Chapter 14

Postharvest supply chain management protocols and handling of physiological disorders

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14.1 Harvest and packaging

Fresh-market peaches are produced in the northern hemisphere from April through September and in the southern hemisphere, from November to March. However, its availability in stores is rather limited due to their reduced storage potential. Peach harvest has a relatively broad window (firm to fully ripe). Fruit should be harvested with maximum care, regardless of the picking maturity stage. It is crucial to always avoid physical damage since it will induce ripening, favour loss, decay, tissue browning and dehydration. Using clean bags or small containers is recommended to prevent bruising, decay, and potential skin inking. Fruit contact with the ground should be avoided to prevent phytosanitary and human disease problems.

Fruit picked at firm stages offers more flexibility regarding postharvest management, but sometimes may affect consumer satisfaction. On the other side, fully ripe peaches are highly susceptible to physical damages and decay but have a flavor surplus. The most commonly practical minimum harvest maturity index used are background color and firmness. As a climacteric fruit, peach background skin color changes from green to yellow and/or even flesh color are being used to assure that fruit will ripe properly after harvest during postharvest handling. In highly red-flushed cultivars that red color covered background color development making difficult to assess minimum maturity, fruit firmness is successfully used as a maximum harvest maturity (Crisosto, 1994; Crisosto et al., 2012 Crisosto and Day, 2020). Maximum maturity index is defined as the minimum flesh firmness at which fruits can be handled without bruising damage (Crisosto et al., 2001; Crisosto et al., 2004; and Crisosto and Costa, 2008). Thus, a maximum harvest maturity (critical bruising thresholds), based on firmness measured at the weakest fruit spot, is being used for fresh commercial cultivars in California, Chile, and other countries (Crisosto et al., 2001; 2004). Maximum maturity indices was developed for different harvesting-packinghouse operations based on their bruising potentials (Table 1) and cultivar critical bruising thresholds that were developed for different stone fruit cultivars (Table 2). Impact location on the fruit was an important factor in the determination of critical bruising thresholds as fruit softening is not evenly across fruit surface. In general, yellow-flesh peach and nectarine tolerated more physical abuse than white flesh peach cultivars. Potential sources of bruising damage during fruit harvesting-packing were determined using an accelerometer (IS-100). A survey of different packinghouse types revealed that bruising potentials varied from 21 to 206 G (Table 1). Bruising potential was easily reduced by adding padding material to the packinglines, minimizing height differences at transfer points, synchronizing timing between components, and reducing the operating speed. Bruising probabilities for the most-susceptible California-grown cultivars at different velocities and Gs have been developed (Table 2).

Table 1. Impacts (G's) recorded at transfer points of stone fruit packinglines.

Transfer points	Mean^z (G's)	S^y	Range (min-max)
Packinghouse A			
Bin Dumper	90.7	48.6	24-180
Bin Dumper To Pony Sizer	110.4	12.1	105-131
Pony Sizer	70.6	13.3	54-84
To Washer/Brusher	80.0	16.8	75-98
To Sorting Tables	102.0	31.6	66-145
To Sizers	88.9	9.5	74-97
Sizer Cups	67.6	5.3	59-72
Sizer Kick Out	57	21.3	25-78
Boxing Line	71	10.2	55-82
Boxing Machine	65	19.8	46-94
Box Volume Fill	47	24.1	28-89
Box Tray Pack	60.6	18.5	33-78
Packinghouse B			
Bin Dumper	94.3	47.3	38-177
Elevator to Pony Sizer	121.8	50.3	72-187
Pony Sizer to Washer/Brusher	83.4	10.4	71-98
Brusher to Sorting Tables	130.9	29.7	58-180
Sorting to Sizers	94.2	13.7	72-117
Sizer to Sizer Cups	61.0	10.3	38-74

Transfer points	Mean[z] (G's)	S[y]	Range (min-max)
Sizer Cups Kick Out		Not detectable	
Drop Down to Packing Belt	94.9	56.9	30-165
Box Volume Fill	103.8	32.8	70-146
Packinghouse C			
Bin Dumper	82.8	16.5	73-107
Dumper to Elevator	57.9	26.2	25-114
Conveyor to Washer	68.4	21.4	42-106
Washer to Waxer	24.5	4.4	19-33
Waxer to Sorting Tables	25.1	3.5	21-32
Sorting to Sizers	90.6	11.6	72-110
Sizers to Conveyor	71.6	50.8	23-170
Conveyor to Packing Tables	97.5	14.7	83-126
Box Tray Pack	61.5	31.9	27-117
Box Volume Fill	143.0	28.1	111-206

[Z] Means were calculated using the peak impact measured during each of the 10 trips of the instrumented sphere across each transfer point.

