27

Postharvest Handling and Marketing of Horticultural Products

Purpose and Expected Outcomes

This chapter discusses the methods used to preserve the quality of horticultural products after harvesting and strategies for marketing products.

After studying this chapter, the student should be able to

1. Describe the various methods of cold storage of horticultural products.
2. Describe how products are handled while being transported.
3. Describe methods of processing products.
4. Discuss the advantages and disadvantages of direct and nondirect product marketing alternatives.
5. List and describe the basic elements in a product marketing operation.
6. Discuss the role of intermediaries in the marketing process.

Overview

Horticultural crops and ornamental plants are grown with certain markets (consumers) in mind. Whereas some operations are small and limited to home consumption, others are large scale and designed to sell produce. Some horticultural products are harvested as mature and dry items, while others are harvested fresh. Some products are designated for processing and others for table use. Whether planted for the table or processing, the producer may target a multitier of consumers—those with discriminating taste and willing to pay premium prices and those looking for bargains. All of these and other factors affect how crops are managed in production and handled after harvesting. If ornamental plants and crops are grown for sale, a paramount consideration in postharvest activities is preservation of product quality so that it reaches the consumer in the best desirable state. The discussion in this chapter focuses on edible products. Handling of nonedible products such as cut flowers is discussed in Chapter 24.

27.1 Economic Importance of Postharvest Losses

Horticultural production is a business. Consequently, the goal of the producer is to maximize the yield of the economic product and to deliver it to the market or consumer at the highest quality for maximum profitability. Because many harvested horticultural products (fruits, vegetables, flowers, etc.) are perishable, they are prone to rapid deterioration soon after harvesting. Product spoilage is responsible for reduction in farm income by about 25 percent and sometimes much higher in tropical developing countries. Such places often experience extreme abiotic conditions that favor diseases and plant physiological abnormalities that lead to spoilage of products. Socioeconomic constraints in these regions also prevent the acquisition of appropriate technologies for harvesting, processing, and handling horticultural products.

27.1.1 CAUSES OF POSTHARVEST LOSSES

Fresh produce consists of about 65–95 percent water, depending on the plant species and the economic part harvested. Physiological activities (respiration and transpiration) continue for some time after harvesting, because the tissues are living. Consequently, as the produce loses its water reserves, the cells die and start to decay. High temperature and low atmospheric humidity tend to accelerate the rate of natural deterioration, causing abnormal ripening, development of off-flavor, and changes in texture of the produce. Improper handling during harvesting may cause mechanical or physical damage to the produce. Bruising provides access to microbes that cause tissue decay or exposure of internal tissue for accelerated dessication. Another major cause of postharvest losses is disease and pests that may originate in the field or the storehouse. It is important to stress that these factors usually interact to cause deterioration of fresh horticultural produce.

27.1.2 POSTHARVEST PHYSIOLOGY

Respiration and transpiration are the two key physiological processes that occur in harvested fresh produce. Because no new dry matter is added to the produce after harvesting, respiration depends on stored photosynthates while transpiration depends on stored water in the tissues. As both processes occur, the stored resources are gradually depleted. Poor ventilation of the storage environment depletes the oxygen concentration and brings about fermentation, which causes off-flavors and rapid ageing of the produce. Similarly, fresh produce is prone to moisture loss, an event that occurs rapidly under low atmospheric humidity and fast air circulation. Produce such as leafy green vegetables (e.g., spinach) are more susceptible to dessication than others with a thicker epiderminal layer (potato). The greater the surface area of the plant part to its volume, the more rapid will be the loss of water. As previously discussed, fruit ripening may be a postharvest event in some crop produce (e.g., banana, tomato). Furthermore, ethylene gas is important in initiating ripening of fruits.

27.2 Harvesting

Since postharvest activities have a significant bearing on how products are handled, it is useful to precede discussions on postharvest activities with how horticultural products are harvested. It is fair to say that, regarding storage performance, if poor-quality products go into storage, poor-quality products come out. Harvesting is a very timely and expensive operation. The difficulty (or ease) of the harvesting operation and how it is done depends on factors such as the crop, the part of economic importance, the growth habit (annual or perennial), the market needs or uses, the maturity pattern, and others. Peppers are harvested differently from apples. Potatoes are dug up (they have underground tubers of economic importance),

whereas oranges are picked (they have fruits borne above ground on branches). In harvesting annuals, the whole plant may be cut or destroyed in the process without any consequence to the enterprise as a whole. On the other hand, when harvesting perennial crops such as apples and oranges, one must be careful to leave the trees healthy for production in subsequent years. The same crop may be harvested in two different ways for two different target markets. High-premium produce for the table is harvested with great care (e.g., handpicked), whereas produce for canning can have bruises and cracks without any adverse consequences. Some cultivars are determinate in growth habit and therefore exhibit even maturity and ripening. In other cultivars and certain species, the product matures at different times and hence requires multiple rounds of harvesting. Growers devise harvesting strategies to suit various production operations in order to cut costs.

