FOOD SAFETY CONSIDERATIONS FOR POSTHARVEST WASHING OF PRODUCE AND SANITATION OF PACKING AREAS

Many food safety issues that occur in postharvest unit operations are associated with:

1. Cross contamination between contaminated and uncontaminated produce during washing, or
2. Improper cleaning and disinfection of tools, equipment, and facilities used during packing and holding of produce.

For these reasons, we will focus on proper use of two commonly used sanitizers, chlorine and peroxyacetic acid (PAA) during postharvest washing as well as how to develop a robust sanitation program for your farm or packinghouse.

What Exactly is a Sanitizer?

While we hear the term ***sanitizer*** daily, we may not realize exactly what that term means. The term ***sanitize*** has been defined by the FDA (2019) as, "to adequately treat cleaned surfaces by a process that is effective in destroying vegetative cells of pathogens, and in substantially reducing the numbers of other undesirable microorganisms, but without adversely affecting the product or its safety for the consumer" (21 CFR part 117.3). Sanitizing is used as a step to reduce the number of disease-causing bacteria and viruses to a safe level, and to prevent cross contamination and the formation of biofilms.

The EPA has stringent standards that a compound must meet to be considered a sanitizer for food contact surfaces. In this evaluation, the compound has to cause a 99.999% reduction of a specific set of bacteria within 30 seconds to be considered a sanitizer. These compounds must be registered by the EPA and are considered antimicrobial pesticides. Sanitizers are used in two primary ways in the produce industry:

1. In the washing and transportation steps, and
2. To disinfect various surfaces in the packinghouse and on equipment and tools after they are cleaned.

Washing Produce

Markets require many types of produce to be washed prior to sale in order to remove dirt and other debris. Foodborne pathogens (harmful microorganisms that can make people ill) are not seen with the naked eye, and produce can be contaminated with these pathogens before it enters the packinghouse. This makes the washing step one of the most important steps in packing, because, if not controlled, it can be a source of cross contamination (when foodborne pathogens fall off of contaminated produce into the water they can contaminate more produce). Sanitizers, such as chlorine and PAA, should be used during the washing step to eliminate cross contamination because, if pathogens are on the surface of produce, some will be dispersed into washing water and contaminate any fruits or vegetables that are washed following the contaminated produce. These sanitizers are designed to inactivate any bacteria that are introduced into the water, drastically reducing the possibility of cross contamination (Figure 1, page 2).

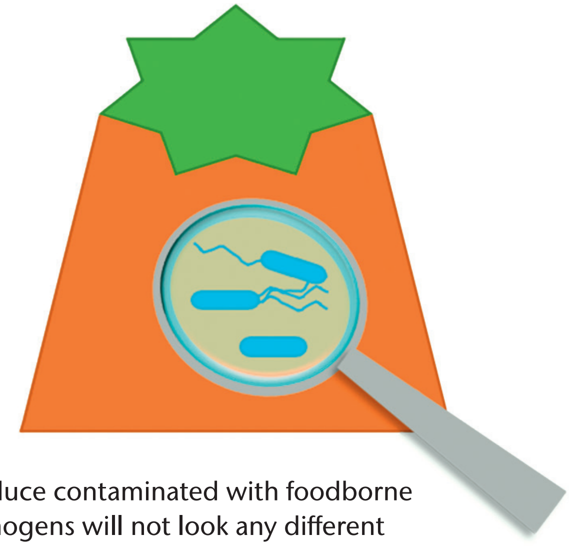
NOTE: Washing will not remove or inactivate foodborne pathogens or chemical contaminants on the produce itself, so good agricultural practices (GAPs) must always be followed.

Chlorine Basics

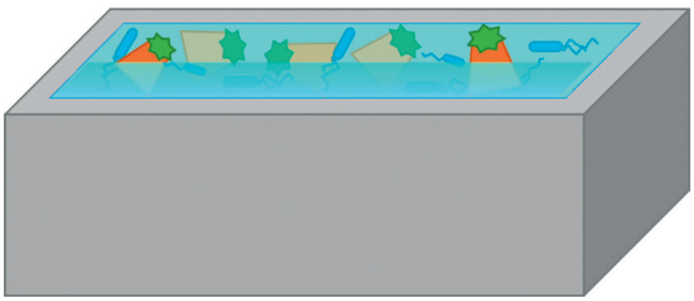
Chlorine is one of the most widely used sanitizers in food production due to its low cost and ease of application.