[Y] Indicates standard deviation. Source: Crisosto et al., 2001

Table 2. Minimum flesh firmness (measured at the weakest point on the fruit) necessary to avoid commercial bruising at three levels of physical handling.

	Drop Height[z]			
Cultivar	(1 cm) ~66 G	(5 cm) ~185 G	(10 cm) ~246 G	Weakest position
<u>Peaches</u> (yellow flesh)				
Queencrest	0	4	9	Tip
Rich May	0	0	9	Tip
Kern Sun	2	6	9	Tip
Flavorcrest	3	5	6-9	Tip
Rich Lady	6	10	11	Shoulder
Fancy Lady	3	7	11	Shoulder
Diamond Princess	0	0	9	Shoulder
Elegant Lady	3	5	6-9	Shoulder
Summer Lady	0	0	8	Shoulder
O'Henry	3	5	6-9	Shoulder
August Sun	3	4	9	Shoulder
Ryan Sun	0	0	10	Shoulder
September Sun	0	4	9	Shoulder
<u>Nectarines</u> (yellow flesh)				
Mayglo	4	8	11	Tip
Rose Diamond	6	7	8	Suture/Shoulder
Royal Glo	0	9	11	Shoulder/Tip
Spring Bright	6	10	10	Shoulder
Red Diamond	6	7	11	Shoulder
Ruby Diamond	4	9	9	Shoulder
Summer Grand	2	5	6	Shoulder
Flavortop	3	6	6	Tip
Summer Bright	0	6	8	Shoulder
Summer Fire	0	0	9	Shoulder
August Red	2	12	12	Shoulder
September Red	0	0	10	Shoulder

Fruit firmness measured with an 8 mm tip
[z]Dropped on 1/8" PVC belt. Damaged areas with a diameter equal to or greater than 2.5 mm were measured as bruises. Source: Crisosto et al., 2001

From the consumer point of view, consumers tend to widely accepted fruit with force firmness below 3 to 4 kg (‘ready to transfer or buy’) measured on the cheek with an 8 mm tip), while fruit having 1-2 kg force firmness are considered ‘ready to eat’ defined as the stage that fruit reached the highest flavor expression for consumers (Crisosto and Mitchell., 2016). Furthermore, it has been validated that non-destructive firmness measurements can be directly used to identify the stage of ripeness (‘ready to transfer’ and ‘ready to eat’) and potential susceptibility to bruising during postharvest changes (Crisosto and Valero, 2006; Valero et al., 2007).

An array of protocols for harvesting and packaging have been developed, depending on the fruits’ destination, desired postharvest life, and available infrastructure (Crisosto and Mitchell, 2016; Crisosto and Day, 2012; Manganaris et al, 2020a).

