr>
<td>- Toughness</td>
<td>Asparagus</td>
</tr>
<tr>
<td>Color, external</td>
<td>All fruits and most vegetables</td>
</tr>
<tr>
<td>Internal color and structure</td>
<td>Formation of jelly-like material in tomato fruits</td>
</tr>
<tr>
<td>Internal ethylene concentration</td>
<td>Apples</td>
</tr>
<tr>
<td>Compositional factors</td>
<td></td>
</tr>
<tr>
<td>- Total solids</td>
<td>Avocado, kiwifruit</td>
</tr>
<tr>
<td>- Starch content</td>
<td>Apples, pears</td>
</tr>
<tr>
<td>- Sugar content, acid content, and/or sugar/acid ratio</td>
<td>Apples, pears, stone fruits, grapes, pomegranates, citrus, papaya, melons</td>
</tr>
<tr>
<td>- Juice content</td>
<td>Lemons, limes</td>
</tr>
<tr>
<td>- Oil content</td>
<td>Avocados</td>
</tr>
<tr>
<td>- Astringency (tannin content)</td>
<td>Persimmons, dates</td>
</tr>
<tr>
<td></td>
<td>Apples</td>
</tr>
</tbody>
</table>
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 injuries, 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 CO$_2$ and water through respiration. Breakdown of pectins and other polysaccharides results in softening of fruits and a consequent increase in susceptibility to mechanical injuries. 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.
Chilling injury of Persimmons
AFTER 12 WKS + 4 DAYS AT 20°C

Chilling injury of Pomegranate
Chilling injury of Olive
Sunburn of apple
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.
Core breakdown of pear

Bitter pit of apple
Internal browning of apple

Peach Inking
Storage scald of apple
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 CO$_2$ and ethylene production by the commodity.
Pits caused by a drop to a rough surface
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.
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 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.
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.
Preparation for market eliminates unwanted material and selects items of similar grade in order to improve the value of the marketed portion of the crop. If the value of the crop is not improved by packing, it is a waste of money to run the crop through a packinghouse.

The preparation of fruits and vegetables for marketing can be a very simple operation, as in the harvesting and field packing of lettuce, or it may involve many separate handling steps. Field packing has the following advantages over a packinghouse operation: less material to transport and dispose, fewer handling steps, less damage to the commodity, better quality, and less initial cost. It has its disadvantages, however. It offers less control over quality, and calls for a skilled labor force. Operations also depend on good weather more than packinghouse operations do, and it may be difficult to cool some commodities in containers.
Field packing strawberries:
A self-propelled field pack system allows field workers to cut, trim, tie/wrap and pack in the field, thus eliminating the expense of operating a packing shed. In the illustration below, a flat bed truck is moving along-side the field pack system, and packed produce is being loaded for transport.

SELF PROPELLED FIELD PACK SYSTEM
Packinghouse Facilities

The primary components of a packinghouse include the following:

❖ Shaded produce assembly area, unloading dock, and scale for weighting received products.
❖ Several packing lines that can be adjusted to accommodate various commodities. The number and size of packing lines will depend on the kinds and quantities of commodities that need to be prepared for market each day. In general, about 1.5 m² of packinghouse floor space will be needed for each ton of product to be handled per day.
Area for storage of shipping containers and other packaging materials and for box making, and an automated system for delivery of these boxes to the packaging area.

Forced-air cooling facility adjacent to a cold storage facility. About 0.7 m² of cold storage space will be needed per ton to be handled per day. Two cooling and storage facilities may be needed to accommodate chilling-sensitive and chilling-insensitive commodities (optimum temperatures of about 10°C and 0°C, respectively).