Chlorine comes in three forms:

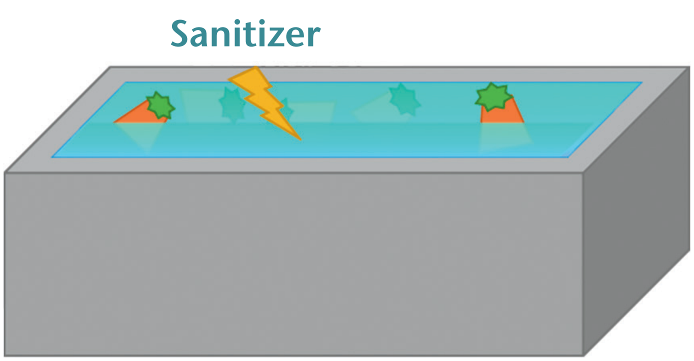
1. Calcium hypochlorite ($CaCl_2O_2$), which comes in a powder or tablet,
2. Sodium hypochlorite (NaOCl), which comes in a liquid and is what we commonly call bleach, and
3. Chlorine gas (Cl_2). Calcium hypochlorite and sodium hypochlorite are most commonly used by small to medium growing operations.



Produce contaminated with foodborne pathogens will not look any different than uncontaminated produce. Expect that, occasionally, pathogen-contaminated produce will enter the packinghouse.



During washing, some foodborne pathogens will fall off of the contaminated produce and into the wash water where they can cross contaminate other produce.



Using a sanitizer will not inactivate the bacteria that remain attached to produce, but works very well to inactivate those that fall into the wash water.

Figure 1. An overview of foodborne pathogen entry into washing systems and the role of sanitizers in wash water to limit cross contamination.

When these compounds are dissolved in water they can form hypochlorous acid, which can kill target microorganisms. However, as shown in Figure 2, when the pH of the sanitizer solution increases above 7.0, the negatively charged hypochlorite ion predominates, which does not rapidly kill microorganisms.

There are several terms associated with chlorine use that you should be familiar with, including:

Free or available chlorine is used to describe the amount of chlorine in the form of chlorine gas, hypochlorous acid, or hypochlorite ion. As the available chlorine concentration increases in a solution, microbial inactivation increases.

Combined chlorine is the quantity of chlorine that has reacted with nitrogen-containing compounds in the water (such as ammonia) to form chloramines. These do not work well in a sanitizing capacity.

Total chlorine is the sum of free (available) and combined chlorine.

Several factors impact chlorine's activity as a sanitizer, and it is important for your sanitizing program that you be aware of these.

pH. The effectiveness of chlorine can largely be influenced by the pH of the solution it is in. The pH scale ranges from 0 to 14 where 7 is a neutral point. For reference, the normal pH range of drinking water is 6–8.5. The pH scale indicates the acidity (0–6.5) or alkalinity (7.5–14) of a solution or of water itself. Minerals found naturally underground—including calcium, magnesium, and iron, among others—affect the pH of water. Also, the more chlorine that is added to the water, the more alkaline the water will become. For these reasons, we typically need to adjust the pH of the water to make sure hypochlorous acid predominates.

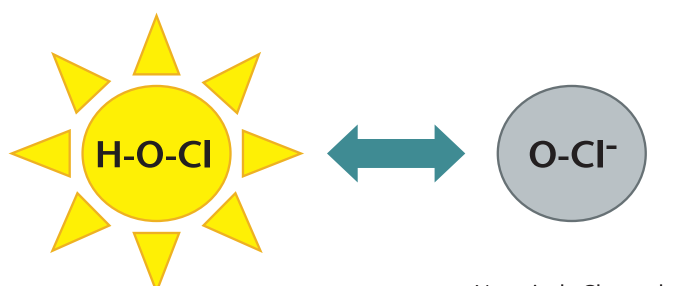


Figure 2. Transition of hypochlorous acid to hypochlorite ion in different pH conditions.

The pH of a solution can be lowered by using an acid (<7) or raised by using a base (>7). If any chemicals are used to alter or buffer the pH of a sanitizing solution, these also must be "food grade." Adding organic acids such as food grade hydrochloric, sulfuric, or citric acid will lower the pH, while lime (calcium hydroxide), lye, or soda ash will raise the pH. For a sanitizing solution, a pH between 6 and 7.5 is ideal. Checking the pH of the water regularly (before and after adjustments to pH and chlorine concentrations), will help ensure that you get the most effectiveness out of your chlorine sanitizer. If the pH is not within the acceptable range, it can:

- become highly corrosive to equipment (pH <6),
- form chlorine gas (pH <5) that releases irritating fumes, or
- irritate the skin or lose effectiveness as sanitizer (pH >8).