27.2.1 PREPARING TO HARVEST

It would be a shame to invest resources into growing a good crop to maturity only to lose the crop at harvest time. A poor harvesting operation would result in poor-quality produce and a low selling price. The grower should plan the harvesting operation with great care, especially when the enterprise is on a commercial scale. Labor equipment and transportation should be prearranged. Labor should be trained to pick the produce at the right stage (market-harvest) and the proper manner (e.g., plucking, cutting, digging) without bruising the produce. Mechanical injury is reduced by training workers to use the appropriate containers in the best shape (not rough edges of lining), to avoid rough handling (throwing, dropping), and to pack properly. Some produce many be harvested and packed in the field and transported directly to the market. Workers should be trained to sort as they pick and avoid contact with soil. Some products are placed in special market packages. Harvesting equipment should be cleared and readied for the operation.

27.2.2 WHEN TO HARVEST

From a physiological standpoint, a crop is ready for harvesting when it has attained *physiological maturity*. At this stage, no additional dry matter accumulates, even if production inputs are increased. This stage may have readily recognizable signs in some crops. In practice, fresh produce is harvested at *harvest maturity* when it has developed to its optimum stage for marketing or consumption. *Ripening* follows physiological maturity and consists of processes that result in changes such as the fruit's texture, sugar content, flavor, and color. These qualities differ depending on whether the fruits are ripened on the vine or in storage. Generally, while **vine-ripened fruits** are tastier, they are also more prone to rotting. Growers often have ways of determining readiness for harvesting their crops from experience. On certain occasions (e.g., commercial production), special instruments may have to be used for precision to obtain the highest quality of product. For example, the percentage of soluble solids (primarily sugars) is important in fruits such as pear, whereas sugar-acid balance is important in blueberry. In certain crops, color development is critical for premium price; growers may thus delay harvesting until the desired color has developed. In certain fruits, the degree of softness (upon applying a gentle squeeze or thumb pressure) is used to indicate readiness for harvest. In pod crops, the way the pod snaps may indicate maturity.

Vine-ripened Fruits
Fruits picked after they are ripe and ready for immediate use.

Sometimes crops are harvested prematurely for certain markets and uses. For example, green beans or peas may be harvested when the pods are only partially filled so that they can be eaten fresh. When the pod matures it becomes too stringy (fibrous) to be desirable for use in this fashion. Fiber development is also not desired in celery. In crops such as banana and others that have to be transported over long distances, harvesting is usually done at physiological maturity but before ripening. The fruits are forced to ripen artificially under a controlled environment (enriched with ethylene gas) to obtain the characteristic bright-yellow color for the market. Most horticultural products are highly perishable and should be harvested and used promptly.

Apart from developmental readiness for harvesting, the time of harvesting depends on weather conditions and the market demand. Whenever possible, fresh produce should be harvested in the cool of the day (early morning or late afternoon) to reduce desiccation. Harvesting wet produce predisposes it to disease in storage and hence should be avoided. The producer will obtain a high price for the produce if it is sold at a time when demand for it is high. Whereas some crops can be harvested over a protracted period, others (e.g., berries) have a short window during which they must be harvested or risk severe losses. The vagaries of the weather may prohibit timely harvesting of crops. A wet field is not suitable for mechanized farming, and, of course, the produce will be wet.

27.2.3 METHODS OF HARVESTING

Hand harvesting of vegetables varies with the economic parts being harvested and may or may not be aided by a tool. For crops with aboveground economic parts, the stem may be snapped off by hand only (e.g., spinach, broccoli, rape, Brussel sprout) or cut with a knife (cabbage, lettuce). For those with underground parts, they are harvested by pulling (e.g., onion, leek) or digging with a fork (mature bulb of onion, garlic).

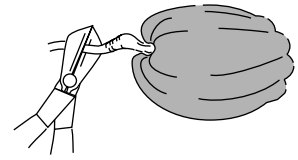
Ripe fruits with a natural break-point attachment to the stem of a branch (e.g., apple, tomato) are harvested by first lifting, twisting, and then pulling. Highly located fruits may be picked by using aids such as picking pole. Immature fruits are more delicate and best cut with a sharp knife (e.g., okra, papaya, peppers, zucchini).

Hand harvesters may carry sacks or bags with shoulder or waist sling (e.g., for citrus). Containers should be free from rough lining that can bruise the fresh produce.

Harvesting may be done by hand or as a mechanized operation (Figure 27–1). Several factors are considered in deciding on the appropriate method of harvesting a crop. Some crops offer no choice since machines have not yet been developed for harvesting them. In other cases, the product is so delicate that mechanical harvesting becomes a great challenge and is not cost effective. Where human labor is plentiful and inexpensive, handpicking may be economical. Sometimes the acreage of the crop is too large for hand harvesting to be carried out in a timely fashion. Crops that are commonly machine harvested include corn, tomato, carrot, beet, and potato. In vegetable production, machine-aided hand harvesting is commonly used. Crops such as cauliflower, cabbage, pepper, and broccoli are directly packaged in the field and loaded onto trucks. They are hand harvested and sometimes wrapped and packed in boxes that are then placed on conveyor belts and transported into trucks. Certain crops, such as onion, require some drying or curing in the field after being dug and cut. The harvesting operation is therefore multistage; in the first pass, the vegetables are cut or dug, and in the second, they are picked up and transported. In the production of nuts such as almonds, fruit shakers are used for shaking down the mature fruits, which are then swept into windrows. The rows are picked up by vacuuming into bins.

