22 Harvesting and Postharvest Handling of Peaches for the Fresh Market

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(eds D.R. Layne and D. Bassi)

22.1 Origin

Peach (*Prunus persica* (L.) Batsch) is native to China; at one time it was called 'Persian apple'. Chinese literature dates its cultivation in China to 1000 BC. Probably carried from China to Persia (Iran), the peach quickly spread from there to Europe. In the 16th century, peaches were established in Mexico, probably by the Spaniards. In the 18th century Spanish missionaries introduced the peach to California, which turned out to be the most important production area after China and Italy (LaRue, 1989). In recent years, an important development of fruit with high soluble solids concentration (SSC), high aromatic white flesh, and low-acidity white and yellow cultivars has occurred in all the production areas (Okie, 1998; Sansavini *et al.*, 2000; Crisosto *et al.*, 2001a; Crisosto, 2002).

22.2 Fruit Composition and Antioxidant Capacity

Fruit composition

Peaches are characteristically soft-fleshed and highly perishable fruit, with a limited market life potential. A peach fruit is approximately 87% water with 180 kJ (43 kcal) and contains carbohydrates, organic acids, pigments, phenolics, vitamins, volatiles, antioxidants and trace amounts of proteins and lipids, which make it very attractive to consumers (Kader and Mitchell, 1989b; USDA, 2003). Immature peach fruit contain very low or no starch grains and these starch grains are rapidly converted into soluble sugars as the fruit mature and ripen. Consequently, there is no significant increase in soluble sugars during storage and ripening (Romani and Jennings, 1971). Soluble sugars contribute approximately 7–18% of total weight and fibre contributes approximately 0.3% of fresh weight (FW) of total fruit. Sucrose, glucose and fructose represent about 75% of peach fruit soluble sugars. Malic acid is the predominant organic acid in mature peach fruit followed by citric acid. These organic acids (0.4–1.2% FW) are important because it has been reported that the ratio of soluble solids to titratable acidity determines consumer perception in most ripe peach cultivars. In most peach cultivars, we found that acidity decreased about 30% during ripening. Peach fruit has low protein content (0.5 to 0.8% FW) but these small-size proteins have an important function as enzymes catalysing the various chemical reactions responsible for compositional changes. Despite lipids constituting only 0.1 to 0.2% FW, they are important because they make up surface wax that contributes to fruit cosmetic appearance and cuticle that protects fruit against water loss and pathogens. Lipids are also important constituents of cell membranes, which influence physiological activities of fruits. Minerals in fruits include base-forming elements (Ca, Mg, K, Na) and acid-forming elements (P, Cl, S). Ca associated with cell wall structure is important in fruit softening and Ca in the apoplast has been related to senescence. Postharvest changes in mineral content in fruits are small. Volatile compounds in very low concentrations include esters, alcohols, aldehydes, ketones and acids, and these are responsible for the characteristic fruit aroma. Lactones may be organoleptically important in peach flavour but more detailed studies are needed on this topic.

Ascorbic acid, carotenoids and phenolic composition

Peach fruit has ascorbic acid (vitamin C), carotenoids (provitamin A) and phenolic compounds which are good sources of antioxidants (Tomás-Barberán *et al.*, 2001; Byrne, 2002). Since these compounds are located in a high concentration in the fruit peel, which constitutes only about 15% of total fruit FW, most of the antioxidant potential is restricted to the peel; thus, it is recommended to eat peaches with the peel to ensure intake of most of the antioxidant compounds. The total ascorbic acid (vitamin C) content in a survey of ten cultivars of California peach ranged from 6 to 9 mg/100 g in white flesh and from 4 to 13 mg/100 g in yellow flesh (Gil *et al.*, 2002). Accordingly, similar concentrations of ascorbic acid (5–6 mg/100 g) have been found in European peach cultivars (Carbonaro *et al.*, 2002; Proteggente *et al.*, 2002). Total carotenoids concentration was in the range of 71–210 μg/100 g FW for yellow-fleshed and 7–20 μg/100 g FW for white-fleshed peach cultivars (Gil *et al.*, 2002). Thus, there were about ten times more carotenoids in yellow-fleshed than in white-fleshed peach cultivars. The main carotenoid detected was β-carotene (provitamin A), but also small quantities of α-carotene and β-cryptoxanthin are present in some peach cultivars.

The total phenolics concentration expressed as mg/100 g FW varied from 28 to 111 for white-fleshed and from 21 to 61 for yellow-fleshed California cultivars (Gil *et al.*, 2002). Other European cultivars had values of 38 mg/100 g (Proteggente *et al.*, 2002), while the Spanish cultivar 'Caterina' showed values of 240 and 470 mg/100 g for pulp and peel, respectively (Goristein, *et al.*, 2002). Fruit phenolics have a role in fruit visual appearance (colour), taste (astringency) and health antioxidant property (Tomás-Barberán *et al.*, 2001). The predominant hydrocinnamic acid is chlorogenic acid. Catechin and epicatechin are the main procyanidins identified and their concentrations are higher in white-fleshed than in yellow-fleshed peaches. Cyanidin-3-glucoside is the predominant anthocyanin, which, along with other anthocyanins, is present mainly in the skin. Concentrations of flavonols (including quercetin and kaempferol) are higher in yellow-fleshed than in white-fleshed peaches (Gil *et al.*, 2002).