A shaded loading dock connected to the cooling and cold storage facilities for loading the commodities into refrigerated transport vehicles.
- A ripening facility if mature-green tomatoes and other commodities that need ethylene treatment will be handled.
- An enclosed area for partial or complete processing of commodities that are not usable for the fresh market.
- A cull (select) accumulation area.
- Offices for management personnel.
- Laboratory and office space for quality and safety assurance personnel.
- Designated area for workers including assigned lockers, tables and chairs, restrooms, and vending machines for snacks and drinks.
The typical series of operations in a packinghouse
Packinghouse Operations

Products assemble
  Dumping (dry or in water)
  Initial sorting (to remove culls and foreign materials) → Cull accumulation bin
  Presizing (small size eliminator)
  Washing #1 (to remove most of the organic materials)
  Washing #2 (to clean commodity with water + detergent + 100–150 ppm chlorine)
  Rinsing with chlorinated water
  Removal of surface moisture (sponge rollers + air draft)
  Sorting to remove No. 3 grade and overripe fruits
  Washing (if used)
  Sorting by color (if needed)

Partially-ripe  Mature-green  Ripe → Accumulation of Commodities for Processing
FIGURE 15-3. Flow diagram of packinghouse operations for fresh fruits and vegetables.
Packinghouse Operations

Dumping may be accomplished either in water or dry. The dump tank should be designed for rapid emptying and filling and for easy cleaning. Cleaning vegetables and fruits may be done by dry brushing. In most cases, however, washing with water containing a detergent and/or 100 to 150 ppm chlorine will be required. A final rinse with clean water usually follows washing. Sorting for removal of defects and for quality grading is done manually. Effective sorting requires adequate belt space, ability to adjust product flow, assignment of responsibility among workers, adequate lighting, and worker training and supervision. The sizer must also be of adequate capacity in relation to the product volume. Weight or machine vision sizers are more versatile and should be used for a multipurpose packing line.
Dry dumping

FIELD CONTAINER

RAMP

CONVEYOR BELT

PADDED RAILS
Sorting and packing stand

- Packing bin (wire mesh covered with canvas or sacking)
- Sorting bin (canvas bottom)
- Package shelf (for containers)

Dimensions:
- 150 cm
- 75 cm
- 90 cm
- 45 cm
Single size hand held sizing ring:

Multiple size rings:

85  80  75
Waxing of certain fruits and fruit-vegetables is used mostly for enhancing *appearance* and reducing *water loss* by about 30 to 40 percent, especially if the commodity is exposed to less-than-optimal temperature and relative humidity conditions. An increasing number of consumers however, prefer unwaxed fruits and vegetables. A more effective (and possibly more expensive) alternative to waxing is *wrapping* individual or multiple units of the commodity with thin *polymeric films* that restrict water vapor movement without significantly altering diffusion of O₂, CO₂, and ethylene.
The waxing device

LID

SOLUTION

FELT

POLYETHYLENE SHEET

FRUIT

BRUSHES
The *packing method* should immobilize the commodity within the *shipping container* as much as possible to reduce vibration bruising. It should avoid overfilling, which causes compression bruising, and should be cushioned against impacts to reduce impact bruising. The shipping containers used should be selected for strength and stacking ability and should be adequately ventilated (at least 5 percent of the surface) for both vertical and horizontal air flow during cooling, storage, and transport. Shipping containers should have attractive *labeling* that includes the commodity's optimal holding temperature (color coded in accordance with the color coding proposed for the storage rooms at the distribution center). A *code stamped* on each box indicating production area, grower, cultivar, and shipping date would help trace possible causes of problems.
Box at a minimum 12° to 15° incline above horizontal

Worker positioned so upper arms are nearly vertical

Adjustable height floor to allow worker's forearms to be nearly horizontal

Lamp provides 500 to 1,000 lux at work surface

Packing materials

Box supply conveyor

Hand-carried box of unpacked product

Packed box conveyor

Cull fruit chute

Cull fruit conveyor
Cooling and Cold Storage Facilities

Forced-air cooling is the most versatile cooling method provided that the relative humidity of the air is kept above 95 percent. Hydrocooling is a faster cooling method, but not all commodities tolerate wetting. *Waxed cartons* must be used if the commodity is hydrocooled after packing.

