28

Postharvest Handling Systems: Stone Fruits

I. Peach, Nectarine, and Plum

Carlos H. Crisosto and F. Gordon Mitchell

California is a major producer and shipper of peach, nectarine, and plum fruits in the United States. Fresh peaches, nectarines, and plums constitute the bulk of the California fresh tree-fruit industry, and current shipments approach 60 million 11.4-kilogram (25-lb) packages of more than 450 cultivars of these three kinds of stone fruits. In the San Joaquin Valley, harvest of early cultivars starts in late April, and harvest of late cultivars of nectarines, peaches, and plums is completed in early October. In recent years, a large increase in the production of white-flesh peach and nectarine cultivars has occurred. Peach, nectarine, and plum exports are mainly to Canada, Taiwan, Hong Kong, Mexico, Brazil, and New Zealand.

DETERIORATION PROBLEMS

Stone fruits are characteristically soft-fleshed and highly perishable, and they have a limited market life potential. Because of the large number of cultivars spanning a 5-month harvest season, long-term storage has historically not been a concern in California. Potential opportunities for export marketing, combined with the desire to store some late-season cultivars to extend the marketing season, has increased interest in procedures to extend postharvest life.

INTERNAL BREAKDOWN

The major physiological cause of deterioration in peach, nectarine, and plum is a low-temperature or chilling injury problem generically called internal breakdown (IB). The disorder can manifest itself as dry, mealy, woolly, or hard-textured fruit (not juicy); flesh or pit cavity browning; and flesh translucency usually radiating through the flesh from the pit (fig. 28.1). An intense red color in the flesh ("bleeding"), usually radiating from the pit, may be associated with this problem in some cultivars. In all of the cases, flavor is lost before visual symptoms are evident. However, there is large variability in internal breakdown susceptibility among peach, nectarine, and plum cultivars. In general, peach cultivars are more susceptible than nectarine and plum.

In susceptible cultivars, internal breakdown symptoms develop faster and more intensely when fruit are stored at temperatures between about 2° and 7°C (36° and 45°F) than when similar fruit are stored at 0°C (32°F) or below but above the freezing point (fig. 28.2). At the shipping point, fruit should be cooled and held near or below 0°C (32°F) if possible. During transportation, if IB-susceptible cultivars are exposed to approximately 5°C (41°F), it can significantly reduce their postharvest life.

Several treatments to delay and limit development of this disorder have been tested. Among them, preripening fruit before storage is used commercially within the United States. The success of CA treatment (6% O_2 with 17% CO_2) in ameliorating chilling injury depends on cultivar market life, fruit maturity, shipping time, and fruit size.

FRUIT DECAY ORGANISMS

Postharvest loss of stone fruits to decay-causing fungi is considered

Figure 28.1

Internal breakdown symptoms in peaches and nectarines include mealiness (left) and browning (right).

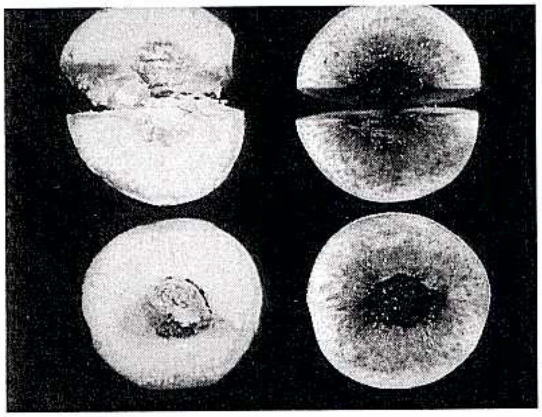
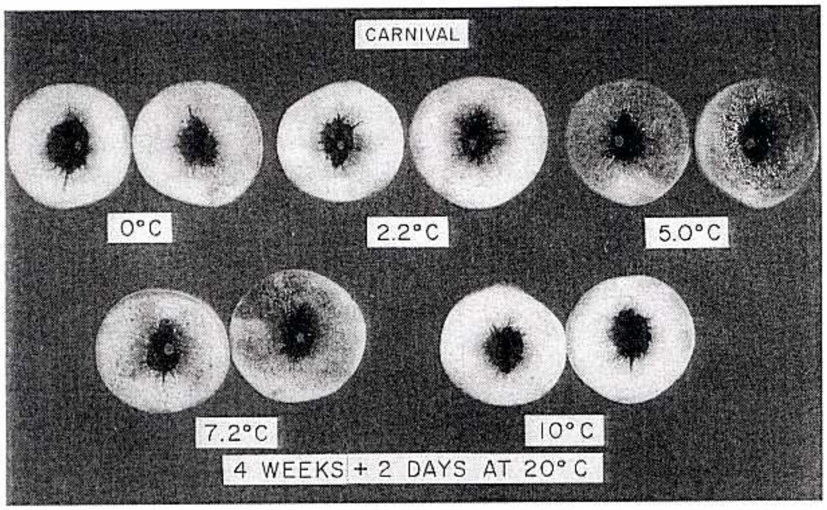


Figure 28.2

Storage temperature influences incidence and severity of internal breakdown in stone fruits.



the greatest deterioration problem. Worldwide, the most important pathogen of fresh stone fruits is Botrytis rot, caused by the fungus *Botrytis cinerea*. In California an even greater cause of loss is brown rot, caused by the fungus *Monilinia fructicola*. Good orchard sanitation practices and fungicide applications are essential to reduce these problems. It is common to use a postharvest fungicidal treatment against these diseases. An EPA-approved fungicide is often incorporated into a fruit wax for uniformity of application. Careful handling to minimize fruit injury, sanitation of packinghouse equipment, and rapid, thorough cooling to 0°C (32°F) as soon after harvest as possible are also important for effective disease suppression.

