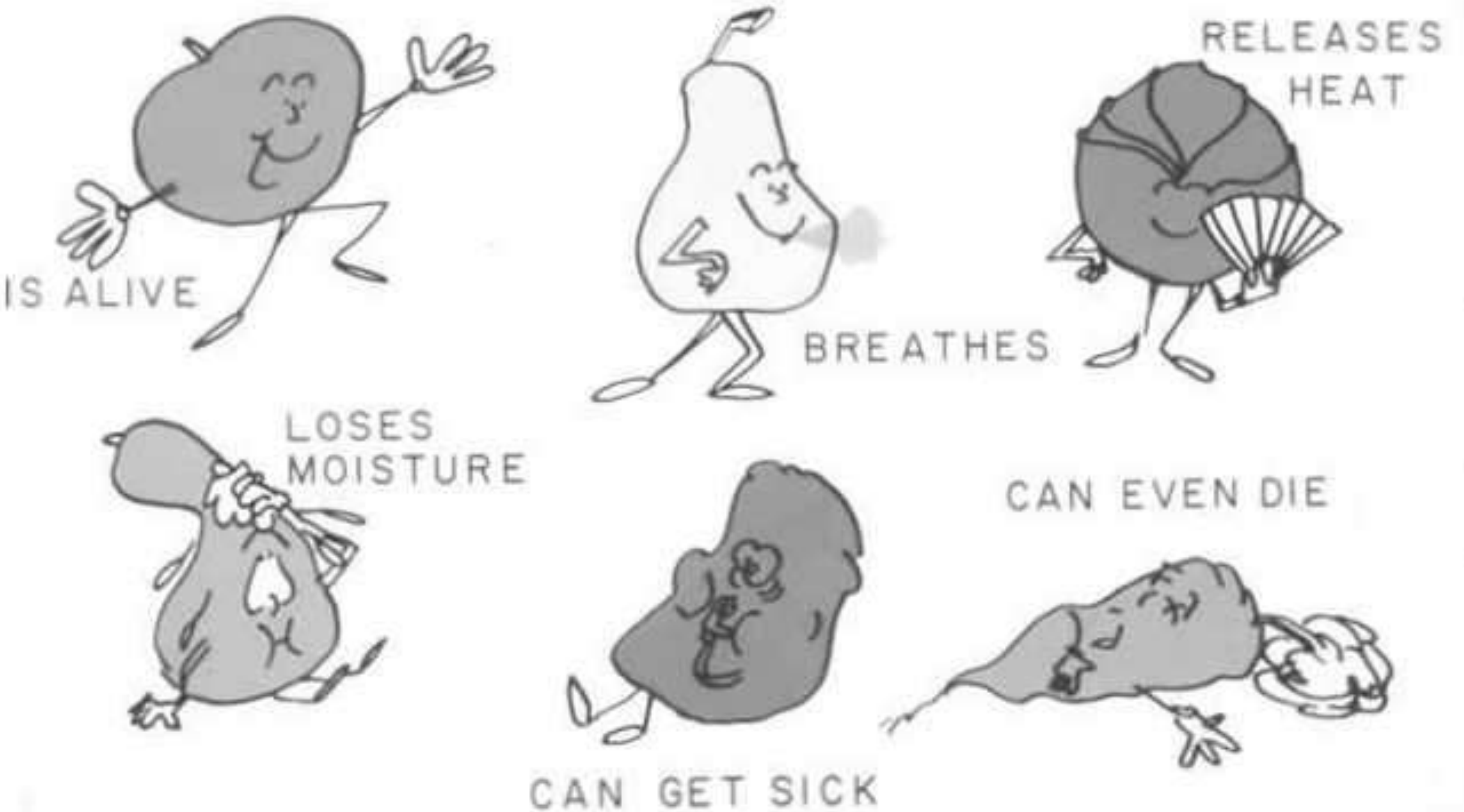
POSTHARVEST HANDLING

FRESH PRODUCE



Quality and Maturity

Components of Quality

Quality Standards

Maturity in Relation to Quality

Biological Factors Involved in Deterioration

Respiration

Ethylene Production

Compositional Changes

Growth and Development

Transpiration or Water Loss

Physiological Breakdown

Physical Damage

Pathological Breakdown

Environmental Factors Influencing Deterioration

Temperature

Relative Humidity

Atmospheric Composition

Ethylene

Light

Food Safety

Harvesting

Harvest Methods

Management of Harvesting Operations

Preparation for Market

Packinghouse Facilities

Packinghouse Operations

Cooling and Cold Storage Facilities

Ripening Facility

Transportation

Quality Control

Storage

Storage Temperature and Relative Humidity

Ethylene Exclusion or Removal

Treatments to Reduce Ethylene Damage

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 <u>deterioration</u> 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

Components of quality of fresh horticultural crops (2)

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 (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

Commodity	QUALITY FACTORS
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, <u>the optimum eating quality</u> 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.

Maturity indices for selected fruits and vegetables (1)

INDEX	EXAMPLES
Elapsed days from full bloom to harvest	Apples, pears
Mean heat units during fruit development	Peas, sweet corn
Development of abscission layer	Muskmelon
Surface morphology and structure	Cuticle formation on grapes and tomatoes Gloss of some fruits (development of wax)
Size	All fruits and many vegetables
Specific gravity	Cherries, watermelons, potatoes
Shape	Angularity of banana fingers Compactness of broccoli and cauliflower

Maturity indices for selected fruits and vegetables (2)

INDEX	EXAMPLES
Solidity	Lettuce, cabbage, Brussels sprouts
Textural properties	
Firmness	Apples, pears, stone fruits
Tenderness	Peas
Toughness	Asparagus
Color, external	All fruits and most vegetables
Internal color and structure	Formation of jelly-like material in tomato fruits Flesh color of some fruits
Compositional factors	
Total solids	Avocado, kiwifruit
Starch content	Apples, pears
Sugar content, acid content, and/or sugar/acid ratio	Apples, pears, stone fruits, grapes, pomegranates, citrus, papaya, melons
Juice content	Lemons, limes
Oil content	Avocados
Astringency (tannin content)	Persimmons, dates
Internal ethylene concentration	Apples

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 (O_2) is used in this process, and carbon dioxide (CO_2) 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 O_2 (less than 8 percent) or ethylene is competitively inhibited by elevated CO_2 (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 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.

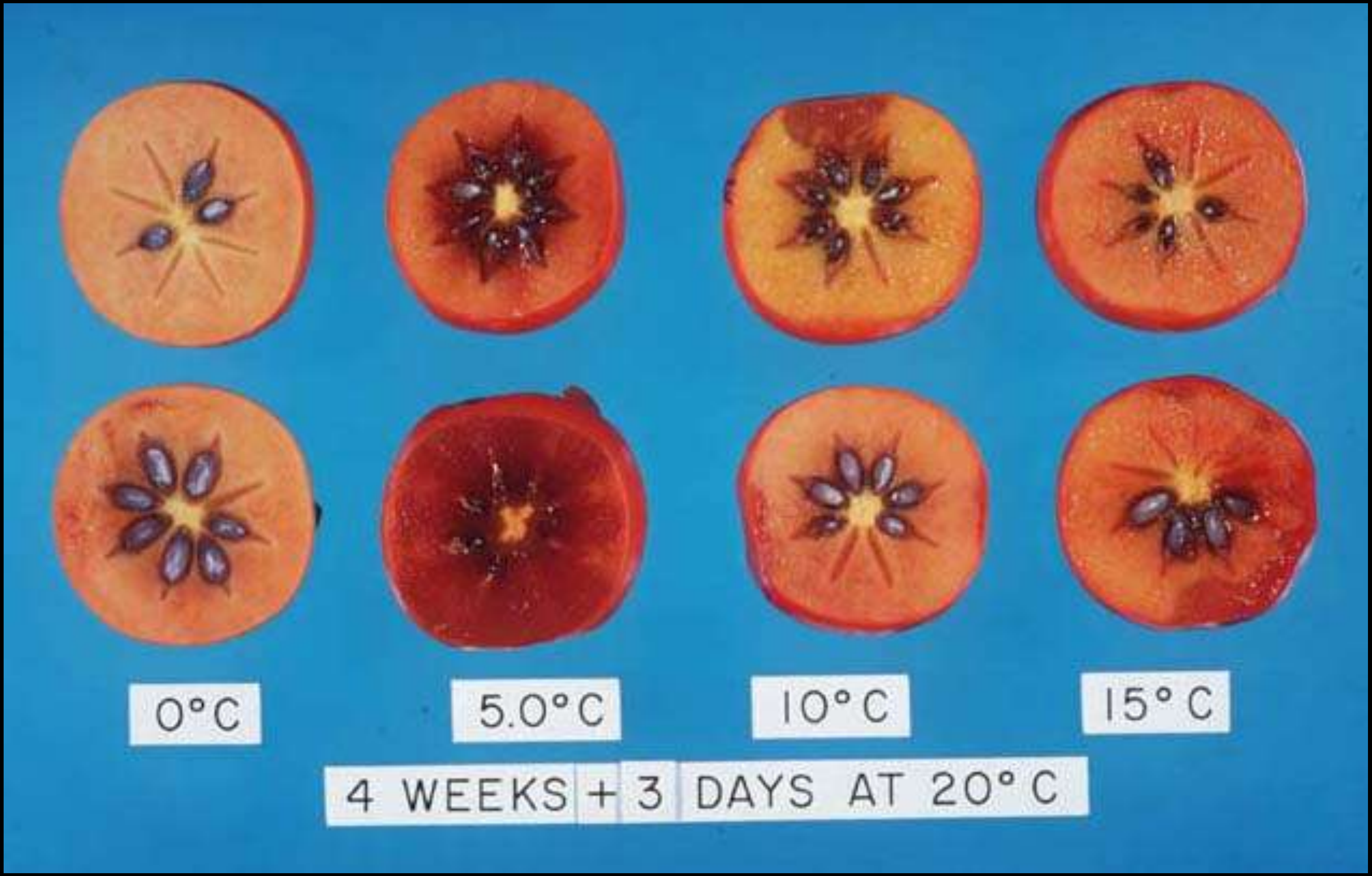
Transpiration or Water Loss

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.

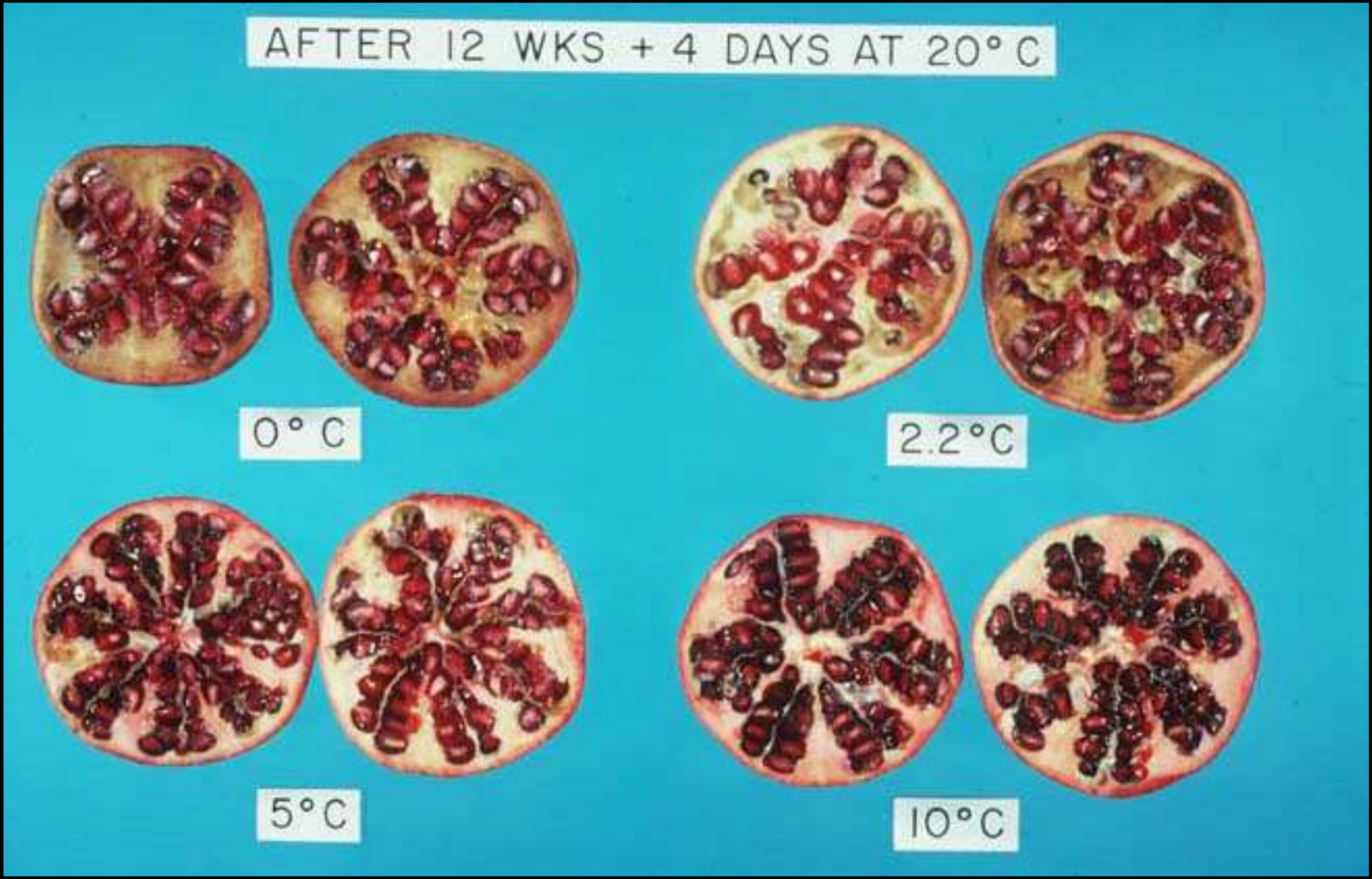
Transpiration rate is influenced by internal or commodity factors (morphological and anatomical characteristics, surface-to-volume ratio, surface injuries, and maturity stage) and external or environmental factors (temperature, relative humidity, air movement, and atmospheric pressure). Transpiration (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.



