Postharvest Handling Systems: Tropical Fruits

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The most important tropical fruit by far in temperate-zone markets is the banana; its per capita consumption in the United States is higher than any other tropical fruit. Its popularity among consumers is enhanced by a reasonable price, high fruit quality, and year-round availability. The other fresh tropical fruits commonly found in the temperate-zone markets are mango, papaya, and pineapple. The influx of many people from tropical countries into the United States has increased the demand for these and other tropical fruits.

BANANAS

The banana is a large herbaceous plant. The underground tuberous stem, or "bulb," gives rise to leaves and the fruit bunch. The aboveground trunk of the banana tree is a pseudostem consisting of tightly oppressed leaf bases. The pseudostem dies after a fruit bunch has been harvested and is replaced by one of the young pseudostems that have emerged. The banana inflorescence has three types of flowers. The fruit originate from female flowers that are produced first, followed by hermaphrodites, and lastly male flowers.

The postharvest operations required for bananas include transportation to packinghouse, dehanding, washing to remove dirt and latex, disease control, packaging, transportation to market, ripening, and retail sale (fig. 31.1).

HARVESTING

Bunches are examined about 3 months before harvest. Those that have completed their female (fruit-producing) stage have their buds removed to prevent further floral development. One or two apical hands are also removed at this time to promote development of the remainder. Removed buds may be consumed or discarded.

Each bunch is covered with a polyethylene bag. The top of the bag is secured to the stalk and a colored ribbon is attached to the end of the bag or inflorescence. Different colored ribbons are used each week as a ready record of bunch age. The polyethylene bag protects the bananas from leaf scarring and keeps dust off, and the bag may be impregnated with an insecticide.

During fruit development, the bunches may require props to support the inflorescence weight (fig. 31.2). Sometimes a pseudostem is provided with twine guys from the crown to the bases of nearby pseudostems.

Bananas are harvested green at about the 75% mature stage and are ripened in market areas. More-mature fingers often split and tend to be mealy. The maturity at which bananas are harvested depends on the time required to get them to market. Fruit shipped from Central America to Europe are usually harvested less mature than those shipped to North America. Of course, a penalty of lost finger weight is paid when bunches are harvested before fingers are fully developed. Expanded use of controlled atmospheres (CA) during transport to prevent ripening has facilitated harvesting more-mature bananas regardless of the intended market. The sizes and shapes of finger sections at various stages of maturity are illustrated in figure 31.3.

At harvest, crews pass through the plantation, usually at 3- or 4-day intervals, selecting bunches for harvest. Colored ribbons provide information regarding age. The diameter (caliper) of fruit is also monitored.

Harvesting and field handling vary with location. However, harvesting is usually a two-person operation. The cutter makes a cut with a

Figure 31.1

Postharvest handling of bananas.

Harvesting (cutting of bunches)
↓
Transport by cableway or other means to packing station
↓
Accumulation in shaded holding area
↓
Fruits checked for grade (fullness of fingers, size, freedom from defects), and divided into:
- Processing grade (for banana puree)
- Fresh market grades
↓
Cut hands
↓
Float hands in water to reduce bruising and remove latex
↓
Remove floral relics from fingertips, separate hands into clusters (4 to 10 fingers each), and remove any damaged, deformed, or blemished fingers
↓
Remove clusters from water tank, label with brand name
↓
Treat with a postharvest fungicide [benzimidazole (usually TBZ) or imazalil] and an antioxidant (alum = aluminum potassium sulfate)
↓
Pack into 18.2-kg (40-lb) boxes lined with polyethylene film
↓
Packed boxes are transported and loaded into:
- Containers to be loaded aboard ships
- Trucks
- Rail cars

Trucks and Rail cars ↓
Refrigerated ships holds (80,000 to 200,000 boxes each)
↓
Transport at 14° to 15°C (57° to 59°F) to ports of importing countries
↓
Unload and transport to distribution centers
↓
Ethylene ripening treatment
↓
Retail markets

machete, partially severing the pseudostem at about its midpoint. A backer, positioned under the bunch, catches and braces the

Figure 31.2

Banana fruit bunches are enclosed in plastic bags, and guys are run to prevent pseudostems from falling.

bunch firmly. The cutter then severs the bunch from the pseudostem, just below the basal hands.

TRANSPORTATION TO PACKING STATION

Many banana plantations are equipped with a system of cableways. A backer carries a cut bunch to the nearest cableway, where the bunch is attached by its base to a roller on the cable. The bunches are separated by spacer bars to prevent contact. A train of up to 75 or 150 bunches of 30 to 60 kg (66 to 132 lb) each forms and is pulled along the cableway to the packing area by a small tractor. A tractor that hangs from the cable has the advantage of not requiring roadways or bridges to cross drainage ditches. Bananas waiting to be packed are held in the shade to prevent sunburn (fig. 31.4).

In Queensland and New South Wales, Australia, winter temperatures limit banana production to sunny, northern exposures, often on very steep hills. Some cableway systems have been installed that use gravity as the means of locomotion. Otherwise, bunches accumulate at roadways that have been bulldozed across the slopes. Bunches are placed on small trucks or on trailers, usually two or three bunches deep. Padding is placed on the vehicle bed and between bunches to limit damage. Low tire pressure and low speed during transit are important injury avoidance measures.

In some operations, the hands are separated from the bunch soon after harvest and placed on a padded vehicle bed with pads between the hands to minimize abrasion damage during transport to the packinghouse.

Figure 31.3

Changes in size and shape of banana fruit sections at various stages of maturity.

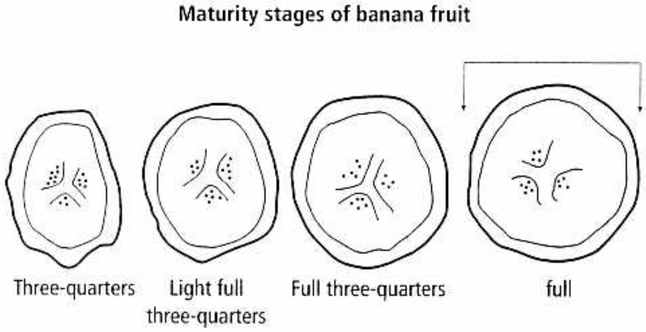


Figure 31.4

A train of banana stems moves to the packinghouse by aerial tramway.