MECHANICAL INJURIES

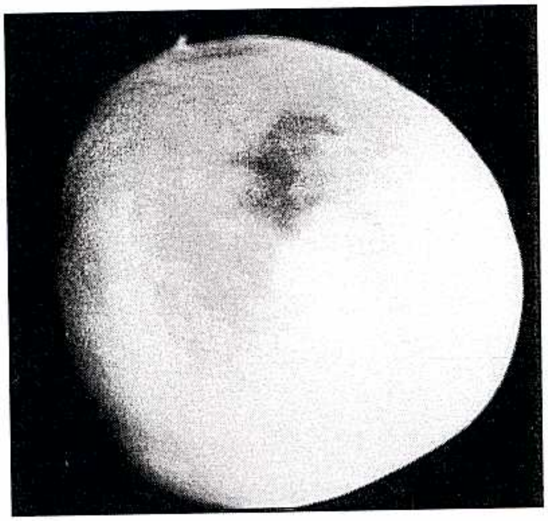
Stone fruits are susceptible to mechanical injuries including impact, compression, and abrasion (or vibration) bruising. Careful handling during harvesting, hauling, and packing operations to minimize such injuries is important because the injuries result in reduced appearance quality, accelerated physiological activity, potentially more inoculation by fruit decay organisms, and greater water loss. Incidence of impact and compression bruising has become a greater concern as a large part of the California industry is harvesting fruit at more advanced maturity (softer) to maximize fruit flavor quality. Several surveys carried out in the Fresno area indicated that most impact bruising damage occurs during the packinghouse operation and during long transportation from orchard to packinghouse. Critical impact bruising thresholds (the minimum fruit firmness measured at the weakest point to tolerate impact abuse) has been developed for many peach, nectarine, and plum cultivars. Plums are less susceptible to impact bruising than peaches and nectarines.

Abrasion damage can occur at any time during postharvest handling. Protection against abrasion damage involves procedures to reduce vibrations during transport and handling by immobilizing the fruit. These procedures include installing air suspension systems on axles of field and highway trucks, using plastic film liners inside field bins, installing special top pads on bins before transport, avoiding abrasion on the packing line, and using packing procedures that immobilize the fruit within the shipping container before they are transported to market. Using half-size plastic bins can also reduce abrasion and impact damage.

If abrasion damage occurs during harvesting on fruit that have heavy metal contaminants, such as iron, copper and/or aluminum, on their skin, a dark discoloration is formed on the surface of peaches and nectarines (fig. 28.3). These dark or brown spots or stripes (inking or skin discoloration) are a cosmetic problem and a reason to cull the fruit. Heavy metal contaminants on the surface of fruit can occur as a consequence of foliar nutrients and/or fungicides applied within 15 days or 7 days before harvest, respectively. Light brown spots or stripes are also produced on the surface of white-flesh

Figure 28.3

Surface discoloration (inking) on peaches and nectarines.



peaches and nectarines as a consequence of abrasion occurring mainly during harvesting and hauling operations.

WATER LOSS

Loss of approximately 5 to 8% of the fruit's water content, based on weight at harvest, can cause visual shrivel in peaches and nectarines. While there is a large variability in susceptibility to water loss among cultivars, all stone fruits must be protected to assure the best postharvest life. Fruit waxes that are commonly used as carriers for postharvest fungicides can reduce the rate of water loss when brushing is not excessive. Mineral oil waxes can potentially control the rate of water loss better than vegetable oil and edible coatings. Because fruit shrivel results from cumulative water loss throughout handling, it is important to maintain low water deficit conditions throughout harvesting, packing, storage, transport, and distribution. Short intervals between harvest and cooling, efficient waxing with gentle brushing, and fast cooling followed by storage under constant low temperature and high RH are the main ways of limiting water loss. Because of injuries caused on peaches when they are brushed to remove the trichomes ("fuzz"), this treatment increases water loss.

TEMPERATURE MANAGEMENT

Cooling requirements depend in part upon the scheduling of the packing operation. Fruit can be cooled in field bins using forced-air cooling or hydrocooling. Forced-air cooling in side-vented bins can be by either the tunnel or the serpentine method (see chapter 11 for more details on cooling). Hydrocooling is normally done by a conveyor-type hydrocooler. Cooling of packed fruit is normally by forced air, using either the tunnel or cold wall method. Fruit in field bins can be cooled to intermediate temperatures (5° to 10°C [41° to 50°F]) provided that packing and subsequent forced-air cooling will occur the next day. If packing is to be delayed beyond the next day, fruit should be thoroughly cooled in the bins to near 0°C (32°F). With IB-susceptible cultivars, fast cooling within 8 hours and maintaining fruit temperature near 0°C (32°F) are recommended.

Fruit in packed containers should be cooled to near 0°C (32°F). Even fruit that were thoroughly cooled in the bins will warm substantially during packing and should be thoroughly recooled after packing. Forced-air cooling is normally indicated after packing. An exception to the need for cooling after packing would be a system that handles completely cooled fruit and provides protection against rewarming during packing.

