POST-HARVEST MANAGEMENT: PEACH SKIN DISCOLORATION AND WATER QUALITY MANAGEMENT

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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, Crisosto 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 during 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 management 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 (1996) recommends a PSD-based pre-harvest 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 destined to develop PSD time to show symptoms. There have been cases of fruit harvested in the morning and packed in the afternoon with no symptoms of PSD, but during overnight shipment severe PSD developed, rendering the load unmarketable.

(8) Be sure that the sponge drying rollers ("donuts") 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 ammonia leaks. Brennan et al. reported that exposure 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 susceptible.

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

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 treatment 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, chlorinated 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 those 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 1). The efficacy of chlorine as a disinfectant depends largely on the free chlorine concentration and the pH of the solution (Figure 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.

Table 1. Common chlorine products for packing house operations

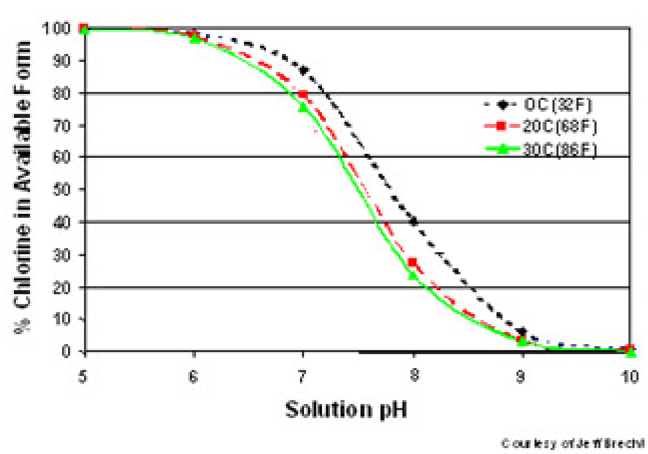

Figure 1. Percent free or available chlorine is dependent on the pH of the hydrocooling solution.

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 2 offers guidelines for supplying chlorine to hydrocooler water.

Determination of Chlorine Additions for Hydrocoolers.

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

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

Table 2. Calculated chlorine additions to charge hydrocooler water to 100 ppm chlorine/chloride

% Chlorine in Undilute/Undissolved Product	Ounces of Product Addition/100 Gallon Hydrocooler Water
100	1.28†
68	1.9
12.5	10
5.25	24.4

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

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 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 pre-dissolved 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.

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