Antioxidant capacity

The antioxidant capacity per peach fruit serving based on the intake of a fruit serving of 100 g (peel + flesh) varied widely according to cultivar. In general, white-fleshed peaches were slightly higher in total antioxidant capacities than yellow-fleshed peaches. The total antioxidants ranged from 13 to 107.3 mg of ascorbic acid equivalents when evaluated by the DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical method and from 19 to 119.6 mg of ascorbic acid equivalents when evaluated by the FRAP (ferric reducing ability plasma) method (Tomás-Barberán *et al.*, 2001). When these values are compared with the amount of ascorbic acid equivalents provided by 100 ml of red wine, 100 g of 'Snow Skin' (white flesh) or 'September Sun' (yellow flesh) will provide the same amount, while approximately 1000 g of 'Summer Sweet' (white flesh) or 'Flavorcrest' (yellow flesh) would have to be consumed to match the same amount of antioxidant capacity in 100 ml of red wine. In fact, the total antioxidant activity of peach is similar to that reported for pear, apple and tomato; and significantly lower than those observed in strawberry, raspberry and red plum (Proteggente *et al.*, 2002).

22.3 Deterioration Problems

Commercial postharvest losses are mainly due to decay and internal breakdown (IB) or chilling injury (CI) (Ceponis *et al.*, 1987; Mitchell and Kader, 1989a). Postharvest loss of stone fruits to decay-causing fungi is considered the greatest deterioration problem. Worldwide, the most important pathogen of fresh stone fruits is grey mould or *Botrytis* rot, caused by the fungus *Botrytis cinerea*. In California, an even greater cause of loss due to decay is caused by the fungus *Monilinia fructicola* (brown rot). Details on the fungi life cycle, epidemiology, orchard sanitation practices, fungicide applications and pre-/post-harvest management to reduce these problems are presented in Chapter 15 of this book.

Internal breakdown

This phenomenon (IB or CI) is genetically controlled and triggered by storage temperature. It manifests 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. 22.1/Plate 232). An intense red colour development of the flesh ('bleeding') usually radiating from the pit may be associated with this problem in some peach cultivars. Recently released cultivars rich in skin red pigment showed flesh bleeding that is not affecting fruit taste. The development of this symptom has been associated with fruit maturity rather than storage temperature. In all of the cases, in susceptible cultivars flavour is lost before visual CI symptoms are evident (Crisosto and Labavitch, 2002). There is large variability in IB susceptibility among peach cultivars (Mitchell and Kader, 1989a; Crisosto *et al.*, 1999c). In general, most of the mid-season and late-season peach cultivars are more susceptible to CI than early-season cultivars (Mitchell and Kader, 1989a), although as new cultivars are being released from a new genetic pool, the susceptibility to CI is becoming random in the new cultivar population (Crisosto *et al.*, 1999c; Crisosto, 2002). It has been widely reported that the expression of CI symptoms develops faster and more intensely when susceptible fruit are stored at temperatures between about 2.2°C and 7.6°C ('killing zone' temperature) than when stored at 0°C or below but above their freezing point (Harding and Haller, 1934; Smith, 1934; Mitchell and Kader, 1989a). Therefore, market life is dramatically reduced when fruit are exposed to the 'killing zone' temperature (Crisosto *et al.*, 1999c). In addition, the severity of CI depends on the ripening stage at harvest since higher incidence was reported for 'Maycrest' cultivar picked at more advanced ripening stage (Valero *et al.*, 1997), although the opposite has been found in other cultivars (Von Mollendorff *et al.*, 1992).

Several treatments to delay and limit development of this disorder have been tested, such as controlled atmosphere (CA) environment,

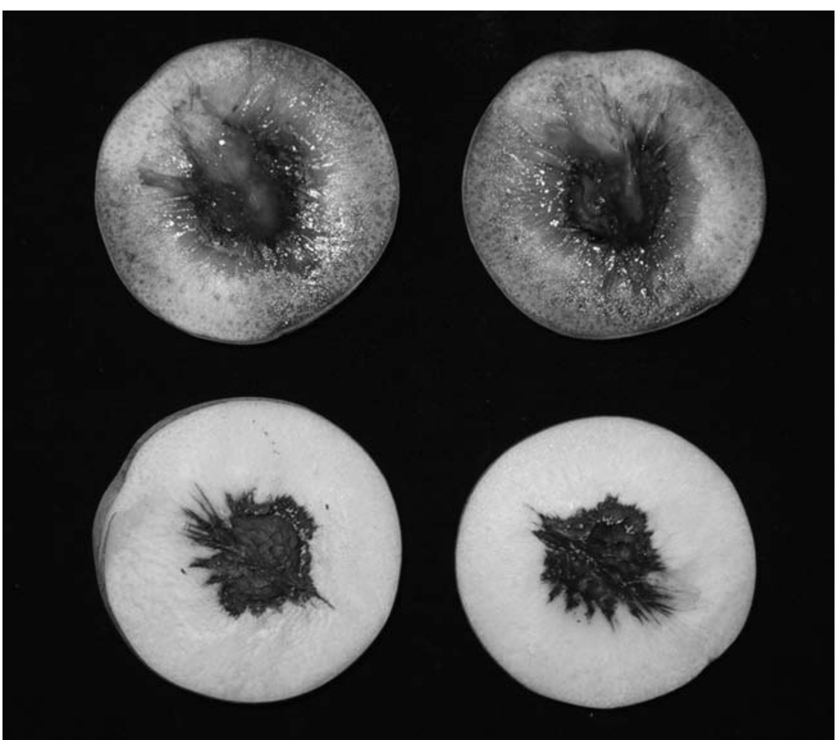

Fig. 22.1. Internal breakdown symptoms in peaches (top of image) include flesh mealiness, flesh browning and loss of flavour.