Stone fruit storage and overseas shipments should be at or below 0°C (32°F). Maintaining these low temperatures requires knowledge of the freezing point of the fruit and knowledge of the temperature fluctuations in the storage system. Temperatures during truck transportation within the United States, Canada, and Mexico should be kept below 2°C (36°F). Holding stone fruits at these low temperatures minimizes the losses associated with rotting organisms, excessive softening, and water loss, as well as the deterioration resulting from internal breakdown in susceptible cultivars.

HARVEST MATURITY

The maturity at which stone fruits are harvested greatly influences their ultimate flavor and market life. Harvest maturity controls the fruit's flavor components, physiological deterioration problems, susceptibility to mechanical injuries, resistance to moisture loss, susceptibility to invasion by rot organisms, market life, and ability to ripen. Stone fruits that are harvested too soon (immature) may fail to ripen properly or may ripen abnormally. Immature fruit typically soften slowly and irregularly, never reaching the desired melting texture of fully matured fruit. The green ground color of fruit picked immature may never fully disappear.

Because immature fruit lack a fully developed surface cuticle, they are more susceptible to water loss than properly matured fruit. Immature and low-maturity fruit have lower soluble solids content and higher acids than properly matured fruit. This contributes to inadequate flavor development. Low-maturity fruit are more susceptible to abrasion and the development of internal breakdown symptoms than properly matured fruit.

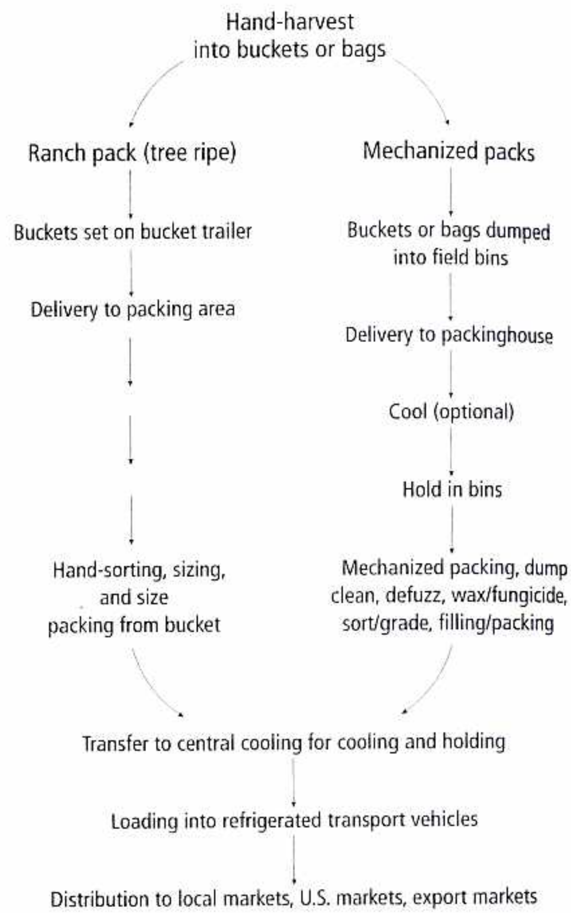
Overmature fruit have a shortened postharvest life, primarily because they are already approaching a senescent stage at harvest. Such fruit have partially ripened, and the resulting flesh softening renders them highly susceptible to mechanical injury and microbial invasion. By the time these fruit reach the consumer they may have become overripe, with poor eating quality including off-flavors and mealy texture.

The optimal maturity for stone fruit harvest must be defined for each cultivar. The highest maturity at which a cultivar can be successfully harvested is limited by postharvest handling and temperature management procedures. Although maturity selection is more critical for distant markets than for local markets, this does not necessarily mean lower maturity for distant markets. When stone fruits are harvested at low maturity to reduce senescent breakdown problems during long-distance marketing, they become more susceptible to losses from internal breakdown.

Because of the availability of new cultivars that adapt well to harvesting at a more mature stage (softer), and because of the increase in demand for high-quality, less-firm fruit and the use of more sophisticated packinghouse equipment, a larger proportion of California stone fruits are being picked in a more advanced maturity stage.

Figure 28.4

Postharvest handling of fresh-shipped stone fruits.



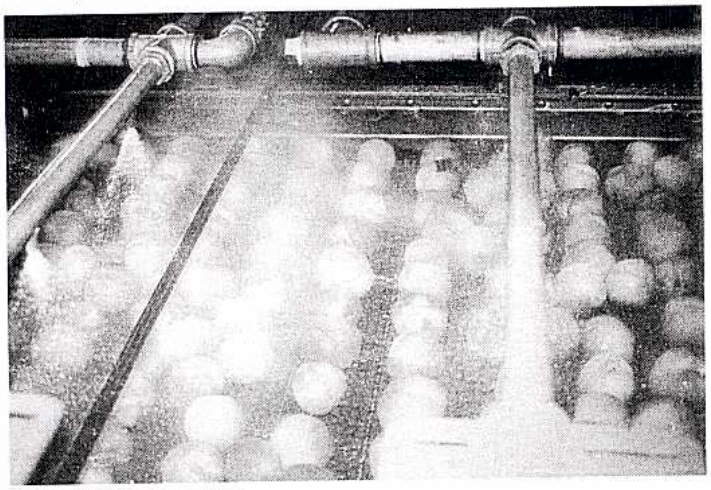
FIELD HANDLING

Peaches, nectarines, and plums are hand-picked into bags, baskets, or totes (fig. 28.4). The fruit are dumped in bins carried by trailers in the orchard. Totes are placed directly inside the bins; baskets are placed on modified trailers. Fruit picked at advanced maturity stages, and white-flesh peaches or nectarines, are generally picked and placed into baskets or totes. The fruit are hauled for short distances by trailers, but if the distance is longer than 10 km (6 mi), the bins are loaded on a truck for transportation to packinghouses.