In most countries, Pickers working from the ground or ladders are hand-picked into bags, totes or buckets and dumped into wooden or plastic bins in the field. The fruit are dumped into bins that are distributed on the field or top of trailers between rows in the orchard (Fig. 1). Plastic bin liners and padded bin covers have shown to reduce transport injury in some sensitive conditions. Plastic totes are placed directly inside the bins and buckets are placed on modified trailers. Fruit picked at advanced maturity stages, as well as white-flesh peaches are generally picked and placed into backets or totes. Depending on the cultivar and specific situation, a worker can usually harvest 1½ to 3 full-size bins of fruit per day. Early-season cultivars are usually picked every 2-3 days, and by mid- to late-season, the interval can stretch to as much as 7 days between harvests. In general, early ripening cultivars are harvested twice, mid and late-ripening cultivars are harvested 3-6 times according to cultivar, season and prices. Tree heights are commonly 3.7-4.7 m, and workers require ladders to reach the uppermost fruits. The recent establishment of pedestrian orchards that include different training-pruning and the use of size control rootstocks are reducing the use of ladders as tree are harvested from the ground. Ladders are made of aluminum and are 3.7-4.0 m in length. Either 4 or 6 rows are harvested at a time, with an equitable number of pickers distributed in each row as conditions warrant. Workers pick an entire tree and leapfrog one another down the rows. The foreman is responsible for moving the pickers between rows to maintain uniformity. Then the bins are taken to a centralized area and unloaded from the bin-trailers or truck to await loading by forklift onto flatbed trailers for delivery to the packing facility. Full bins are typically covered with canvas to prevent heat damage, and loading areas are usually bordered by large shade trees that serve to help reduce fruit exposure to the sun. In instances where the orchard is close to the packing plant, the fruit can be conveyed there directly on the bin-trailers or truck. The fruit are hauled for short distances by trailers, but if the distance is longer than 10 km, the bins or totes are loaded on a truck for transportation to packinghouses. Picking platforms have been tried, but they are not an economically viable way of reducing reliance upon ladders due to their cost and the vast differences in tree and workers efficiencies.

Fig. 1 Peach dumping in plastic bins prior to transfer to packinghouse. Courte Echeverria.

In few cases (i.e. Greece), field packing strategies is being applied for fresh consumed freestone and some clingstone cultivars to minimize manipulation and mechanical damage (Fig. 2). Such products of advanced ripening are mainly destined for the domestic market.

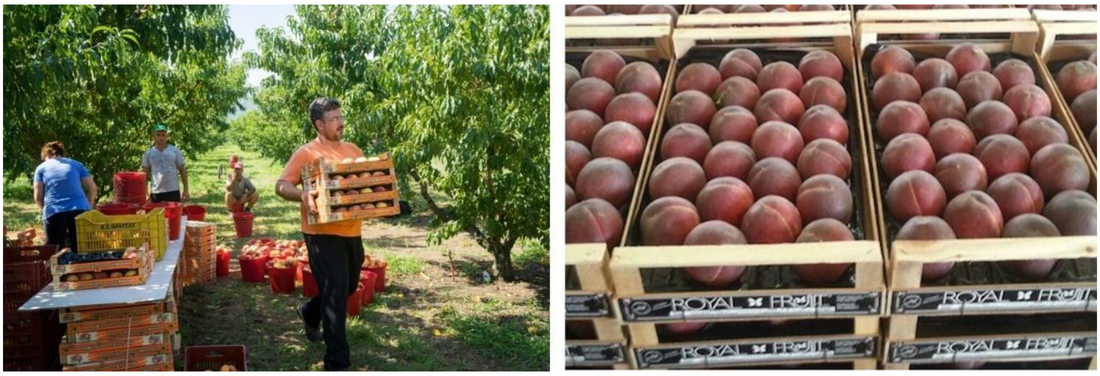

Fig. 2 Harvest and in-farm packaging of peach fruit in Greece. Courtesy Manganaris.

Then, harvested peaches are transported to a packinghouse for cooling, packaging, storage, and distribution**.** In all situations, at the packinghouse, some peaches are packed upon arrival from the orchard, others are partially cool and packed next day. In general, if fruit will not be packed within 2-3 days, they should be cooled close to 0°C to protect from deterioration.

Peach packaging normally include the following operations: dumping, washing, rinsing, grading, brushing, fungicide spraying application, sorting, and packing Fig. 3). At the packinghouse, the fruit are dumped and cleaned using a sanitation unit equipment where debris is removed, and sanitized. Peaches are normally washed and wet brushed to remove the trichomes, or fuzz, which are single cell extensions of epidermal cells. Water containing chlorine is used to wash and as a first attempt to sanitize peaches and nectarines. Ideally, this area is ideally located outside the packing area. After brushing-washing, fruit go through a short drying area in preparation for the waxing-fungicide application (when allowed). Waxing, and approved fungicide treatments follow in next other protected section area. Water-emulsified waxes are normally used, and fungicides may be incorporated into the wax. Waxes are applied cold and no heated drying is necessary to provide shinning and spread and hold the applied fungicide. Sorting or grading is done to eliminate fruit with visual defects and sometimes to divert fruit of high surface color to a high-maturity pack. Attention to details of sorting line efficiency is especially important with peaches and nectarines where a range of colors, sizes, and shapes of fruit can be encountered. Sizing segregates fruit by either weight or dimension carried out by operators or electronic computer-controlled system. Sorting and sizing equipment must be flexible to efficiently handle large volumes of small fruit or smaller volumes of larger fruit. Most of the yellow-fleshed peaches and nectarines are packed in one (flat) or two-tray boxes. In some cases, electronic weight sizers are used to automatically fill shipping containers (volume fill packed) with the fruit automatically filled by weight into shipping containers. 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. Most of the white-fleshed peaches and "tree ripe" are packed into one-tray box (flat), punnets, or clamshells.