Hand harvesting is labor intensive, expensive, and slow, but this produce will usually not have cracks or other injuries associated with harvesting by machines. Hand harvesting also allows fruits and other produce to be picked selectively. This approach saves the extra time and cost of cleaning and sorting after harvesting, which is required for certain crops. It is suitable for crops that mature over a protracted period (not all at once), requiring the plant to be visited multiple times during the growing season. Mechanized harvesting, on the other hand, is generally indiscriminate, picking up good and bad fruits along with plant debris. Mechanization is also capital intensive. However, a large acreage can be harvested in a shorter time with mechanization. Further, it reduces the tedium of harvesting crops such as roots and tubers that require digging. Products are more prone to bruising and other physical injuries when mechanically harvested. Plant breeders often breed special cultivars of crops for mechanized harvesting. Mechanized harvesting is also adapted to crops that mature uniformly so that they can be harvested all at once.

(a)



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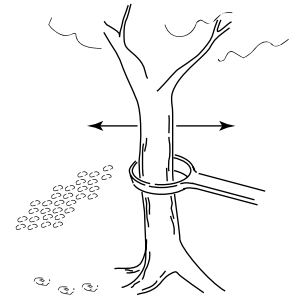
(c)



(d)

(e1)

(e2)

(f)

FIGURE 27–1 Some methods of harvesting horticultural produce: (a) handpicking of fruits, (b) harvesting vining fruits by cutting the vine, (c) lifting underground modified structures such as tubers of potato by the potato rake, (d) harvesting nuts by mechanical tree shaker, (e) harvesting lettuce by hand, and (f) harvesting lettuce by machine. (*Source*: For (e) and (f), USDA)

27.3 HANDLING

Before a horticultural product reaches the table or the consumer, it undergoes a number of postharvest handling processes, as described in the following sections.

27.3.1 WASHING

Vegetables are generally not washed before packaging or marketing. They are usually managed such that they are clean while growing in the field (e.g., by mulching to prevent soil from being splashed onto the harvestable parts during rainfall or irrigation). Where chemicals (i.e., pesticides) are used in production, they should be timed such that no active residue will be on the produce at harvesting. The proper waiting period is indicated on the pesticide label. Fruits such as apples may be washed before packaging or marketing. Root vegetables and crops (e.g., carrot, turnip, and beet), whose commercial parts are developed underground, are generally washed to remove the soil before marketing. Onions and other bulbs are not washed. Because horticultural products from aboveground plant parts are not washed before packaging, the consumer should routinely wash the products before use.

27.3.2 SORTING AND GRADING

Grading
The process of assigning products to categories according to predetermined standards.

Warehousing
Holding of products in storage prior to sale.

Horticultural products destined for the fresh market are delicate and should be handled with great care. They are often hand harvested and hence are more expensive. *Sorting* and **grading** are two postharvest operations designed to group products into quality classes for pricing and use. As indicated earlier in this section, hand harvesting allows only a certain quality of product to be picked, and hence sorting and grading may be done in one operation in the field for certain crops. In fact, some products are packaged as they are picked and transported directly from the field to the intended market or consumers, without **warehousing.**

Harvested products may be hand sorted, especially those destined for the fresh market. Mechanized grading units are also used for certain crops. During the process of sorting, defective and immature products are eliminated, as are diseased products. However, cracked or broken products and those with blemishes are removed but not always discarded. They are placed in a lower-quality category or grade and sold at a lower price. Premium grade, for example, may comprise products with no blemishes, uniform in maturity and size, of good uniform color and firm flesh, and with unbruised, clean skin. A lower grade, on the other hand, may have a mixture of sizes, different maturity days, possibly some cracks in the fruit, and poor color. While lower grades may still be sold on the fresh market, they may also be sold for processing. Each crop has its own quality standards that are used for sorting and grading. Fruits are frequently graded on the basis of size.

27.3.3 TREATMENT

After washing, some produce may be given additional cosmetic treatments to enhance their appearance (e.g., waxing) or treatments to protect from diseases and pests (e.g., fungicidal sprays, fumigation). Sprout suppressants may be applied to tubers and root crops.

