6.1 HARVESTING AND HANDLING PEACHES

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Harvest and conveyance of ripe fruit to the packing house concludes the orchard management phase of peach production. It initiates a new phase of management that requires its own unique skills. A series of systematic quality-oriented harvest and post-harvest operations, beginning with harvest and ending when the consumer utilizes the product, is a key to success in any peach operation. Managers must assess fruit maturity to balance between the optimal quality of a truly tree-ripe peach and retention of resilience and durability required to harvest, transport, grade, package, and market fruit. Each time the fruit is handled or moved is a step that should be analyzed as an individual component to optimize fruit quality. An understanding of fruit physiology pre- and post-harvest and of conditions that maintain fruit quality is essential.

HARVESTING

Proper Maturity at Harvest
Peaches must be picked at a stage of development that is advanced enough to allow the fruit to ripen to high culinary quality, yet early enough to minimize bruising and premature softening during storage and transit. Deciding when to pick is difficult. Selection of picking dates is as much art as science. Variability in maturity, quality, and anticipated durability after harvest place a premium on experience and decision-making. Although every tested variety has an estimated ripening date relative to that of Elberta, the grower must adjust to annual fluctuations in ripening.

Excessively green fruit or soft fruit are undesirable, and over-mature fruit will be subject to rapid deterioration. Harvest workers should be trained to select for size and maturity. Green and undersized fruit should be left on the trees until they reach shipping maturity.

Multiple pickings are usually required for each variety to cope with the variable ripening of peaches. Picking must be selective, removing only those fruit mature enough to ship. Color and firmness are the two factors most employed in selecting fruit for picking. Environmental factors such as chill or frost can affect color, size, occurrence of soft tips, or striping of peel color. Parameters for judging maturity will continue to change with the releases of new varieties. Level of acceptability is a sliding scale that changes within each season by variety.

Ground color is the best field indicator of peach maturity. Considerable research effort has been given to the development of harvest standards based on color. The ground color of a peach
approaching maturity is light green. A break in color toward yellow is the first definite indication of maturity. Brightening of the red over-color of the skin is another, though less reliable, index of maturity. Red color is typically dull prior to the green to yellow break. When the underlying ground color breaks to yellow, the red brightens and can easily be selected. Color judgments are reliable with many older varieties, but new highly colored varieties with higher percentages of red over-color have diminished the usefulness of color in maturity determination.

Varietal tendencies must be understood to make proper picking decisions. Some varieties can hang on the tree longer when ground color has broken to yellow, although others may have so much red over-color that the green to yellow break is hard to detect.

With highly colored varieties, firmness and size are key determinants of ripeness. Some varieties are firm when mature, while others begin to soften as soon as ground color breaks. Firmness may vary year-to-year on the suture, opposite the suture, and at the tip. These variations limit the value of objective pressure testing by instruments. Day-to-day picking judgments must be made for each variety. Many newer varieties are firmer at eating maturity and can hang on the tree longer.

As breeding efforts introduce non-melting flesh into the germplasm, estimation of maturity will become even more challenging and quality parameters of acidity and soluble solids may become more important. Clearly, orchard history and the grower's experience are critical to the proper determination of fruit maturity.

Experience and the General Rule. A break in ground color and a perceptible cushioning of firmness are frequently the best indicators of maturity. Growers and picking crews must be sensitive to changes in fruit shape and size as the fruit moves through its final swell to packing maturity to minimize soft tips, sutures, and shoulders.

Orchard to Packing House: Optimal Fruit Handling to Reduce Handling Injury
Injury from rough handling is a key cause of fruit quality reduction. Bruises, cuts, punctures, compression, and abrasion injuries can be found on almost any fruit in a retail display. Consumers consistently avoid damaged fruit if undamaged fruit are available. The physiology of fruit is altered dramatically by wounding: (1) respiration increases with a corresponding decrease in shelf life; (2) ethylene production increases, which accelerates deterioration of the wounded fruit and adjacent sound fruit in the container; (3) undesirable color changes, such as flesh browning, occur; and (4) open wounds are a point of entry for pathogens, leading to decay. An important objective for any crew or packing house manager is the reduction of handling injury during harvest and post-harvest operations.

Handling injury is cumulative. When several steps in the handling system wound fruit, injuries accumulate, sometimes to the point fruit are down-graded or unmarketable.

Picking is step one in harvest and post-harvest management. Ideally, picking should be done in early morning when temperatures are lower. Rapid conveyance to the packing house and shading harvested fruit will reduce overheating and slow the post-harvest ripening.

The hands of harvesters are the most important hands that touch the fruit. A single careless step in harvesting can injure a peach and render it unmarketable. Workers should not have long, sharp fingernails. Gloves are desirable. Workers should not drop or toss the fruit. They should be taught to empty their bags, boxes, or buckets carefully, especially if the receiving container is empty. They should not overfill any container that might later have another container stacked on top.

Picking bags, bins, buckets, boxes, trailers, and all other field containers should be frequently examined for sharp edges, protruding nails or staples, and sand or gravel that could cause injury to fruit. Padding should be used in containers whenever possible to reduce impact and abrasion injuries.

An often-cited harvest management study by Ramsey in 1912 highlights common-sense steps to improve quality. Decay was less when: smaller picking bags were used; the manager did not harvest, but was free to manage the harvest crew full-time;
and the manager took time to randomly inspect product piece by piece for harvest injury as well as proper maturity.

Farm roads are seldom smooth surfaces and are difficult to maintain. Moderation in transport speed, use of shock absorbers on trailers or flatbed trucks, and the use of plastic rather than wooden bins are all steps that help reduce fruit injury.

**Published Quality Standards in the U.S.**

**U.S. Department of Agriculture Standards** must be met for each of the four grades if classified by the U.S. Department of Agriculture.

**U.S. Fancy** requires that the peaches have at least 1/3 of their surface showing blushed pink or red color and that at least 90% of them meet this color standard. U.S. Fancy has a 2% allowance, or tolerance, for soft or overripe fruit at destination.

**U.S. Extra No. 1** requires that the peaches should have at least 1/4 of their surface showing blushed pink or red color and that at least 50% of the fruit meet this color standard. As with U.S. Fancy, 2% are allowed to be soft or overripe at destination.