calcium applications, warming cold storage interruptions (Anderson, 1979; Nanos and Mitchell, 1991; Garner *et al.*, 2001), plant growth regulators and controlled delayed cooling. The major benefits of CA during storage/shipment are retention of fruit firmness and ground colour. CA conditions of 6% O_2+17% CO_2 at 0°C have shown a limited benefit for reduction of IB during shipments for yellow-fleshed cultivars (Crisosto *et al.*, 1999a) and white-fleshed cultivars (Garner *et al.*, 2001). The CA efficacy is related to cultivar (Mitchell and Kader, 1989a), preharvest factors (Von Mollendorff, 1987; Crisosto *et al.*, 1997), temperature, fruit size (Crisosto *et al.*, 1999a), marketing period and shipping time (Crisosto *et al.*, 1999c). Another tool that reduced CI in peach was modified atmosphere packaging (MAP). Thus, 'Paraguayo' cultivar (flat type) showed reductions in CI severity using polypropylene standard film with steady-state atmosphere of 12% CO_2 and 4% O_2, or oriented polypropylene (23% CO_2 and 2% O_2) (Fernández-Trujillo *et al.*, 1998). The preconditioning treatment (Crisosto *et al.*, 2004) prior to storage/shipment has shown to be effective in delaying IB symptoms and is successfully being used commercially on Californian and Chilean fruit shipped to the USA and England (Crisosto *et al.*, 2004). The 'Paraguayo' cultivar subjected to intermittent warming cycles of 1 day at 20°C every 6 days of storage at 2°C was also effective in reducing CI symptoms although scald and translucency occurred (Fernández-Trujillo and Artés, 1998).

Mechanical injury

Peaches are susceptible to mechanical injuries including impact, compression, abrasion (or vibration), bruising, and wounds or cuts, which can occur during harvest and transport (Mitchell and Kader, 1989a). Impact bruising is the result of dropping, bouncing or jarring. Compression bruising occurs primarily when bins are overfilled and stacked, and fruits are 'crushed' against each other. Abrasion bruising results from fruit rubbing against each other or against container surfaces. Proper fruit handling and transport will reduce these types of injury and contribute to the production of a high-quality final product. 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 entry points for and 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 peach industry is harvesting fruit at more advanced maturity (softer) to maximize fruit flavour quality. Our observations indicate that most impact bruising damage occurs during long hauling from orchard to packinghouse and during the packinghouse operation. Critical impact bruising thresholds (the minimum fruit firmness measured at the weakest point to tolerate impact abuse) have been developed for many peach and nectarine cultivars (Crisosto *et al.*, 2001b). Physical wounding or cuts on peaches can occur at any time from harvest until consumption. Good worker supervision assures adequate protection against impact bruising during picking, handling and transport of fruit.

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, plastic film liners inside field bins, the use of plastic bins, installing special bin top pads 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. 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. Some research indicates that treatment of peaches with plant growth regulators (i.e. polyamines and gibberellic acid) before handling and storage is also effective in reducing the fruit susceptibility to mechanical damage by increasing fruit firmness and thus inducing resistance to compression forces (Martínez-Romero *et al.*, 2000). Additionally, preharvest application of Ca+Mg+Ti spray led to firmer fruits (Serrano *et al.*, 2004), which would be another way to increase the fruit resistance to mechanical damage.

Inking

In situations when abrasion damage occurs during harvesting on fruit that have heavy metal contaminants on their skin (i.e. Fe, Cu and/or Al), a dark discoloration referred to as inking, staining or peach skin discoloration occurs on the skin (Cheng and Crisosto, 1997). These dark or brown spots or stripes on the fruit surface are a cosmetic problem that is limited to the skin but they lead to market rejection and financial loss to the grower (Fig. 22.2/Plate 233). Light brown spots or stripes are also produced on the surface of white-fleshed peaches and nectarines as a consequence of abrasion occurring mainly during harvesting and hauling operations. These symptoms appear generally 24–48 h after harvest. This problem is usually triggered during the harvesting and hauling operations, but it may also occur later during postharvest handling (packaging). Heavy metal contaminants on the surface of the fruit can occur as a consequence of foliar nutrients and/or fungicides sprayed within 15 or 7 days before harvest, respectively. Gentle fruit handling, short-distance hauling, avoiding any foliar nutrient sprays within 15 days of harvest, and following the suggested preharvest fungicide spray interval guidelines are our recommendations to reduce inking incidence (Crisosto *et al.*, 1999b).