Chilling injury of Persimmons



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 CO_2 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 O_2, CO_2, 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


Granny Smith
Water Core

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.

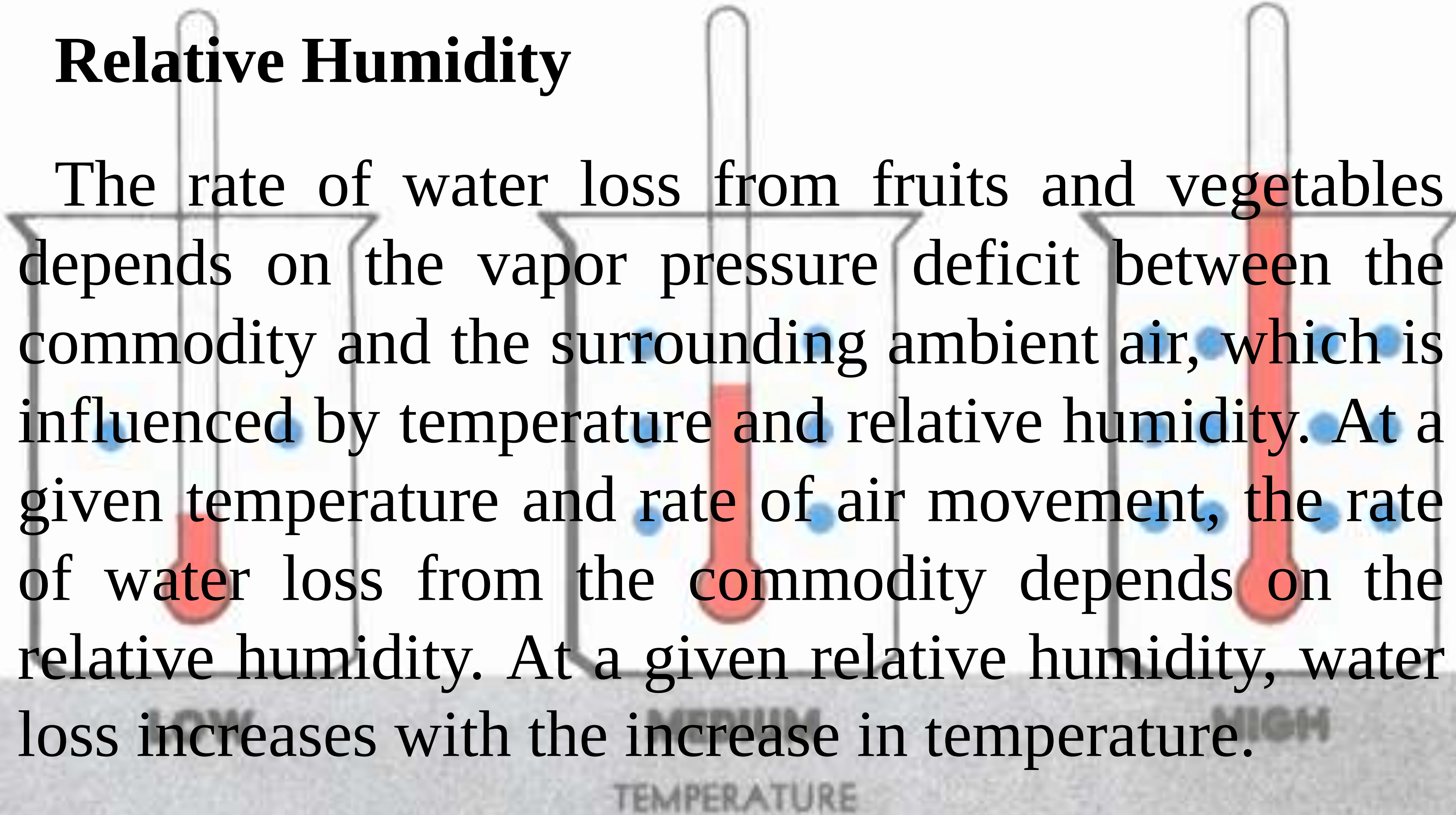
ENVIRONMENTAL FACTORS INFLUENCING DETERIORATION

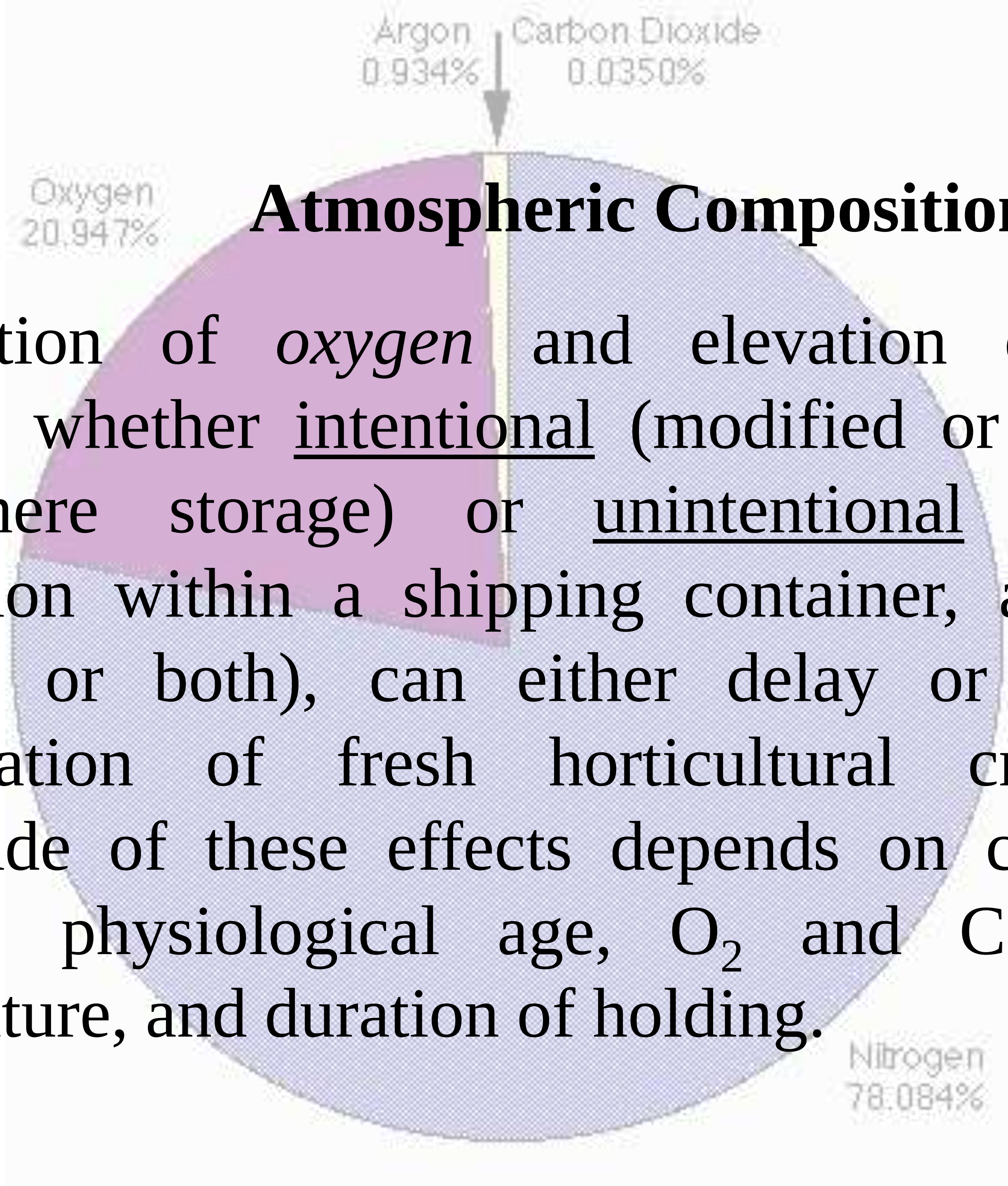
Temperature

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.





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, O_2 and CO_2 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 (hátrányos) 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;

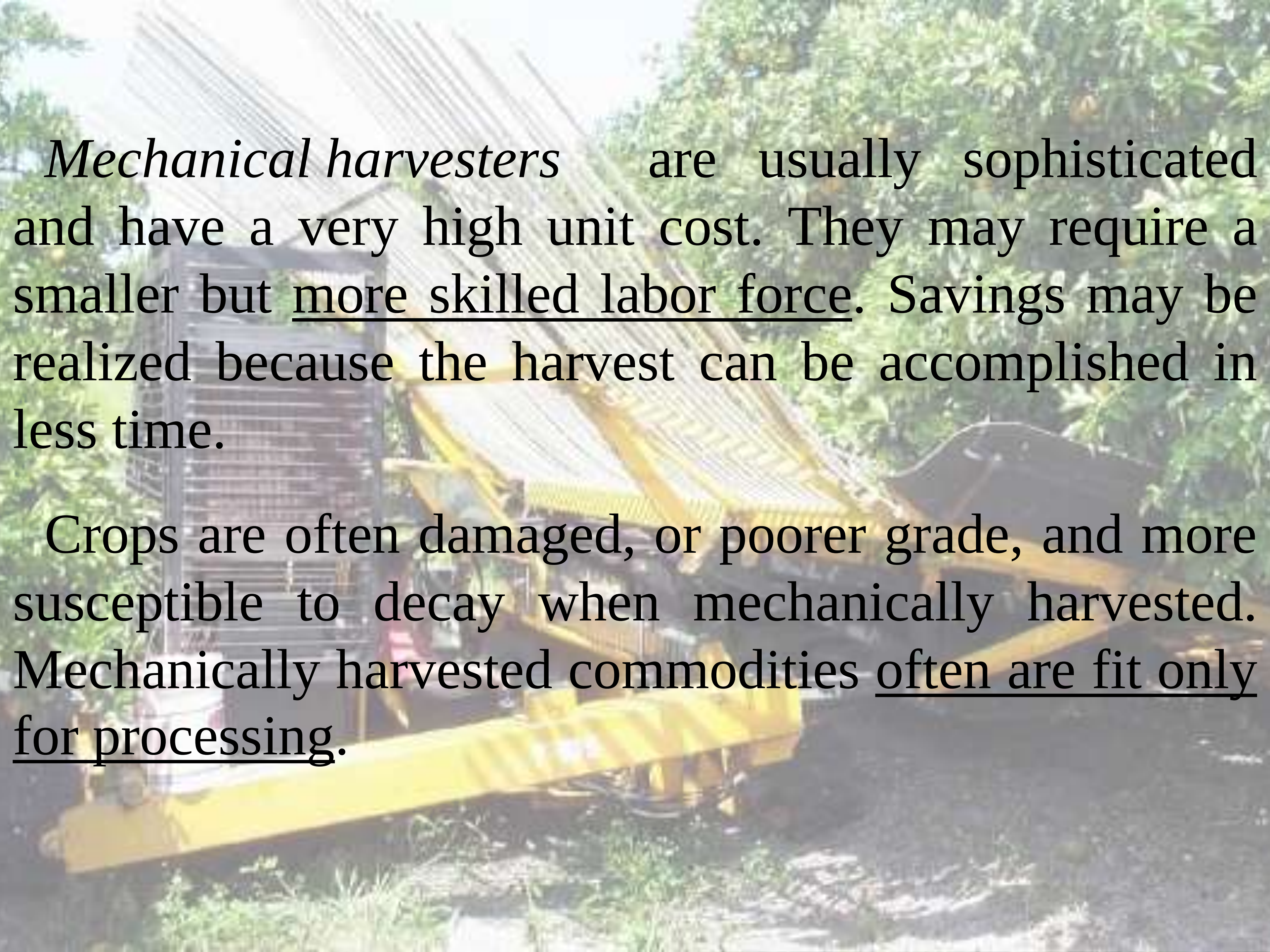
(5) The use of animal manure or municipal biosolid wastes as fertilizers should be closely managed in order to minimize the potential for microbial contamination of fresh produce; and

(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 <u>more skilled labor force</u>. 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 <u>often are fit only for processing</u>.