**U.S. No. 1** peaches do not have a color standard, but should be mature with a 2% allowance for soft or overripe peaches at destination.

**U.S. No. 2** has no color standards and it allows for a greater percentage of fruit that are poorly shaped. As with all USDA grades, the tolerance for soft or overripe fruit at destination is only 2%.

**California Well Matured** fruit are mature enough to complete the ripening process without additional ethylene exposure. The over-blush is usually 90% of total for a given variety. Ninety percent of the lot must meet the color standard. There is a non-severe open suture tolerance of 25%.

**U.S. Mature** covers all U.S. No. 1 peaches, stipulating that fruit are mature enough to complete the ripening process without additional ethylene exposure. There is a non-severe open suture tolerance of 25%.

**PHYSIOLOGY OF THE PEACH AFTER HARVESTING**

Peaches are climacteric fruit, they can be harvested when they are still firm but physiologically mature, which means they will continue to ripen after harvest. This is analogous to the “California Well Matured” grade. A harvested peach is alive and is physiologically active as it ripens and eventually becomes senescent. If the fruit is injured by storage at inappropriate temperatures or improper handling, its senescent phase is advanced, significantly shortening shelf life. In peaches, advanced senescence brings unfavorable mealy flesh textures and undesirable flavors, particularly the absence of typical peach flavor volatiles. Flesh discoloration and internal browning can be initiated by improper storage conditions. Temperature and humidity are the key post-harvest environmental factors influencing the quality and shelf-life of the harvested peach.

Softening of a harvested peach is prompted by cell-wall-degrading enzymes that become active during the final stages of ripening. Softening occurs more rapidly in freestone fruit than in cling peaches. The levels of ripening enzymes vary from one variety to the next, which affects their natural flesh firmness. Higher temperatures increase the activity of ripening enzymes. In general, a peach will ripen as much in a day at 70°F as it will in a week at 32°F. Obviously, refrigeration is an effective way of slowing the rate of ripening.

During the ripening process, respiring fruit utilize oxygen and metabolize sugars, converting sugars by enzymatic action into heat, chemical energy, carbon dioxide (CO₂), and water. Heat is given off by the fruit into the environment; the chemical energy is used to maintain cell and fruit integrity, to support enzyme activity, and for synthesis of ripening compounds; the CO₂ is expelled into the atmosphere; some water is used for enzyme activity, some accumulates in the tissues, and some evaporates. The production of energy from sugars is called respiration. Under proper conditions, respiration keeps the fruit in a fresh and constantly changing condition. Eventually, sugars and other stored components are depleted, which reduces flavor. Respiration can be slowed to prolong ripening. As respiration slows, fruit produce less heat, softening by enzymatic reactions is retarded, and flavor changes due to metabolism of sugars are reduced. Temperature reduction slows enzymatic action, as do reduced oxygen and increased CO₂, which in turn reduces respiration rate. A 10°C (50°F)
A 1/2 times. Respiration peaks when fruit go from optimal ripeness to over-maturity or senescence. This physiological watershed between underripe and overripe is referred to as the climacteric. To maintain fruit quality, peaches must be picked early enough to reach the consumer before the fruit becomes overripe. The climacteric is easily reached in peaches stored at 50°F or above, which accelerates the progress toward fruit senescence, and deterioration of flavor and texture.

Temperature is the most important determinant of the shelf life of fruit. Uncooled fruit can deteriorate more in 1 hour at 90°F than in 1 day at 40°F or in 1 week at 32°F. Most of the physiological processes associated with fruit deterioration operate more rapidly at high temperatures. Understanding the relationship between temperature and fruit senescence is required in order to properly handle peaches during the post-harvest period.

During refrigerated storage of peaches, air exchange is required to dissipate CO₂ and heat of respiration. Slightly elevated CO₂ may reduce the respiration rate, but levels above 5% can induce flesh browning around the pit. Any interference in gas exchange that restricts oxygen absorption and causes internal build-up of CO₂ shortens the storage life of peaches and promotes development of off-flavors. Even heavy wax on the fruit surface may cause undesirable internal conditions (anaerobic respiration) that will cause the formation of alcohols detected as an off-flavor. The heat of respiration must be constantly dissipated. Warm peaches in an inadequately cooled and ventilated truck may actually grow warmer while in transit. It is very important to thoroughly cool fruit before shipping or storage.

**Challenges to Meeting Quality Standards**

The many fruit choices available to consumers mean peaches must be attractive, flavorful, and free of internal breakdown to sell competitively. The difficulties with harvesting southeastern peaches at tree-ripeness have been recognized for decades. The region's uneven growing conditions increase variability in maturity at harvest, with corresponding variability in the rate of softening.

Studies in South Carolina and Georgia have documented variability in firmness at harvest. Puncture pressures varied from 5 to 22 pounds. This great a range of firmness at harvest dramatically increases the range of firmness throughout storage, in the supermarket, and in the consumer's refrigerator. In the same studies, temperatures varied from 38° to 51°F over 5-day storage periods; storing peaches in this temperature range is very detrimental to quality. University of California studies have shown this temperature range encourages mealiness, internal browning of the flesh, and inconsistency of ripening.

Fruit held at ambient temperature (roadside market conditions) soften at a rapid rate. If these fruit are sold by the second day after harvest, the consumer will have a fruit of nearly perfect eating quality. By the third or fourth day, the fruit will be completely soft, so fruit picked at a tree-ripe maturity must be moved virtually overnight if they are held without cooling.

**TEMPERATURE MANAGEMENT**

**Pre-cooling** is the rapid removal of field heat to reduce fruit temperature. Ideally, the internal fruit temperature is reduced to the desired range (32° to 37°F) for shipment within 24 hours of harvest. Peaches are generally pre-cooled by hydrocooling or forced-air cooling. In the Southeast, the traditional method of choice has been hydrocooling. Simply placing the fruit in a refrigerated storeroom does not constitute precooling. For the grower who is still flexible in the selection of cooling method, there are a variety of theoretical and practical considerations that should be reviewed.