Figure 31.5

Inspecting banana stems.

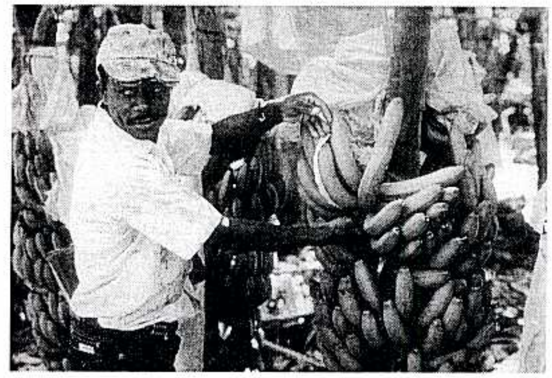


Figure 31.6

A worker cuts the hands from banana stems. Hands are placed in water to clean the fruit and avoid latex stains.

PACKINGHOUSE OPERATIONS

Upon entering the packinghouse, bananas are checked for finger fullness and length, and for blemishes from leaf rub, insect activity, pathogens, and handling bruises (fig. 31.5). Those not meeting a fresh fruit grade can be ripened and processed as puree, sold on secondary markets, or discarded.

Most bananas from the American tropics are shipped as hands in fiberboard cartons. Hands are removed from the stalk by the dehander, using a sharp curved knife (fig. 31.6). When the hand is cut away, latex flows from the wound. If the latex is allowed to coat the surface of the fingers, the resulting stains seriously detract from appearance. Consequently, the hands are immediately placed in water to coagulate the exuded latex and reduce staining (fig. 31.7). Dust and dirt are also removed at the same time.

Selectors at the dehanding tank remove dead floral parts still adhering to the end of the fingers and sort out undersized, damaged, deformed, and blemished fingers. Large hands are divided into smaller clusters to facilitate packing and provide a convenient unit for the consumer. The bananas may be floated in a second water tank for an additional 10 or 15 minutes to permit latex exudation.

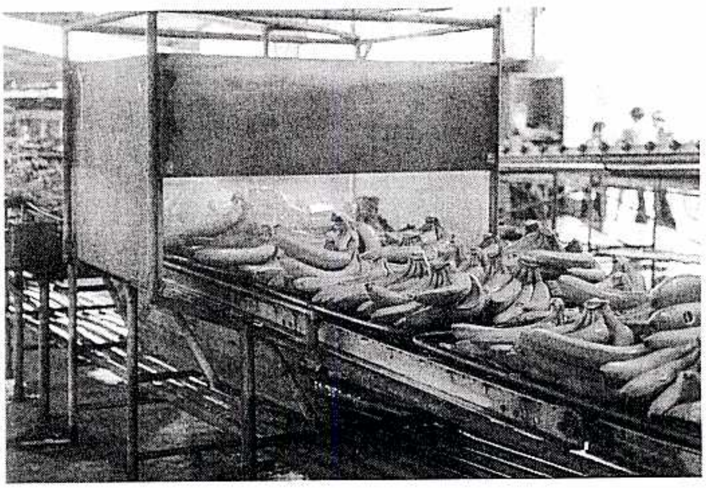
The water tank is a potential source of serious disease problems. Fungus spores on dead floral parts may accumulate in the

Figure 31.7

Bananas are floated in water to coagulate latex exuding from cut surfaces. Withered floral parts are removed from the fingers.

Figure 31.8

Banana hands emerge from a plastic enclosure where the fruit were sprayed with TBZ for disease control and alum as an added precaution against latex staining.



water and contaminate the cut surfaces of freshly cut hands. In particular, crown rot results from inoculation by mixed spores of *Colletotrichum musae*, *Fusarium roseum*, *Nigrospora sphaerica*, *Thielaviopsis paradoxa*, *Botryodiplodia theobromae*, and other fungi.

Sodium hypochlorite in the water is used to kill spores and reduce the likelihood of inoculation. Chlorine concentrations must be carefully monitored and maintained between 75 and 125 ppm. Indicator papers provide a simple and inexpensive means of checking chlorine concentrations. Water should be changed regularly to minimize accumulation of organic materials.

As an alternative, a fungicide (such as TBZ, or imazalil), is added to the wash water instead of as a separate treatment. Relatively large amounts of the fungicide are usually required because the wash water becomes dirty and must be changed from time to time. The fungicide must be included with fresh water.

A fungicide may be applied as a separate dip or spray treatment after washing (fig. 31.8). Alum (aluminum potassium sulfate), which may be applied at the same time, serves as an antioxidant to prevent subsequent latex exudations from darkening and staining the fruit surface. This is the last step before packing. The shorter the time between dehanding and fungicide application the better the subsequent decay control.

PACKING AND SHIPPING

In the American tropics, clusters of fruit are packed in corrugated fiberboard cartons lined with a thin polyethylene film to prevent scuffing of the fingers against the fiberboard (fig. 31.9). The cartons are then moved to conveyors for loading onto trucks or trains for transportation to the wharf. Cartons move by conveyer to an elevated conveyer, or gantry, that lowers them into the hold of a ship. The ship's refrigeration system cools the fruit and holds it at 13° to 14°C (56° to 58°F).

Marine shipment of bananas in refrigerated containers on container ships (fig. 31.10) continues to increase. Faster loading and unloading is an economic advantage for container ships. Containers allow the use of pallets and forklift trucks, and are adaptable to intermodal transportation. Fruit cartons can be loaded into containers at the packing stations and remain untouched until arrival in the destination market area. Presumably, the reduced handling minimizes fruit bruising.

HANDLING IN MARKET AREAS

Banana fingers should be green upon arrival in market areas to provide time for ripening and distribution to retail markets. Facilities for controlled ripening are often provided at produce distribution centers (figs. 31.11 and 31.12). Ripening is triggered by an ethylene exposure of about 24 to 48 hours; by scheduling temperatures and time, distributors have a measure of control over the stage of fruit ripeness delivered to retail stores.

Figure 31.9

Bananas are hand-packed into polyethylene-lined corrugated paper containers.