Management of Harvesting Operations

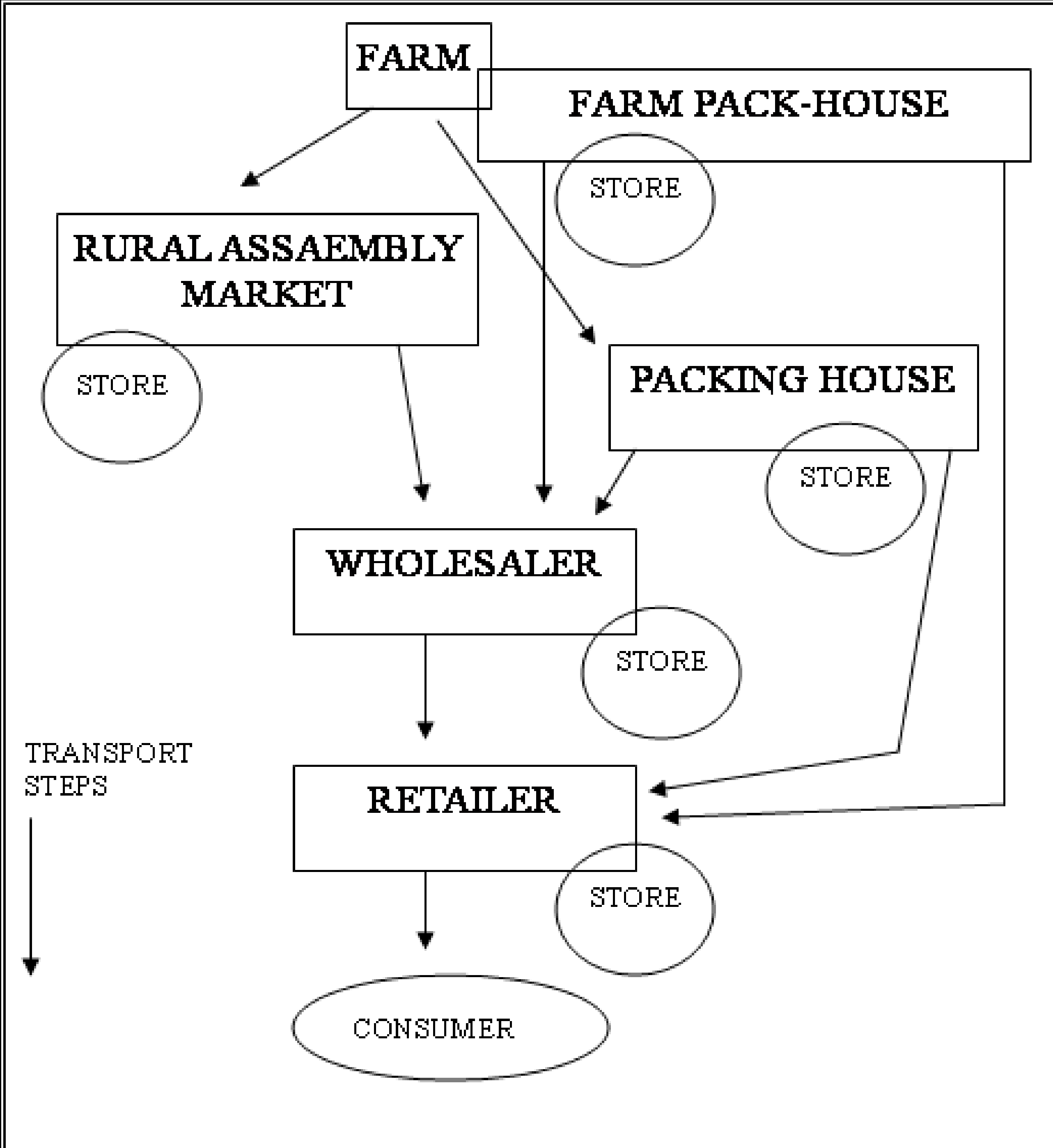
Management of harvesting and delivery to the packinghouse operations to maintain the commodity's quality may involve some or all of the following aspects:

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

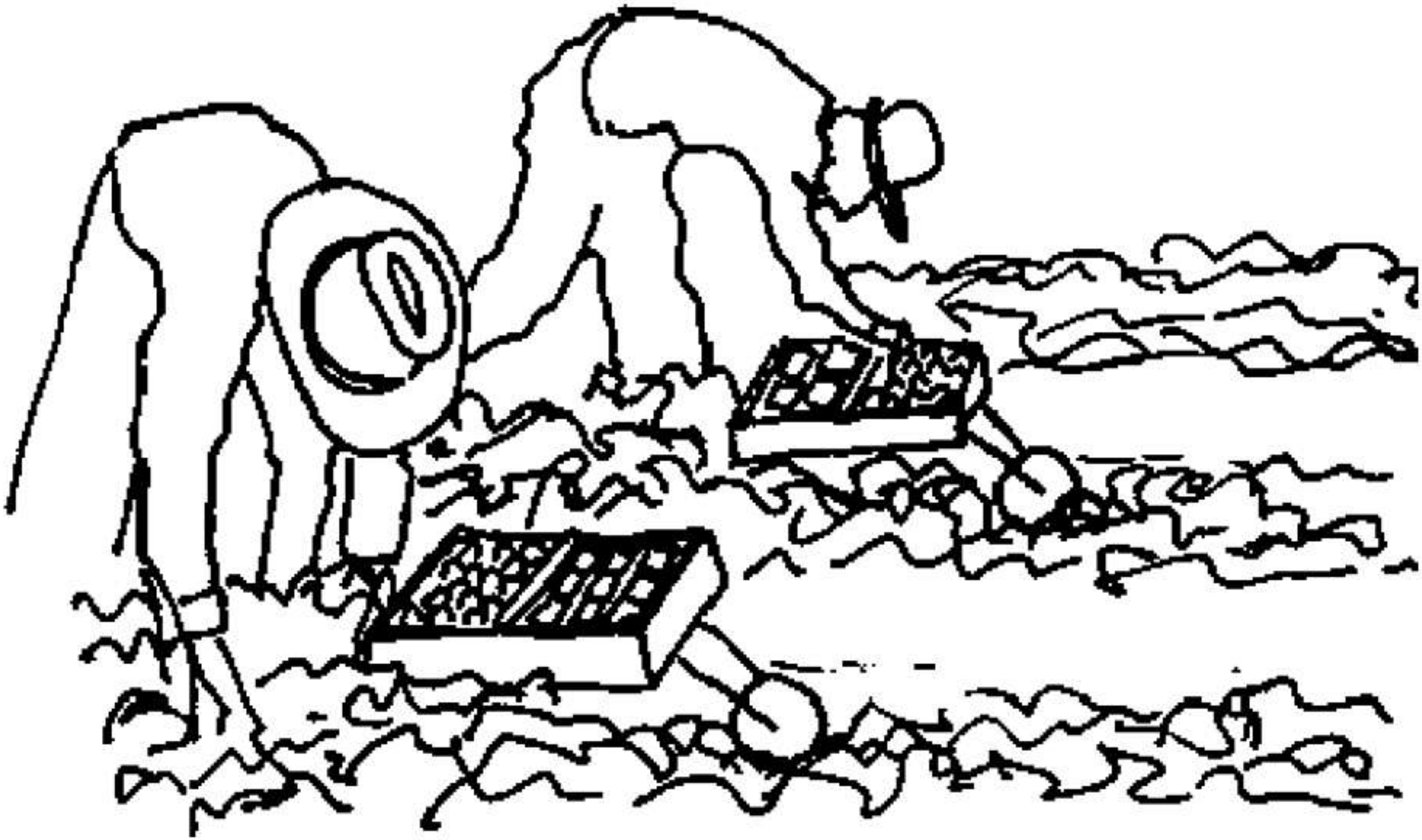

FARM
FARM PACK-HOUSE
STORE
RURAL ASSAEMBLY MARKET
STORE
PACKING HOUSE
STORE
WHOLESALER
STORE
TRANSPORT STEPS
RETAILER
STORE
CONSUMER

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.

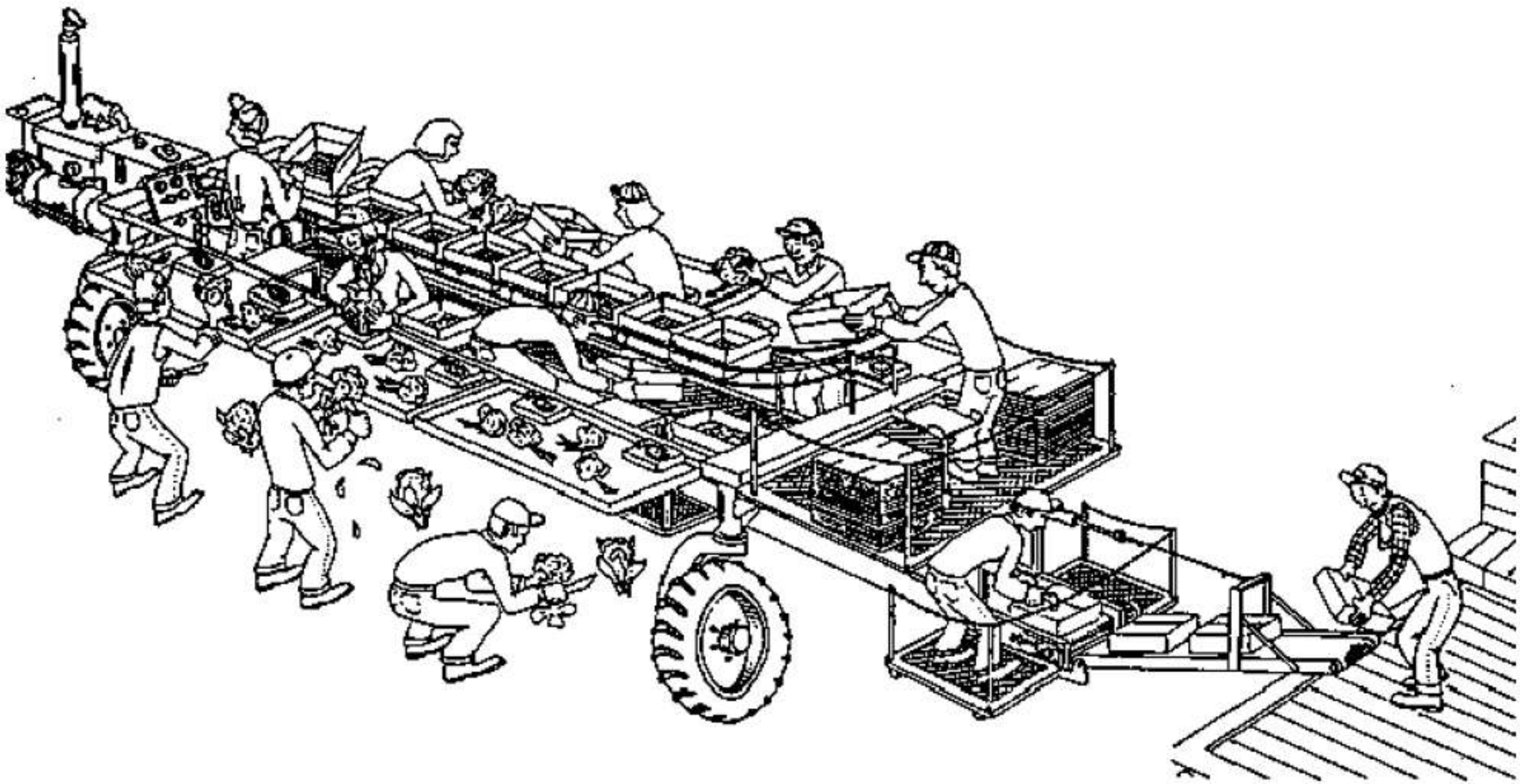
Field packing has the following **advantages** over a **packinghouse operation**: less material to transport and dispose, fewer handling steps, less damage to the commodity, better quality, and less initial cost. It has its **disadvantages**, however. It offers less control over quality, and calls for 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 fiat bed truck is moving along-side the field pack system, and packed produce is being loaded for transport.