Temperature. Water temperature can play a role in produce safety as well as postharvest handling. In general for postharvest handling, the rapid removal of field heat can reduce spoilage and decrease the loss of produce freshness and quality. It is important, however, to be aware of the inside, or fruit pulp temperature, of the produce in relation to the temperature of water used for immersion applications. The water temperature should be within 10°F of the fruit pulp temperature. This is because warm produce can create a vacuum and pull water, and any contaminants such as foodborne pathogens in that water, inside the fruit. Heating chlorinated water can increase off-gassing and should be done with caution. The drop of water temperatures can also affect the required contact time of the sanitizer. Typically, a temperature range of 55–75°F is desirable.

Contact time. The length of time the produce is actually in contact with the chlorinated water affects the ability of the active chlorine (hypochlorous acid) to inactivate pathogens. Generally, a 1–2 minute exposure is sufficient but be sure to follow the EPA label for your specific sanitizer.

Organic matter. Organic matter from soil, leaves, and other debris can quickly use up all the "free" chlorine. Organic matter in the water can appear as cloudiness, or turbidity, and indicates you need to check your water quality. Prewashing produce with potable water can reduce the amount of organic matter going into your wash water. The frequency with which you change the water should be gauged from the look of the water as well as using chlorine test strips that measure the free, or available, chlorine.

Implementing Chlorine during Packing

Only food grade, EPA-registered chlorine sanitizers should be used during produce washing or equipment sanitizing. During the registration process, the EPA reviews the compound's activity, toxicology, and proposed label before it grants approval. Always make sure you are only using sanitizers that have an EPA registration (Reg.) number, not to be confused with an EPA establishment (Est.) number. Some commercially available household chlorine bleaches contain fragrances or other additives not labeled for food use. The EPA label on the bottle will clearly indicate intended uses, concentrations, methods of use, and contact times as well as any additional steps, such as following with a potable water rinse after application.

From Label to Implementation

The term ***concentration*** refers to the percentage of active ingredient of the labeled product. It is essential to know the percentage of your product before you begin mixing your sanitizer solution. Many liquid bleach solutions have concentrations ranging from 8.3 to 12.75% sodium hypochlorite. Knowing the concentration of your starting material is essential; otherwise, you'll make your sanitizing solution too weak or too strong. To determine what concentration of chlorine to use, look at the U.S. EPA label, under the "intended use" section. Remember, the EPA label for the sanitizer will set forth the specific concentrations for food contact surfaces, equipment, porous and non-porous surfaces, as well as use in fruit or vegetable washing. The Produce Safety Alliance (2020) has compiled a list of sanitizers in an Excel file linking to the EPA's intended uses labels. This tool will help you learn specifics for the commodities that you package and is available at: http://bit.ly/PSA_sanitizer.

Critical Parameters for Postharvest Water

The label must be followed when applying any sanitizers. The label will need to be evaluated for the following information:

- EPA registration number and FDA (2019) clearance (21 CFR Part 173.315 or Generally Recognized as Safe status) for use on food contact surfaces.
- Labeled for postharvest washing of produce.
- Minimum and maximum concentration.
- Contact time.
- Other label requirements, such as a potable water rinse.

Excerpt of an EPA approved label.

FRUIT & VEGETABLE WASHING: Thoroughly clean all fruit and vegetables in a wash tank. Thoroughly mix 5 oz. of this product in 200 gallons of water to make a sanitizing solution of 25 ppm available chlorine. After draining the tank, submerge fruit or vegetables for 2 minutes in a second wash tank containing the recirculating sanitizing solution. Spray or rinse vegetables with the sanitizing solution. Rinse fruit with potable water only prior to packaging.

Commodity	ppm Available Chlorine
Apple	150–200
Artichoke	100–150

Determining Amount of Sanitizer to Achieve Desired ppm

Let's say you would like to prepare 5 gal of a 200 ppm solution, starting from a registered product containing 12.5% sodium hypochlorite (NaOCl or chlorine). We'll use the equation:

Ci × Vi = Cf × Vf ; where,

Ci = initial concentration of hypochlorite

1) label says: 12.5%
2) we will need to convert from % to number like this 12.5/100 = 0.125
3) next we will convert to parts per million by multiplying by a million 0.125 × 1,000,000 = 125,000 ppm. We now have Ci.

Cf = final hypochlorite concentration desired (e.g., we want 200 ppm).

Vi = initial volume of hypochlorite to add to water. This is what we don't know yet but will determine using the formula.

Vf = final solution volume in milliliters.