Heat is removed from the pit and interior pulp to the surface by a process known as conduction and from the fruit surface to the cooling medium by convection. Cooling or heat transfer can be achieved through air or water flow. The rate of fruit cooling is influenced by the fruit's temperature at harvest, the thermal conductivity of the peaches, the temperature difference between the peach surface and the cold water or air, and on the heat transfer efficiency between the fruit surface and the cooling medium. Because water conducts heat more quickly than air, hydrocooling is more rapid than forced-air cooling. It is important to
continuously maintain the cooling medium close to the target temperature for the fruit, especially during the last portion of the cooling period.

Cooling time is influenced by product diameter, with larger fruit requiring more cooling time. Internal fruit temperature should be monitored every 30 to 40 bins to assess the effectiveness of cooling. Cooling schedules usually are designed to achieve seven-eights cool (Figure 6.1.1).

Typically, peaches with an average temperature of 90°F should be cooled to at least 40°F before storage or shipment.

Hydrocooling provides very rapid cooling (Table 6-1-1). Refrigeration capacity, Btu's/hr, required for hydrocooling is therefore greater for hydrocooling than for other, slower cooling methods. Table 6-1-1 lists the refrigeration heat loads and refrigeration requirements for hydrocooling 100 bushels of peaches per hour at typical temperature reductions. Forced-air cooling is slower, so the refrigeration capacity required is proportionately less. However, more cooled space is required to cool a similar volume of fruit.

Hydrocooling is popular because of its efficiency and speed. The heat transfer coefficient from the surface of peaches to water is up to 20 times greater than to air, depending upon the relative flow rates of the two cooling mediums. With hydrocooling, 15 to 30 minutes is generally sufficient if the water is 35°F.

**TABLE 6-1-1. Refrigeration requirements for hydrocooling 100 bushels of peaches per hour.**

<table>
<thead>
<tr>
<th>TEMPERATURE REDUCTION (°F)</th>
<th>HEAT LOAD (BTU/HR)</th>
<th>REFRIGERATION REQUIREMENT (TONS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>165,600</td>
<td>13.8</td>
</tr>
<tr>
<td>40</td>
<td>220,800</td>
<td>18.4</td>
</tr>
<tr>
<td>45</td>
<td>248,400</td>
<td>20.7</td>
</tr>
<tr>
<td>50</td>
<td>276,000</td>
<td>23.0</td>
</tr>
<tr>
<td>55</td>
<td>303,600</td>
<td>25.3</td>
</tr>
<tr>
<td>60</td>
<td>331,200</td>
<td>27.6</td>
</tr>
</tbody>
</table>
The chief weakness of hydrocooling is potential contamination and spread of decay-causing organisms to clean fruit. Hydrocooler water should be changed frequently and kept at a chlorination level which provides surface sanitation of the fruit.

Criteria for Efficient Hydrocooling:

1. In shower-type coolers, water flow over fruit in shallow, single bin layers should be 7 to 10 gallons per minute per square foot (gpm/ft²) of cooling area. In double-stacked pallet bins, with about 4 ft. of product depth, flow rates should be 20 to 25 gpm/ft².

2. Hydrocoolers should be designed so that the water never falls more than 8 inches before reaching the fruit. A water-drop of more than 8 inches can cause surface injury. If the hydrocooler water must fall more than 8 inches, bins should be covered with perforated lids to reduce effective water-drop height.

3. Interference with contact between fruit and cooling medium, for instance, containers, films, or tight fill, reduces cooling effectiveness.

4. Although it is difficult in actual practice, water temperature should be ideally kept at 32° to 33°F.

5. For adequate water flow through the package, containers must have top and bottom venting.

6. In addition to bin design for free flow of water, bins should be kept free of leaves or other debris that block vents and cause water channeling.

7. Use potable hydrocooler water that is clean and free of decay-causing organisms to prevent spread of decay throughout the lot of fruit.

8. Maintain chlorine levels of 50 to 150 ppm at a pH of 6.5 to 7.0. At lower pH levels, equipment corrosion problems and release of toxic chlorine gas can occur, and metals such as iron are more soluble and prone to cause inking. The hypochlorite ion that is formed above pH 7.5 is not very germicidal. Refer to hydrocooler water sanitation section for more recommendations.

9. Change cooler water daily or more often depending on hydrocooler usage.

10. Cooler design should allow easy inspection of the water distribution pan for plugged holes. Remove debris and sediments from the reservoir frequently. Self-cleaning trash screens should be used.

11. Unless all metal surfaces are stainless steel, maintain them with adequate paint coverage to reduce the corrosive effects of chlorine and contamination of hydrocooler water with iron.

Forced-air cooling is commonly used in the western growing areas of the United States. Packaged fruit in vented containers are stacked in patterns with air baffles to channel cold air that is drawn or forced through the containers. With forced-air cooling, a tunnel is formed by bins or pallets of fruit. Air is pulled through the stacks of fruit by a fan. A slight pressure drop is formed across containers when the cooling tunnel is tarped. The movement of cold air across warmer fruit results in a more even, efficient form of room cooling. Air flows of one to three cubic feet per minute per pound of fruit are recommended. A minimum of four hours is suggested to cool fruit by this method, but in practice six to eight hours are more likely required to accomplish the task. The chief disadvantage of forced-air cooling is the requirement of a larger refrigeration system and more cooled space to compensate for the increased cooling time compared to hydrocooling. The greatest advantage of forced-air cooling is its low propensity to spread fruit rots.

Preconditioning is a delay in cooling fruit to the target shipping temperature in order to allow the ripening process to begin prior to shipment. Some western shippers have adopted the practice, but it is not commonly employed in the Southeast.

Table 6-1-2 compares the advantages and disadvantages of hydrocooling vs. forced-air cooling.

PACKING

A peach packing line is a tightly integrated series of individual operations designed to off-load, convey, wash, sort size, and package fruit with minimal damage to the fruit. Additional steps may
### TABLE 6-1-2. Comparison of hydrocooling and forced-air cooling processes.