Fig. 3. Peach packinghouse operation in Spain. Courtesy Echeverria.

Packinghouses currently offer a wide range of package options adapted to customer's needs. Fruit may be packed in an array of containers including polyethylene bags, punnets, net bags, and single or multi-layered boxes. Subject on marketing's requests, peaches are single-layer trays, multilayer boxes, and netted punnets. First category fruit is normally exported, whereas second category is directed to less stringent domestic markets, especially to small stores and organic groceries. Boxes are unitized in a pallet unit for easy and efficient handling. In most countries, the 1.2 x 1.0-meter (UK pallet) is the standard requested by supermarkets. In USA, there is maximum weight (36,288 Kg) per truck to protect the highway system. Thus, the total number of tiers per pallet will depend on total weight allow per container in each country. However, the height of the pallet is limited by height of container doors and the inside container height allowance for proper air volume distribution (Crisosto and Mitchell, 2016; Crisosto and Day; 2012; Thompson; 2016). In Europe fruit is commonly packed is a single tray with a net weight of 4.5 kg and gross weight of 5 kg, while in USA, most of peaches are packed using two trays or layers, to protect ripe peaches, with a box net weight of 9.1 kg and gross weight of 10 kg. In very few places, and when less mature peaches are used, volume-fill could be done with a net weight of 11.3 kg and 12.3 gross weight peer box. Under these package uses, total pallet weight varies from 720 kg (single layer), 800 kg (two layers) to 994 kg (volume-fill) (Crisosto and Mitchel., 2016). All box-pallet loads should be stabilized with netting or strapping and corner boards. Box size, design and pallet placement that include venting shape-area and perforation locations (side and/or bottom) to assure cold air movement throughout the fruit box venting should be designed to provide enough air flow and force air path (convective cooling) to reach fruit inside (Mitchell et al., 1998)

The packages with its own brand, used for high quality or premium fruit, is exported to both national and international markets with single-layer tray of 50 x 30 x 9.5 cm. Peach trays could be made of cardboard, wood, or reusable plastic. The requirements of the fruit shipped in trays are frequently more stringent than those for punnet peaches which also usually include smaller fruit. Once packed and consolidated, the fruit should be forced air-cooled and placed in a cold storage (**Fig. 4**).

Fig. 4. Forced-air cooling facilities of peach. Courtesy Echeverria.

14.3. Cold storage and Transportation

Peaches are chilling sensitive fruit with damage symptoms being more intense between 2 and 7°C. Since keeping the fruit at temperatures higher than 10°C would rapidly result in excessive softening and decay 0°C or below but but above the tissue's freezing point to maximize peach storage potential and shelf-life. Thus, this temperature between 2 and 7ºC is called the 'killing temperature zone' (Crisosto et al., 1999b; Lurie and Crisosto, 2005; Manganaris et al., 2019&2020). Appropriate relative humidity (*ca.* 85%) is also crucial to minimize dehydration when condensation does not occur. Maintaining these low pulp temperatures and relative conditions require knowledge of the freezing point of the fruit, the temperature fluctuations in the storage system, loading techniques, and equipment performance.

Peach fruit transportation is commonly conducted by truck when delivery is within a week of production area. Marine transportation is used for long distance markets and their conditions may lead to abnormal ripening due to extended cold storage periods. Air freight is used for transportation for premium markets to justify the high transportation cost. Pre-cooling transportation containers at 0°C before loading among other recommendations is crucial to assure that load is at the desired storage temperature and a safe arrival (Thompson, 2016; Thompson and Crisosto, 2016). Stone fruit storage and overseas shipments should be at or below 0°C. Temperature during truck transportation within the U.S., Europe, Canada, and Mexico should be below 2.2°C. Holding stone fruits at these low temperatures minimizes both the losses associated with rotting organisms, excessive softening, water losses, and the deterioration resulting from chilling injury in susceptible cultivars (Crisosto et al., 1999).