SELF PROPELLED FIELD PACK SYSTEM



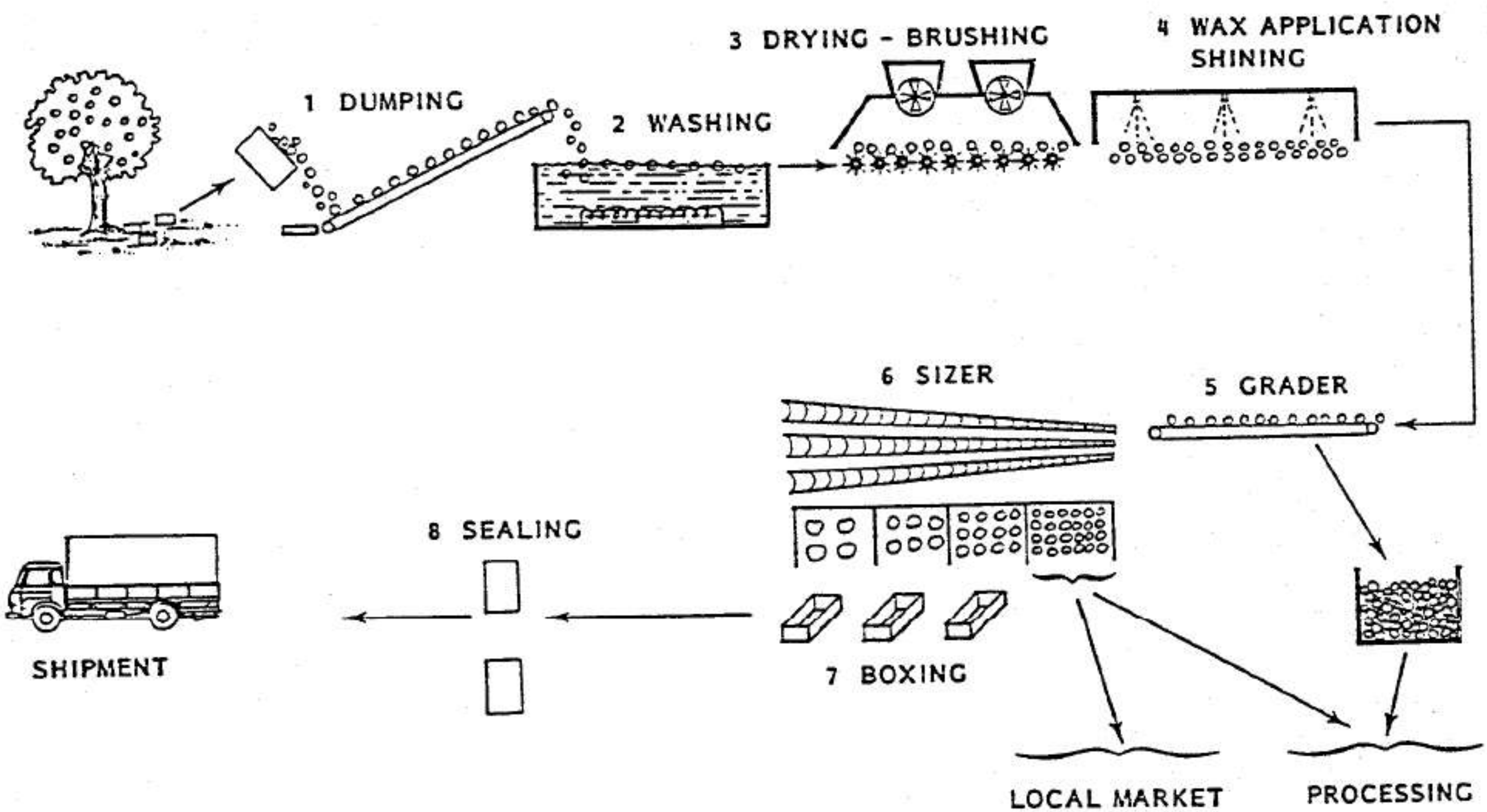
Packinghouse Facilities

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 m^2 of packinghouse floor space will be needed for each ton of product to be handled per day.

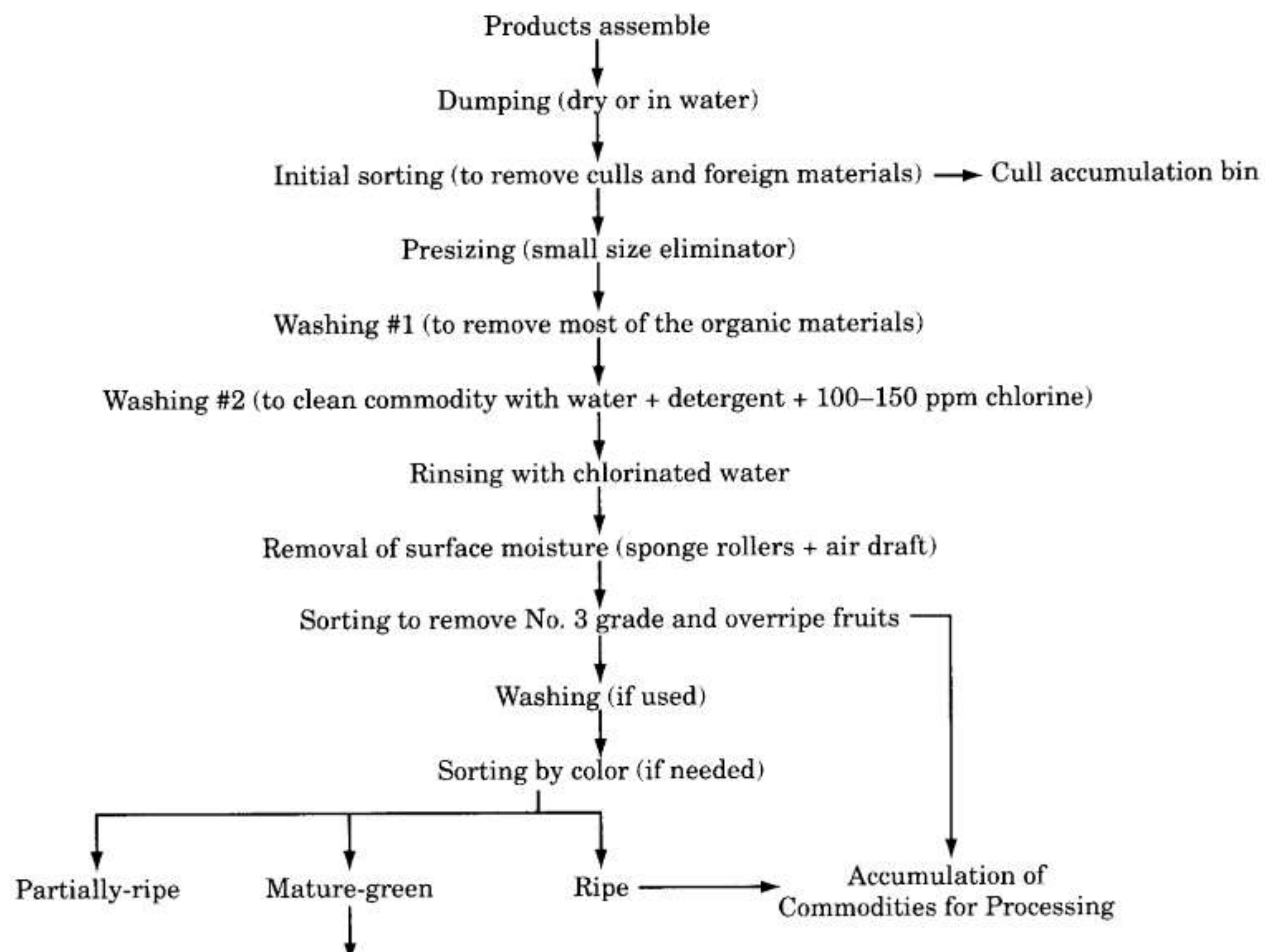
- Area for storage of shipping containers and other packaging materials and for box making, and an automated system for delivery of these boxes to the packaging area.
- Forced-air cooling facility adjacent to a cold storage facility. About 0.7 m^2 of cold storage space will be needed per ton to be handled 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 (selejt) 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



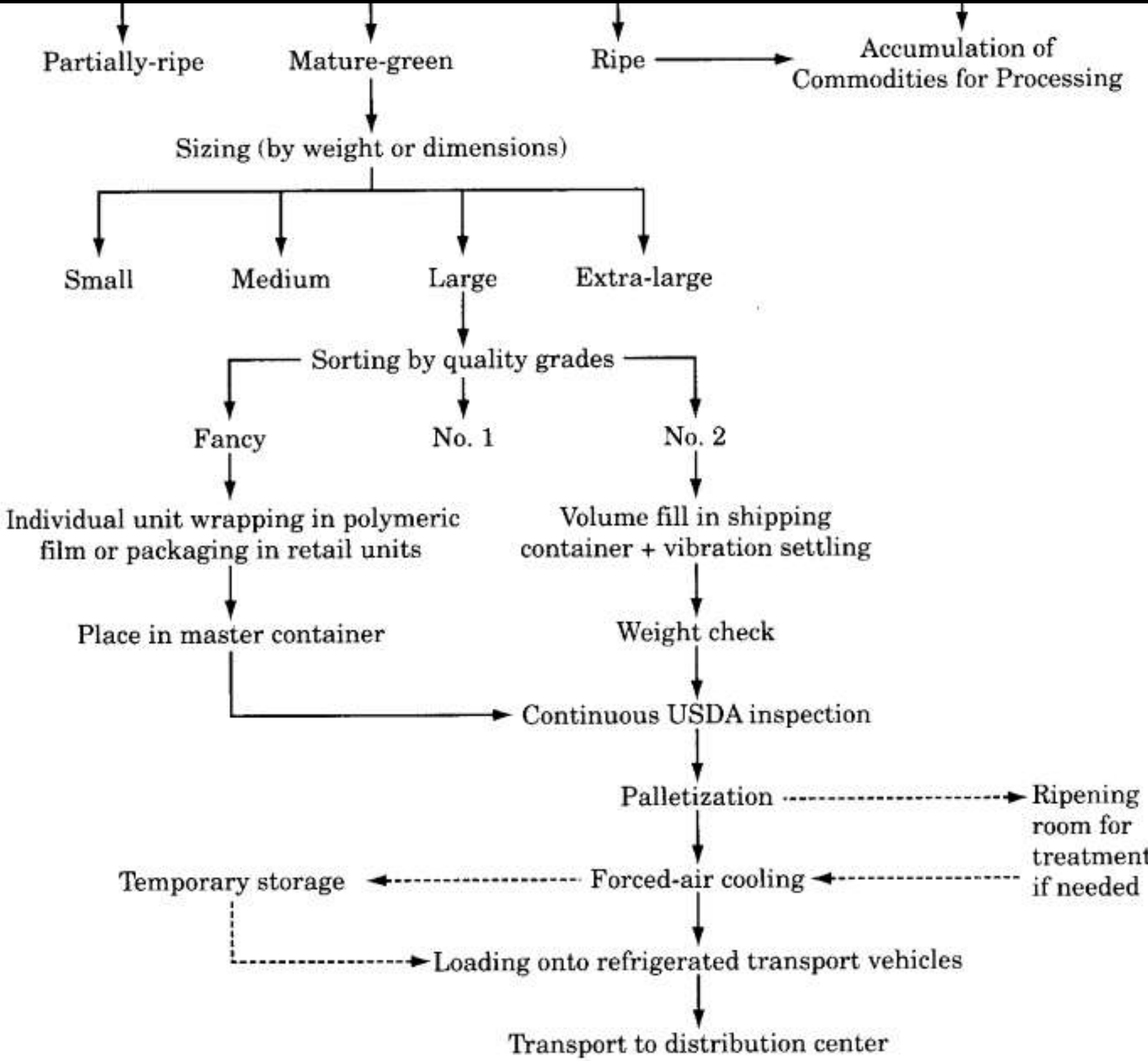
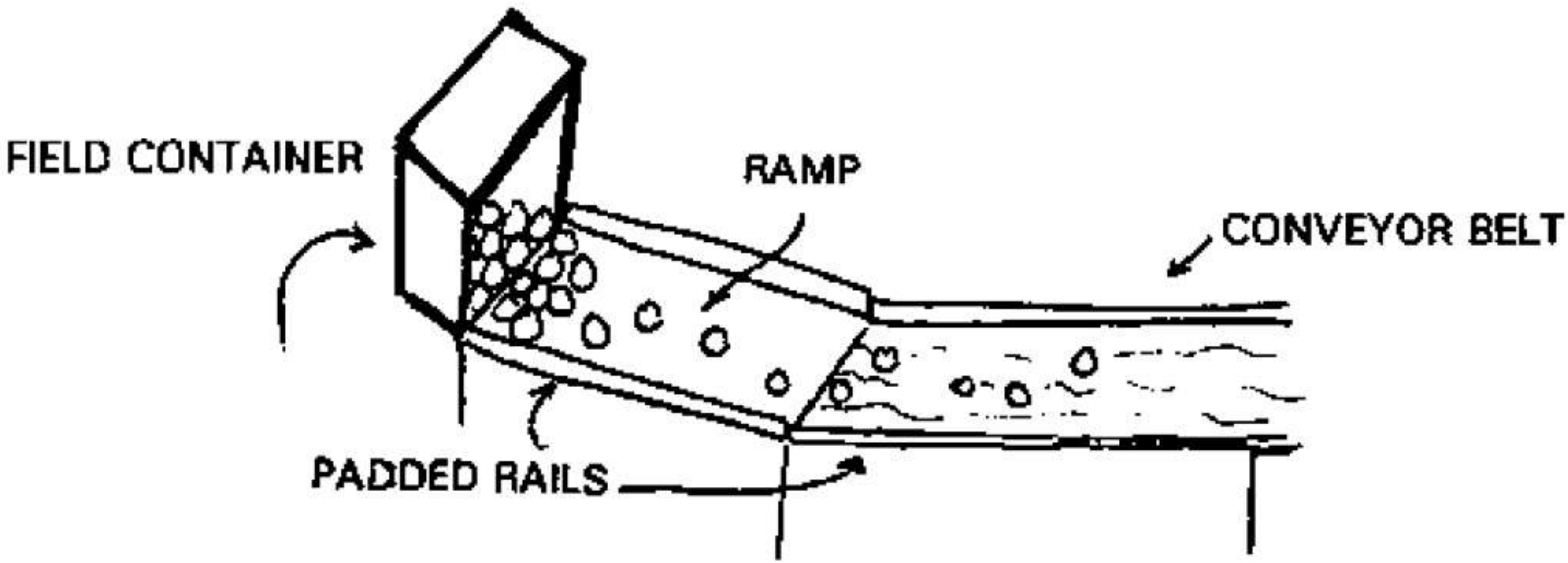