<table>
<thead>
<tr>
<th>Container Design</th>
<th><strong>HYDROCOOLING</strong></th>
<th><strong>FORCED-AIR COOLING</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Requires water resistant containers.</td>
<td>Package design for adequate air flow.</td>
</tr>
<tr>
<td>Speed</td>
<td>Fast thermal transfer through water.</td>
<td>Slow thermal transfer through air.</td>
</tr>
<tr>
<td>Space</td>
<td>Much less space required because fruit are moved through in less than one hour.</td>
<td>High volume capacity required to cool a similar amount of fruit in a packing facility.</td>
</tr>
<tr>
<td>Fruit Dehydration</td>
<td>None</td>
<td>May be reduced by short cooling periods and 80% relative humidity.</td>
</tr>
<tr>
<td>Tendency to Increase Fruit Rots</td>
<td>Water sanitized to reduce rots. Even with sanitation, use of water cooling medium increases prevalence of rots.</td>
<td>Slower field heat removal lowers overall tendency to rot compared to hydrocooling.</td>
</tr>
<tr>
<td>Energy Efficiency</td>
<td>3.5 times more energy efficient than forced-air. Difficult to optimize and maintain at highest efficiency.</td>
<td>Easier to optimize and maintain at most energy-efficient conditions possible with forced-air.</td>
</tr>
</tbody>
</table>

Be incorporated into the packing line: a cooling operation (either before the line or integrated in the line) and fruit waxing to improve fruit appearance and reduce water loss. A post-harvest fungicidal treatment can be considered to prevent fruit rots and may be more advisable if rots are abundant. The packing line should package well-graded, attractive peaches, and it is the manager’s responsibility to do so economically and without over-handling of fruit. Each element in a packing line is an opportunity to improve fruit quality or prevent its deterioration. Growers operating orchards of 100 acres or less are typically well advised to arrange for packing of their crop at other packing houses if commercial shipments are desired.

Packing house layout demonstratively impacts efficiency, and planning begins with analysis of present and future hourly packing rates. Decisions on operational steps are needed to establish the specific sequence in fruit handling. Equipment selection and design of the layout are done simultaneously to optimize efficiency. A representative layout rated for a capacity of 350 bushels packed fruit per hour would often include the operations illustrated in Figure 6.1.2. The greatest cost in packing line construction is its length. Generally, packing designs that accomplish volume movement with wider conveyors cost less to build and operate than those that do so with longer conveyors. Conveyor velocity and width should be designed to accommodate fruit packing during peak loads.

The packing line itself can be a significant source of fruit injury, but it is one of the easiest areas in which to diagnose problems and implement solutions. Transfer points, where the fruit move from one machine to the next, are the most common problem areas. Strategic use of deceleration curtains and padding can virtually eliminate bruising in the packing house. Such modifications are inexpensive and effective.

**Dumping** of fruit from field bins onto the packing line must be accomplished with as little bruising and abrasion as possible. In the eastern United States, both wet and dry dumps are in use. The dumping operation is one of the most troublesome areas for impact injury. If fruit are dumped onto a dry surface, look for ways to minimize the distance that the product is dropped and utilize padding on rigid surfaces. The use of water dump tanks (tank capacities range from 500 to 1,500 gallons).
can help reduce the shock of emptying fruit, but carefully manage the water quality to minimize the spread of fruit decay. Fruit are lifted from the dump tank water by simple conveyors, roller conveyors being the most common. Conveyor sides should be covered with padding to minimize fruit abrasions.

Pregrading for removal of trash, particularly leaves, along with removal of undersized or damaged fruit, follows dumping. This process can be accomplished on an apron conveyor or sloping belt trash eliminator, supplemented with hand separation to remove rots or splits.

Defuzzing is a standard practice in most peach packing houses. Defuzzing is usually combined with a wash. Fuzz is removed using wet knives, high-pressure streams of water, or by brushing. High-pressure water defuzzing uses high-pressure water sprays against fruit rotating on metal rollers. The spray pattern is flat and fan shaped and the force of the spray removes peach fuzz. This method reduces the hazard of brush abrasions, but does not produce the close and uniform defuzzing action of brushes. Brush defuzzing is generally done by moving fruit along banks of transverse rotating nylon brushes washed by fresh water sprays. If the flow of fruit is interrupted, fruit should be manually raked across the brushes to avoid excess brushing. Surface moisture can be removed from peaches by use of polyurethane or sponge rollers. Rollers should be well washed in detergent before mounting and as part of the daily packing line maintenance to reduce the risk of purple or black discoloration.

Peaches are sorted and sized by manual, mechanical, and electronic options. Mechanical devices effectively accomplish sizing, although in smaller packing houses manual sizing is practical. Dimension and weight sizers are the most frequently used equipment. Dimension sizing is based on moving fruit over a series of conveyors or tapered rollers with progressively larger openings. The small fruit removed at the narrow end are generally the less mature. Electronic systems for sizing and, in some cases, color sorting are also used. Most electronic sizing systems sort by weight, but newer optical technology is being developed to sort on the basis of spherical size. Electronic color sorters split the line into two or three conveyors based on hue properties of the fruit surface.

Control of fungal pathogens in peaches is an indispensable aspect of peach crop management. A good pre-harvest integrated pest management program of well-timed fungicidal applications is necessary. Water quality management and temperature are very important components of the decay-control program. Supplemental decay control is often desired. Packing line application of fungicidal compounds is the next line of defense for rot control. When post-harvest fungicides are used, they are introduced after the pre-grading and may be mixed with wax.

Waxing peaches can be an important cosmetic enhancement that reduces water loss from the fruit and has the additional value of providing a carrier for post-harvest fungicide application. A variety of commercially manufactured waxes employ either water-soluble paraffin base waxes or
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emulsifiable mineral or vegetable oils. If post-harvest fungicides are used, they can either be premixed into wax concentrates or can be sprayed onto the fruit prior to waxing. Wax is best applied over a bed of brushes. As with any brushing operation, fruit must be manually raked through the waxer if there is an interruption in flow or if mechanical rakes malfunction.

Grading occurs in an initial or pre-grading step, followed by a detailed grading, normally after sizing. Good fruit presentation on well-lit, flat-belt conveyors materially improves the quality sorting. Overripe, misshapen, or blemished fruit are removed in this operation.

In the southeastern United States, peaches are generally placed into 1/2 bushel (25 lb.) boxes by volume. Mechanical fillers normally handle eight to twelve boxes per minute. Volume filling can bruise fruit. Impact forces as much as four times the acceptable force have been measured at some fillers. Fruit bruising during box filling can effectively be minimized by elimination of excess impact force by shortening drops; use of well-placed curtains to slow fruit velocity; employing sloped box fillers to reduce drop distance; and use of box cushioning to allow transfer of impact force from the fruit to the cushioning device.