22.4 Peach Maturity

Maturity and quality

The maturity at which peaches are harvested greatly influences their ultimate flavour, market life and quality potential (Von Mollendorff, 1987; Lill *et al.*, 1989; Kader and Mitchell, 1989a; Crisosto *et al.*, 1995). Peach maturity controls the fruit's flavour components, physiological deterioration problems, susceptibility

Fig. 22.2. Peach inking or staining as a consequence of abrasion combined with heavy metal contamination during harvesting and hauling operations.

to mechanical injuries, resistance to moisture loss, susceptibility to invasion by rot organisms, market life and ability to ripen (Shewfelt *et al.*, 1987; Crisosto, 1994). Peaches 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. Green ground colour 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 SSC and higher acids than harvested matured fruit, all of which contribute to inadequate flavour development and low consumer acceptance. Over-mature fruit have a shortened postharvest life, primarily because of rapid softening and 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 fungus invasion. By the time such fruit reach the consumer they may have become overripe (senescent), with poor eating quality including off-flavours and irregular or mushy texture.

Maturity definition

Optimum maturity must be defined for each peach cultivar to assure maximum taste and storage quality but in all cases it should assure that the fruit has the ability to ripen satisfactorily (Kader and Mitchell, 1989a). Peach quality was discussed in detail in Chapter 20 of this book. The ideal maturity varies according to markets; for example, a more advanced maturity is recommended for near-distance markets than for long-distance markets.

Maturity indices

Several information sources from different production areas have reported that flesh colour, firmness and background colour changes are well correlated to chemical and physical fruit changes during maturation and ripening (Crisosto, 1994). Based on this information, maturity indices based on skin background colour and firmness are being used to determine and supervise harvesting operations. In California and other places, harvest date is determined by skin background colour changes from green to yellow in most cultivars. A colour chip guide is used to determine maturity of most cultivars except for white-fleshed cultivars. Fruit skin background colour is a useful, non-destructive method of estimating fruit maturity, and is most easily employed and understood by field workers during harvesting operations. Since the proper background colour for estimating optimum harvest maturity varies by cultivar, experience with a particular cultivar is helpful in making the correct decision. In California, for new cultivar releases where skin ground colour is masked by full red colour development prior to maturation, fruit firmness is being used to determine how long fruit can be left on the tree before harvest. In Europe, fruit firmness on fresh market peach is not very reliable, so maximum maturity index is recommended. Maximum maturity is defined as the minimum flesh firmness at which fruits can be handled without bruising damage. Maximum maturity varies among peach cultivars and handling situations (Crisosto *et al.*, 2001b).

Field application of maturity indices

In applying either one of these two maturity indices (background colour and flesh firmness) at the start of a block or cultivar, proper, easily understood directions for estimating maturity should be given to the workers. By selecting a few fruit of varying maturity and demonstrating what maturity level is acceptable and unacceptable, many mistakes can be avoided. It is recommended to leave these samples with the crew leader as a reference throughout the day. When a maturity index based on fruit firmness is used, the instructions to the harvesters will also imply minimum size and location of the fruit in the tree canopy. The value of a good and expert crew leader cannot be overemphasized. This person should be considered essential and integral in the harvesting process. He should be instructed to continually monitor the fruit being picked and the fruit remaining on the tree to determine if the correct balance is achieved. Orchard managers should involve the crew leader in all stages of the decision-making process when determining optimum harvest maturity. Doing so will give him greater understanding and experience in the process. More importantly, it will solidify in his mind the importance of his role in harvesting fruit at the proper maturity.

A number of factors can affect how quickly fruits ripen. Trees tend to ripen from top to bottom and periphery to interior. This is probably related to the amount of sunlight they receive. Consequently, fruit of a given cultivar on weak trees tend to ripen earlier than on strong trees, as do fruit on summer-pruned trees. Fruit of a given cultivar on girdled trees or trees in sandy areas ripen earlier than fruit on non-girdled trees or in loamy soils. These fruit also tend to ripen more uniformly within the tree from top to bottom. A skilful manager will consider these factors, as well as others, and judge when and how often an orchard should be harvested, and how much fruit can be removed in any one picking. Because of the complexity of these factors, there is no substitute for experience in making these decisions. Strategies that are effective for one grower may be ineffective for another because of different organizational and marketing situations and tactics. An example of differing strategies is demonstrated by grower A, who prefers to harvest five to eight times for each cultivar where each harvest is 2 to 3 days apart. This is in contrast to grower B, who prefers to pick only two or three times with a longer interval in between harvests. Grower A may decide that he does not mind spending the extra money on increased labour because he is achieving a higher packout percentage (less cullage). Grower B may not mind a reduced packout percentage (more cullage) because he is saving money on labour.

In Spain, the indigenous cultivar 'Calanda' is much appreciated by European consumers and it dominates the late fresh market because of its special characteristics. Fruit is individually wrapped in a paper bag, is free of pesticides, and during the development on the tree reaches a uniform cream or straw colour (Ferrer *et al.*, 2005). For marketing purposes, only slight blush is accepted, but green or orange-yellowish colours are refused. In this cultivar, firmness and skin colour charts have been proposed to estimate the optimal harvest point.

22.5 Temperature Requirements and Management

Ideal storage conditions

The ideal peach storage temperature is −1°C to 0°C. The flesh freezing point varies depending on SSC. Storage-room relative humidity should be maintained at 90–95% and air velocity of approximately 0.0236 m^3/s is suggested during storage (Lill *et al.*, 1989; Thompson *et al.*, 1998).