27.3.4 PACKAGING

It is most convenient to market most fresh produce in quantities rather than individual units. Consequently, many products (e.g., tomato, onions, apples, potatoes) are packaged in sacks or containers. Packaging is critical for transporting the produce. It protects the produce and also facilitates handling. The packaging material is variable and includes wood, plastic, foam, or cardboard. It is desirable that the container is reusable and light weight. Natural materials are less rigid, difficult to clean, and susceptible to collapsing when not staked properly. Molded plastics and wooden crates are easy to clean and stack. Although packaging has obvious advantages, it can be a source of substantial postharvest losses. Rigid containers may have rough sides that may bruise the produce. Improper packing or an unsuitable container type may cause squashing of soft produce. Injury to produce may be caused by dropping and throwing of crates by workers, and shaking during transportation. Improper packing and poor ventilation may cause heat buildup in the container, leading to produce deterioration.

To reduce packaging injury, containers may be lined or individual fruits may be prevented from touching by wrapping each fruit or including loose-filling materials. Only boxes that are rigid should be stacked to avoid collapsing into lower boxes. The boxes or containers should be adequately ventilated to avoid heat and carbon dioxide buildup. The size of containers should be selected for easy handling and for adequate ventilation on inner parts. Separator trays may be used when packing multilayers of produce.

27.3.5 TRANSPORTING TO MARKET

As previously discussed, proper packaging is essential for safe transportation of produce. Fresh produce is best transported in a refrigerated truck or vehicle for long-distance transportation. The container should be stacked safely and prevented from shifting (poor stowage) in transit. Ventilation should be adequate to avoid overheating. Loading of packages onto pallets enhances air circulation.

27.4 POSTHARVEST CHANGES IN PRODUCTS

As mentioned previously, many horticultural products are highly perishable and hence should be handled appropriately to maintain good quality (appearance and condition) for the market. The shelf life of produce is reduced drastically if harvesting occurs under unfavorable conditions. While some crops do not continue ripening after harvest, others do. Products tend to lose moisture from bruises or the point of attachment to the plant, which results in weight loss, wrinkling, and, in extreme cases, shriveling. Fruits that continue to ripen after harvesting (e.g., pear and banana) experience changes in flavor and sugar content (carbohydrates change to sugars), skin color, and softness. Dormancy may be broken in certain crops to initiate sprouting, as is the case in potatoes. If not properly protected, eventually the perishable product begins to rot.

27.5 STORING UNPROCESSED PRODUCTS

Dry products such as nuts and grains store for long periods in dry environments. Fruits and vegetables have a much shorter shelf life, unless preservation measures are taken to prolong it. The storage conditions (especially temperature, humidity, and light) and the kind of crop (regarding quality characteristics and condition at time of storage) affect the duration of storage the crop can withstand before deteriorating (Table 27–1). Even under the best conditions, poor-quality produce deteriorates rapidly. The general goals of storage are to slow the rate of respiration occurring in living tissues, which also slows the rate of microbial activity, and to conserve moisture in the tissues (prevent excessive dehydration). These goals are accomplished by providing the appropriate temperature (usually cool to cold), maintaining good levels of oxygen and carbon dioxide, and controlling humidity. Bruised products respire at a higher rate than intact ones, and the areas around the wounds become discolored. Certain crops have an inherent genetic capacity for prolonged storage. Those with dormancy mechanisms have a reduced respiration rate in storage.

As a general rule, cool-season crops are stored at low temperatures (0 to 10°C or 32 to 50°F) while warm-season crops are stored at warmer temperatures (10 to 12°C or 50 to 54°F). However, sweet corn, a warm-season crop, should not be stored at warm temperatures, which causes sugar to convert to starch, an event that reduces the sweetness of the corn. Instead, sweet corn that is not going to be used soon after harvesting should be placed in cool storage. Fresh fruits and vegetables should be stored at high relative humidity to retain their succulence and general quality. Crops such as lettuce and spinach require higher relative humidity (90 to 95 percent) than crops such as garlic and dry onion (70 to 75 percent).

TABLE 27–1 Selected Vegetables and Fruits and Their Susceptibility to Injury from Cold Temperature When Stored below Freezing

Crop	*Susceptibility*
Fruits	
Apricot *(Prunus armeniaca)*	VS
Apple *(Pyrus malus)*	MS
Blueberry (*Vaccinium* spp.)	VS
Blackberry *(Rubus argustus)*	VS
Grape (*Vitis* spp.)	MS
Peach *(Prunus persica)*	VS
Plum *(Prunus domestica)*	VS
Squash *(Cucurbita mixta)*	VS
Pear *(Pyrus communis)*	MS
Vegetables	
Asparagus *(Asparagus officinalis)*	VS
Brussels sprouts *(Brassica oleraceae* var. *gemmifera)*	RR
Carrot (with top) *(Daucus carota)*	MS
Cucumber *(Cucumis sativus)*	VS
Celery *(Apium graveolens)*	MS
Cauliflower *(Brassica oleraceae* var. *botrytis)*	MS
Onion (dry) *(Allium cepa)*	MS
Turnip *(Brassica rapa)*	RR
Rutabaga *(Brassica campestris* var. *napobrassica)*	RR
Beet (with top) *(Beta vulgaris)*	RR
Spinach *(Spinacia oleracea)*	MS

VS, very susceptible; MS, moderately susceptible; RR, relatively resistant

Darkness or subdued light should be provided in storage areas. Light may cause products such as potato tubers to green (from the development of chlorophyll). The two general methods of storage for unprocessed products are described in the following sections.