After check weighing on an over-under scale, boxes are lidded and conveyed to the stamp and labeling machine. Lidded and labeled boxes are then palletized before cold room storage or placement onto trucks for transport. Proper placement of boxes on the pallet facilitates efficient air movement when the fruit are stored prior to and during shipment.

**STORAGE**

Successful storage of peaches, whether for two days or two weeks, requires proper refrigeration and high humidity.

Most sound and well-matured peaches can be stored for two weeks at 31° to 34°F and 90% relative humidity with no significant loss in dessert quality. Some freestone varieties and most clingings may be held for longer periods. If the peaches are underripe or if temperatures range from 36° to 50°F, some deterioration of flavor and texture occurs. Freezing occurs at 30°F or lower. At relative humidity lower than 90%, weight loss and shriveling occur.

Internal breakdown of peach pulp is expected to occur from 36° to 50°F. Packing house storage facilities have been seen to fluctuate in this range. Maintaining cold room temperature below 36°F is difficult, but important. Doors in coolers must be opened frequently to move fruit into or out of the rooms and even with well-maintained, flexible curtains, excessive air exchange often occurs. Also, warm fruit often is placed in the same room with chilled fruit, which makes it harder to maintain proper fruit temperature. Finally, adjustment of the delivery air to a lower temperature that can compensate for the heat load creates a risk of freezing fruit. Ideally, rooms should be equipped with very large heat exchange coils and effective thermostatic control systems to meet these challenges. Although southeastern peaches are seldom stored long enough for internal breakdown symptoms to become apparent, there is considerable interest in prolonging storage times to buffer the impact of poor prices. If storage is to be used in this way, temperatures must be consistently maintained in the 31° to 34°F range.

Refrigeration systems are expensive to install and costly to operate. Consult a professional refrigeration engineer in an analysis of any refrigeration project. The major refrigeration equipment requirements for cold room storage are the evaporator, compressor, and condenser. In addition, fans, valves, gauges, switches, and liquid refrigerants are required. The equipment must be compatible and capable of meeting the refrigeration requirements of the storage room during peak loads. Evaporator surfaces must be large enough to function with no more than a 2°F dry bulk temperature difference between the refrigerant temperature and the room air temperature. The compressor must have enough unloader capability to reduce capacity when peak loads are over.

Key factors in a properly constructed cold storage room are the vapor barrier and insulation. The vapor barrier consists of a watertight resin or polymer coating or a metal foil or plastic fiber
placed on the cold side of the insulation. This barrier prevents the movement of moisture through the walls, which will saturate insulation and lessen its ability to insulate. The insulation should be three to six inches of materials of expanded polyurethane or polystyrene, or a urethane coating foamed on site. A well-designed vapor barrier and insulation system permits economical temperature control and the maintenance of the high humidities required for the storage of peaches. Cold room layout should consider placement of palleted loads or stacks of bins so fruit can be efficiently cooled through ventilation slots in the fruit boxes or forklift openings in bins via forced-air cooling.

Periodic, scheduled cleaning of the storage facility is imperative to reduce the level of disease inoculum that accumulates in cold rooms. Cleaners should have both cleaning and disinfectant properties.

**LOADING AND SHIPPING**

Prior to loading any trailer, inspect it for cleanliness. Require drivers to thoroughly clean and disinfect trailers after transit of unsanitary products. Pre-cool trailers prior to loading. Peaches should be loaded so they are protected from physical damage caused by container shifting and from overhead weight and vibration. Use stacking patterns that will promote adequate air circulation through the load to uniformly maintain flesh temperature. Facilitate airflow through the use of loading patterns that provide lengthwise air channels through the load so heat can be removed by the refrigeration system. To provide maximum access openings to all air channels, a starter stack should be placed against the front bulkhead of the trailer (Figure 6.1.3). Subsequent stacks should be loaded in a 7 x 6 pattern (Figure 6.1.4) that will provide air channels in alternating layers. So that airflow in the air duct will not be restricted, boxes should be loaded to a height that will be no closer than 10.5 inches from the ceiling of the trailer. One row of “floaters” may be loaded adjacent to the sidewall to within one inch of the ceiling of the trailer. All boxes should be loaded tightly from the front to the rear of the trailer, neither loosely spaced nor flush with the rear door. Boxes should not protrude beyond the extruded flooring at the rear of the trailer, as this hinders airflow and circulation. When space remains between the last stack and the rear door of the trailer, an end gate or other type of load-securing device should be placed against the rear face of the last stack in the load to prevent load shifting and to maintain the alignment of the boxes and loading pattern.

Under no circumstances should peach boxes be loaded beyond their stacking strength limitations. Generally, boxes with combination board weight strengths of only 350 lbs. for the body and 275 lbs. for the cover should not be stacked more than seven layers high.

Highway trailers should be loaded with 750 to 1,500 1/2 bushel boxes, depending on trailer length. Stacking of eight or more layers high is excessive and may lead to crushing and damage. Trailer temperatures should be maintained at 32° to 34°F. Growers should be familiar with the truck driver, intended route and timetable, and the likelihood of mixed loads. Other horticultural commodities that have requirements compatible to peaches may be shipped with peaches in mixed loads.

**WHOLESALE AND RETAIL HANDLERS**

Managers of wholesale warehouses and retail outlets are important participants in a peach quality program. Of special importance is temperature management. If peaches have been produced, packed, and shipped in a process that is well integrated and managed to assure uniformity of fruit condition, then the wholesale and retail managers may be able to manipulate temperature so that the fruit is ready to eat at the point of sale.

Everyone who handles peaches has a responsibility to the consumer to deliver the best possible quality.
REFERENCES


Bennett, A. H., R. E. Smith and J. C. Fortson. 1965. Hydrocooling peaches a practical guide for determining cooling requirements and cooling times. USDA Information Bull. 293.


6.2 SPLIT PIT

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VISIBLE SPLIT PITS

Split pits are openings or splits of the pit at the stem end of the fruit. This split becomes evident during final swell, the third stage of fruit growth. The actual weakening of pits, which leads to openings at the stem end, probably occurs in the latter stages of pit hardening. Immature fruit that have abnormal shapes or sutures often manifest split pit symptoms during final swell (Figure 6.2.1). Split pits are a long-recognized problem in peach production.