Cold storage rooms should be adjacent to the cooling facility in order to facilitate transfer of the cooled commodity into the storage area and to prevent rewarming of the commodity before it is loaded into the transport vehicle.
Ripening Facility

A ripening facility may be needed for initiating ripening of some commodities such as mature-green tomatoes, bananas, avocados, mangos, and some muskmelons. Such a facility may include several rooms equipped with systems for temperature and relative humidity control as well as for ethylene introduction and uniform distribution within the room. The optimum temperature range for ripening is 15° to 25°C; the higher the temperature, the faster the ripening. The optimum relative humidity range is 90 to 95 percent.
Transportation

The comparative advantages and disadvantages of truck versus rail transport should be examined in relation to cost, speed, reduction in handling steps, and extent of physical injuries due to transport. Many improvements in insulation, air flow systems, and thermostats have been recently introduced in some of the refrigerated transport vehicles. Whenever possible, such improved transport vehicles should be used because they provide better temperature maintenance. Also, trucks with air suspension systems significantly reduce vibration bruising of the commodity during transport.
Transport vehicles should be cooled to the desired temperature before loading the commodity. The pallets should be center-loaded, leaving air channels between the load and walls of the transport vehicle. The load should be secured to prevent shifting of the load during transport. A system for monitoring temperature during transport should be followed using recording thermometers or time-temperature indicators. Transportation during the night can provide better temperature management.
Brace load away from side walls and stabilize load with small plastic air bags.

Stabilize last pallets with load locks.
The condition of the inside of a refrigerated trailer affects its ability to maintain desired temperatures during transport. Handlers should inspect the trailer before loading, and check these features:

- Air delivery chute intact?
- Door seal damage?
- Side door seal tight?
- Door damage?
- Wall damage?
- Front bulkhead installed?
- Floor clean?
- Floor drains open (clean)?
- Inside width adequate for load?
- Inside height adequate for load?
- Door height adequate for load?
- Load bars used to secure load?
- Trailer precooled before loading?
- Refrigeration unit operates satisfactorily?
Maintaining the Cold Chain for Perishables

**Harvest**
- Protect the product from the sun
- Transport quickly to the packinghouse

**Cooling**
- Minimize delays before cooling
- Cool the product thoroughly as soon as possible

**Temporary Storage**
- Store the product at optimum temperature
- Practice first in first out rotation
- Ship to market as soon as possible

**Transport to Market**
- Use refrigerated loading area
- Cool truck before loading
- Load pallets towards the center of the truck
- Put insulating plastic strips inside door of reefer if truck makes multiple stops
- Avoid delays during transport
- Monitor product temperature during transport

**Handling at destination**
- Use a refrigerated unloading area
- Measure product temperature
- Move product quickly to the proper storage area
- Transport to retail markets or foodservice operations in refrigerated trucks
- Display at proper temperature range
Quality Control

An effective quality control system throughout the handling steps between harvest and retail display is essential to provide a consistently good-quality supply of fresh fruits and vegetables to the consumers and to protect the reputation of a given marketing label. Quality control starts in the field with the selection of the proper time to harvest for maximum quality. Careful harvesting is essential to maintain quality. Each subsequent step after harvest has the potential to either maintain or reduce quality. Few postharvest procedures can increase the quality of individual units of the commodity.
Quality control personnel should devote full time and attention to their function and should have the authority to make needed changes in the harvesting and handling operations when required to obtain and maintain the desired quality. They should also be involved in training workers within their organizations on the importance of quality attributes of each commodity and on procedures for postharvest quality maintenance.
Many attempts are currently being made to automate the separation of a given commodity into various grades and the elimination of defective units. The availability of low-cost microcomputers and solid-state imaging systems have made computer-aided video inspection on the packing line a practical reality. Solid-state video camera or light reflectance systems can be used for detection of external defects, and x-ray or light transmittance systems can be used for detecting internal defects.
Quality control procedures include the following steps:

<table>
<thead>
<tr>
<th>Operation</th>
<th>Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvesting</td>
<td>Check proper maturity and quality.</td>
</tr>
<tr>
<td>Preparation for market</td>
<td>Monitor effectiveness of the various steps (washing, sorting, waxing, sizing, fungicide treatment, and so on); check culls to determine causes of cullage and sorting accuracy; check shipping containers and other packing materials against specifications; check packed containers for compliance with grade, size, and weight regulations.</td>
</tr>
<tr>
<td>Cooling</td>
<td>Monitor product temperatures at key points in the handling system, especially before and after cooling.</td>
</tr>
<tr>
<td>Transportation</td>
<td>Check transit vehicles for cleanliness and cooling before loading, loading pattern, load immobilization, thermostat setting, and placement of recording thermometer.</td>
</tr>
<tr>
<td>Destination Market</td>
<td>Check quality and condition of the product and shipping container.</td>
</tr>
</tbody>
</table>
STORAGE
Night air ventilation in storage building

Warm air out via gable fan

Cool air in during night time though opened vents
Storage Temperature and Relative Humidity

*Temperature is the most important environmental factor influencing the deterioration of harvested commodities.* Most perishable horticultural commodities last longer at temperatures near 0°C. At temperatures above the optimum, the rate of deterioration increases twofold to fourfold for every 10°C rise in the temperature. Temperature also influences how other internal and external factors influence the commodity and has a dramatic effect on the germination and growth of pathogens.
Temperatures outside the physiological norm can cause rapid deterioration due to the following disorders:

**Freezing injury.** In general, perishable commodities have high water content and large, highly vacuolated cells. The *freezing point* of the tissue is high, and the disruption caused by freezing usually results in *immediate collapse of the tissues* and total loss. Freezing is normally the result of inadequate refrigerator design or poor setting or failure of thermostats. In winter conditions, freezing can occur if produce is allowed to remain for even short periods of time on unprotected transportation docks.
Susceptibly to freezing injury
These products can be injured by one light freezing:
apricot
asparagus
avocado
banana
beans (snap)
berries (except cranberries)
cucumber
eggplant
lemons
lettuce
limes
okra
peaches
peppers (sweet)
plums
potatoes
squash (summer)
sweet potato
tomatoes
**Heat injury.** High temperatures are also very injurious to perishable products. In growing plants, transpiration maintains temperatures in the optimal range. Organs removed from the plant lack the protective effects of transpiration, and direct sources of heat - for example, full sunlight - can rapidly heat tissues to above the *thermal death point* of their cells, leading to localized bleaching, necrosis (sunburn or sun-scald), or general collapse.
**Chilling injury.** Some commodities (chiefly those native to the tropics and subtropics) respond unfavorably to storage at low temperatures, even temperatures well above the freezing point but below a critical temperature termed the chilling threshold temperature. Chilling injury is manifested in a variety of symptoms including surface and internal discoloration, pitting, water soaking, failure to ripen, uneven ripening, development of off flavors, and heightened susceptibility to pathogen attack.
Classification of fresh horticultural crops according to their relative perishability (romlandóság) and potential storage life in air within their optimal at near optimum temperature and relative humidity ranges