Chilling injury (CI) is the main physiological disorder limiting export and long-distance peach distribution (Crisosto, 1999b, Lurie and Crisosto, 2005; Martinez et al., 2011; Manganaris et al., 2019 & 2020). The different manifestations of CI symptoms in peach are evident as (1) mealiness or woolliness (perception of a dry and wooly texture due to lack of free juice upon consumption), (2) leatheriness (hard-textured fruit with no juice), (3) flesh breakdown evident as flesh browning (Fig. 5) and (4) red flesh pigmentation or bleeding (Fig. 6). Such symptoms are accompanied by loss of flavor that is the most frequent complaint by consumers and wholesalers and the main barrier to consumption. 'Off flavor' development is one of the initial symptoms of CI prior to flesh mealiness and browning development, while susceptibility to CI is largely dependent on genotype and are triggered by a combination of temperature and time of exposure to chilling temperature. Chilling injury represents a major problem because its symptoms remain unnoticed until peaches reach customers at a ready-to-eat stage (Crisosto et al., 1999b) Lurie and Crisosto, 2005). At advanced stages damaged fruit has no obvious abnormal external appearance but lack juiciness and have a highly dry texture not related to water loss since both mealy peaches and nectarines have similar water content with juicy fruit (Manganaris et al., 2019 & 2020).

Fig. 5 'Andross' peach fruit with evident flesh browning symptom after cold storage (5°C) and additional ripening at room temperature for 5 days. Courtesy Manganaris.

Fig. 6 Fruit showing mild severity (left) or severe bleeding symptoms (middle) or in combination with mealy texture (right). Courtesy Manganaris.

14.6 Strategies to alleviate chilling injury

Selection of chilling tolerant cultivars: This is the most practical and fast protocol to deal with the problem. Peach and nectarine cultivars are characterized by a different degree of CI susceptibility (**Fig. 7**). The susceptibility of cultivars to CI is being constantly evaluated in the most currently planted yellow and white flesh peach, nectarine, and plum cultivars from different breeding sources and fruit types (Crisosto et al., 1999b; Crisosto et al., 2008; Martínez-García et al., 2011; Echeverria et al., 2021). In general cultivars are segregated into three categories (A, B, and C) according to their susceptibility to CI symptoms (mealiness and flesh browning) when exposed to 0°C or5 °C storage temperatures. Cultivars in Category A did not develop any symptoms of CI after 5 weeks of storage at either temperature. Cultivars in Category B developed symptoms only when stored at 5°C within 5 weeks of storage. Cultivars were classified in Category C when fruit developed CI symptoms at both storage temperatures within 5 weeks of storage. Most of the yellow and white flesh peach cultivars developed CI symptoms when stored at both storage temperatures (Cat. C). Based on this data, a market life potential a concept that can be used for marketing was developed and it is used for different export companies. An application of the market life potential concept was recent study carried out by the Institute for Research and Technology in Food and Agriculture (IRTA) that segregated 29 peach cultivars into five categories according to commercial market life depending to their tolerance to CI: up to 14, 21, 28, 35 and 42 days, as well as logistics information on the transport -marketing period to any port in the world (Echeverria et al., 2021).The work results demonstrated the importance of proper genotype selection and temperature management during postharvest handling. Current genotype CI evaluations revealed that new cultivars are less susceptible to CI due to breeding program selection (Peace personal communication).

Fig. 7 Peach and nectarine cultivars with varying CI manifestations. Courtesy Camer Peace.

Preharvest factors and harvest maturity: Few studies have been conducted so far towards dissecting a link between fruit susceptibility to CI and preharvest factors, partially due to the large seasonal variations (Campos-Vargas et al, 2006). Low crop loads have been empirically correlated with increased incidence of flesh browning and mealiness. Shaded fruit also had lower storage potential and were more prone to postharvest disorders (Lurie and Crisosto, 2005; Crisosto and Costa 2008). Early harvested fruit are considered to be more susceptible to CI, especially to flesh browning, during storage. However, over-ripening also leads to flesh browning problems, at least in some cultivars, such as Big Top. As a general rule, maturity stage at harvest appears to have a direct effect on fruit susceptibility to CI with ripe fruit being less susceptible.