Fruit with visible split pits are highly undesirable. Split pit fruit are often misshapen and detract from the overall quality of the pack. Grade standards may exclude visible split pit. They are quite prone to rot problems, and rots can spread rapidly from split pit fruit to sound fruit in the packing house.

Breeding programs focus on developing new varieties with fewer split pit problems. Some level of split pit must be accepted, especially in early selections. Fruit having visible split pits are eliminated as culls during grading. Varieties such as Candor, Camden, or Springold may have in excess of 20 percent split pits, especially if overthinned.

SHATTERED PIT-GUMMING PROBLEM

Pits can also shatter with no attendant opening. Internal gumming is often associated with shattered pits. Gumming, shattered pits are deemed an internal defect. Fruit with pits broken into more than three pieces plus gum deposits near the flesh are out of grade.

The shattered pit-gumming condition is internal and can be present in an otherwise normal-appearing fruit (Figure 6.2.2). Fortunately, pit fracturing and internal gumming are more common in malformed fruits that are fairly easily removed from the packing line. However, even the trained eye cannot detect internal pit breakage that occurs in fruit that appear normal.

Shattered pits occur primarily at the blossom end (bottom) of the fruit. Visible split pits develop at the stem end. Internally shattered pits cause the greatest problems as they are, of course, more difficult to grade cut. Internal gumming increases as the pit fractures into more pieces. Gumming is generally confined to the pit cavity, but some

FIGURE 6.2.1. Typical visible split pit peach (right) compared to a normal peach (center) and fruit with drop shoulder (left).
In general, cultural practices that enhance fruit size (thinning, good nutrition programs, irrigation), increase the level of split pit and shattered pit damage. However, recent studies suggest that girdling (and possibly scoring) may enhance fruit size and yield without appreciably aggravating the well-known split pit-shattered pit problem of varieties such as Camden and Springold.

When freezes excessively reduce fruit loads, pit shattering generally increases. This occurs with some varieties in some peach-producing regions of the country nearly every year. Excessive rainfall in the latter stages of fruit growth is another uncontrollable variable that aggravates pit breakage problems.

CONTROL MEASURES

Cultural options to minimize pit breakage problems are limited. Development of varieties less prone to the problem is the best approach. However, superior varieties are not available to replace early, split pit prone varieties.

With Junegold and Camden, growers have reduced pit breakage problems by leaving heavier crop loads. In so doing, they settle for smaller fruit. Markets reward large fruit, so growers must balance between larger, more profitable fruit and losses associated with increased split pit-shattered pit problems.

The following is a brief summary of steps growers should consider to minimize shattered pit-gumming problems.

1. Leave heavier crops on problem varieties.
2. Avoid excessive nitrogen applications, especially close to harvest time.
3. Use stricter packing house grading for problem varieties to remove questionable or misshapen fruit. These fruit are most at-risk for split pits.
4. Plant superior selections of the same ripening season as they become available, while eliminating plantings of the more troublesome varieties.
PEACH SKIN DISCOLORATION

Peach skin discoloration (PSD) is a disorder that has also been called inking, ink spot, black spot, grease spot, purple streak, purple spot, browning, blackening, or streaking. For simplicity, any type of skin discoloration discussed here will be referred to as PSD. No microorganism, pathogenic or otherwise, has been isolated from affected fruit or identified as a cause of PSD. The disorder appears to result from a combination of physical, chemical, and physiological factors.

PSD symptoms may vary from a barely detectable discoloration that, depending on the cause, can be reversible, to severe blackening that covers most of the fruit. Usually PSD is associated with red areas of the fruit, but there have been reports of browning, sometimes called grease spot, that is restricted to the yellow and orange areas. Most significant peach-producing areas worldwide have at some time reported PSD problems.

Early work by Van Blaricom and Webb in South Carolina focused on identification of the cause of PSD. They induced PSD by exposing fruit to abrasion on sponge rubber rollers. Treatment with solutions of sodium carbonate, chlorinated water, hot water, zinc, copper, and iron all induced the development of PSD. However, in almost all cases, abrasion from contact with a variety of roller or brush types was necessary in order for the symptoms to appear. These results were later confirmed by Hopfinger in New Jersey who added ammonia exposure to the list of PSD causes. More recently, Crisostomo and co-workers have conducted intensive studies in California to define the physical, chemical, and physiological interactions that ultimately result in PSD development. Current understanding of PSD relies heavily on their research.

What are the cellular events that lead to PSD? The red color of peaches is due to pigments called anthocyanins in the cells of the skin. Phenolics are the other chemical constituents of peach skin that have color. When cells are ruptured by physical injury, particularly by abrasion, anthocyanins and phenolics can react with heavy metals, causing the pigments to turn various shades of red, purple, brown, and, in severe cases, completely black.

Where do the heavy metals come from? Iron, copper, and aluminum are the most damaging contaminants, but zinc and manganese have also been implicated as possible causal factors of PSD. These metals are naturally present in the fruit tissues at very low concentrations. They also are present in the soil, in certain fungicides and insecticides, and in micronutrient sprays. A certain amount of PSD may be present on the fruit before it is harvested due to in-orchard abrasion and contamination of the fruit with dust or chemical sprays.

What are the management practices that can help reduce the incidence of PSD?

(1) Reduce rough handling injury to the fruit, especially abrasion injury. Harvest management practices and packing line design considerations
that reduce abrasion are discussed in more
detail in sections on these topics. Tractor and
truck drivers should use care to minimize the
amount of bouncing, rolling, rubbing, and
vibration that the fruit are subjected to dur-
ing transport. Replacement of wooden bins
with plastic bins has been a positive step. If
still in use, wooden bins should be lined with
bubble plastic to prevent direct contact of the
fruit with wooden surfaces.

(2) Cleanliness helps reduce PSD. Keep your
operation clean. Soil contains the heavy metals
that are problematic. Picking bags, bins or
other field containers, trailers, and so on
should be cleaned frequently. PSD has been
reported on fruit on the trees, and as fruit
arrived at the packing house. Managing PSD
entails pre-harvest as well as post-harvest
considerations.