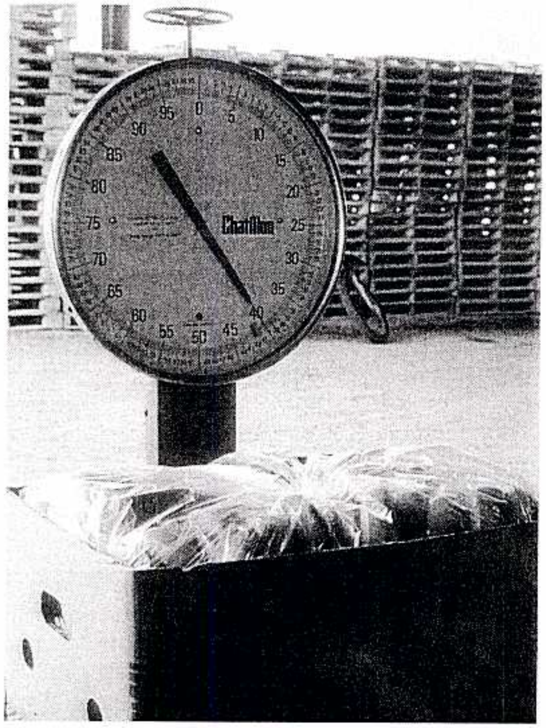


Figure 31.10

Containerized marine transport of bananas.

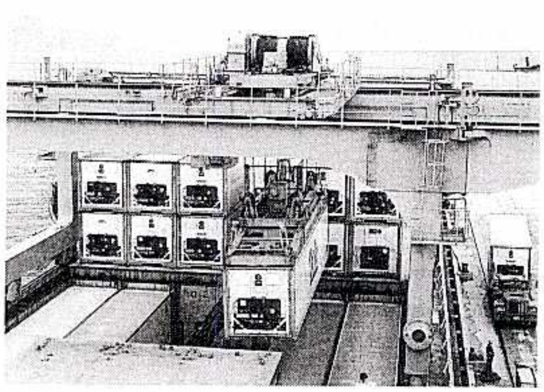


Figure 31.11

Ripening rooms for bananas.

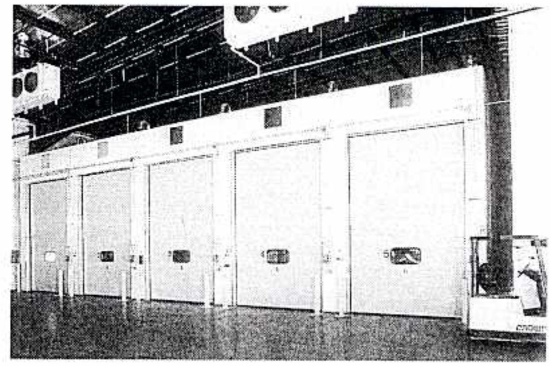
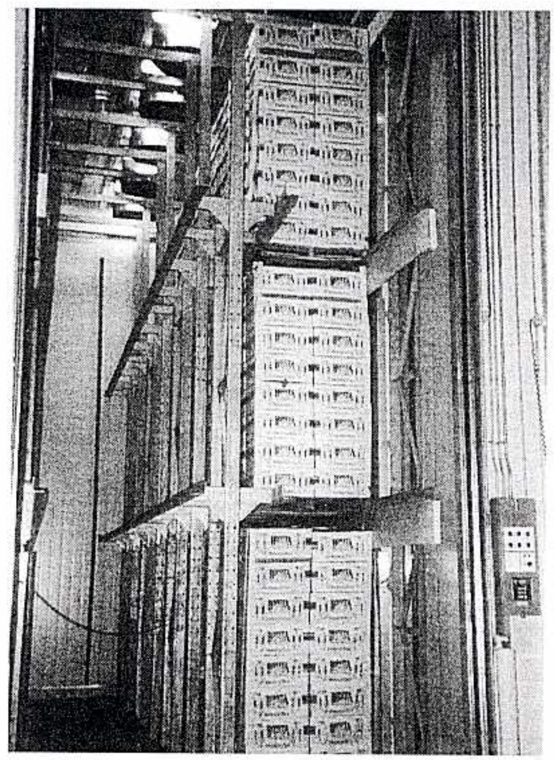


Figure 31.12

Forced-air ripening of bananas on pallets.



RIPENING FACILITIES

Ripening rooms require close temperature control. The rooms must be well insulated and provided with heating and refrigeration. Vigorous air circulation is required to thoroughly disperse the ethylene and remove respiration heat from the fruit. Rooms are made as nearly airtight as possible to contain the ethylene. High RH (90 to 95%) is essential in ripening rooms to avoid fruit dehydration. Moisture may be introduced automatically in the form of steam or a mist or spray of water at ambient temperature. In the absence of a special system, walls and floors may be wetted before closing the room to initiate ripening.

The size of ripening rooms varies with the volume of bananas handled. In modern facilities, bananas are normally handled in palletized cartons. Valuable floor space is better used if rooms are designed for pallets stacked two or three high on supporting framework.

To provide ripening bananas continuously to retail stores, a minimum of three ripening rooms is required; bananas can be delivered from each room on two successive days. Fruit leaving on the second day are somewhat riper than the first day's output. With six or more ripening rooms, all fruit from a single room can be delivered the same day.

CONTROLLED RIPENING

The objective of controlled ripening is to provide retail stores with bananas at a stage of ripeness desired by consumers. The state of ripeness is judged primarily by skin color, using a color number scale of 1 to 7 common in the industry:

1: The finger is hard and completely green
2: Green but with a trace of yellow
3: About half green and half yellow
4: More yellow than green
5: Yellow with green tips
6: Fully yellow
7: Yellow with brown spots

Fruit should be ripened at least to color number 3 before delivery to retail stores, or ripening may not continue normally. Generally, the fruit are not riper than number 4 when shipped from the distribution center to the retail store, as fruit may suffer handling injury if too ripe.

Ripening is initiated by releasing ethylene into the ripening room for 24 to 48 hours with fruit pulp temperatures at 15.5° to 18°C (60° to 65°F) and RH maintained at 90 to 95%. Enough gas is used to provide a concentration, by volume, of 100 to 150 ppm in air with vigorous air circulation, such as forced-air systems to ensure uniform distribution of ethylene. The rate of ripening can be controlled by selecting the appropriate temperature/time schedule.

The ripening rate varies to some extent between lots. Cloudy conditions or low temperature during growth may slow the rate of ripening. Temperature conditions during handling and transit may also affect the ripening rate. In particular, if elevated temperatures have caused some bananas to ripen en route, as shown by slight color changes or slight softening of pulp, the rate of ripening will be much faster than average. The more mature the fingers at harvest the better the quality when bananas ripen.