27.5.1 LOW-TEMPERATURE METHODS

Fresh products retain the capacity for certain physiological activities such as respiration. Because respiration produces heat, ventilation in storage is critical for fresh produce to prevent excessive heat buildup, which causes rotting. The respiration rate of crops such as spinach is very high. At a given temperature, strawberries can respire about six times as much as lemons. Temperature is known to affect the rate of respiration; lower temperatures slow biochemical and enzymatic reactions. Temperate or cool-season crops generally tolerate lower temperatures than tropical crops, which are readily injured by cold.

Whether at home or in a commercial setting, the *mechanical refrigerator* is the mechanism for cooling. Refrigerated trucks and containers are used to transport fresh horticultural products over long distances. For products such as cut flowers, strawberry, and lettuce that should be stored dry (no contact with moisture), a *forced-air cooler* system is used to pass cooled air through a stack of the product in a cold room. Some commercial growers use *vacuum cooling* for the direct field packaging of leafy crops. *Package icing* involves the use of slush ice for certain crops. In fall, vegetable produce may be stored outside in earthen mounds or trenches.

The rate of respiration is affected by the concentration of carbon dioxide and oxygen in the environment. Where carbon dioxide levels are very high (low oxygen), respiration slows down. The normal levels of oxygen and carbon dioxide in the air are 21 and 0.03 percent, respectively, nitrogen being 78 percent. Incidentally, in an airtight room full of fresh fruits such as apples, the oxygen soon gets used up in respiration and

is replaced by the by-product of respiration (carbon dioxide). As such, after a period in storage, the carbon dioxide level reaches about 21 percent (the previous level of oxygen). At this stage, the fruits respire anaerobically (fermentation), a process that produces alcohol. Fermentation is undesirable, and hence growers should ventilate such a storage room before anaerobic respiration sets in. It has been determined that when the carbon dioxide level is raised, fruits can be stored at high temperatures of 3 to 7°C (37 to 45°F) instead of low temperatures of −1 to 0°C (30 to 32°F).

The gaseous environment during storage can also be enriched with a variety of volatile organic compounds to influence ripening. One of the most common is ethylene, which is used to commercially ripen banana. Bananas are harvested when mature but still green in skin color. When left to ripen on the tree, they split and lose quality in terms of taste and texture. The bunch is cut into "hands" consisting of about 4 to 15 fruits. These are then shipped in polyethylene wraps. At the destination, bananas are kept at temperatures of between 13.5 and 16.5°C (56 and 62°F) and humidity of about 85 to 95 percent. While in this airtight room, 1 percent (1,000 ppm) ethylene gas is introduced for about 24 hours. To initiate ripening, additional ethylene is introduced at the rate of 0.09 cubic meters (3 cubic feet) per 90 cubic meters (3,000 cubic feet) of space. Fruits are ready for sale when they begin to yellow.

Certain fruits produce ethylene naturally as they ripen. Since the gas is harmful to cut flowers, fruits (e.g., apples) should not be stored in the same room with cut flowers. The storage environment should be maintained at an appropriate humidity level to prevent excessive moisture loss from fresh products. High humidity predisposes stored products to decay. A relative humidity of 90 to 95 percent is appropriate for most fruits including apple, banana, pear, and pineapple. In the case of leafy vegetables that are prone to wilting, a high relative humidity of 95 to 100 percent is recommended. Examples of such crops are lettuce, broccoli, celery, and root crops such as carrot and turnip. On the other hand, vegetables such as garlic, dry onion, and pumpkin store better at 75 to 85 percent relative humidity. It is important to maintain good ventilation when manipulating relative humidity to prevent condensation and the accumulation of undesirable gases.

27.5.2 LOW-MOISTURE METHODS

Many crops including grape, plum, date, fig, and apple may be preserved for long periods by drying. **Solar dehydration** is a relatively inexpensive method for drying in areas where a long, dry, and reliable sunny period occurs (Figure 27–2). The product is spread in appropriate containers and exposed to dry and warm air. For more rapid dehydration of large quantities of product, the *forced hot air* method, which involves air heated to 60 to 70°C (140 to 158°F), is used. This method removes water by

Solar Dehydration
Drying of produce by direct energy from the sun.

FIGURE 27–2 Dried grapes between fresh grapes.
(Source: USDA*)*

dehydration. However, water may also be removed by *sublimation* to ice at temperatures below the freezing point by using the *freeze-drying* method. This method is expensive, but the product quality is restored by rehydration to the level of quality of products stored by freezing. As occurs in cold storage, the oxygen concentration of the storehouse may be reduced by increasing the carbon dioxide concentration. Fresh products stored in conditions of reduced oxygen, as indicated previously, respire slowly and thus deteriorate slowly.