Temperature management

The application of the ideal cooling requirements will depend on the specific operation and the way to apply these requirements depends on the scheduling of the packing operation (Mitchell, 1987). Fruit can be cooled in field bins by hydro-cooling or pre-cooling (Fig. 22.3/Plate 234). Hydro-cooling is normally done by a conveyor-type hydro-cooler. Fruit in field bins can be cooled to intermediate temperatures (5–10°C) provided packing will occur the next day. If packing is to be delayed beyond the next day, then fruit should be thoroughly cooled in the bins to near 0°C. In IB-susceptible cultivars fast cooling within 8 h and maintaining fruit temperature near 0°C are traditionally recommended (Mitchell, 1987). Fruit in packed containers should be cooled to near 0°C. Even fruit that were thoroughly cooled in the bins will warm substantially during packing and should be thoroughly re-cooled after packing. Forced-air cooling is normally indicated after packing (Fig. 22.4/Plate 235). A rare exception to the need for cooling after packing would be a system that handles completely cold fruit and provides protection against warming during packing.

Fig. 22.3. Bin of peaches being pre-cooled on a conveyor-type hydro-cooler prior to packing.

Fig. 22.4. Packaged fruit in unitized pallet loads are stacked to form a forced-air cooling tunnel.

Water loss control

Economic loss to the grower can result when as little as 8% of the fruit fresh weight is lost (Crisosto *et al.*, 1994). The economic loss is due to both decreased weight of the fruit and the unsightly shrivelling that occurs. While there is a large variability in susceptibility to water loss among cultivars, all cultivars must be protected to ensure the best postharvest life. Fruit waxes or coatings that are commonly used as carriers for postharvest fungicides can reduce the rate of water loss when excess surface brushing has not occurred. Mineral oil waxes can potentially control water loss better than vegetable oil and edible coatings, although the use of waxes or coatings is regulated according to destination point requirements. The main ways to limit fruit water loss include short cooling delays, efficient waxing with gentle brushing, fast cooling followed by storage under constant low temperature and high relative humidity.

New temperature management approach

A new technique to delay IB symptoms and preripen fruit has been successfully introduced to the California and Chilean industries. This technique, described above, consists of a ~48 h controlled cooling delay (Crisosto *et al.*, 2004). A preconditioning protocol has been developed and promoted among packers/shippers (Crisosto *et al.*, 2004). In this delivery system, preconditioned peaches should be arriving at the distribution centre at ~2.3–3.6 kgf firmness, measured at the weakest point on the cheeks. This new fruit delivery system is one more approach to limit IB and enhance the fruit-eating experience for consumers. Due to physical and chemical changes occurring in the fruit during a well-controlled preconditioning treatment, peaches undergo fruit softening to the 'ready to buy' stage (~2.7–3.6 kgf). Thus, fruit become tastier, more aromatic and juicier, resulting in high consumer acceptance. Generally, all peach cultivars should be kept out of the 'killing zone' temperature range of 2.2–10°C (Fig. 22.5/Plate 236). The ideal storage temperature is from 0°C to 1.7°C. Keeping fruit at this temperature will slow softening and reduce shrivelling, decay and the incidence of IB or mealy fruit. The exact temperature management will be part of a broader fruit preparation for consumers that takes into account the firmness on arrival of fruit and the fruit turning schedule (time that

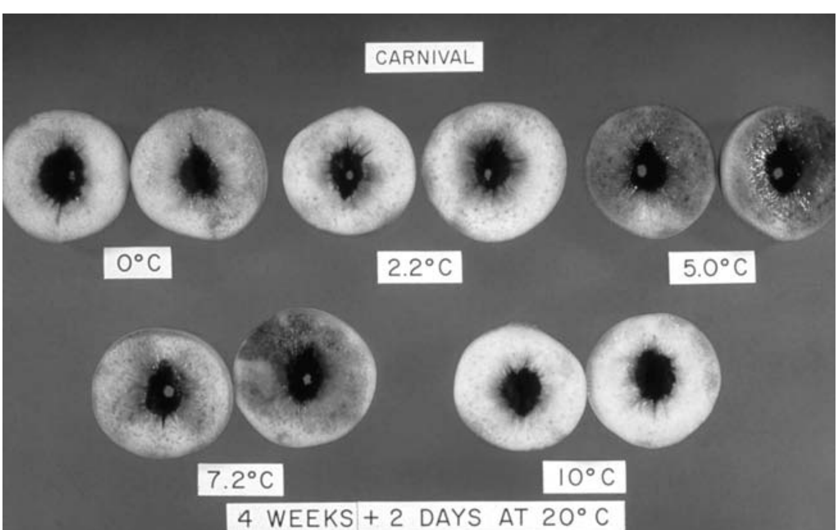

Fig. 22.5. Storage temperature influences incidence and severity of internal breakdown in susceptible cultivars.

fruit remain on display tables). This needs to be coordinated with the store-level demand and it will depend on a particular company's anticipated sales/consumption schedule (fruit turning schedule). Cheek firmness is a good tool to determine ripening stage (transfer point, ready to buy, ready to eat, etc.), while firmness measured at the weakest position (shoulder, tips or suture) is well related to potential impact and transportation damages. Fruit firmness does not accurately certify the quality of the preconditioning execution, however.

22.6 Field Harvesting, Hauling and Packaging

The goals of fruit harvesting should be to pick fruit at optimum maturity and transport fruit to the packing facility with no deterioration in fruit quality. To do this requires proper coordination between human resources, fruit maturity, environmental factors, technical resources and equipment. An understanding of these factors and their relationship is essential to making the proper management decisions for a given orchard situation.