RESPONSE TO CONTROLLED ATMOSPHERES (CA)

A CA of 2 to 5% O_2 and 2 to 5% CO_2 delays ripening and reduces respiration and ethylene production rates. Exposure to less than 1% O_2 and/or more than 7% CO_2 may cause undesirable texture and flavor. Postharvest life of mature green bananas ranges from 4 to 6 weeks in CA versus 2 to 4 weeks in air at 14°C (58°F). CA of 2% O_2 and 10% CO_2 can be used to delay ripening of partially ripe (color 3 or 4) bananas for up to 1 week at 14°C (58°F).

CHILLING INJURY

Symptoms of chilling injury include surface discoloration, dull or smoky color, subepidermal tissues with dark-brown streaks, failure to ripen, and, in severe cases, flesh browning. Fruit exposed for extended periods to temperatures below about 13°C (56°F) for a few hours to a few days (depending on cultivar, maturity, and temperature) exhibit symptoms of chilling injury. For example, moderate chilling injury will result from exposing mature-green bananas to 1 hour at 10°C (50°F), 5 hours at 11.7°C (53°F), 24 hours at 12.2°C (54°F), or 72 hours at 12.8°C (55°F). Chilled fruit are more sensitive to mechanical injury.

PAPAYAS

Handling and market preparation requirements are influenced greatly by mechanical injury and the susceptibility of papayas to certain diseases. The most important of these is anthracnose, caused by the fungus *Colletotrichum gloeosporioides* (see chapter 18). Infections occur on the tree by direct fungal penetration during fruit development, but disease development does not proceed at this fruit stage because of the almost-complete immunity of the fruit flesh. Infections remain latent until the start of ripening, when the climacteric rise in respiration rate occurs. Fungicidal sprays in the orchard during fruit development are essential for disease control. These sprays do not eliminate the need for postharvest treatments, but they reduce disease pressure considerably. Control requires the use of postharvest treatments.

The major postharvest diseases other than anthracnose are stem-end rots caused by *Ascochyta caricae-papayae* (see chapter 18), *Phomopsis caricae-papayae*, and *Phytophthora nicotiana* var. *parasitica*. Although characteristically colonizing the fruit stem, these fungi often invade wounds caused by handling.

The presence of the Mediterranean, oriental, and melon fruit flies in Hawaii necessitates postharvest treatment to eliminate flies before shipment to noninfested areas. Fruit handling after disinfestation must be in screened areas. Packages must be sealed to avoid reinfestation, unless they can be loaded into marine containers with screen protection.

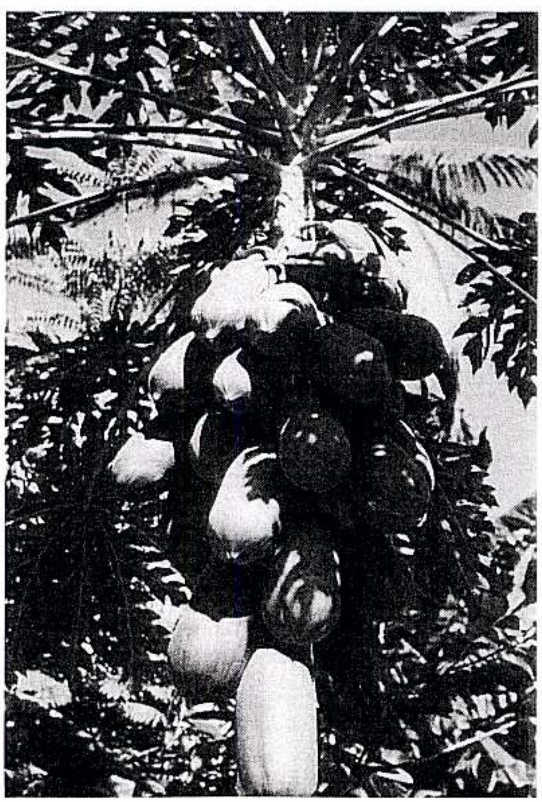
HARVESTING

Papaya trees normally have a single trunk, and the lowermost fruits are the oldest. The fruit's position on the tree, therefore, provides an indication of relative maturity (fig. 31.13).

Fruit are generally picked when they exhibit a slight overall loss of green color, with some hint of yellow at the blossom end. Riper fruit are categorized as one-quarter, one-half, and three-quarters yellow. A minimum soluble solids content of 11.5% is required by the Hawaiian grade standards, and this requires the fruit to be at the color-break stage at harvest.

Figure 31.13

Developing papayas are produced successively on the stem. The lowest fruit are the oldest. Size is variable despite position.



For long-distance shipment, fruit are generally harvested at color break or between color break and one-quarter color. To obtain maximum fruit life for long-distance surface shipments to mainland North America, the fruit are better harvested at the color-break stage. It is difficult to distinguish immature-green from mature-green fruit. Immature-green fruit will not ripen after long-distance refrigerated transport.

Fruit can be harvested by pickers standing on the ground while trees are small. As the fruit-bearing area progresses higher, a long-handled suction cup (plumber's friend) is positioned by the picker over the stylar end of the fruit. A twist of the handle breaks the fruit's pedicel, and the picker catches the fruit if it falls from the suction cup. Fruit are placed in a pail and transferred to field boxes or bins. Motorized picking platforms are used in large plantings as a harvesting aid. Bins or other containers on the picking aid machines permit accumulation of the fruit.

TRANSPORTATION AND PACKINGHOUSE OPERATIONS

Bulk bins and 18.2-kg (40-lb) field boxes are used. Extreme care is essential when filling bins or boxes and transporting them to the packinghouse, because of the fruit's sensitivity to abrasion injury. Compression or impact bruises of partially ripe papayas result from careless handling or transportation over rough roads. Sometimes equally serious is abrasion damage to the fruit's tender skin. The damaged skin area generally does not de-green as the fruit ripens.

Preliminary operations include washing and sorting to separate cull and ripe fruit (which are diverted to processing) from those suitable for fresh marketing. This reduces the volume of fruit that must be heat-treated for insect disinfestation and handled within the insect-proof packinghouse.