The succulence of fresh products depends on how well they retain their moisture content. A high relative humidity reduces the rate of water loss from plant tissue, but in the presence of high temperature, the combination might encourage the growth and spread of disease-causing organisms. Storage room ventilation ensures that condensation of moisture does not occur, and that harmful gases do not build up.

27.6 Temperature-Induced Injury

Fresh horticultural products, both ornamentals (e.g., cut flowers) and food (e.g., fruits and vegetables), are stored at a low temperature to slow down deterioration after harvesting. However, extreme temperature is injurious to fresh products, the susceptibility varying widely among products. Freezing is usually not tolerated by fresh produce; it often becomes soft and soggy after thawing. Some products are tolerant of chilling, but not freezing, temperatures, especially temperate species. Symptoms of chilling injury vary among species. They include external discoloration (e.g., browning of skin in banana), pitting (lime, beans, cucumber), internal discoloration (potatoes), abnormal ripening of fruits (tomato, mango), and decay (pumpkins). To avoid low temperature-induced injury, store bananas at 12–14°C (54–57°F), ripe tomatoes at 7–10°C (45–50°F), sweet peppers at 7°C (45°F), potatoes at 4°C (39°F), and oranges at 7°C (45°F). Fresh produce may also be injured by exposure to high temperatures. It is important that freshly harvested field produce be placed in a cool and well-ventilated environment to avoid scorching by the sun.

27.7 Fumigation

Storage of dry grain and fruits, such as grapes and citrus, benefits from fumigation to rid the environment of rodents, insect pests, and decay-causing organisms. One of the widely used fumigants is methyl bromide, which is effective against insects in storage houses. Sulfur dioxide is used to protect grapes from decay.

27.8 Processing of Horticultural Products

27.8.1 Freezing

One of the quickest and most commonly used methods of crop product preservation is *quick freezing,* whereby a fresh product is kept in a freezer. The main disadvantage of this method is the damage it causes to the physical or structural integrity of some products. For example, frozen tomato does not remain firm after thawing but assumes a soft texture; consequently, use of the product may be limited by freezing. For best results, freezing should be done rapidly. Slow freezing causes larger ice crystals to form in the cells of the tissue and ruptures them. These large reservoirs of water in fractured cells give frozen products a soft texture upon thawing. Rapid freezing results in tiny crystals that do not rupture cells. Quick freezing temperatures are around −22.3°C (−10°F).

Stored produce may lose some color, flavor, and nutrients. To protect against dehydration, products to be frozen must be packaged (e.g., in plastic wrap). Failure to do so will lead to *freezer burn,* resulting from sublimation of water to ice, with adverse consequences such as deterioration of flavor, color, and texture.

27.8.2 CANNING

A common household processing method is the preservation of products in sterilized water. *Canning* is another method used in processing (Figure 27–3). After placing the products in airtight or hermetically sealed containers, they are sterilized in a pressure cooker. Instead of using water, *brine* (a salt solution) may be used to process vegetables such as onion, beet, and pepper. The intense heat used in sterilization changes some quality traits such as color, texture, and flavor, as well as nutritional value. Low-acid products (pH 4.5 to 7.0) such as vegetables require very high temperatures for sterilization to kill the bacteria that cause food poisoning *(Clostridium botulinum).* Canned products can stay in good condition for several years. However, because heat treatment does not kill all bacteria, spoilage sets in after some time in storage. The salt in canning corrodes the can and reduces the shelf life. Likewise, humidity and high temperatures accelerate spoilage.

27.8.3 FERMENTATION

Fermentation involves bacteria that decompose carbohydrates anaerobically. Some of the products of fermentation prevent the growth of bacteria. The products differ according to the organism, conditions, and duration of the process. Fermentation may produce alcohol and lactic acid, products that affect the flavor of fermented foods. Alcohol may further ferment to produce vinegar. Certain fruit juices are deliberately fermented to produce alcoholic beverages (e.g., grape juice becomes wine). A special fermentation process involving the use of salt is called **pickling.** Vegetables that are pickled include cucumber, onion, cauliflower, and tomato; pickled cabbage is called *sauerkraut.* Instead of using bacteria in pickling, pickles may be produced by placing products directly in citric acid or vinegar.

Pickling
Fermentation of produce in high concentration salt.

27.8.4 PROCESSING WITH SUGAR

High concentrations of sugar may be used to process certain fruit products. The sugar increases the osmotic pressure to a degree that prohibits microbial activity and thereby reduces spoilage opportunities. Different fruit products may be preserved in this way. When fruit juice is used, the product is called *jelly. Jam* involves concentrated fruit, while *marmalade* is sugar-processed citrus fruit and rind. When whole fruits are used, the product is called a *preserve.*

FIGURE 27–3 Preservation of fruits. Fruits are processed to varying degrees in canning. They may be ground into sauce, diced, sliced, or canned whole. *(Source: George Acquaah)*

27.9 Marketing Alternatives

Marketing in its simplest form entails the supply of satisfactory products by a producer to a consumer at a price acceptable to both. In more advanced market economies (and even in less advanced ones), where division of labor occurs, a host of service providers (called **intermediaries**) operate between the producer and the consumer. The services provided include packaging, storage, transportation, financing, and distribution. Sometimes the fresh product changes in nature between the farm gate and the consumer's door, as is the case when intermediaries **add value** to the product by processing it into other secondary products. In spite of the activities of intermediaries, some growers deal directly with consumers. Notwithstanding the mechanics of marketing, certain general principles and characteristics of a horticultural enterprise should be well understood:

Intermediaries
Persons who provide services that link the producer to the consumer.