(3) Check your packing house water to determine
if any of the metals listed above are present in
significant amounts. As little as 5 to 10 ppm
iron can cause PSD with poor water pH
management. If metals are present, it does
not necessarily mean that the water cannot be
used in agricultural operations. It simply
means that vigilance to water quality manage-
ment practices, especially pH adjustment, will
be necessary in order to avoid PSD. These
management practices are discussed in the
next section.

(4) Maintain a clean hydrocooler to prevent the
effects of iron contamination. Take care to
reduce bare metal surfaces (or non-stainless
steel) to reduce iron contamination of water.
Vigilantly adjust the low water pH levels that
are common in the Southeast to near neutral.

(5) Foliar nutrients and some fungicides should
not be applied as the fruit near maturation.
This will help avoid the presence of metal
residues on the fruit at the time of harvest.
Crisosto recommends a PSD-based pre-har-
vest interval for a variety of pesticides. Check
current recommendations against Crisosto's
PSD pre-harvest guidelines.

(6) Some peach workers in the Southeast have
noted PSD in peaches that received captan
application close to harvest. Captan spray
solution contains low levels of iron (approx.
1.34 ppm) and aluminum (approx. 1.04 ppm).
However, there is presently no direct evidence
of captan causing PSD. A cautious approach
would be to avoid captan 20 days prior to first
harvest until more detailed work is done.

(7) If you suspect that your fruit are at high risk
of developing PSD, delay shipment for at
least 48 hours to allow fruit that may be de-
estined to develop PSD time to show symp-
toms. There have been cases of fruit harvest-
ed in the morning and packed in the after-
noon with no symptoms of PSD, but during
overnight shipment severe PSD developed,
rendering the load unmarketable.

(8) Be sure that the sponge drying rollers (“do-
nuts”) and brushes in your packing line are
clean and wet before you start running fruit.
If these components are dry, they are more
likely to cause abrasion. Polyurethane drying
rollers are less likely to induce PSD than latex
rollers.

(9) Check your refrigeration systems for ammo-
nia leaks. Brennan et al. reported that expo-
sure of peaches to 500 ppm ammonia for one
hour caused PSD injury, but it was reversible
when fruit were removed to fresh air.
Increasing the ammonia concentration to
1,500 ppm for one hour caused irreversible
injury. All peach varieties tested were suscep-
tible.

(10) The influence of temperature on PSD de-
velopment is not well defined. Managers should
give attention to temperature-management
protocols discussed elsewhere in this refer-
ence.

All varieties of peaches are thought to be PSD
susceptible. The problem is not limited to the
high red varieties. Calcium sprays, which may be
beneficial for some post-harvest problems, did
not alleviate PSD in peaches. Waxing and treat-
ment with chlorine solutions did not induce PSD
under laboratory or small-scale hydrocooler or
packing line studies. Attention to timing of pre-
harvest fertilizer and pesticide applications and to
water quality management will significantly
reduce the probability of PSD.

It should be noted that although chlorine levels
alone are not implicated as a cause of PSD, chlo-
rinated water at the wrong pH can contribute to
PSD. Abrasion injury appears more damaging in the presence of excessive chlorine, especially at chlorine concentrations above 300 ppm.

**WATER QUALITY MANAGEMENT**

Peaches are perhaps the most demanding of edible horticultural commodities in terms of the post-harvest water quality management. Although it is possible to hand-pack peaches without the use of water, almost all commercial packing operations utilize water either for hydrocooling, dumping, rinsing, wax and fungicide application, and, in some cases, for all of these operations.

Pure water itself is not a problem. Foreign materials that water can carry are causes for concern. The condition of water has implications for fruit quality, food safety, and incidence of decay. Careful attention to water quality management can alleviate practically all of these concerns. Failure to do so can result in substantial losses.

**Peach Skin Discoloration (PSD).** Water contaminants can contribute to PSD development on peaches. The primary concern is the presence of metals in the water and the solubility of these metals. Ionic forms of iron in the range of only 5 to 10 ppm can cause severe PSD if the iron is soluble. **Metals are more soluble at low pH; it is imperative that the pH of all packing house water uses be adjusted to near neutral.** Rushing et al. exposed peaches to hydrocooler water containing low levels of iron at pH 3.5, resulting in severe PSD and rejection of the peaches at the market destination. Thorough washing of the hydrocooler and adjustment of pH to near neutral eliminated the further occurrence of PSD.

**Decay Control and Food Safety.** Water is an efficient vehicle for the dispersion of microbes, including plant pathogens and human pathogens. When its quality is properly managed, water can also be a useful tool for reducing microbial contamination. Close attention to water quality is required or it becomes the source of potentially serious problems. Packing house managers should implement practices that ensure and maintain water quality.

Avoid the introduction of decayed fruit into hydrocoolers, dump tanks, or onto the packing line. Water will spread decay-causing microorganisms to other fruit. Likewise, avoid the introduction of human pathogens into water by ensuring that you have implemented recognized Good Agricultural Practices (GAPs) and Good Manufacturing Practices (GMPs) in all of your operations.

Change water in hydrocoolers and dump tanks as often as necessary to help maintain sanitary conditions. Develop Standard Operating Procedures (SOPs) that include water change schedules and washing of the equipment. Clean and sanitize water contact surfaces frequently, including water reservoirs, packing line rollers, brushes, and conveyers. Install backflow devices to prevent contaminated water from mixing with clean water. To ensure efficient operation, routinely inspect and maintain equipment designed to assist in maintaining water quality, such as chlorine injectors, filtration systems, and backflow devices.

**Water Sanitizing Treatments.** Beuchat published an excellent review of surface decontamination for fresh fruit and vegetables. Packing house water is sanitized primarily to prevent or minimize the dispersion of pathogens in the water rather than to disinfect the peaches. Managers have several options for sanitizing water. The same practices used for sanitizing hydrocoolers must be employed if wet dumps are used.