Papayas are sorted for off-size or defective fruit as they move on conveyor belts. Fruit can be sized by automatic weight sizers (fig. 31.14). Uniformly sized fruit are hand-packed into shipping cartons (fig. 31.15).

For decay control, bins or pallet loads of fruit may be submerged for 20 minutes in water at 46° to 50°C (114.8° to 122°F) with vigorous circulation. As the fruit warms, the water may cool several degrees.

Figure 31.14

A weight sizer is often used with papayas.

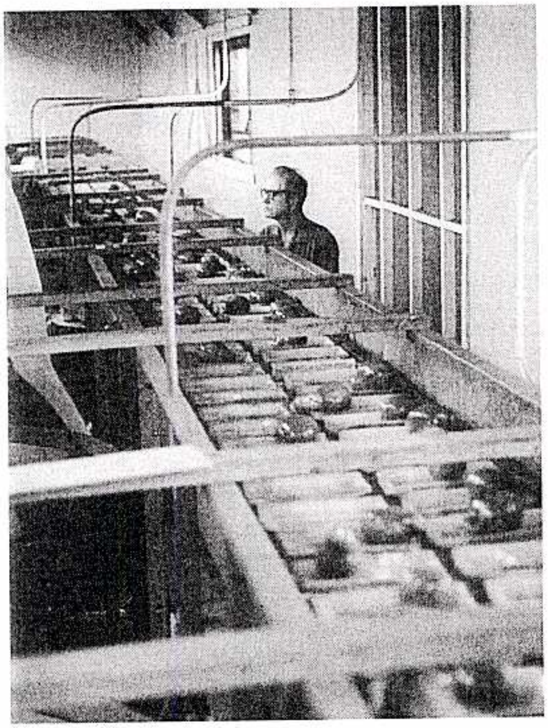
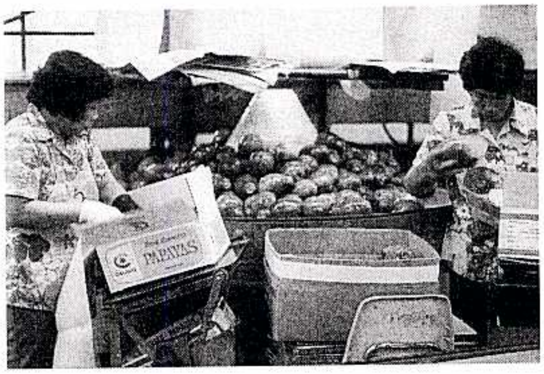


Figure 31.15

Workers hand-pack papayas.



The heat treatment operation, in some cases, has been integrated into the packing-house line. At the speed at which fruit moves through such lines, the dwell period in the hot water (without excessively long tanks) would necessarily be very brief. To obtain enough heat penetration for fungicidal effectiveness, the temperature of the water must be very high, 54°C (129°F) for 3 minutes. Positive movement of fruit through such a spray to insure that each fruit is exposed to an exact dwell time is essential. Longer periods lead to heat injury. In papayas, heat injury results in scald, failure to degreen, and increased decay incidence.

HEAT TREATMENTS FOR INSECT CONTROL

There are currently two approved heat treatments for papayas: vapor heat and forced hot air. The vapor treatment is administered in a room with accurate temperature control and adequate air circulation. Fruit temperature is raised until the center of the fruit reaches 47.2°C (117°F) at a RH of 60 to 95%, depending upon treatment.

In 1989 a multistage high-temperature forced-air heat treatment was approved as follows:

Temperature		
Air °C(°F)	Seed cavity °C (°F)	Time (hr)
43 (109.4)	41 (105.8)	2
45 (113.0)	44 (111.2)	2
46.5(115.7)	46 (114.8)	2
49 (120.2)	47.2 (117.0)	Final

After reaching the final stage, the fruit is then immediately cooled in water at 20° to 25°C (68° to 77°F).

TRANSPORTATION AND STORAGE TEMPERATURES

Optimal temperatures: 0°C (50°F) for mature-green to one-half yellow papayas for less than 21 days; 7°C (45°F) for ripe (greater than one-half yellow) papayas.

Chilling injury. Symptoms include blotchy coloration, uneven ripening, skin scald, hard core (hard areas in the flesh around the vascular bundles), air pockets in the tissues, and increased susceptibility to decay. Increased Alternaria rot is observed in mature-green papayas kept for 4 days at 2°C (36°F), 6 days at 5°C (41°F), 10 days at 7.5°C (45°F), or 14 days at 10°C (50°F). Susceptibility to chilling injury varies among cultivars and is greater in mature-green than ripe papayas: 10 versus 17 days at 2°C (36°F); 20 versus 26 days at 7.5°C (45°F).

Heat Injury. Exposure of papayas to temperatures above 30°C (86°F) for longer than 10 days or to temperature-time combinations beyond those needed for decay and/or insect control results in heat injury (uneven ripening, blotchy ripening, poor color, abnormal softening, surface pitting, accelerated decay). Quick cooling to below

30°C (86°F) after heat treatments minimizes heat injury.

RESPONSES TO ETHYLENE TREATMENT

Exposure to 100 ppm ethylene at 20° to 25°C (68° to 77°F) and 90 to 95% RH for 24 to 48 hours results in faster and more uniform ripening (skin yellowing and flesh softening, but little or no improvement in flavor) of papayas picked at color break to one-quarter yellow stage. Commercial treatments are not recommended due to the rapid softening.

RESPONSES TO CONTROLLED ATMOSPHERES

Optimal CA for papaya is 3 to 5% and 5 to 8% CO_2. Benefits of CA include delayed ripening and firmness retention. Postharvest life potential at 13°C (55°F) is 2 to 3 weeks in air and 2 to 4 weeks in CA, depending on cultivar and ripeness stage at harvest.

MANGOES

The essential operations that prepare mangoes for market include harvesting, transport to packing area, washing, sorting, sizing, packaging, and transport to market. Frequently, mangoes must be treated for quarantine purposes before fruits can enter certain markets.

HARVESTING

Mangoes picked for nearby markets may exhibit color changes from dark green to light green or even to light yellow. Fruit are harvested while still dark green if destined for distant markets requiring several days of transit. Harvesting mangoes prior to external color change makes it difficult to discriminate between fruit that can ripen to an acceptable quality and those that cannot. In general, dark-green mature fruit are harvested when the cheeks have filled out. In some cultivars, maturity is indicated by the degree to which the shoulder extends out at the stem end.