Add Value
The processing of raw products into secondary products, the latter being more expensive than the former.

1. Horticultural products are highly perishable; they lose quality rapidly.
2. Many horticultural products are bulky to transport.
3. Prices for horticultural products are not stable.
4. Some storage may be required in a production enterprise.
5. It is important to identify a market before producing horticultural products.

Ultimately, the market is the most critical consideration in a crop production enterprise. Growers should not grow what they cannot sell, since horticultural products are highly perishable. Marketing alternatives should be discussed *before* production starts. The various marketing methods are described in the following sections.

Two basic marketing alternatives are available to the producer—direct marketing and nondirect marketing. Either one has advantages and disadvantages.

27.9.1 DIRECT MARKETING

The producer may market produce directly to consumers via one of several alternative mechanisms, the common ones being pick-your-own, roadside sales, and farmers' markets. The producer interacts with customers on a one-on-one basis and should be ready to provide honest and convincing information about the operation.

Pick-Your-Own

In pick-your-own (U-pick) operations, consumers go to the farm where they harvest their own produce (usually fruits and vegetables) and present the produce to the farmer for pricing. Pricing may be on a weight, volume, or count basis, depending on the produce. To be successful, the crop should mature uniformly and be of very high quality, and the farm should be located near potential customers. It is advantageous if the farmer produces different varieties of the crop or different crops so that customers have choices. Consumers patronize this system of marketing for the high quality of fresher produce they expect.

The layout of the farm should facilitate easy and safe movement of customers. Some fruits may require some supervision for proper and safe harvesting by customers. The sale should be advertised to the public through local newspapers, fliers, radio, and so on. The most effective advertisement is probably by word-of-mouth from satisfied customers. Signs should be placed near roadsides and sometimes throughout the farm to direct customers. Furthermore, adequate parking should be available for customers.

Proper pricing is critical to the success of such an operation. Customers expect to pay less than they would pay in grocery stores because they are aware that overhead cost is low (no transportation cost, no labor for harvesting, no packaging, no intermediaries, no storage costs, etc.). However, if the quality of produce is excellent, the farmer can obtain a high price for it. Some farmers allow some haggling, whereas others are firm

with pricing. When selling by volume, it is advantageous to provide containers to customers, even though some will find a way to overfill a container.

The checkout station should be readily visible to customers and provide some storage space since some customers may make several trips to the field. It may help to have chairs and tables for weary customers to rest. For a large operation, farm assistants should be available to assist customers. The disadvantages of pick-your-own include liability for accidents assumed by the producer, and the need to work long hours during harvesting season. Inclement weather would prevent an open field sale from taking place.

Roadside Sale

Heavy traffic may create congestion and discourage some potential customers from stopping to buy items. Weekends (when people are not hurrying to or from the workplace) may attract more customers. Furthermore, locating the operation along roads with low or moderate speed limits (35–50 mph) will be safer for drivers to pull over and will attract more customers. The produce should be attractively displaced to draw customers. Sales increase when a diversity of products are offered for sale. Prepackaging of produce diminishes from the fresh-farm image of roadside marketing.

Farmers' Market

Farmers' markets are owned by a grower organization, community development groups, or a state or local government. The partners in the operation share operating costs (insurance, advertising, facilities, etc.). Consumers associate farmers' markets with lower prices, fresh produce, and high-quality produce. Unlike pick-your-own, the business hours of farmers' markets are set by the coordinator or organizer. The produce should be competitively priced since there may be other producers selling the same produce.

27.9.2 NONDIRECT MARKETING

In nondirect marketing, the producer reaches the consumer through a third party that may include terminal market firms, wholesalers, brokers, processors, cooperatives, private packing companies, and buyers for retail outlets.

Terminal Market Firms

Terminal market firms purchase produce for chain stores or large wholesalers. They are usually interested in doing business with producers who can supply large volumes of consistently high-quality produce. However, they have specific stipulations concerning product quality, quantity, and packing. Furthermore, because prices are based on current retail prices, the prices they pay for produce are variable. Producers are also responsible for delivering produce to the designated terminal market.

Brokers

Brokers are agents, individuals, or firms that negotiate sales contracts between producers (sellers) and buyers, without taking physical custody of the produce. The producer retains responsibility for most of the marketing functions (grading, handling, packing). The broker (selling or buying) locates the produce of desired quality and quantity at a price acceptable to both seller and buyer and arranges the appropriate contract. Though brokers may be involved in invoicing and collecting payments, they are not responsible for payment if the buyer defaults on the contract.