Harvesting

Peach fruit are hand picked using bags (Fig. 22.6/Plate 237), baskets or totes. Most commercial peach fruit operations use picking bags and bins in their harvest operations (Corelli Grappadelli, 2001). Peaches are dumped in bins (Fig. 22.7/Plate 238) that are on the top of trailers between rows in the orchard. If totes are being used, they are placed directly inside the bins. Baskets are placed on top of modified trailers. Fruit picked at advanced maturity stages and white-fleshed peaches are generally picked and placed into baskets or totes. Because of the availability of new cultivars that adapt well to harvesting more mature (softer), the increase in popularity of

Fig. 22.6. Peaches for fresh market are hand picked. Harvesters work on ladders using picking bags or baskets.

Fig. 22.7. Harvesters transfer peaches to field bins which are moved through the field on low trailers.

high-quality, less firm fruit (more mature) and use of more sophisticated packinghouse equipment, a large proportion of stone fruits are being picked at a more advanced maturity stage than historically.

Regardless of maturity, a number of precautions should be taken with any harvest operation (Mitchell and Kader, 1989b). Harvesters should be instructed to treat the fruit as gently as possible at every stage of the harvest process. When emptying bags into the transport bins, care should be taken to ensure that the fruit are not dumped into the bin from a high height. Again, this is where the crew leader is helpful in reducing problems. Picking bags and buckets should be kept clean. There appears to be a relationship between inking, surface abrasion and dirty containers. Washing picking bags at regular intervals may be helpful in reducing this problem. After harvest, but while still in the field, fruit should be protected from exposure to direct sunlight and excess heating (Fig. 22.8/Plate 239). Insulated bin covers are the most beneficial shading technique. Some growers use cloth coverings to protect the fruit. On very hot days these should be supported above the fruit because direct contact can allow enough heat to pass through to cause fruit scald. After harvest fruit should be hauled to a cooling facility as quickly as possible. If there is a delay in transportation, fruit should be stored in a cool, shaded area. Temporary structures near the harvest location are often constructed from shade cloth material. Care should be taken as the harvested fruit are being loaded for transport to the packing facility. Forklift drivers should be informed of the importance of treating fruit gently when loading and unloading bins of fruit.

Fruit hauling

Fruit are hauled for short distances by trailer, but if the distance is longer than 10 km, bins

Fig. 22.8. View of a shaded loading area to protect fruit from excess heating while awaiting transportation to the packinghouse.

are loaded on trucks for transportation to packinghouses. Peaches are transported from orchard to packinghouse and cooler as soon as possible after harvest. Fruit should be shaded during any delay between harvest and transport. Tractor drivers should be instructed to drive slowly and smoothly. Severe fruit damage can result from poor driving practices, especially on turns and starts. There appears to be a benefit to using 'suspension-type' bin trailers instead of solid axle trailers. These trailers tend to ride more smoothly. Similar results can be obtained to a lesser degree by lowering tyre air pressure. Both of these procedures are probably more helpful for road transport conditions than field transport. Unloading of trailers should also be performed as gently as possible. Care should be taken to educate workers as to the importance of this process. It is helpful if the unloading area is smooth and spacious to eliminate bumping and jarring. During hauling, drivers should reduce and eliminate jarring and bouncing. By choosing proper transportation routes and avoiding rough, bumpy roads fruit injury can be minimized. Position of fruit on the trailer is also important. Within-bin vibration levels are highest at the front of the trailer, intermediate in the rear, and lowest in the middle of the trailer. The addition of air-suspension systems to trailers has been shown to be of tremendous value in reducing this type of fruit damage. Plastic bin liners and padded bin covers have also been demonstrated to reduce transport injury. Research has shown that thick bubble padding is more beneficial than thin, and that larger bubbles are preferred to small (Mitchell and Kader, 1989b).

Fruit packaging

At the packinghouse the fruit are dumped (mostly using dry bin dumps, Fig. 22.9/Plate 240) and cleaned (Mitchell and Kader, 1989b). Here debris is removed and fruit may be washed with chlorinated water. Peaches are normally wet-brushed to remove the trichomes (fuzz), which are single-cell extensions of epidermal cells and protect fruit from new inoculations. Waxing and fungicide treatment may follow, depending on country regulations (http://www.fas.usda.gov/htp/MRL.asp).

Fig. 22.9. Dry bin dumping of fruit on to a commercial packing line.

Water-emulsifiable waxes are normally used, and fungicides may be incorporated into the wax.

Sorting and sizing operation

Sorting is carried out to eliminate fruit with visual defects, cuts and wounded areas and sometimes to divert fruit of high surface colour to a high-maturity pack (Fig. 22.10/Plate 241). Attention to details of sorting line efficiency is especially important with peaches, where a range of fruit colours, sizes and shapes can be encountered. Sizing segregates fruit by either weight or dimension. Sorting and sizing equipment must be flexible to efficiently handle large volumes of small fruit or smaller volumes of larger fruit. In California, most yellow-fleshed peaches are packed into two-layer (trays) boxes (Fig. 22.11/Plate 242). In the eastern USA, most are volume-fill packed. Electronic weight sizers are used to automatically fill shipping containers (Fig. 22.12/Plate 243). Most of the white-fleshed peaches and 'tree ripe' peaches are packed into one-layer (tray) boxes (flat). In some cases, peaches are also packed in small-size plastic bags or clamshell plastic containers. In some operations, 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 high-maturity peaches are 'ranch' or 'field' packed at the point of production. In a typical 'ranch' or 'field' packed operation, fruit of high maturity and quality are picked into buckets or totes that are carried by trailer to the packing area. These packers work directly from the buckets to sort, grade, size, and pack fruit into plastic trays. In these cases, the fruit are not washed, brushed, waxed or fungicide-treated. In other cases, fruit are picked into buckets or totes but then dumped into a smooth-operating,

Fig. 22.10. Sorting peaches by skin colour and removing blemished fruit.