<table>
<thead>
<tr>
<th>Relative Perishability</th>
<th>Potential Storage Life (weeks)</th>
<th>Commodities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>&lt;2</td>
<td>Apricot, blackberry, blueberry, cherry, fig, raspberry, strawberry; asparagus, bean sprouts, broccoli, cauliflower, green onion, leaf lettuce, mushroom, pea, spinach, sweet corn, tomato (ripe); most cut flowers and foliage; minimally processed (fresh-cut) fruits and vegetables</td>
</tr>
<tr>
<td>High</td>
<td>2-4</td>
<td>Avocado, banana, grape (without S0₂-treatment), guava, loquat, mandarin, mango, melons (honeydew, Crenshaw, Persian), nectarine, papaya, peach, plum; artichoke, green beans, Brussels sprouts, cabbage, celery, eggplant, head lettuce, okra, pepper, summer squash, tomato (partially ripe)</td>
</tr>
<tr>
<td>Moderate</td>
<td>4-8</td>
<td>Apple and pear (some cultivars), grape (S0₂ treated), orange, grapefruit, lime, kiwifruit, persimmon, pomegranate; table beet, carrot, radish, potato (immature)</td>
</tr>
<tr>
<td>Low</td>
<td>8-16</td>
<td>Apple and pear (some cultivars), lemon; potato (mature), dry onion, garlic, pumpkin, winter squash, sweet potato, taro, yam; bulbs and other propagules of ornamental plants</td>
</tr>
<tr>
<td>Very low</td>
<td>&gt;16</td>
<td>Tree nuts, dried fruits and vegetables</td>
</tr>
</tbody>
</table>
Ethylene Exclusion or Removal

Undesired accelerated softening and ripening of fruits during transport and storage result in shorter postharvest life and faster deterioration. For example, the presence of ethylene in cold storage facilities of apples, kiwifruits, and avocados kept in air or in controlled atmospheres can significantly hasten softening and reduce storage life of these fruits. The incidence and severity of ethylene damage depend on its concentration, duration of exposure, and storage temperature.
Following are a few examples of ethylene injury: russet spotting of lettuce; development of bitter flavor in carrots; leaf and flower abscission and yellowing of broccoli, cabbage, cauliflower, and ornamental plants; failure to open some cut flowers (such as carnations). Ethylene damage can be greatly reduced by holding the commodity at its lowest safe temperature and by keeping it under modified or controlled atmospheres. Under such conditions, both ethylene production by the commodity and ethylene action on the commodity are significantly reduced.
Ethylene may be excluded from storage rooms and transport vehicles by avoiding mixing ethylene-producing commodities with those sensitive to ethylene. Ethylene may be removed from storage rooms and transport vehicles by using adequate air exchange (ventilation) and using ethylene absorbers such as potassium permanganate. The air within the room or transit vehicle must be circulated past the absorber for effective ethylene removal. It is also very important to replace the used absorbing material with a fresh supply as needed. Catalytic combustion of ethylene on a catalyst at high temperatures (greater than 200°C) and use of ultraviolet radiation can also be used to remove ethylene.
Ethylene control:

to DECREASE:

- potassium permanganate
- activated charcoal
- catalytic oxidation

ETHYLENE SCRUBBER: place Purafil® pellets (KMnO₄) in shallow layers on screen trays sealed inside a solid wooden box. Air must flow through 3 or 4 trays of pellets for successful removal of ethylene gas.
Classification of fruits and vegetables according to their sensitivity to chilling injury and ethylene production rates at optimum handling temperatures

*Ethylene production rate by fruits and fruit-vegetables is greatest as they approach the eating-ripe stage.