Physical wounding of stone fruits can occur at any time from harvest until consumption. Good worker supervision helps assure adequate protection against impact bruising and mechanical damage during picking, handling, and transport of fruit. Protection against roller bruising may require modifications of transport equipment and procedures, as described in chapter 8. If severe injuries are encountered, consider using a top bin pad that maintains a slight tension across the top fruit. It is also helpful to grade farm roads to reduce roughness, avoid rough roads during transport, and establish strict speed limits for trucks operating between orchards and packinghouses.

Figure 28.5

Washing of stone fruits at the packinghouse.



PACKING AND HANDLING

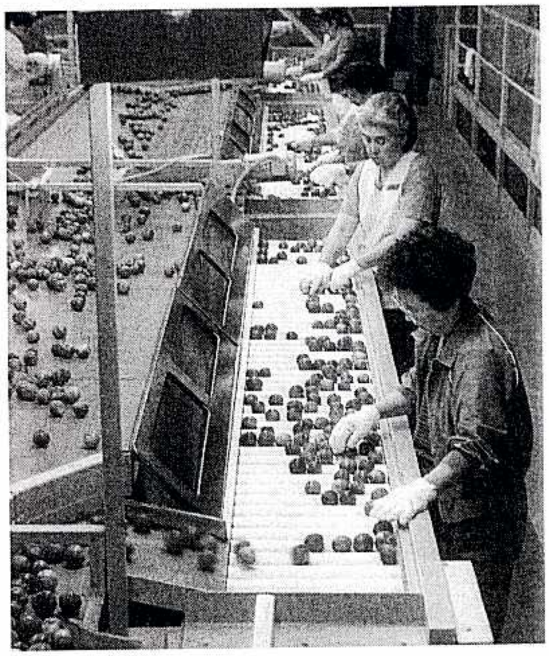
Stone fruits are transported from orchard to packinghouse and cooler as soon as possible after harvest (see fig. 28.4). Fruit should be shaded during any delay between harvest and transport. Stone fruits are often cooled as soon as they arrive from the orchard, then packed cool the next day. Some fruits are packed upon arrival from the orchard and cooled immediately after packing. At the packinghouse the fruit are dumped (almost exclusively using dry bin dumps) and cleaned. Here trash is removed and fruit may be washed with detergent. Peaches are normally wet-brushed (fig. 28.5) to remove the trichomes (fuzz), which are single-cell extensions of epidermal cells. Waxing and fungicide treatment may follow. Water-emulsifiable waxes are normally used, and fungicides may be incorporated into the wax. Waxes are applied cold. In most of the "ranch pack" operations, peaches are not normally brushed.

Sorting is done to eliminate fruit with visual defects and sometimes to divert fruit of high surface color to a high-maturity pack (fig. 28.6). Attention to details of sorting line efficiency, as described in chapter 8, is especially important with stone fruits, where a range of fruit colors, sizes, and shapes can be encountered. Sizing segregates fruit by either weight or dimension. Sorting and sizing equipment must be flexible to efficiently handle a broad range of fruit sizes and volumes.

Most plums and some yellow-flesh peaches and nectarines are volume-fill packed,

Figure 28.6

Sorting plums by skin color at the packinghouse.



with the fruit automatically filled by weight into shipping containers. Most white-flesh peaches and "tree ripe" stone fruits are packed into one-layer (tray) boxes (flat). Yellow-flesh peaches, nectarines, and a few plums are packed into two-layer (trays) boxes. In some cases, mechanical place-packing units use hand-assisted fillers where the operator can control the belt speed to match the flow of fruit into plastic trays.

Limited volumes of stone fruits are "ranch packed" (tree ripe) at the point of production. In a typical ranch pack operation, fruit are picked into buckets or totes that are carried by trailer to the packing area. These packers work directly from the buckets to select, grade, size, and pack fruit into plastic trays (fig. 28.7). In these operations, the fruit are not washed, brushed, waxed, or fungicide treated. In other operations, fruit are picked into buckets or totes but then dumped into a smooth-operating, low-volume packing line for washing, brushing, waxing, sorting, and packaging. In both types of operations, because of the lesser amount of fruit handling, a higher maturity standard can be used, and growers can benefit from increased fruit size, red color, and greater yield. High-quality fruit can also be produced by managing the orchard factors (fruit thinning, girdling, fertilization, irrigation) properly and picking firm fruit. In this

Figure 28.7

Ranch packing system for stone fruits.

case, ripening at the shipping or retailer points is essential to assure good flavor quality for consumers.

RIPENING PROTOCOL FOR RECEIVERS

Stone fruits are usually harvested when they reach a minimum (or higher) maturity, but they are not completely ripe ("ready to eat") when harvested. Initiation of the ripening process must occur before consumption to satisfy consumers. This section describes a protocol designed to properly ripen peaches, nectarines, and plums at destination handling facilities.