Fig. 22.11. Packers sizing, sorting and packing fruit by hand into two-layer tray packs.

Fig. 22.12. Fruit moving on to an electronic weight sizer.

low-volume packing line for washing, brushing, waxing, sorting and packaging. Because of less handling of the fruit, a higher maturity can be used, and growers can benefit from increased fruit size, red colour and greater yield. High-quality fruit can also be produced by managing orchard factors properly and picking fruit that are firm. But in this latter case, ripening at the retailer will be essential to ensure good flavour quality for consumers.

Shipping and transportation

At the shipping point, fruit should be cooled and held near or below 0°C according to their freezing point. During transportation, if IB-susceptible cultivars are exposed to 5°C their postharvest life can be significantly reduced (Mitchell and Kader, 1989a). Peach storage and overseas shipments should be at or below 0°C. Maintaining these low pulp temperatures requires knowledge of the freezing point of the fruit, the temperature fluctuations in the storage system and equipment performance (Thompson *et al.*, 1998; Thompson, 2002). Holding peaches at these low temperatures minimizes both the losses associated with rotting organisms, excessive softening and water losses, and the deterioration resulting from IB in susceptible cultivars, therefore optimizing their postharvest life (Mitchell, 1987).

22.7 Cull Utilization

Potential uses

The main use of peach culls is for cattle feed because culled peach is palatable and a good source of energy (Fig. 22.13/Plate 244), but it is low in protein and has other characteristics that make it different from other feed sources (Thompson, 2002). For example, peaches contain ~85% water, 9% digestible dry matter, 5% pits and 2% indigestible dry matter. The high

Fig. 22.13. Cull removal and disposal can be a major problem and expense in peach packing.

water content diminishes the real value as feed because it makes culls expensive to transport, requires large trough volumes, and allows the feed to spoil quickly. If fed in large proportions, culled fruit causes almost continuous urination and consequently the animals require a high amount of salt. The only potential advantage to the high water content is that animals in a remote, dry location will not need extra water hauled to them. Low protein levels in culled fruit limit the quantity that can be fed where rapid weight gain is important, such as in feed lots. For example, only about 20% of the ration can be composed of culls (Thompson, 2002).

The use of culls for fuel alcohol production is limited mainly by the low sugar content; thus peach is not included in this group (Thompson, 2002). The 8 to 12% sugar content of most culled peaches results in an alcohol yield of about 42 l/t (10 gal/t) of fruit, which is too low compared with potatoes (83 to 104 l/t) or maize (375 l/t). This low yield makes it uneconomical in addition to the waste management problem. Unfortunately, the limits to the use of culls often result in large portions of them being discarded. Improper disposal can cause sanitary and pollution problems (Thompson, 2002). Flies and odour problems can be prevented by ensuring rapid drying. Fly maggots hatch into adults within 7 to 10 days, and odour problems can develop before flies appear. The culls should be crushed and spread no more than one or two layers deep; sometimes this is done on orchard roads or fallow fields. Culls can be disked into the soil, although this tends to cover the fruit with soil and slows drying; also, insects or diseases that may have caused the fruit to be culled in the first place may infect a future crop. Disposal sites should be as far away from neighbours as possible. Flies can travel up to 8 km (5 miles) from the place where they hatch. Culls should not be dumped near streambeds. Fruit cull piles can attract the dumping of many other kinds of refuse. If culls are deposited away from the point of production, use municipal solid waste disposal sites if available. Some culls can be turned into dried fruit for human consumption. However, good-quality dried fruit is made only from good-quality fresh fruit. Only undersized or slightly overripe fruit should be considered for drying.

Situation in California

In general, peach culls are going for frozen or canned peaches or juice, dried for charity donation, or used for livestock feed. When fruit have worms and decay they are utilized as green waste for compost. The amount of culls varies according to season, cultivar and other conditions from ~10 to 30% of total production. The decision on the cull utilization is made based on returns. In general, when the reason for disposal has been small sizes and mainly cosmetic blemishes, fruit still have value for human consumption and can be frozen, canned or used for making juice or other value-added products.

Other uses

A very limited peach fresh-cut business has been developed because of the short market life of this produce (Gorny *et al.*, 1999). The optimal ripeness for preparing fresh-cut peach slices is when the flesh firmness reaches 1.4–2.7 kgf, and these slices can retain good eating quality for 2–8 days (depending on cultivar) while kept at 5°C and 90–95% relative humidity. Post-slice dips in ascorbic acid and calcium lactate or use of MAP may slightly prolong the shelf-life of peach slices. Recently, mild heat pre-treatments (40°C for 70 min) before minimal processing and packing under passive MAP conditions were effective in inducing firmness (Steiner *et al.*, 2006), while preserving nutritional quality (organic acids and vitamins).