<table>
<thead>
<tr>
<th>RELATIVE ETHYLENE PRODUCTION RATE (µL/KG • HR) AT 20°C</th>
<th>NONCHILLING SENSITIVE</th>
<th>CHILLING SENSITIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low (&lt;0.1)</td>
<td>Artichoke, asparagus, beets, cabbage, carrot, cauliflower, celery, cherry, garlic, grape, leeks, lettuce, onion, parsley, parsnip, peas, radish, spinach, strawberry, sweet corn, turnip</td>
<td>Ginger, grapefruit, lemon, lime, melons (casaba, Juan canary), orange, pomegranate, potato, snap beans, sweet potato, tangerine, taro (dasheen)</td>
</tr>
<tr>
<td>Low (0.1-1.0)</td>
<td>Blackberry, blueberry, broccoli, Brussels sprouts, endive, escarole, green onion, kiwifruit (unripe), mushrooms, persimmon (Hachiya), raspberry, tamarillo</td>
<td>Cranberry, cucumber, eggplant, okra, olive, peppers (sweet and chili), persimmon (Fuyu), pineapple, pumpkins, summer squash, watermelon</td>
</tr>
<tr>
<td>Moderate (1.0-10)</td>
<td>Figs</td>
<td>Banana, guava, lychee, mango, melons (cantaloupe, crenshaw, honey dew, Persian), plantain, tomato</td>
</tr>
<tr>
<td>High (10-100)</td>
<td>Apple, apricot, kiwifruit (ripe), nectarine, peach, pear, plum</td>
<td>Avocado, feijoa, papaya</td>
</tr>
<tr>
<td>Very High (&gt;100)</td>
<td></td>
<td>Cherimoya, mammee apple, passion fruit, sapote</td>
</tr>
</tbody>
</table>
Treatments to Reduce Ethylene Damage

Treating ornamental crops with 1-methylcyclopropene (1-MCP), which is an ethylene action inhibitor, provides protection against ethylene damage and has been used commercially since 1999. The first commercial application is its use on apples to retard their softening and scald development and to extend their postharvest-life.
Controlled and Modified Atmospheres

The terms *controlled atmosphere* (CA) and *modified atmosphere* (MA) refer to atmospheres in which the composition surrounding the commodity is different from normal air. Usually this involves reduction of $O_2$ levels, elevation of $CO_2$ levels, or both. **Low-pressure** (hypobaric) **storage** is one method to establish a CA atmosphere in which the commodity is held under **partial vacuum**, which results in reduced $O_2$ levels and increased diffusivity of ethylene and other gases. MA differs from CA only in the degree of precision in controlling partial pressures of $O_2$ and $CO_2$; CA is more exact than MA.
Fresh fruits and vegetables vary greatly in their relative tolerance to low O$_2$ concentration and elevated CO$_2$ concentrations. These are the levels below which (for O$_2$) or above which (for CO$_2$) physiological damage would be expected. These limits of tolerance can be different at temperatures above or below recommended temperatures for each commodity.
### A summary of CA and MA use for short-term storage or transport of fresh horticultural crops

<table>
<thead>
<tr>
<th>Primary benefit of CA/MA</th>
<th>Commodities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay of ripening and avoiding chilling temperatures</td>
<td>Avocado, banana, mango, melons, nectarine, papaya, peach, plum, tomato (picked mature-green or partially ripe)</td>
</tr>
<tr>
<td>Control of decay</td>
<td>Blackberry, blueberry, cherry, fig, grape, raspberry, strawberry</td>
</tr>
<tr>
<td>Delay of senescence and undesirable compositional changes (including tissue brown discoloration)</td>
<td>Asparagus, broccoli, lettuce, sweet corn, fresh herbs, minimally processed (fresh-cut) fruits and vegetables</td>
</tr>
</tbody>
</table>
CA and MA use of short-term storage or transport of fresh horticultural crops has increased during the past few years and will continue to increase, supported by technological developments in transport containers, MA packaging, and edible coatings.

CA and MA conditions, including MA packaging (MAP), can replace certain postharvest chemicals used for control of some physiological disorders such as scald on apples. Furthermore, use of some post-harvest fungicides and insecticides can be reduced or eliminated in cases where CA or MA conditions provide adequate control of postharvest pathogens or insects.
Use of CA or MA may facilitate the picking and marketing of more mature (better-flavored) fruits by slowing down their postharvest deterioration rate to permit transport and distribution. Another potential use for CA and MA is in maintaining quality and safety of minimally processed (fresh-cut) fruits and vegetables, which are increasingly being marketed as value-added, convenience product.