At arrival to packinghouse, fruit can be cooled in field bins using forced-air cooling or hydrocooling. Conventional cold storage just above the freezing point is the most convenient condition to delay CI manifestations, while avoiding the 'killing temperature range (2-8 °C) as elsewhere described. The ideal peach storage temperature is -1 to 0°C. The flesh freezing point varies depending on TSS. Storage-room relative humidity should be maintained at 90–95 % and airflow of approximately 0.0236 cubic meter per sec per ton is suggested during storage (Mitchell, et al, 1998; Crisosto and Mitchell, 2016; Manganaris et al, 2020).

Application of a controlled atmosphere (6% O_2 + 17% CO_2) has been proven beneficial to delay fruit deterioration (Crisosto et al., 2009b; Manganaris and Crisosto, 2020a). However, the most evident effect was on controlling flesh browning and softening with the effects on mealiness and off flavor development being modest (Crisosto et al., 2009b). Modified atmosphere packaging (MAP) has been tested in several peach cultivars, mostly without success (Zoffoli et al., 2002; Lurie and Crisosto, 2005).

Overall and regardless of some promising strategies at a lab scale, proper temperature management remains to date as the most efficient strategy to delay CI.

Conditioning: Conditioning (delayed cold storage) at 20 °C and 95% RH followed by forced air cooling (right) prior to cold storage could be applied to fruit harvested at firm-ripe stage to reduce CI susceptibility and assure successful ripening upon removal from cold storage (Crisosto et al, 2004; Crisosto and Mitchell., 2016). When these treatments are applied properly, market life increased by up to two weeks in the cultivars tested (Crisosto et al., 2004). Careful monitoring of weight loss and firmness during delayed cooling and proper use of fungicides is highly recommended for success of this strategy (Lurie and Crisosto, 2005). This method can also be used to pre-ripen peaches to deliver into the market a ready-to-eat product (Crisosto et al., 2004).

Fruit with greater capacity to produce ethylene after cold storage have been reported to have less severe CI (Zhou et al., 2001a; Gine-Bordonaba et al. 2016). Therefore, 1-methylcyclopropene, an ethylene antagonist that was proven beneficial for shelf-life extension of an array of climacteric type fruits, is considered detrimental for peach fruits destined for cold storage (Dong et al., 2001).

Heat treatments: Heat treatments have shown some benefits on CI prevention, without however being applied at commercial scale (Murray et al., 2016). Their efficacy is also highly dependent on the cultivar, pre-harvest factors, and shipping duration. Intermittent warming (IW) has been also reported as a CI delaying strategy. In this case, fruits are subjected to cold storage with interludes at room temperature. The basis for IW is to remove the fruit from the stress condition before it gets into the phase at which irreversible damage may occur. When two days of IW at 20 °C was applied every 12 days during 0^{o}C storage, mealiness was reduced (Zhou et al., 2001b). This protocol was tested at commercial scale in South Africa, yet it was proven to be difficult to apply at commercial scale, while the benefits are modest.

Chemical treatments: An array of chemical treatments, mainly hormone applications, has been applied to prevent and/or alleviate CI on peach fruit with variable success. Chemical treatments included the application of salicylic acid, methyl Jasmonate, oxalic acid, γ-aminobutyric acid, and gibberellic acid (Jin et al., 2009, 2014; Yang et al., 2011, 2012, Shan et al., 2016). The most promising results were provided through preharvest gibberellin application that appeared to induce protection to CI (Pegoraro et al., 2015). This protection has been attributed to the transcriptional changes triggered by GAs at early stages of fruit development that could affect subsequent responses to stress after harvest (Pegoraro et al., 2015). Such treatments still need to be validated on commercial settings.