Maturity indices commonly used with other fruits have not proven adaptable to dark-green mangoes. Changes in flesh texture (softening), total soluble solids, and acidity have not proved useful, as they occur mostly after the proper harvest time for distant markets. Studies suggest that flesh color, starch content, and specific gravity might be useful indices for some cultivars.

Figure 31.16

A picking pole of the type commonly used for mangoes or fruits of other large trees.

Mangoes are harvested by hand if the pickers can reach them. The fruit is twisted sharply sideways or upward to break the pedicel. To avoid stem punctures, any long pedicels are trimmed flush with the stem end of the fruit. Fruit on high branches are harvested with a picking pole that has a cloth bag and cutting knife at the top (fig. 31.16). When the pedicel is severed, the fruit drops into the bag, the picking end of the pole is gently lowered to the ground, and fruit placed into 18- to 23-kg (40- to 50-lb) field boxes or bins for transport to the packinghouse.

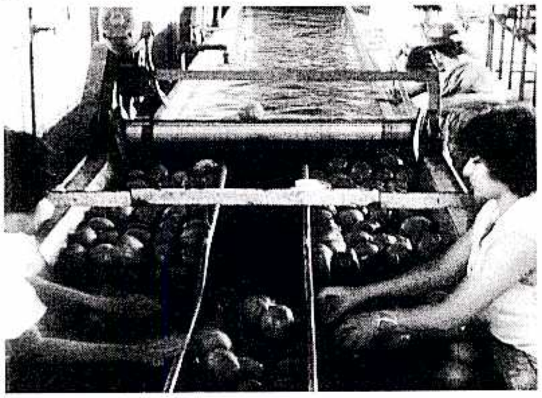
PACKINGHOUSE OPERATIONS

Mature-green mangoes exude a large amount of latex from the cut stem. This is washed off with water in a tank. The water may contain imazalil (or thiabendizole, TBZ) fungicide, mainly to control anthracnose caused by the fungus *Colletotrichum gloeosporioides*. Disease control is more effective if the solution is heated (fig. 31.17). Postharvest fungicidal treatments commonly consist of water at 50°C ± 2°C (122°F ± 4°F) containing 0.1% TBZ. Mangoes are submersed in the water for 5 to 10 minutes (depending on fruit size).

Sorters generally examine fruit as it passes on moving belts. Fruit that are judged immature, overmature, or undersized, and those exhibiting limb-rub or other defects, are diverted. Sizing is usually by eye, but use of weight sizers and other mechanical sizers is increasing.

Figure 31.17

Mango packinghouse. A hot water–thiabendazole bath is in the background, and a sorting table is in the foreground.



Although various containers are used, mangoes are commonly packed in one or more layers in fiberboard boxes that may have individual compartments for separating fruit.

Postharvest quarantine treatment for fruit flies

A hot water dip treatment is now registered for mangoes. The duration and temperature of the treatment varies with the country of origin, cultivar, and fruit size. Pulp temperature prior to treatment for all mangoes must be a minimum of 21.1°C (70°F). Generally the fruit are treated in hot water at 46.4°C (115.5°F) for 65 to 90 minutes. The fruit pulp temperature must be between 45.6°C (114°F) and 46.1°C (115°F) for 10 minutes during this treatment. Exceeding the time or temperature combinations recommended for decay or insect control causes heat injury (skin scald, blotchy coloration, uneven ripening).

MANAGEMENT OF RIPENING

Mature-green mangoes may be subjected to an ethylene treatment of 100 ppm for 24 to 48 hours at 20°C (68°F) and 90 to 95% RH to promote faster and more uniform ripening. The treatment may be applied at the shipping point if transit time to market is less than 5 days, or at the destination if transit times are longer.

TRANSPORTATION AND STORAGE TEMPERATURES

Mature-green mangoes should be handled at 13°C (55°F) while partially ripe mangoes can be kept at 10°C (50°F). At lower temperatures mangoes are susceptible to chilling injury, depending on the duration. Symptoms include uneven ripening, poor color and flavor, surface pitting, grayish scald-like skin discoloration, increased susceptibility to decay, and, in severe cases, flesh browning. Chilling injury incidence and severity depend on cultivar, ripeness stage (riper mangoes are less susceptible), and the temperature and duration of exposure.

PINEAPPLES

The pineapple fruit is a multiple structure that evolved, presumably, from a racemose inflorescence. Berrylike fruitlets, generally 100 to 200 in number, and their subtending leafy bracts are together fused to the core, a continuation of the fibrous peduncle. The fruitlets are in a regular spinal pattern on the fruit axis, the pattern usually consisting of two distinct spirals, one turning to the left and the other to the right.

The short, shootlike, leaf-bearing growth at the top of the fruit is called the crown. The crown is a continuation of the original meristem of the plant's main axis extending through the fruit. Crowns are frequently used as planting materials after they are removed from fruits that are to be processed. Slips and suckers developing from axillary buds at the base of the leaves below the fruit and base of the plant, respectively, are other choices for planting materials.

The most widely grown pineapple cultivar is the Smooth Cayenne, although other cultivars are locally important, especially for the fresh market. These include Red Spanish, Queen, Singapore, Spanish, Selangor Green, Sarawak, and Maritius. Postharvest handling operations are shown in figure 31.18.

MATURITY

During maturation pineapples increase in weight, flesh soluble solids, and acidity. During ripening, the carotenoid pigments and soluble solids of the flesh increase dramatically, and the fruit attains its maximum aesthetic and eating quality. During ripening, the shell of the pineapple loses chlorophyll rapidly, starting at the fruit base, in a process similar to that of de-greening citrus fruit.

Approximately 110 days elapse between the end of flowering and ripeness. Ethephon may be sprayed about 6 days before planned harvest to stimulate color change from green to yellow.

Harvest time is often when the base of the fruit has changed from green to yellow or light brown. Fruit may be harvested for fresh market before striking color changes have occurred, since acceptable quality may develop before color changes occur in the shell. Since the pineapple fruit has no accumulation of starch, there is no reserve for major postharvest quality improvements. As a nonclimacteric fruit, obvious compositional changes after harvest are mostly limited to de-greening and a decrease in acidity. A minimum soluble solids of 12% and a maximum acidity of 1% will assure minimum flavor acceptability by most consumers.