**Chlorine** is by far the most common water treatment because it is the cheapest and easiest to manage. Chlorine gas (Cl₂), liquid sodium hypochlorite (NaOCl), and granular calcium hypochlorite (Ca(OCl)₂) all are approved for use in packing operations (Table 6-3-1). The efficacy of chlorine as a disinfectant depends largely on the free chlorine concentration and the pH of the solution (Figure 6.3.1). The addition of any chlorine compounds has an impact on pH of the water, so water quality management programs involving chlorine also must include on-going pH management. Liquid sodium hypochlorite and granular calcium hypochlorite increase pH, whereas chlorine gas reduces pH. The pH range of 6.0 to 7.0 is generally recommended.
Soil and organic matter in the water are contaminants that rapidly bind chlorine, which reduces the amount of chlorine available for disinfection. Tests in stone-fruit hydrocoolers demonstrated that chlorine levels can drop 50 percent after cooling 48 bins over a period of a few hours. It is important to frequently monitor and adjust to maintain pH (6.0-7.0) and chlorine concentration (100 ppm) to ensure that a germicidal level of free chlorine is always present. Calculations for chlorine additions to hydrocooler water follow. Table 6-3-2 offers guidelines for supplying chlorine to hydrocooler water.

**Chlorine gas** historically has been the least expensive form of chlorine to use, but it requires the installation and maintenance of an injection system. When chlorine gas is introduced into water, the primary product in solution is hypochlorous acid. Addition of chlorine gas lowers the pH of the water. Addition of alkaline material will be required to bring the pH back up to near neutral. Chlorine gas injectors are usually equipped with a bed of crushed oyster shells or limestone, which neutralizes acidity before the water is injected into the reservoir. Managers must take care to check that the neutralizing material is not depleted; otherwise, the pH of the

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>FORMULATION</th>
<th>% CHLORINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine gas</td>
<td>Gas</td>
<td>100</td>
</tr>
<tr>
<td>Calcium hypochlorite</td>
<td>Granular</td>
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</tr>
<tr>
<td>Sodium hypochlorite</td>
<td>Liquid</td>
<td>12.5</td>
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<tr>
<td>Sodium hypochlorite</td>
<td>Liquid</td>
<td>5.25</td>
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</table>

**DETERMINATION OF CHLORINE ADDITIONS FOR HYDROCOOLERS.**

The volume of NaOCl needed = \( \frac{\text{(desired ppm of free chlorine)} \times \text{(total tank volume)}}{\text{(% NaOCl in concentrate)} \times (10,000)} \)

In this demonstration, we have the following criteria:
- The concentrated NaOCl is 5.25% (the concentration of household bleach).
- The desired concentration in our processing water is 100 ppm.
- The total volume of the reservoir of water is 2,000 gallons.

Now we plug the above values into our formula and calculate as follows.

Volume of NaOCl needed = \( \frac{(100 \text{ ppm of free chlorine}) \times (2000 \text{ gallons}) \times 128 \text{ oz./gallon}}{(5.25\% \text{ NaOCl}) \times (10,000 \text{ ppm/\%})} = 488 \text{ oz.} \)

**TABLE 6-3-2. Calculated chlorine additions to charge hydrocooler water to 100 ppm chlorine/chloride.**

<table>
<thead>
<tr>
<th>% CHLORINE IN UNDILUTE/UNDISSOLVED PRODUCT</th>
<th>OUNCES OF PRODUCT ADDITION/100 GALLON HYDROCOOLER WATER</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1.28†</td>
</tr>
<tr>
<td>68</td>
<td>1.9</td>
</tr>
<tr>
<td>12.5</td>
<td>10</td>
</tr>
<tr>
<td>5.25</td>
<td>24.4</td>
</tr>
</tbody>
</table>

† or 10 ml chlorine gas/100 gallon hydrocooler water/hr.

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water in the reservoir can drop to injurious levels for the peaches. Sodium hydroxide and sodium bicarbonate also have been used to raise pH, but by far the simplest method is to use a bed of alkaline material as described.

**Sodium hypochlorite**, which is common household bleach, and **calcium hypochlorite** both yield primarily hypochlorite ion when they are dissolved in water. Use of these materials produces an alkaline reaction, therefore an acidic material is necessary to reduce the pH to near neutral. Muriatic or hydrochloric acids may be used. However, care must be taken handling these strong acids. Care must be taken not to overdose and lower pH excessively. Citric acid also may be used. It is a weaker acid and the risk of overdosing is less, but it is also more expensive. Food grade buffers are available, but this usually is the most expensive of methods for pH control.

The dry chlorine formulation is less costly than the liquid formulations, which give quick, reliable recharge to the final chlorine concentration. Dry formulations do not dissolve in cold water and undissolved particles can cause bleaching or product burns. **Dry chlorine products must be predissolved in warm or tepid water prior to adding to the hydrocooler water.** Even during the initial charge of the hydrocooler each day, predissolving the granular form is necessary. Another dry formulation, chlorine tablets, is added directly to the cooler reservoir and, if properly used, will slowly dissolve, providing continuous chlorine supply.

Throughout each day, free chlorine levels will need to be replenished. If NaOCl is used, consider that excess sodium concentrations can cause damage to some fruit. A 100 ppm HOCl solution made from NaOCl will have a sodium concentration of 30 ppm. With NaOCl additions throughout a long packing period, sodium levels can rise rapidly. Levels above 100 ppm have been reported to harm apples. It is not known what sodium levels cause fruit damage in peach.

**Chlorine dioxide** has received more attention in recent years because it is reported to be at least 2.5 times more germicidal than other forms of chlorine and it is not as affected by pH or the presence of organic matter. There are, however, disadvantages. Chlorine dioxide usually is more expensive, unstable, and explosive when concentrated. To date, chlorine dioxide has not seen widespread use in the peach industry.

**NON-CHLORINE MATERIALS**

Ozone, hydrogen peroxide, irradiation, bromine and iodine all have been tested in fresh produce operations, but these sanitizing agents have not become widely used.

**Water testing** is a foundational element of any water quality management program. Even if your packing house is equipped with automated water quality control equipment, it still is advisable to do manual tests periodically to verify that the automated equipment is working properly. Various types of paper test strips and chemical test kits are available for chlorine testing from pool chemical suppliers and from some agrochemical suppliers. Test strips provide rapid results and are easy to use. Typically, hydrocooler water should be diluted 10- to 100-fold and the chlorine concentration from the test multiplied by that dilution factor to properly use pool chlorine test strips. Electrode-type pH meters are also available.
REFERENCES