1. **Check the initial fruit ripeness.** Flesh firmness is the best indicator of stone fruit ripeness and a good predictor of potential shelf life. A penetrometer with an 8 mm (5⁄16 in) tip is a quick and simple device for determining fruit firmness. Either a hand-held or drill-press-mounted instrument can be used. The drill-press-mounted instrument is recommended for greater accuracy and consistency. Fruit that reach 27 to 36 N (6 to 8 lbf) are considered "ready-to-buy." Fruit that reach approximately 9 to 13.5 N (2 to 3 lbf) flesh firmness are considered ripe ("ready-to-eat").

2. **Communicate with the merchandisers.** Find out the anticipated consumption schedule (fruit rotation schedule) and establish the ripening protocol accordingly. For IB-susceptible cultivars, fruits should be ripened down to 27 N (6 lbf) and then stored at 0°C (32°F) to avoid mealiness and flesh browning, if necessary.

3. **Determine the rate of softening.** Although the rate of fruit softening varies among cultivars, it is controlled by temperature. A high rate of softening is achieved at 20° to 25°C (68° to 77°F), and a low rate of softening is maintained by using lower temperatures. Temperatures higher than 25°C (77°F) will reduce the softening rate, induce off-flavors, and cause irregular ripening.

4. **Maintain fruit ripening conditions.** Most cultivars that are harvested at (or higher than) the California Well Mature stage do not need treatment with ethylene to ripen properly; the fruit softening rate depends only on temperature. Some plum, nectarine, and peach cultivars need exogenous ethylene treatment (10 to 100 ppm for 1 to 2 days) to initiate ripening. Maintain adequate air circulation within the ripening room to assure uniform fruit temperature. High RH (90 to 95%) around the fruit during the ripening process to prevent fruit shrivel is also necessary. In a tightly sealed room, it is important to assure that CO_2 produced by the fruit does not accumulate above 1% in the room. This can be done by continuously introducing fresh air or by periodically opening the room for an air change. For more details about management of fruit ripening, see chapters 16 and 21.

REFERENCES

Ceponis, M. J., R. A. Cappellini, J. M. Wells, and G. W. Lightner. 1987. Disorders in plum, peach and nectarine shipments to the New York market, 1972–1985. Plant Dis. 71:947–952.

Crisosto, C. H. 1994. Stone fruit maturity indices: A descriptive review. Postharv. News and Info. 5:65N–68N.

Crisosto, C. H., F. G. Mitchell, and S. Johnson. 1995. Factors in fresh market stone fruit quality. Postharv. News and Info. 6:17N–21N.

LaRue, J. H., and R. S. Johnson, eds. 1989. Peaches, plums, and nectarines: Growing and handling for fresh market. Oakland: Univ. Calif. Div. Ag. and Nat. Res. Publ. 3331. 246 pp. (See especially chapters 22 to 29.)

Lill, R. E., E. M. O'Donoghue, and G. A. King. 1989. Postharvest physiology of peaches and nectarines. Hortic. Rev. 11:413–452.

Mitchell, F. G. 1987. Influence of cooling and temperature maintenance on the quality of California grown stone fruit. Internat. J. Refrig. 10:77–81.

II. Apricots

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Most of the apricots grown in the United States are grown in California, with much smaller amounts grown in Washington and Utah. The greatest hazard in handling or shipping apricots is decay, mainly brown rot and Rhizopus rot. Quick cooling of apricots to temperatures of 4°C (39°F) or lower and holding them as near 0°C (32°F) as possible will retard ripening (softening) and decay.

QUALITY AND MATURITY INDICES

Quality indices include fruit size, shape, and freedom from defects (including gel breakdown and pit burn) and decay. High consumer acceptance is attained for fruit with high (>10%) soluble solids content (SSC) and moderate acidity (0.7 to 1.0%). Apricots with 9 to 13.5 N (2 to 3 lbf) flesh firmness are considered "ready to eat." Most apricot cultivars soften very quickly, making them very susceptible to bruising and subsequent decay.

In California, apricot harvest date is determined by changes in skin ground color from green to yellow. The exact yellowish-green color depends on the cultivar and shipping distance. Apricots should be picked when still firm because of their high bruising susceptibility when fully ripe and soft.

PREPARATION FOR MARKET

Apricots are always harvested by hand, usually into picking bags or plastic totes. Apricots are generally handled in half bins or totes and hand-packed. In some cases, apricots are dry-dumped over a soft packing line. Apricots are packed in single- or two-layer trays, or volume-filled (about 10 kg, or 22 lb net). Apricots should be uniform in size, and not more than 5% by count of the apricots in each container may vary more than 6 mm (¼ in) when measured through the widest portion of the cross-section.

STORAGE CONDITIONS

TEMPERATURE AND RELATIVE HUMIDITY

Apricots are seldom stored in large quantities, although they keep well for 1 to 2 weeks, or possibly even 3 to 4 weeks, depending on the cultivar, at –0.5°C to 0°C (31° to 32°F) and a RH of 90 to 95% RH. Susceptibility of cultivars to freezing injury depends on SSC, which may vary from 10 to 14%. The highest freezing point is –1.0°C (30°F).