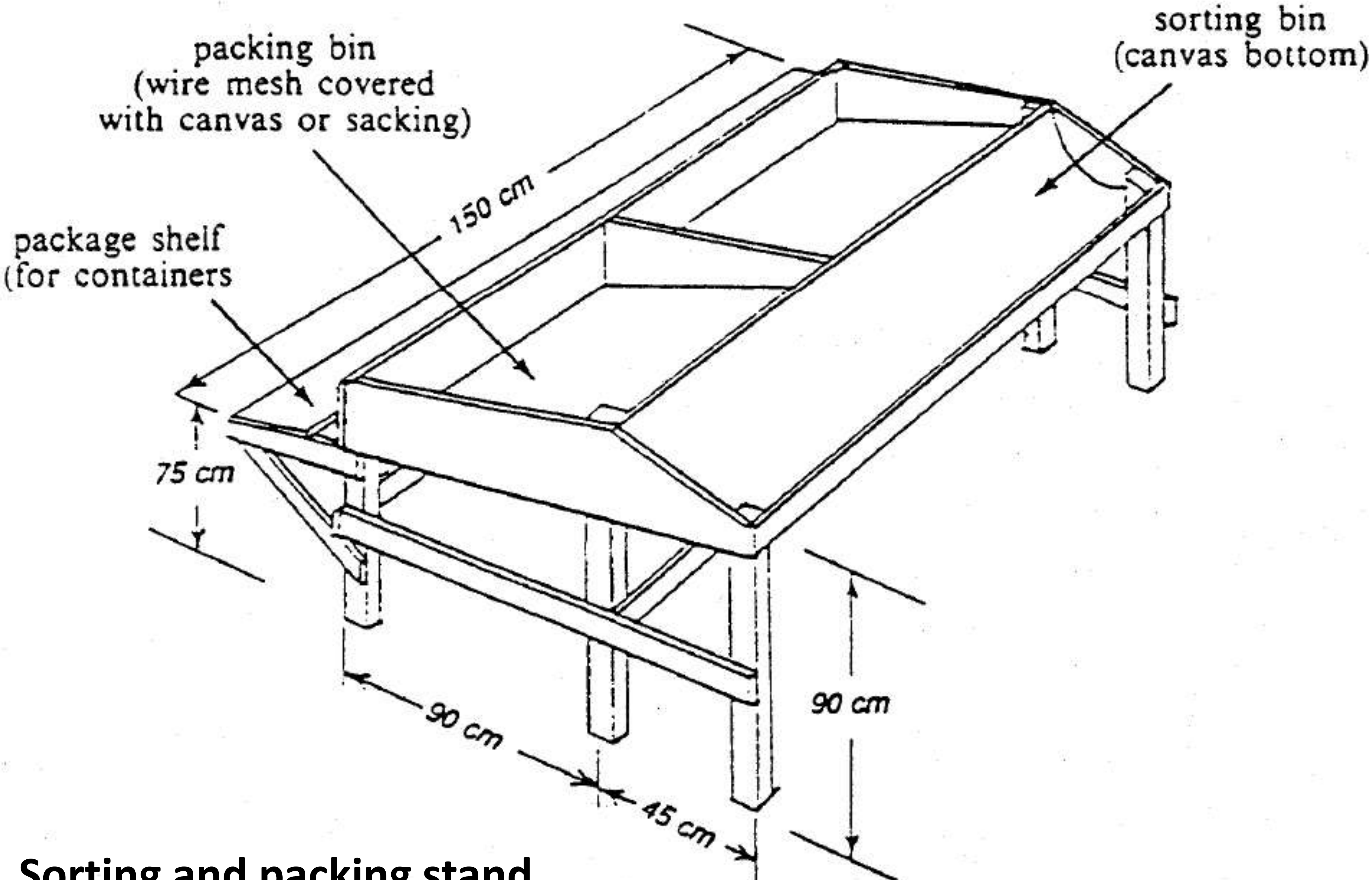
FIGURE 15-3. Flow diagram of packinghouse operations for fresh fruits and vegetables.

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.