Figure 31.18

Postharvest handling of pineapples.

Harvest by hand
↓
Place on conveyor belt
↓
Automatically load into gondolas
↓
Transport to packinghouse or processing plant
↓
Dump
↓
Trim stem to 1 to 3 cm (0.4 to 1.2 in)
↓
Wax spray or dip with a benzimidazole fungicide
↓
Sort for quality
↓
Sizing
↓
Hand-pack into cartons
(dividers may be used to reduce fruit-to-fruit contct)
↓
Cooling
↓
Load into transit vehicle
↓
Air or marine transport to market

HARVESTING

Pickers select fruit by color, size, or both, and twist it from the stalk. In small operations the harvested fruit may be field-packed or placed in sacks or baskets that are carried to the end of the row for pickup.

Large-scale production avoids hand-carrying by using a harvesting aid consisting of a belt extending across a number of rows (fig. 31.19). Fruit picked by hand are placed on the belt and carried to the machine where the fruit are accumulated in a bin or truck gondola. The machine and belts, usually mounted on a truck chassis, move slowly across the field at a speed determined by the pickers.

PACKINGHOUSE OPERATIONS

At the packinghouse fruit are sorted to eliminate defective fruit. Sizing may be by eye or weight sizers (fig. 31.20).

A fungicidal treatment consists of a Bayleton dip or spray, commonly applied before packing, to control black rot disease caused by the fungus *Thielaviopsis paradoxa*.

Figure 31.19

A pineapple harvest aid in use.

Figure 31.20

Weight-sizing pineapples.

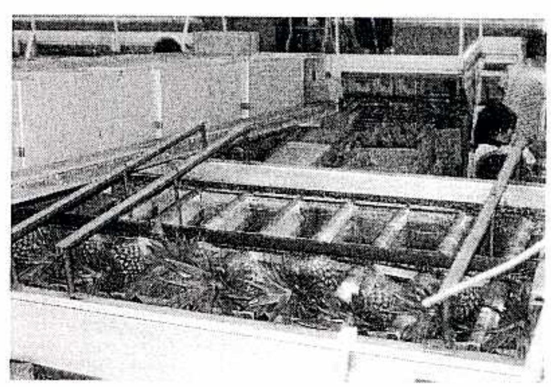


Figure 31.21

Wax is applied to pineapple fruits.

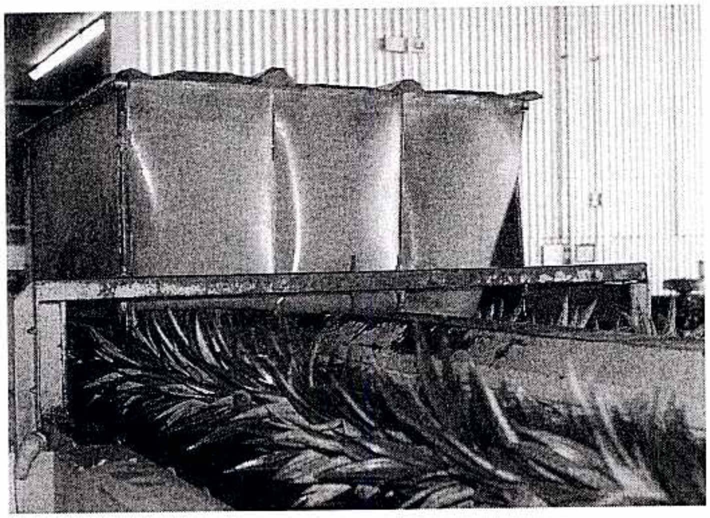


Figure 31.22

Workers hand-pack pineapple fruits.

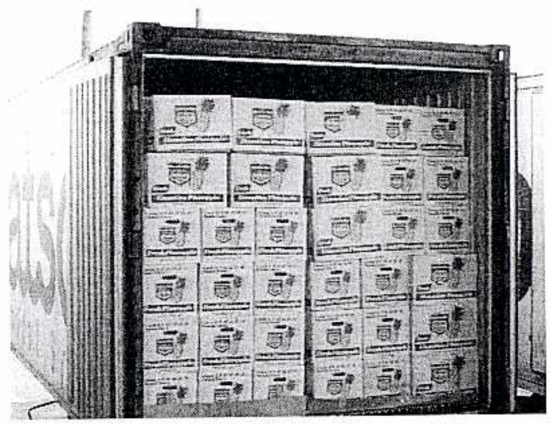
Uncontrolled, the disease is serious in fruit after harvest. The fungus enters the fruit via wounds or at the broken stem and grows rapidly throughout the fruit flesh. A very watery soft rot is produced. In the past, the stem surface was smeared with a paste containing a fungicide such as benzoic acid to prevent water blister.

Figure 31.23

Pineapples are packed in shipping cartons.

Figure 31.24

A refrigerated marine container is loaded with pineapples.



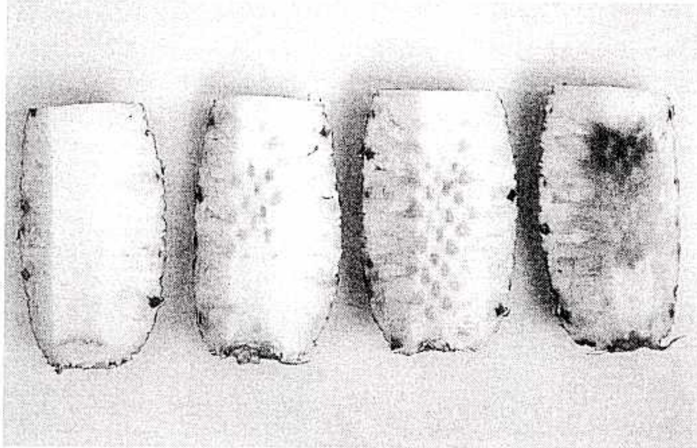
Pineapples are sometimes waxed to reduce chilling disorders (fig. 31.21) and improve appearance. Fruit are packed into single-layer or full telescoping cartons (figs. 31.22 and 31.23) with inside dimensions of approximately 30.5 cm wide by 45 cm long by 31 cm deep (12 by 17.7 by 12.2 in). From 8 to 14 or 16 fruit of uniform size are placed in each container.