Processors

Processors add value to fresh produce. They often purchase large amounts of produce. They contract some of their needs to growers. The producer has the advantage of an assured sale of large quantities of produce. Often, the processor provides some technical

expertise to the producer to ensure that the desired produce quality is attained. On the other hand, the producer is expected to supply a produce at a specified time and quality, demands that may be hard to satisfy all the time.

Cooperatives

Producers of specific produce may join together to form cooperatives for collective bargaining for high prices and guarantee of markets. Members are able to benefit from the use of communal equipment and facilities (e.g., for harvesting, grading, storage, and transportation), some of which they could not afford on their own. By coming together, small producers are able to pool their outputs to satisfy the needs of processors and other purchasers of large quantities.

Whereas cooperatives provide bargaining power for producers, the producers lose their independence to sell for better prices when consumers demand changes. Furthermore, the more efficient producers subsidize the less experienced producers, not being able to receive the optimum returns for their produce.

27.9.3 RETAIL OUTLETS

Retailers usually service relatively smaller markets such as schools, hotels, and prisons. The produce may not require special packaging prior to delivery. Some of these customers may be niche markets that are counted and developed over time (Figure 27–4).

27.10 THE ROLE OF INTERMEDIARIES IN MARKETING

Pick-your-own and roadside sales provide customers direct access to the grower. The product is usually fresh, and the cost is generally lower to the buyer because the grower has less overhead to pass on to consumers. A grower's operation may not be equipped to service individual customers, a role filled by intermediaries. Intermediaries, acting as intermediaries, help in distributing products to customers over a large area. They provide warehousing and storage facilities and transportation that the grower may not have the resources to own or manage. Some intermediaries are processors who are able to preserve the fresh product, thereby extending its shelf life. Because of the added value to fresh farm products, the resulting products usually sell for much higher prices.

FIGURE 27–4 Fresh and dried fruits are sold in small quantities or individually by retailers. *(Source: George Acquaah)*

(a)

(b)

FIGURE 27–5 Horticultural produce is packaged in a variety of ways: (a) fresh or (b) processed. *(Source: George Acquaah)*

27.11 Elements of Marketing

Marketing is a very complex and involved operation. To be successful in marketing agricultural products, the following should be considered:

1. *Packaging.* Many horticultural products are delicate and bruise easily and thus should be packaged or assembled in appropriate containers whenever they are moved or transported. Because some items do not tolerate being piled one upon the other or touching and rubbing against each other, they may be wrapped individually. A variety of packaging materials are available for use (Figure 27–5). Agricultural products for processing may be delivered without packaging; for example, tomatoes may be delivered by the truckload directly to processing plants.
2. *Storage.* Proper storage is required at various stages in the marketing process. Anytime the product will not be sold immediately, storage is necessary to preserve quality at least until it is sold. When fresh products have to be moved over long distances, special provisions should be made for storage in transit. In terms of storage conditions, some products simply need adequate ventilation so that heat does not build up in the package. Processed products (e.g., canned foods) often do not require refrigeration but should be stored in a cool, dry place.
3. *Transportation.* Mechanically refrigerated vehicles, containers, and the like are used to transport fresh products over long distances by road, rail, water, and air.
4. *Distribution.* An effective and efficient distribution network is critical to marketing success. Marketing thrives on supply and demand principles. Products should be moved in a timely fashion to where they are needed when they are needed. Retail chains aid in the distribution of products. To keep products fresh, suppliers are first sought in an area close to the customers.
5. *Financing.* Financing is required not only for marketing but also for the entire production operation. Horticultural crop production is a high-risk operation since products are perishable and cannot be stored for long periods of time. Prices are also unstable in this industry.

Summary

Many horticultural products such as vegetables are perishable and should be used soon after harvesting or as appropriate. Products that are destined for the market may be washed, especially underground parts or tree fruits that were sprayed with pesticides before harvesting. Since crop products do not usually have identical features, the grower often has to sort and grade them into quality classes. During transportation or holding (warehousing) before sale, horticultural products often are stored under cold temperature conditions using mechanical refrigerators or air coolers, for example. Some products may be processed by solar dehydration or freeze-drying, pickling or canning, or other methods of preservation. Those who grow crops with the intention of selling have several options in terms of marketing strategies, including U-pick or self-harvest enterprises, truck or roadside marketing, farmers' markets, or wholesale operations. Marketing is complex, involving packaging, storage, transportation, and distribution.

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Outcomes Assessment

1. Explain why horticultural products like spinach and lettuce require higher relative humidity that dry onion and garlic while in storage.
2. Describe how high temperature in storage affects the quality of freshly harvested sweet corn.
3. Describe how deterioration of freshly harvested produce, due to respiration, can be reduced.
4. Explain why quick freezing is not recommended for produce such as fresh tomato.
5. Describe the operation of sorting and grading in horticultural crop production.