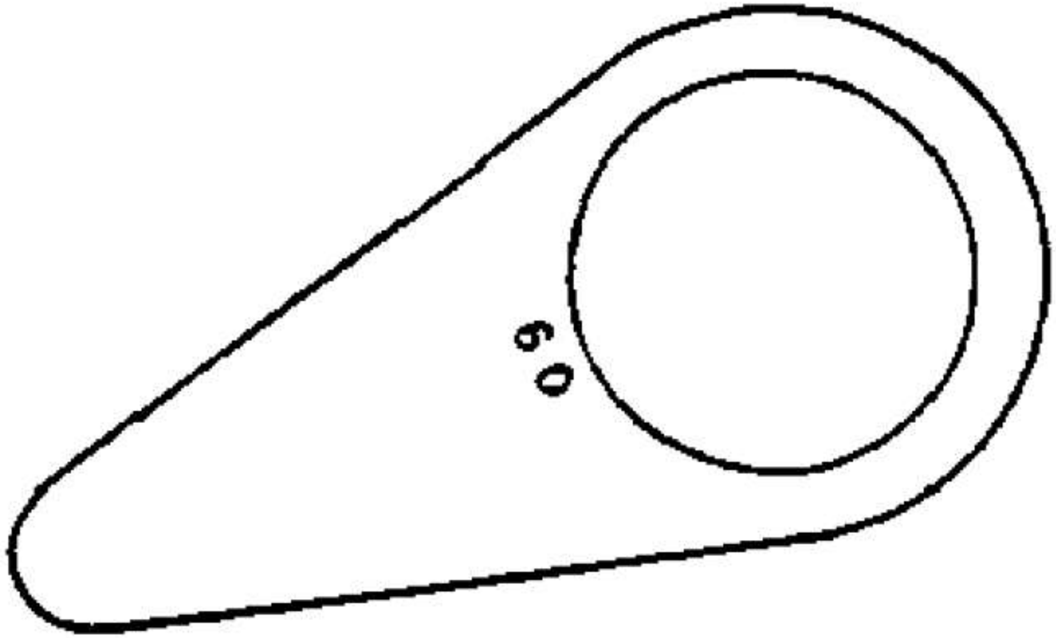
Dry dumping



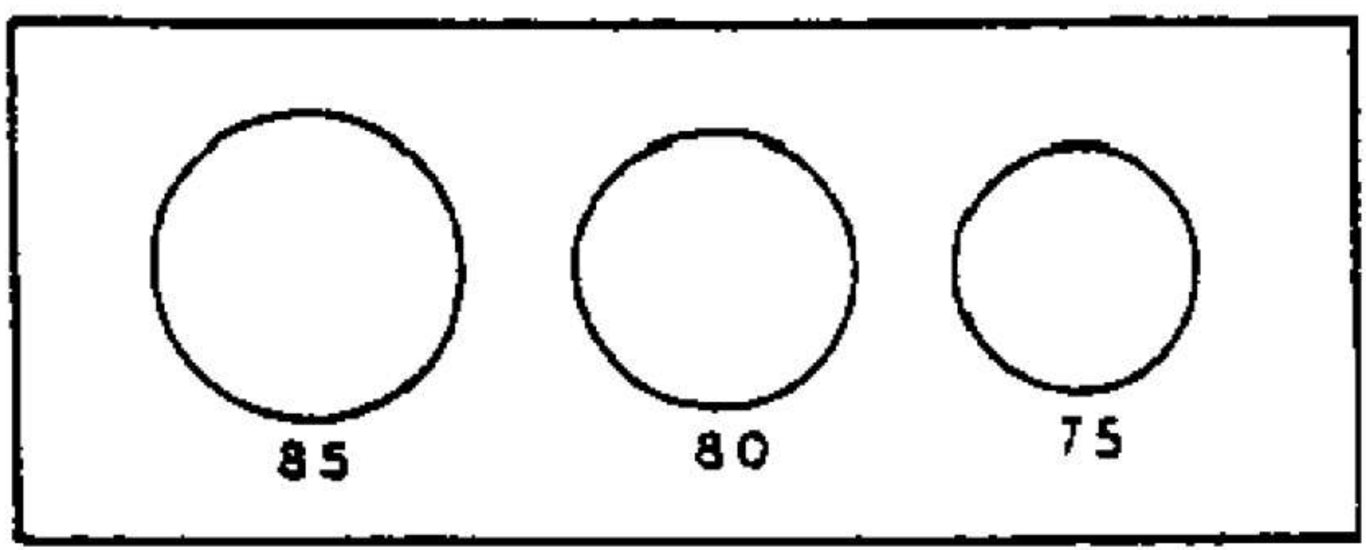


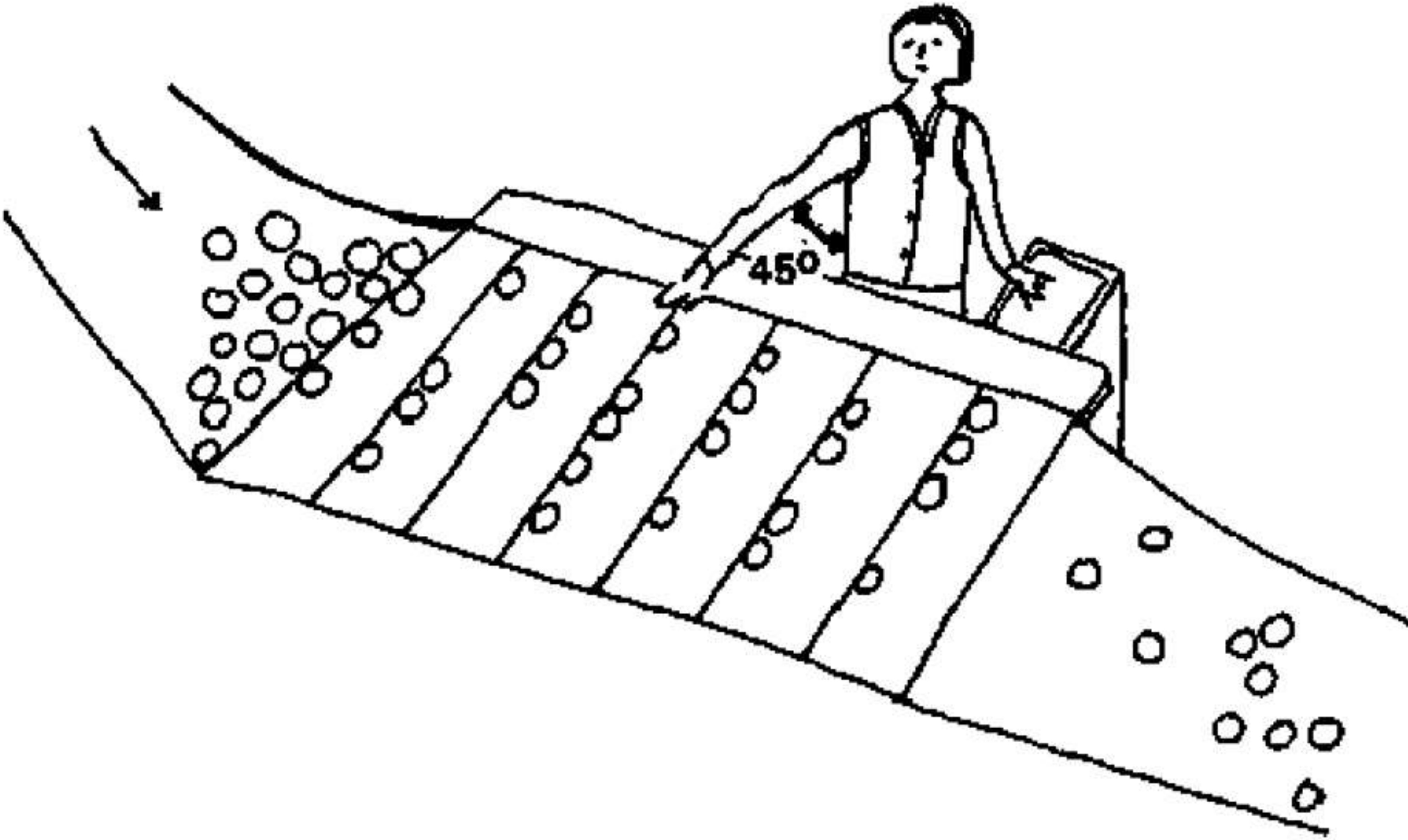
Sorting and packing stand

Single size hand held sizing ring:



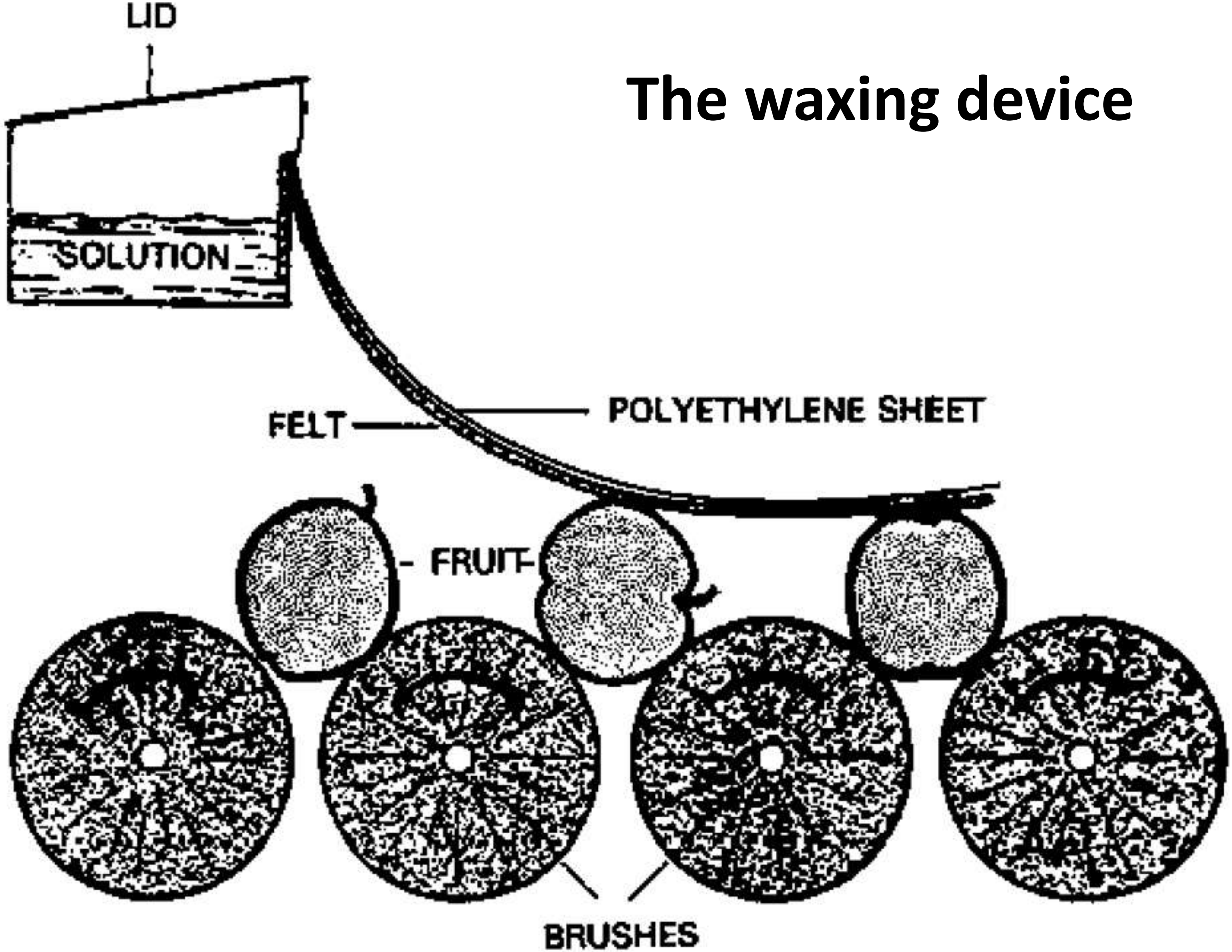
Multiple size rings:



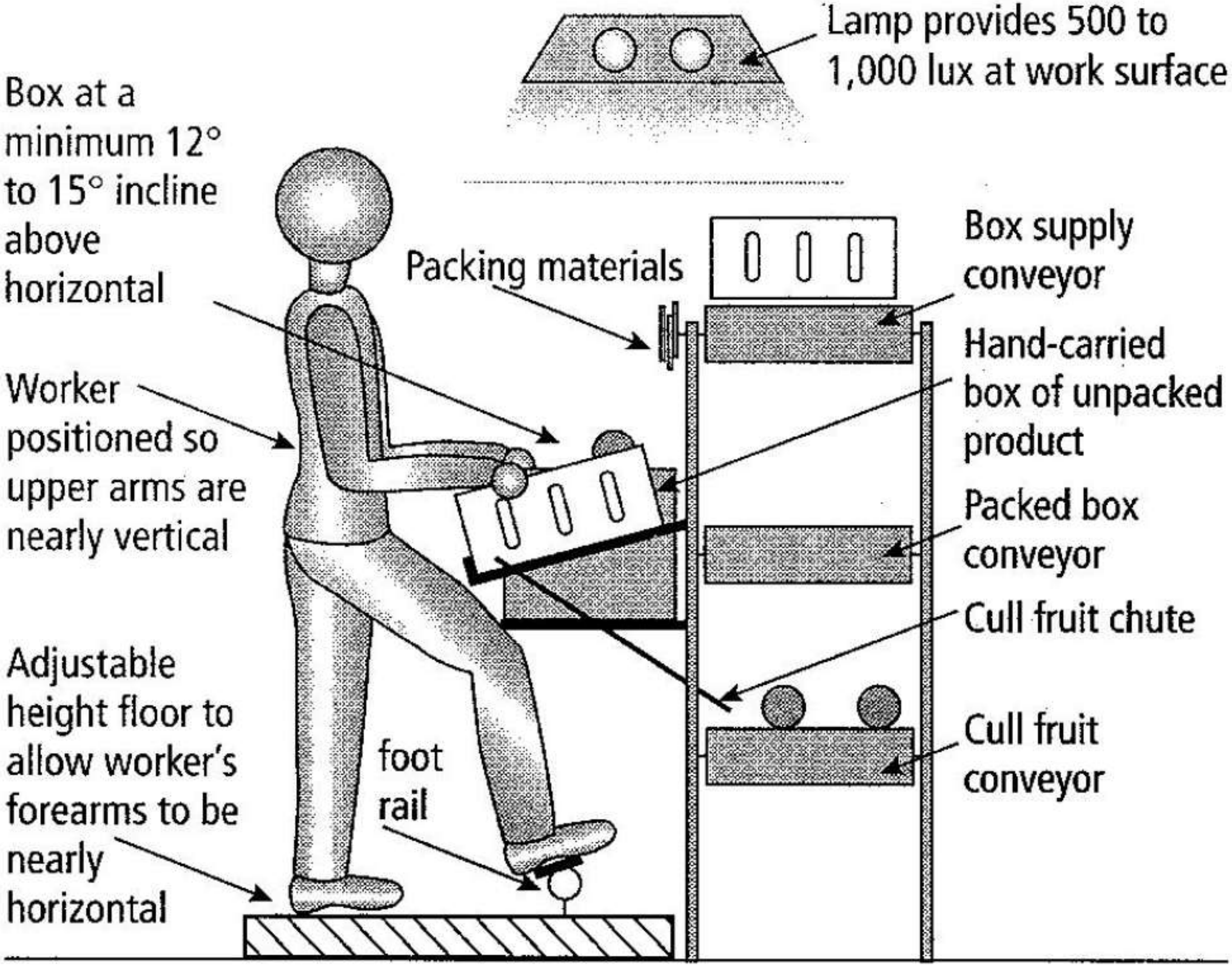

45°

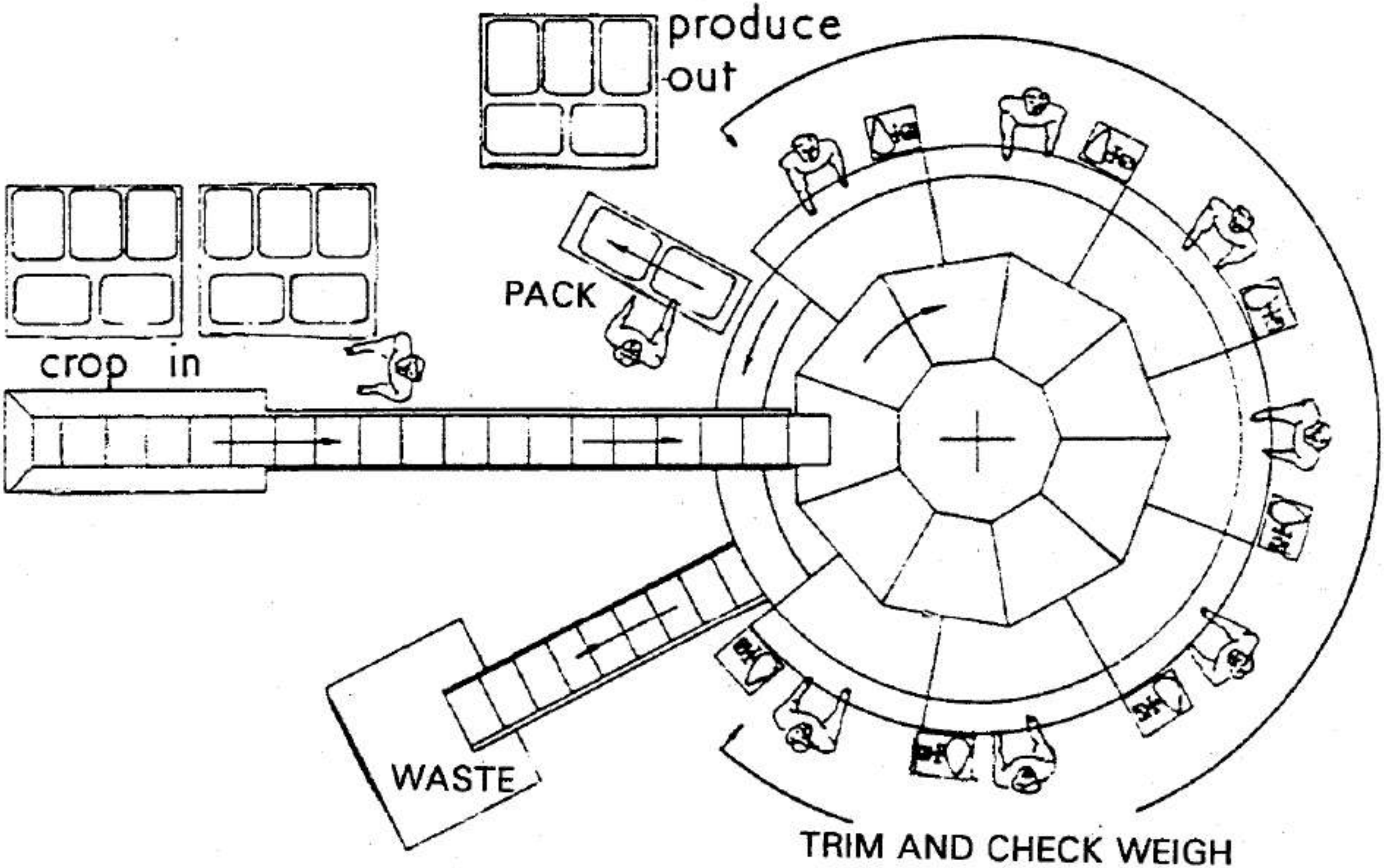
Waxing of certain fruits and fruit-vegetables is used mostly for enhancing *appearance* and reducing *water loss* by about 30 to 40 percent, especially if the commodity is exposed to less-than-optimal temperature and relative humidity conditions. An increasing number of consumers however, prefer unwaxed 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 O_2, CO_2, and ethylene.