HOLDING AND TRANSIT

Pineapple fruit are shipped in marine containers (fig. 31.24) or by air. Postharvest life potential is 2 to 4 weeks in air and 4 to 6 weeks in CA (3 to 5% O_2 + 5 to 8% CO_2) at 10°C (50°F), depending on cultivar and ripeness stage. The pineapple is a chilling-sensitive tropical fruit. Chilling injury symptoms include darkening of flesh tissues, particularly around the central cylinder. This condition was called endogenous brown spot (EBS) and was frequently seen in pineapples (fig. 31.25) harvested in the winter. Temperatures below about 6°C (42.8°F) may result in chilling injury.

Figure 31.25

Endogenous brown spot disorder of pineapples.



Waxing pineapples to encourage accumulation of up to 5 to 8% CO_2 is effective in reducing chilling injury symptoms. A heat treatment at 35°C (95°F) for 1 day has been shown to ameliorate EBS symptoms in pineapples transported at 7°C (45°F) by inhibiting activity of polyphenol oxidase and consequently tissue browning. However, this treatment is difficult to apply on a commercial scale and more expensive than waxing.

REFERENCES

Alvarez, A. M., and W. T. Nishijima. 1987. Postharvest diseases of papaya. Plant Dis. 71:681–686.

Barmore, C. R. 1974. Ripening mangoes with ethylene and ethephon. Proc. Fla. State Hortic. Soc. 87:331–334.

Cappellini, R. A., M. J. Ceponis, and G. W. Lightner. 1988a. Disorders in apricot and papaya shipments to the New York market, 1972–1985. Plant Dis. 72:366–370.

———. 1988b. Disorders in avocado, mango, and pineapple shipments to the New York market, 1972–1985. Plant Dis. 72:270–274.

Chen, N. M., and R. E. Paull. 1986. Development and prevention of chilling injury in papaya fruit. J. Am. Soc. Hortic. Sci. 111:639–643.

Couey, H. M. 1989. Heat treatment for control of postharvest diseases and insect pests of fruits. HortScience. 24:198–202.

Dodd, J. C., D. Prusky, and P. Jeffries. 1997. Fruit diseases. In R. E. Litz, ed., The mango: Botany, production and uses. Wallingford, UK: CAB International. 257–280.

Eckert, J. W., and J. M. Ogawa. 1985. The chemical control of postharvest diseases: Subtropical and tropical fruits. Annu. Rev. Phytopathol. 23:421–454.

Gomez-Lim, M. A. 1997. Postharvest physiology. In R. E. Litz, ed., The mango: Botany, production and uses. Wallingford, UK: CAB International. 425–445.

Hassan, A., and E. B. Pantastico, eds. 1990. Banana: Fruit development, postharvest physiology, handling and marketing in ASEAN. Kuala Lumpur: ASEAN Food Handling Bureau. 147 pp.

John, P., and J. Marchal. 1995. Ripening and biochemistry of the fruit. In S. Gowen, ed., Bananas and plantains. London: Chapman and Hall. 434–467.

Johnson, G. I., J. L. Sharpe, D. L. Milne, and S. A. Oosthuyse. 1997. Postharvest technology and quarantine treatments. In R. E. Litz, ed., The mango: Botany, production and uses. Wallingford, UK: CAB International. 447–507.

Marriott, J. 1980. Bananas—Physiology and biochemistry of storage and ripening for optimum quality. Crit. Rev. Food Sci. Nutr. 13:41–88.

Mendoza, D. B., Jr., and R. B. Wills, eds. 1984. Mango: Fruit development; postharvest physiology, and marketing in ASEAN. Kuala Lampur: ASEAN Food Handling Bureau. 111 pp.

Mitra, S., ed. 1997. Postharvest physiology and storage of tropical and subtropical fruits. Wallingford, UK: CAB International. 423 pp.

Nagy, S., and P. E. Shaw. 1980. Tropical and subtropical fruits—Composition, properties and uses. Westport, CT: AVI. 570 pp.

Nagy, S., P. E. Shaw, and W. F. Wardowski, eds. 1990. Fruits of tropical and subtropical origin: Composition, properties and uses. Lake Alfred, FL: Florida Science Source. 391 pp.

Nakasone, H. Y., and R. E. Paull. 1998. Tropical fruits. Wallingford, UK: CAB International. 445 pp.

Pantastico, E. B. 1975. Postharvest physiology, handling and utilization of tropical and subtropical fruits and vegetables. Westport, CT: AVI. 560 pp.

Paull, R. E. 1993. Pineapple and papaya. In G. B. Seymour et al., eds., Biochemistry of fruit ripening. London: Chapman and Hall. 291–323.

Paull, R. E., and N. J. Chen. 1989. Waxing and plastic wraps influence water loss from papaya fruit during storage and ripening. J. Am. Soc. Hortic. Sci. 114:937–942.

Paull, R. E., and K. G. Rohrbach. 1985. Symptoms development of chilling injury in pineapple fruit. J. Am. Soc. Hortic. Sci. 110:100–105.

Paull, R. E., W. Nishijima, M. Reyes, and C. Cavaletto. 1997. Postharvest handling and losses during marketing of papaya. Postharv. Biol. Technol. 11:165–179.

Seymour, G. B. 1993. Banana. In G. B. Seymour et al., eds., Biochemistry of fruit ripening. London: Chapman and Hall. 83–106.

Shaw, P. E., H. T. Chan Jr., and S. Nagy, eds. 1998. Tropical and subtropical fruits. Auburndale, FL: AgScience. 569 pp.

Slabaugh, W. R., and M. D. Grove. 1982. Postharvest diseases of bananas and their control. Plant Dis. 66:746–750.

Thompson, A. K., and O. J. Burden. 1995. Harvesting and fruit care. In S. Gowen, ed., Bananas and plantains. London: Chapman and Hall. 403–433.

Wainwright, H., and M. B. Burbage. 1989. Physiological disorders in mango (*Mangifera indica* L.) fruit. J. Hort. Sci. 64:125–135.

Yahia, E. M. 1998. Modified and controlled atmospheres for tropical fruits. Hort. Rev. 22:123–183.

Yon, R. M., ed. 1994. Papaya: Fruit development, postharvest physiology, handling and marketing in ASEAN. Kuala Lumpur: ASEAN Food Handling Bureau. 144 pp.