14.7 Other physiological disorders

Field Skin Inking or black staining: It is a type of skin discoloration, causing fruit rejections. The symptoms appear as brown and/or black spots or stripes that are restricted to the skin (**Fig. 8**). The inked areas are normally small but in extreme cases can reach up to 50% of fruit surface. Inking symptoms are triggered during harvest and during transportation to the packinghouse and normally become evident within 48 h after harvest.

Fig. 8 Skin Inking symptoms in peach fruit. Courtesy Crisosto.

Field inking is believed to be caused by abrasion damage in combination with heavy metal contamination. The skin cells, rich in phenolic compounds collapse and their contents react with heavy metals turning their color dark brown/black. Iron (Fe), copper and aluminum are the most deleterious heavy metal compounds that can combine with polyphenols. Trace concentrations of Fe (5-10 ppm of iron) may induce inking at pH ~ 3.5. Metal contamination may occur due to dust deposition on the fruit surface or because of close to harvest, pre-harvest foliar nutrient, fungicide and insecticide sprays that contain the abovementioned metals.

Some prevention and mitigation measures to control inking are (Cheng and Crisosto, 1995, 1997; Crisosto et al., 1999a):

- Reduce fruit contamination by keeping picking containers clean and avoid dust contamination on fruits.
- Reduce fruit abrasion damage by treating fruit gently, use air-ride suspension on trailers, and avoid long hauling (Crisosto et al., 1993).

- Check your water quality for contamination with heavy metals (Fe, Cu, Al) and test pesticides for presence of heavy metals early in the season
- Avoid spraying foliar nutrients or preharvest fungicides that contain Fe, Cu, or Al within 21 days of predicted harvest. Chemical manufacturing companies should attempt to identify and remove from their products any potential sources of contaminants that may contribute to inking formation, and to develop safe pre-harvest spray intervals for foliar nutrients, fungicides, miticides, and insecticides.
- Growers need to know the composition of the chemicals, commonly used in their tree fruit pre-harvest and postharvest operations, and understand how they may affect inking incidence.
- In orchards where inking is a problem, delay packing for ~48 h so you will be able to remove fruit with field inking before placing fruit in the box.
- Fine tune your postharvest fungicide application to assure that your residues are above the effective minimum recommended, but well below the maximum residue limit (MRL) or tolerance.

Skin burning: This is another type of skin discoloration that has become a frequent problem on specific susceptible peach and nectarine cultivars (Cantín et al., 2011). IRTA results from observations over several years indicated that peach and nectarine skin discolorations, field inking and skin burning, are both triggered by a combination of physical damage during harvesting-hauling combined with different postharvest stress factors However, although field inking and skin burn disorders have similar symptoms, they have different triggers and different biological mechanisms of development and therefore it is important to understand the differences between both cosmetic skin disorders.

Fig. 9. Skin Burning symptoms in peach fruit. Courtesy Crisosto.

Skin burning symptoms appear as brown and/or black areas that are restricted to the skin. In contrast to field inking these symptoms are mainly triggered during packing operations, principally at the brushing-washing point, although abrasion that occurs prior to packing may also contribute to its development (Crisosto et al., 2000). Fruit damage is triggered by exposure to high pH and/or dehydration caused by high-velocity, forced-air cooling during packing (Cantín et al., 2011). Symptoms can be observed very soon after packing, but the symptoms rapidly increase during cold storage due to dehydration. In fact, it has been observed that most of the intense skin damage in packed fruit occurred on the exposed part of the fruit above the tray receptacle and no damage occurred under the price-look-up sticker (Cantin et al., 2011). Different susceptibility to skin burning have been observed among peach and nectarine cultivars, depending mainly on the specific phenolics in their skin tissues due to co-pigmentation with anthocyanins, resulting in a change in color of the anthocyanin compound and therefore discoloration of the skin (Cantín et al., 2011).

Some prevention and mitigation measures to control skin burning are:

- Minimize physical damage or abrasion on the fruit surface during pre- and/or post-harvest operations. Handle fruit gently, use air-ride suspension on trailers, avoid long hauling distances and keep harvest containers free of dirt.
- In a standard packing operation, washing water pH in the brushing-washing or hydrocooling operation should be continuously maintained around 6.5-7.0. The installation of automated systems using oxidation-reduction potential (ORP) to monitor

and/or adjust active/effective chlorine and pH levels is critical to control disease effectiveness and decrease potential skin burning development.