The waxing device



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.


Lamp provides 500 to 1,000 lux at work surface
Box at a minimum 12° to 15° incline above horizontal
Packing materials
Box supply conveyor
Hand-carried box of unpacked product
Worker positioned so upper arms are nearly vertical
Packed box conveyor
Cull fruit chute
Adjustable height floor to allow worker's forearms to be nearly horizontal
foot rail
Cull fruit conveyor

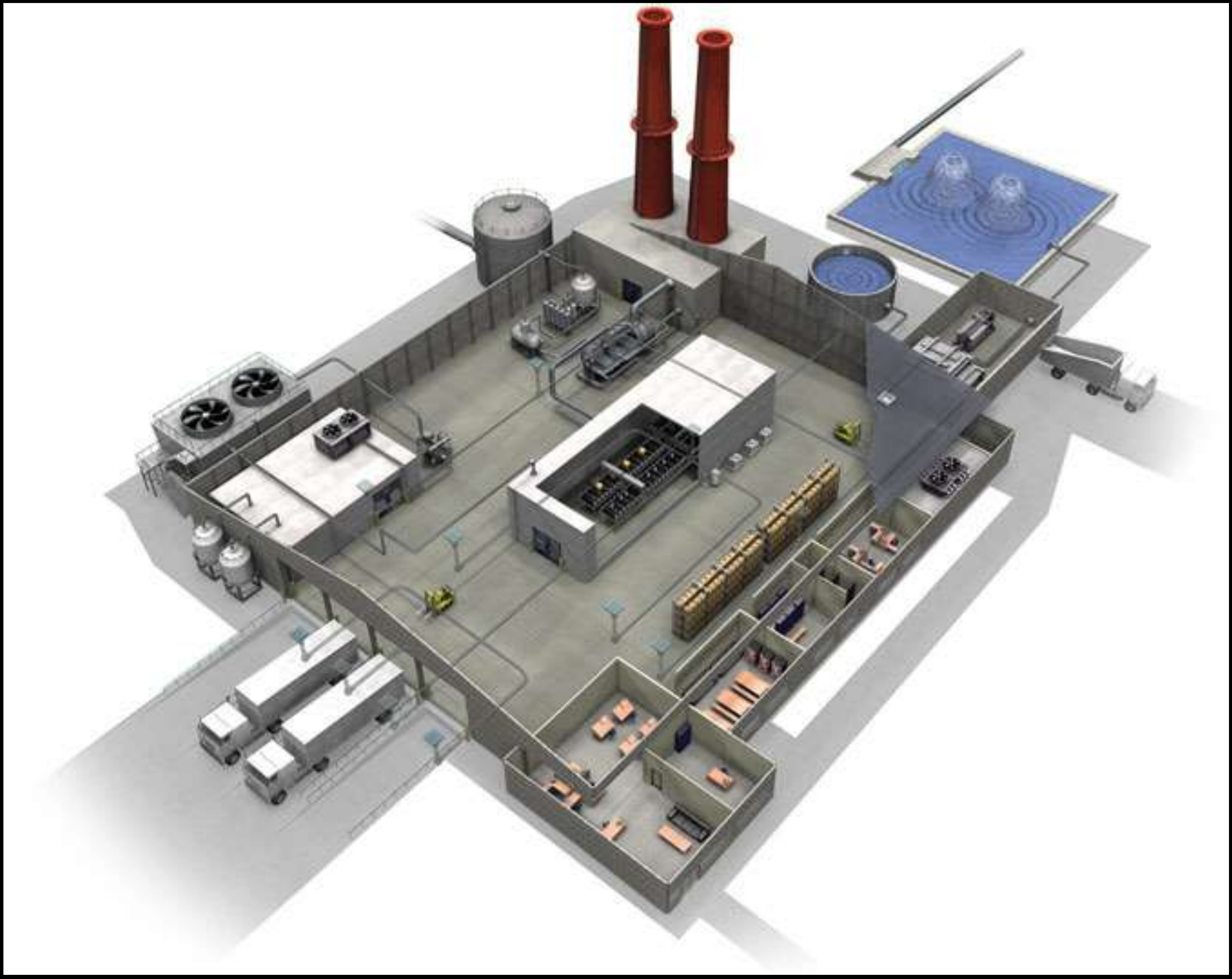

produce
out
PACK
crop in
WASTE
TRIM AND CHECK WEIGH


PINVER
Natural
producido en España
ZELLERSZÁR
870224

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.

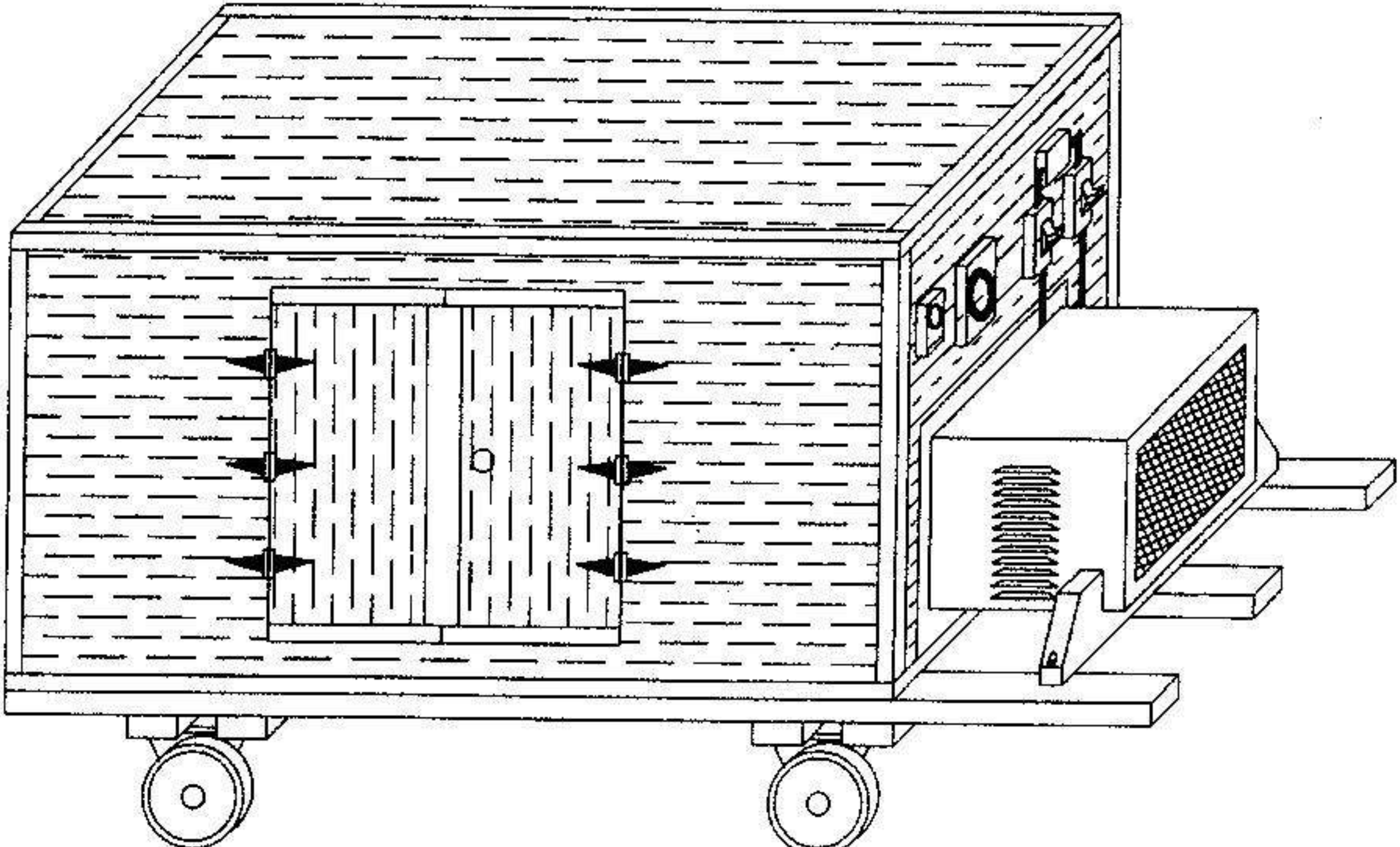


Ripening Facility

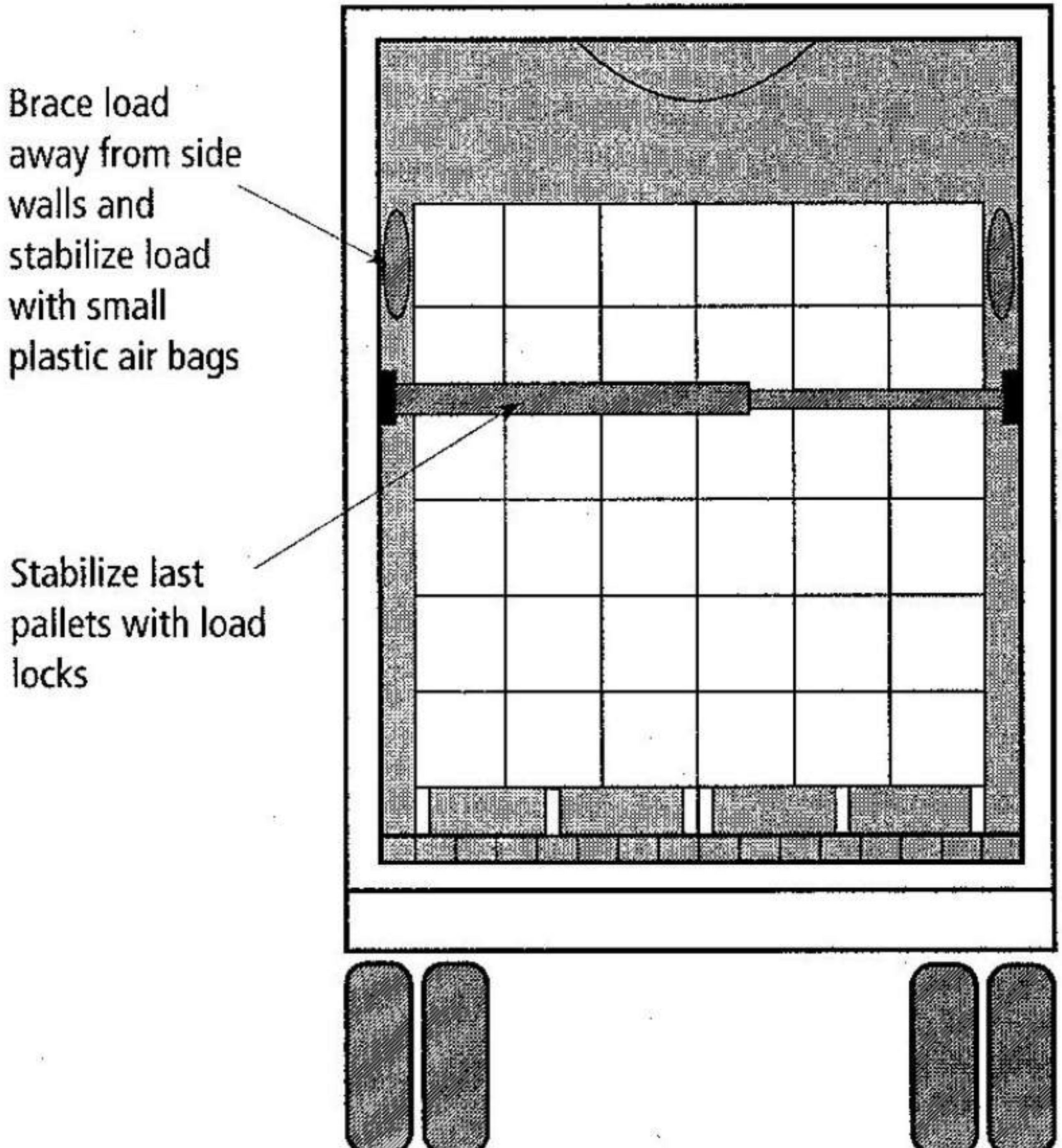
A ripening facility may be needed for initiating ripening of some commodities such as mature-green tomatoes, bananas, avocados, mangos, and some muskmelons. Such a facility may include several rooms equipped with systems for temperature and relative humidity control as well as for ethylene introduction 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