Chilling-sensitive cultivars develop chilling injury symptoms (gel breakdown, flesh browning, loss of flavor) more rapidly at 5°C (41°F) than at 0°C (32°F). Storage at 0°C (32°F) is necessary to minimize incidence and severity of chilling injury on susceptible cultivars.

CONTROLLED ATMOSPHERES (CA)

The major benefits of CA during storage or shipment are to retain fruit firmness and ground color. CA conditions of 2 to 3% O_2 and 2 to 3% CO_2 are suggested for moderate commercial benefits; the extent of benefits depends on the cultivar. Exposure to less than 1% O_2 may result in development of off-flavors; exposure to greater than 5% CO_2 for longer than 2 weeks can cause flesh browning and loss of flavor. The addition of 5 to 10% CO_2 as a fungistat during transport (less than 2 weeks), may improve the potential for benefit from CA. Prestorage treatment with 20% CO_2 for 2 days may reduce incidence of decay during subsequent transport or storage in CA or air.

ETHYLENE PRODUCTION AND EFFECTS

Ethylene production rates increase with ripening and storage temperature (<0.1 µl/kg·hr at 0°C [32°F] to 4 to 6 µl/kg·hr at 20°C [68°F]) for firm-ripe apricots and higher ethylene production rates for soft-ripe apricots. Exposure to ethylene at high temperatures may reduce ripening variability, as indicated by softening and color changes from green to yellow.

DISORDERS AND DISEASES

PHYSIOLOGICAL DISORDERS

Gel breakdown or chilling injury. This physiological problem is characterized in the earlier stages by the formation of water-soaked areas that subsequently turn brown. Breakdown of tissue is sometimes accompanied by sponginess and gel formation. Fruit stored at 2.2° to 7.6°C (36° to 46°F) have short market life and lose flavor.

Pit Burn. Flesh tissue around the stone softens and turns brown when the apricots are exposed to temperatures above 38°C (101°F) before harvest. This heat injury increases with higher temperatures and longer durations of exposure.

POSTHARVEST DISEASES

Brown rot. This fungal disease, caused by *Monilinia fructicola*, is the most important postharvest disease of apricot. Infection begins during flowering. Fruit rots may occur before harvest, but they often occur postharvest. Orchard sanitation to minimize infection sources, preharvest fungicide application, and prompt cooling after harvest are among the control strategies.

Rhizopus rot. A fungal disease caused by *Rhizopus stolonifer*, Rhizopus rot occurs frequently in ripe or near-ripe apricot fruits held at 20° to 25°C (68° to 77°F). Cooling the fruit and keeping them below 5°C (41°F) is very effective against this fungus.

REFERENCES

Andrich, G., and R. Fiorentini. 1986. Effects of controlled atmosphere on the storage of new apricot cultivars. J. Sci. Food Agr. 37:1203–1208.

Brecht, J. K., A. A. Kader, C. M. Heintz, and R. C. Norona. 1982. Controlled atmosphere and ethylene effects on quality of California canning apricots and clingstone peaches. J. Food Sci. 47:432–436.

Trurter, A. B., J. C. Combrink, and L. J. von Mollendorff. 1994. Controlled-atmosphere storage of apricots and nectarines. Decid. Fruit Grower 44:421–427.

III. Sweet Cherry

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Approximately 20,000 hectares (50,000 acres) of sweet cherries are grown in the United States, mainly in California, Washington, and Oregon, producing about 150,000 metric tons (165,000 tons) annually. Approximately 45% of this production is sold fresh, while 35% is brined, and the remaining 20% is canned. The numerous varieties include red sweet cherries, such as Bing and Lambert; yellow sweet cherries, such as Rainier and Royal Anne; and the more heat-tolerant varieties Brooks, Tulare, King, and Garnet.

HARVEST MATURITY AND QUALITY

Being a nonclimacteric fruit, cherries must be harvested fully ripe for good flavor quality. While skin color may become darker red after harvest, sugar content does not increase. Therefore, fruit quality is at its optimum at harvest. Skin color and fruit soluble solids content are the main criteria used to judge fruit maturity and readiness for harvest. The U.S. Standards for maturity state that the fruit should be mature, having reached a stage of growth that will ensure the proper completion of ripening. In addition, the fruit should be "fairly well colored," meaning that at least 95% of the fruit surface should show the characteristic color for mature cherries of that variety. Minimum maturity in California requires that the entire cherry surface have a minimum of light red color and the fruit contain 14 to 16% soluble solids, depending on the variety. The red mahogany stage is recommended for harvest of Brooks, Garnet, Tulare, and King cherries. Fruit eating quality is related to the soluble solids content, titratable acidity, the ratio of soluble solids to titratable acidity, and fruit firmness. Visual quality factors include fruit size, color and luster, and absence of defects such as pitting, cracking, shriveling, decay, and misshapen fruit (doubles, spurs). Green, fleshy stems are often associated with freshness and quality.

HARVEST

Sweet cherries are hand-harvested, with stems attached, into small buckets that are transferred into field boxes or one-half-size field bins (100 by 120 by 60 cm, or 40 by 48 by 24 in). If field boxes are used they are loaded into one-half-size field bins for transport to the packing facility. Most harvesting is completed by midday to reduce the heat load in the fruit at harvest. Fruit maturity on a given tree can be quite variable. Some orchards are color-picked, with the ripest fruit being removed at an earlier pick and the bulk of the fruit removed in a second harvest, while other orchards are harvested in a single pick.