22.8 Fruit Handling at Retail Distribution

Fruit preparation for consumers

Because peaches are a climacteric fruit they are usually harvested when they reach a minimum or higher maturity, but are not completely ripe ('ready to eat'). Initiation of the ripening process must occur before consumption to satisfy consumers. It has been demonstrated that most consumers are satisfied after eating ripe peaches. A ripe or 'ready to eat' peach is defined when flesh firmness is approximately 0.9–1.4 kgf. Peaches with firmness below 2.7–3.6 kgf ('ready to buy') are becoming attractive to consumers while still tolerating retail handling. For this reason, this range is also called the transfer point. Thus, a delivery system should target store displays of peaches with firmness below 2.7–3.6 kgf and ensure that consumers are eating peaches that are 'ready to eat'. Promotional programmes should be established to educate consumers on ripening issues.

As the market for fresh produce is growing steadily, the need for assuring quality is increasing in European markets. In this sense, the market splits into two classes of produce: commodity (low price) and high-quality fruits, which are in demand from the new export markets. Accordingly, the combination of colour measurements using two wavelengths (450 and 680 nm) with non-destructive firmness testing gave a good procedure for classifying peaches for ripeness (Ruiz-Altisent *et al.*, 2006). It has been reported that the presence of γ-decalactone, δ-octalactone and γ-octalactone can be used to indicate the maturity stage for harvesting peaches (Lavilla *et al.*, 2002). Two sensors based on solid-state detection of gas concentration of γ- and δ-decalactone (which increase significantly during the final stages of ripeness) were able to grade peaches by ripening stages. Moreover, the sensors were capable of detecting skin breakage produced by mechanical or pathological causes and showed a good correlation with firmness measurements (Moltó *et al.*, 1999).

Fruit buyer handling

If retailers are receiving mature peaches (4.5–7.3 kgf), the ripening process can be initiated at the distribution centres (receivers). Detailed ripening protocols for retail handlers, warehouse and produce managers have been developed and well promoted (Crisosto and Parker, 1997). In general, peach cultivars harvested commercially will ripen properly without exogenous ethylene application. Temperature conditions for peaches during and after ripening should be adjusted according to the desired sales/consumption schedule. We encourage that further fruit ripening, if necessary, be done at the distribution level. The rate of fruit softening (pressure loss (kgf) per day) varies among peach cultivars and can be controlled by the storage temperature used. Fruit stored at 2.2°C will soften slower than fruit stored at 20°C. When the fruit reaches the transfer firmness mentioned above, the rate of softening slows. However, rate of softening also varies according to orchard and season, so firmness measurements should be taken to protect fruit integrity during the ripening process. These fruit will reach their ‘ready to eat’ firmness of 0.9–1.8 kgf after 2–3 days at room temperature (15–20°C dry retail display). Firmness is measured mid-cheek, perpendicular to the fruit suture.

When kept at 2.2°C or below, peaches should be shipped out of the distribution centre within 4–5 days (ideally within 2–3 days). To the extent that the distribution centre does not have rooms that can maintain temperatures at this 2.2°C and below range, it might make more sense to set up two shipments per week from the shipper to ensure better temperature control and extend the market life of the product. In general, soft fruit are more susceptible to bruising than hard fruit. To reduce potential physical damage occurring during transportation from the distribution centres to retail stores and handling at the retail stores, we suggest transferring fruit to the retail store before fruit reaches no lower than 1.8–2.3 kgf measured on the weakest position for tray-packed peaches and nectarines. In general, the shoulder position is the weakest point on mid- or late-season fruit. As bruising incidence varies among cultivars, and bruising potential is related to each specific operation, producers should fine-tune their transfer points for their handling situation. These are general handling guidelines but they need to be modified and assessed in light of one’s particular company facilities, logistics and customer requirements.

Peach handling at retail stores

Ideally, peaches should be transported at 0–1.7°C from the distribution centre and kept at 0–1.7°C prior to transfer to dry/warm table for display. In situations where fruit temperature cannot be maintained out of the ‘killing zone’, it would be preferable to move fruit fast. Firmness measurements need to be considered in the decision-making process (Crisosto and Mitchell, 2002).

Peaches should ideally be arriving from the distribution centre to the retail stores with

Fig. 22.14. Peach fruit display at a retail store.

firmness in the range of 1.8–2.7 kgf (weakest position) or 2.7–3.6 kgf (cheeks). This fruit is at the 'ready to buy' or 'transfer point' stage of ripening and within ~48–72 h at 20°C should be 'ready to eat' in the 0.9–1.8 kgf firmness range. This is the firmness range at which most consumers claim the highest satisfaction when eating peaches.

Produce managers need to be educated about this new 'ready to buy' type of fruit (preconditioned) to minimize mechanical damage and expedite an effective rotation (first in, first out). Peaches should be displayed on dry tables and labelled well as 'ready to buy/eat', and consumers should understand that this fruit is riper than conventionally packed tree fruit (Fig. 22.14/Plate 245). In order to protect these fruit, the display should be no more than two layers deep and in-box display should be attempted. As tree fruit will continue to ripen on the display warm/dry table, they should be checked often and the softest fruit be placed at the front of the display. Fruit that reach the 'ready to eat' ripeness of 0.9–1.4 kgf cheek firmness need to be sold quickly or refrigerated to extend their shelf-life. It is essential that consumers be instructed that this type of fruit should be refrigerated if it is not going to be consumed within 3 days of purchase.

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