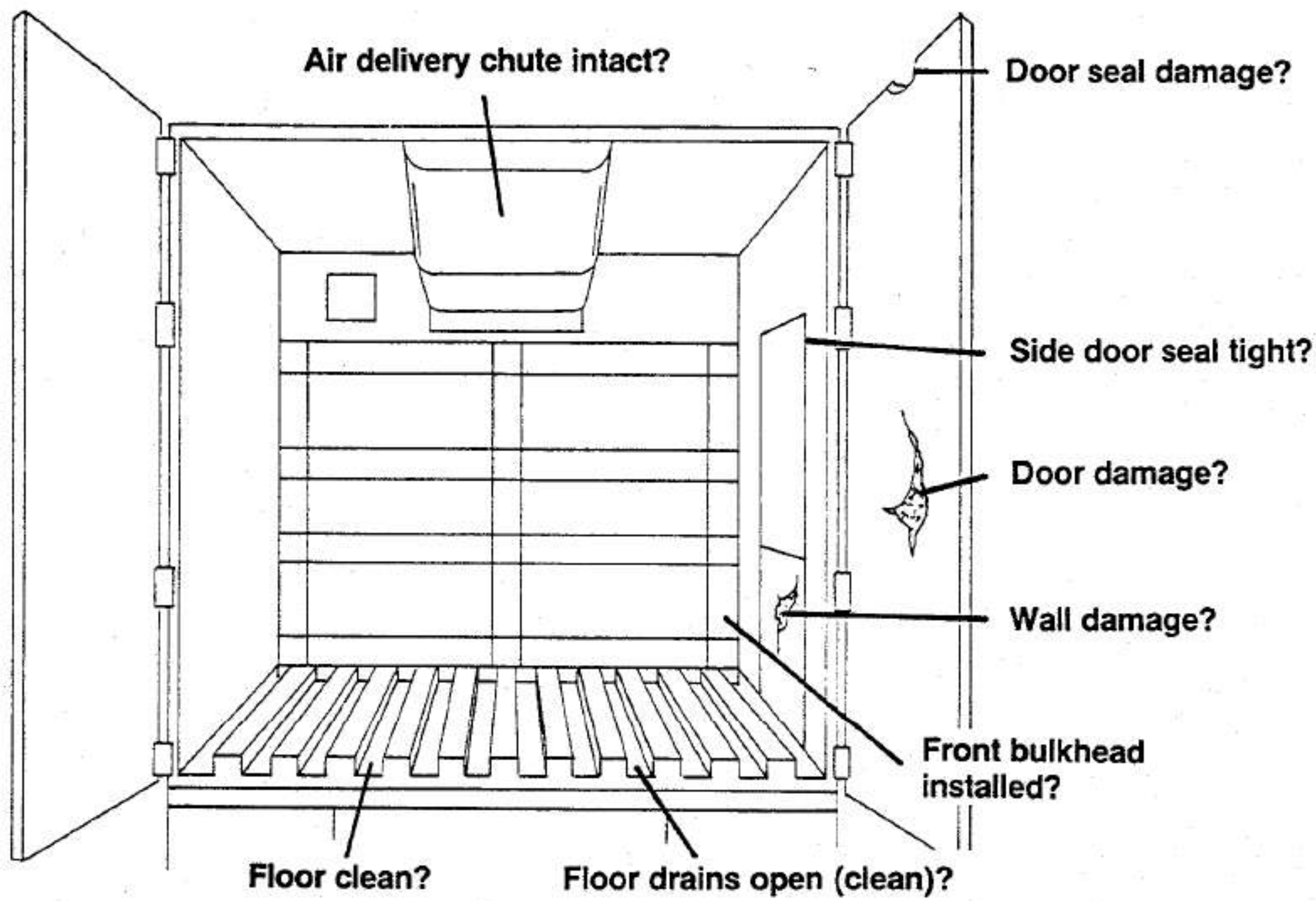
The comparative advantages and disadvantages of *truck versus rail transport* should be examined in relation to cost, speed, reduction in handling steps, and extent of physical injuries due to transport. Many improvements in insulation, air flow systems, and thermostats have been recently introduced 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:



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.

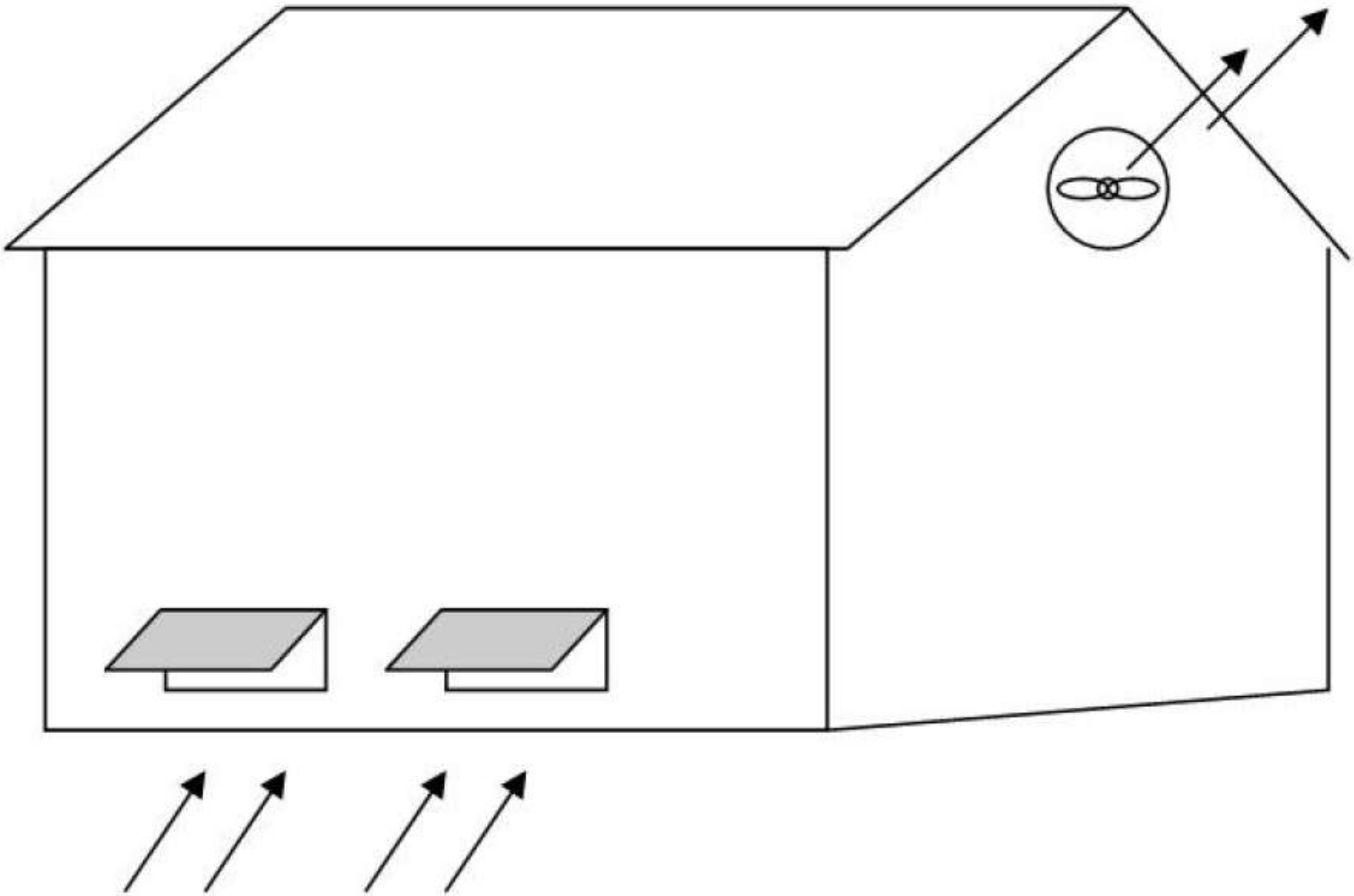
Many attempts are currently being made to automate the separation of a given commodity into various grades and the elimination of defective units. The availability of low-cost microcomputers and solid-state imaging systems have made computer-aided video inspection on the packing line a practical reality. 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:

Operation	Procedures
Harvesting	Check proper maturity and quality.
Preparation for market	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.
Cooling	Monitor product temperatures at key points in the handling system, especially before and after cooling.
Transportation	Check transit vehicles for cleanliness and cooling before loading, loading pattern, load immobilization, thermostat setting, and placement of recording thermometer.
Destination Market	Check quality and condition of the product and shipping container.

STORAGE

Night air ventilation in storage building



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

Relative Perishability	Potential Storage Life (weeks)	Commodities
Very high	<2	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
High	2-4	Avocado, banana, grape (without $S0_2$-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)
Moderate	4-8	Apple and pear (some cultivars), grape ($S0_2$ treated), orange, grapefruit, lime, kiwifruit, persimmon, pomegranate; table beet, carrot, radish, potato (immature)
Low	8-16	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
Very low	>16	Tree nuts, dried fruits and vegetables

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.

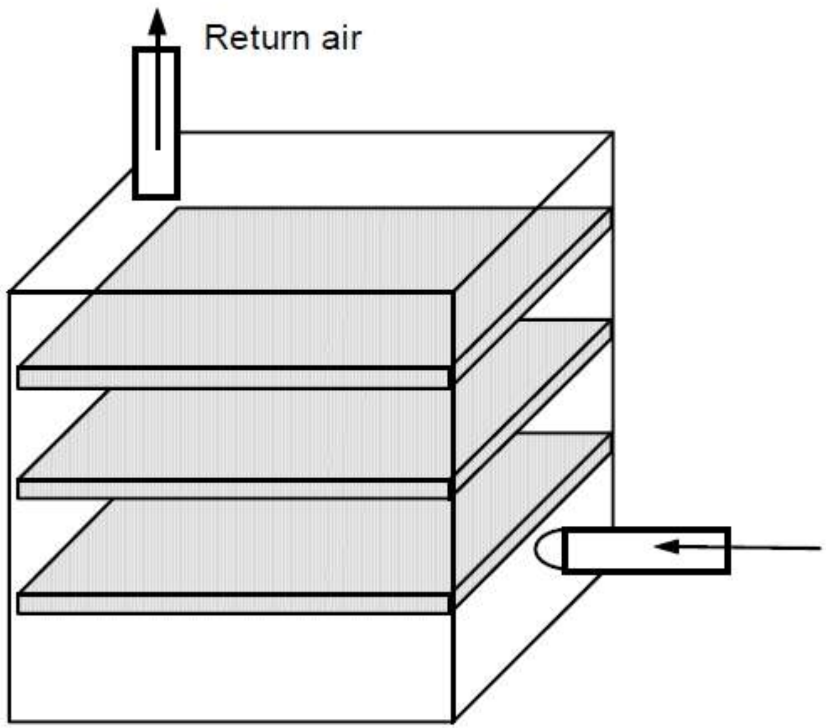
Following are a few examples of ethylene injury: russet spotting of lettuce; development of bitter flavor in carrots; leaf and flower abscission and yellowing of broccoli, cabbage, cauliflower, and ornamental plants; failure to open some cut flowers (such as carnations). Ethylene damage can be greatly 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 <u>ethylene absorbers such as potassium permanganate</u>. 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 ($KMnO_4$) 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.

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

Treatments to Reduce Ethylene Damage

Treating ornamental crops with 1-methylcy-lopropene (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

Primary benefit of CA/MA	Commodities
Delay of ripening and avoiding chilling temperatures	Avocado, banana, mango, melons, nectarine, papaya, peach, plum, tomato (picked mature-green or partially ripe)
Control of decay	Blackberry, blueberry, cherry, fig, grape, raspberry, strawberry
Delay of senescence and undesirable compositional changes (including tissue brown discoloration)	Asparagus, broccoli, lettuce, sweet corn, fresh herbs, minimally processed (fresh-cut) fruits and vegetables

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.

http://postharvest.ucdavis.edu/Pubs/video-library.shtml