Supervision of the picking crew is essential to prevent excessive fruit injury. Pickers should grasp stems rather than fruit and remove clusters from the limb with an upward motion to leave the fruiting spur intact. Fruit should be gently placed (not thrown) into the picking bucket to avoid impact damage. Padding the bottom of the bucket can reduce fruit injury. Fruit should be kept in the shade while awaiting transport to the packinghouse.

PACKINGHOUSE OPERATIONS

If field bins are used, automatic bin dumps are employed. Water bath bin dumps are often used to reduce impact damage, but dry dumps are also used. If field boxes are used, these must be dumped by hand onto a conveyor. A flighted, inclined conveyor lifts fruit out of the water and conveys it under an air stream to remove leaves from fruit on the bar conveyor.

Because sweet cherries are sold based on size, the clusters must be cut in order to size the individual fruit. As fruit move by on a conveyor, tines catch the clusters of fruit and cause the stems to move into a saw, which cuts the stems to separate the fruit. The individual fruit then move through an eliminator, which consists of pairs of smooth, counter-rotating rollers that slope downward so that fruit slides between the rollers. The gap between the pairs of rollers increases slightly in the direction of fruit travel. Under-sized fruit pass between the rollers and are sent to processing outlets or discarded. The remaining fruit are transferred to sorting tables on conveyor belts or in water flumes. Sprays of water are used to lubricate the fruit on the cluster cutter and eliminator.

Fruit are conveyed over a flat belt past sorters who remove damaged, misshapen, or immature fruit. The fruit are then hydrocooled in an inline unit that removes heat by showering fruit with cold water or by moving immersed fruit through a cold water bath. Following hydrocooling, fruit are sized using a set of parallel rollers similar to the eliminator used to remove undersized fruit. Just prior to box filling, a fungicide may be sprayed onto the fruit as it passes by on conveyors. Fruit are generally bulk-filled into containers.

PACKAGING

Sweet cherries are commonly packaged into fiberboard boxes with plastic fold-over liners. Absorbent pads are used to prevent water from accumulating in the bottom of the liner. Boxes are hand-filled by being held under a belt carrying the fruit. The box may pass over a vibrating point in the belt to settle the fruit. Box weight and grade are checked and the box is sealed. Standard box size in the Pacific Northwest is 5.4 or 9.0 kg (12 or 20 lb). In California, the standard is 8.1 kg (18 lb). Fruit may also be packaged into clamshell containers, bags, or other types of consumer packages.

MODIFIED ATMOSPHERE PACKAGING

Fruit in boxes and in consumer packages can be exposed to a modified atmosphere (MA). Fruit can be sealed into MA bags within the fiberboard box. Bag sealing may involve pulling a vacuum on (partially evacuating) the bag of fruit and introducing a premixed atmosphere. Alternatively, the bag can simply be sealed, allowing the fruit to modify the atmosphere through respiration. Consumer packages can be covered with specialized films to achieve the desired package atmosphere. The goal is to achieve 10 to 15% CO_2 and 3 to 10% O_2 within the bag or package. MA packaging has been demonstrated to reduce the growth of decay organisms, reduce the rate of fruit deterioration, maintain soluble solids and titratable acidity concentrations, and maintain green stems. These benefits are more noticeable when fruit are shipped under less than ideal temperatures (>2°C, or 36°F) and the time to destination exceeds 1 week. Flavor volatiles may be reduced following several weeks of CA storage, resulting in fruit of good visual quality but poor eating quality.

COOLING

Cherries should be cooled as rapidly as possible after harvest, and the temperature should be held as close as possible to 0°C (32°F) with 90 to 95% RH during handling, storing, and shipping.

The fruit may be hydrocooled at a field location when the orchard is far from the packinghouse and temperatures are high, or it may be hydrocooled upon arrival at the packinghouse. Cherries are commonly hydrocooled during the packing process. Shower coolers quickly remove heat from the fruit, with an 11°C (20°F) reduction in fruit temperature over a 7- to 10-minute period. Immersion coolers are slower to cool fruit and are often used for fruit that has previously been cooled. Chlorine (100 ppm) should be added to the water system to prevent cross-contamination with disease organisms in the water. Following packaging, cherries may be forced-air cooled to bring their temperature down to 0°C (32°F). Forced-air cooling is more common than hydrocooling in cherry growing areas in Europe. Forced-air cooling can result in fruit and stem desiccation, and the use of plastic liners within boxes reduces the efficacy of this method.

FUMIGATION

Sweet cherries exported to certain markets are currently fumigated with methyl bromide. For codling moth disinfestation, a 2-hour methyl bromide fumigation is required. The concentration of methyl bromide varies with the temperature. In general, methyl bromide treatment, especially at higher temperatures, results in increased fruit pitting and stem browning. In some operations, fruit for export to markets that require methyl bromide move through the packing line and are diverted to bin fillers after the sorting operation. In this way, only fruit of export quality are fumigated. Following fumigation and ventilation, fruit are transferred into a screened packinghouse for additional sorting, cooling, and final packaging. Fruit are generally packaged into unvented boxes to prevent reinfestation. Boxes with screened vents are also used.

SHIPPING

AIR

Thirty to forty percent of sweet cherries grown in the United States are shipped to export markets. A significant number of these, particularly from the early production areas in California, are shipped by air. While air shipment gets product to market rapidly, the breaks in the cold chain create challenges for maintenance of fruit quality. To combat these breaks in the cold chain, many air-shipped fruit are placed under reflective pallet covers with dry cold packs placed over the top of the pallet. This system appears to maintain cooler temperatures around the fruit during transit.