- Apply dry packing (without brushing or a chlorine rinse) for highly susceptible cultivars.
- Avoid high air velocities during forced-air cooling for skin burning susceptible cultivars. For these cultivars, room cooling, without forced air, is suggested.
- As a long-term solution, we suggest screening peach and nectarine breeding parents for their susceptibility to co-pigmentation.

Corky spot: This disorder has been around for long time in California and its intensity varies according to cultivars and season (Day 2006). In the Ebro valley, it appeared during the 2006 season in some nectarine cultivars (Fig. 10). Corky spot symptoms appear as dark sunken spots on the surface of the fruits especially on fruit sides and blossom end. Internally, flesh initially presents reddish spots that turns brown, corky and dry as the fruit ripens, making it unsuitable for market (Day, 2006; Peris and Alegre, 2012).

Fig. 10 Corky spot symptoms in nectarine fruit. Courtesy: Echeverria.

This disorder has been attributed in the excess in fertilization and some water stress conditions during the growing period that could lead to a nutritional imbalance and a deficiency in Ca fruit content (Day 2006; Perís and Alegre, 2012). A significant decrease in the severity and percentage of fruits affected by corky spot was recorded in Ca-treated fruit (Crisosto et al, 2000; Val et al., 2018). The incidence of the disorder also increased with fruit maturation. The common factors that were monitored in affected orchards were:

young trees, vigorous growth and a dry and hot summer. Seasonal variation of the corky spot incidence is thought to be due to hot temperatures prior to harvest. An earlier study in California (Day, 2006), described calcium and boron deficiency, nutritional imbalance done by an excess in nitrogen that promotes vigorous tree growing, seasonal cold temperature and some environmental stress like water deficits in high evaporative demand conditions as possible causes of this disorder (Day, 2006). Overall, orchard conditions, crop load, cultivar, tree age and summer pruning may affect the incidence of the disorder. Avoiding excess in nitrogen and potassium fertilization, and water stress conditions is recommended to prevent corky spot.

Skin bronzing and streaking: Bronzing refers to patches of skin on the fruit that look bronzed on primarily yellow to light red skin background. Depending on severity, the damage may stretch from a single small patch to most of the peach covered. Although research shows that many patches are formed prior to harvest, most of the symptoms only appear after storage. Peach skin streaking is another form of skin discoloration (Hu et al., 2017; Schmitz and Schnabel, 2019). Streaking is referred to symptomology resembling streaks on the fruit finish that follow water droplets formed by dew or rain. The streaks increase in diameter and end abruptly in a club-shaped fashion. Typically, several streaks of similar form and length are being observed on the same fruit in multiple cultivars each season and streaking incidence may range from zero to over 50%. Both bronzing and streaking skin disorders have significant impact on the production of high-quality fruit in the South-eastern United States (Schnabel and Melgar, personal communication).

14.8 Conclusions

Peach is a highly perishable product with limited storage potential. Different handling protocols have been developed throughout the years for proper harvesting, packaging, cooling, storing, and distributing peach fruit. The most relevant issues to consider include the selection of an appropriate firmness, flavor, and color maturity for each distribution setting and avoidance of any type of physical damage. Peach cooling operations include most frequently the use of forced air-cooling and/or hydrocooling equipment and subsequent storage at 0 °C, avoiding the 2-8 °C killing zone. Controlled and modified atmospheres are used only under specific scenarios because they cause modest benefits and highly variable responses. The fruit is finally delivered in all different kinds of packages and presentations according to the requirements of markets and customers. Peach fruit quality can be significantly impaired by different chilling and non-chilling related physiological disorders. CI remain as a major problem for unappropriated handling and /or long-term peach storage and long-distance markets. Thus, several strategies have been developed for CI alleviation, including the use of cultivars with better response to low temperatures and the use of proper conditioning treatments. Genetic improvement leading to CI-tolerant cultivars is a priority goal. It is crucially important put attention to steps at harvest and at the packing houses to assure the competitiveness and sustainability of the peach industry. Considering the excessive number of available peach and nectarine cultivars, analysis should be redirected towards early and late-ripening cultivars to increase the availability worldwide, offering off-season premium products.

14.9 References

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