SEA CONTAINER

The remaining product that is exported overseas is shipped in marine containers, which should be set at 0°C (32°F) to maintain product quality during transit. Many marine containers have bottom airflow, and boxes should be designed with bottom and top vents at the corners to allow air to flow within the box and around the plastic liner. Because of the air restriction caused by the plastic liner, fruit must be thoroughly cooled prior to container loading. Containers can provide a MA for the product with similar benefits to those provided by MA packaging. The difference is that the atmosphere is lost when the container is opened at destination. In export markets where temperature management is very difficult, removal of the MA may be beneficial to prevent product damage caused by harmful atmospheres.

DOMESTIC TRUCK

Nearly all domestic cherries are shipped by truck. Most highway trucks have horizontal air delivery systems, and boxes should have side venting for this shipping method. Thermostats should be set at 0°C (32°F), but product temperature is most important and should be monitored. The loading pattern should allow for good air circulation within the truck.

PHYSICAL AND PHYSIOLOGICAL DISORDERS

Postharvest life of sweet cherries is closely related to the respiration rate of the fruit, which increases with higher temperature and fruit injury. Fruit injury also greatly increases the incidence of fruit decay. Studies have shown that approximately 30% of fruit is damaged upon arrival at the packinghouse, due to harvesting and field operations. Damage from packinghouse operations was shown to vary from 4 to 46%, depending on the operation. In packinghouse operations, damage can be minimized by eliminating drops onto rough surfaces, slowing fruit speed in cluster cutters, operating cluster cutters at high capacities, and reducing the water drop height within shower hydrocoolers to less than 20 cm (8 in).

PITTING

An unsightly indentation in the surface of the fruit is caused by the collapse and death of cells under the skin. These pits appear to result from impact injuries. Firm fruit and cold fruit appear to be more susceptible to pitting damage, but there is less agreement on the relationship between firmness and pitting. Pitting has been shown to be greater when fruit flesh is less than 10°C (50°F) during handling. Hydrocooled fruit may be more susceptible to pitting than air-cooled fruit. Darker-skinned, more mature cherries appear to be less susceptible to pitting injury.

BRUISING

Bruising can result from compression, vibration, or impact damage. Firm fruit and cold fruit are less susceptible to compression bruising damage. Vibration damage is not influenced by fruit temperature. Compression bruising is evidenced by a flat area on the fruit surface and soft tissue beneath that can be detected by feel. While bruises are quite apparent on yellow-skinned cherries, they may not be visible on black-skinned cherries.

CRACKING

Fruit cracking is usually associated with preharvest rains. Splits and cracks in the skin develop around the stem, on the shoulders, or at the blossom end. Cracked cherries are much more susceptible to decay and deterioration and should be removed during sorting.

PATHOLOGICAL DISORDERS

Brown rot, caused by *Monilinia fructicola*, often begins in the orchard and manifests itself in the postharvest environment. The disease can also occur as a result of wounding and inoculation during postharvest handling. Preharvest and postharvest control measures are necessary. Gray mold, caused by *Botrytis cinerea*, can also be significant. This fungus is particularly troublesome because it cannot be completely controlled with temperature management, since it continues to grow even at 0°C (32°F). Blue mold, caused by *Penicillium expansum*, is an opportunistic pathogen that infects wounds on fruit. Rhizopus rot, caused by *Rhizopus stolonifer*, occurs when fruit are exposed to temperatures of 5°C (41°F) or higher.

Proper temperature management, including rapid cooling to and maintenance at 0°C (32°F), can completely control Rhizopus rot and can significantly reduce brown rot and gray mold. Eliminating injured and diseased fruit from the packed box is important to prevent spreading (nesting) of the disease. Preharvest and postharvest fungicide treatments are often beneficial.

REFERENCES

Brown, G. K., and G. Kollar. 1996. Harvesting and handling sour and sweet cherries for processing. In A. D. Webster and N. E. Looney, eds., Cherries: Crop physiology, production and uses. Wallingford, UK: CAB International. 443–469.

Crisosto, C. H., D. Garner, J. Doyle, and K. R. Day. 1993. Relationship between fruit respiration, bruising susceptibility, and temperature in sweet cherries. HortScience. 28:132–135.

Couey, H. M., and T. R. Wright. 1974. Impact bruising of sweet cherries related to temperature and fruit ripeness. HortScience. 9:586.

Facteau, T. J., and K. E. Rowe. 1979. Factors associated with surface pitting of sweet cherry. J. Amer. Soc. Hort. Sci. 104:706–710.

Looney, N. E., A. D. Webster, and E. M. Kupferman. 1996. Harvest and handling of sweet cherries for the fresh market. In A. D. Webster and N. E. Looney, eds., Cherries: Crop physiology, production and uses. Wallingford, UK: CAB International. 411–441.

Mitchell, F. G., G. Mayer, and A. A. Kader. 1980. Injuries cause deterioration of sweet cherries. Calif. Agric. 34(4): 14–15.

Thompson, J. T., J. Grant, E. M. Kupferman, and J. Knutson. 1997. Reducing sweet cherry damage in postharvest operations. HortTechnology. 7:134–138.