1) we need 5 gal, so first convert gallons to liters 5 gal × 3.785411784 liters/gallon = 18.93 L
2) now convert liters to milliliters 18.93 L × 1,000 ml/L = 18,930 ml

Calculations for **Ci × Vi = Cf × Vf :**

1) 125,000 ppm × Vi = 200 ppm × 18,930 ml
2) 125,000 ppm × Vi = 3,786,000 ppm × ml
3) Vi = 3,786,000 ppm × ml/125,000 ppm
4) Vi = 30.29 ml
5) Round to a unit you can accurately measure = 30 ml

Adding 30 ml of a 12.5% sodium hypochlorite solution to 5 gal of potable water will get you to the required 200 ppm concentration for your wash solution.

As an example, an excerpt of an EPA approved label for a 12.5% sodium hypochlorite solution is shown on page 4. This is simply meant to be an example; other EPA approved labels for sodium hypochlorite sanitizers may have different instructions for safe use of the product.

Remember, the label is the law that governs the use of a particular product. Many chlorine labels registered for washing produce also indicate the need for a potable water rinse after sanitizer application. Look for all of these specifications on the label before you start using any sanitizer. By knowing the targeted final concentration (from the EPA label) for the sanitizer and using the initial concentration of the sanitizer plus the final water volume, you can determine the amount of concentrated sanitizer which must be added to the wash water using the formula on page 4.

Verifying Your Actions

Once the chlorine concentration has been determined and the appropriate amount added to the wash tank, you should verify that the proper concentration has been achieved. This is commonly done using chlorine test strips that measure the free or available chlorine or through a titration to determine free chlorine.

Checklist for sanitizing with chlorine solution:

- ✔ Start with potable water.
- ✔ Determine the amount of food grade chlorine to use by checking the % active ingredient on the label and using the formula to calculate the ppm you are targeting.
- ✔ Measure and add chlorine to potable water to make your solution.
- ✔ Check free chlorine concentration (ppm) with free chlorine test strips. This should be what is allowable on the label for fruits and vegetables.
- ✔ Record on log.
- ✔ Check pH of solution with pH test strips. Use food grade buffers to adjust as necessary.
- ✔ Record on log.
- ✔ Check turbidity of wash solutions. Change water when turbidity is high; also check free chlorine concentration (ppm) to ensure solution is still at target level.
- ✔ Record time and ppm on log.

Using Peroxyacetic Acid (PAA) in Fruit and Vegetable Washing and Packing

Peroxyacetic acid, which is also known as peracetic acid or PAA, is a commonly used sanitizer in the produce industry. PAA goes by many trade names, such as Sanidate 5.0 or 12.0, VigorOx 15 F&V, BioSide HS 15%, and Tsunami 100—all of which are a mixture of PAA, water, hydrogen peroxide, and acetic acid (Figure 3). Once dissolved in water, the breakdown products of PAA are carbon dioxide, oxygen, and water.

$$H_2O_2 + CH_3CO_2H \leftrightarrow CH_3CO_3H + H_2O$$

Hydrogen Peroxide | Acetic Acid | Peracetic Acid | Water

Figure 3. Chemical composition of peroxyacetic acid sanitizers.

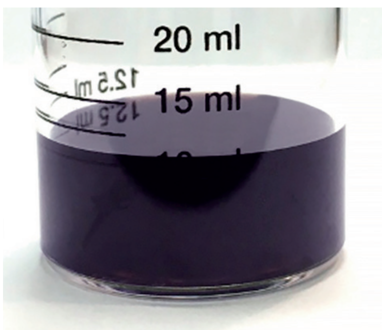
PAA is increasingly being used in the fruit and vegetable industry for postharvest fruit and vegetable washing (21 CFR 173.315) as well as cleaning and sanitizing packinghouse equipment, utensils, bins and other postharvest contact points (21 CFR 178.1010). PAA is also approved as a synthetic substance that is allowed in organic production (7 CFR Sec. 205.601).

Most PAA sanitizers will require you to maintain between 24 and 85 ppm peracetic acid in postharvest processing water. While PAA has a very strong oxidizing capacity, which is what makes it a very effective sanitizer, it also breaks down rapidly. Growers must be diligent about monitoring the levels of PAA in their postharvest washing operations. Based on size and produce throughput in the operation, growers should measure the concentration of PAA anywhere from every 15 minutes to once hourly. Growers with larger throughputs will find a continuous monitoring and automated injection system advantageous. Oxidation-reduction potential (ORP) meters are capable of monitoring many sanitizers. However, data from UC Davis indicates that ORP is not accurate when measuring concentrations of PAA or hydrogen peroxide in postharvest systems (Suslow 2004). There are specific sensors designed to accurately measure concentrations of PAA, if a highly-automated system is desired.

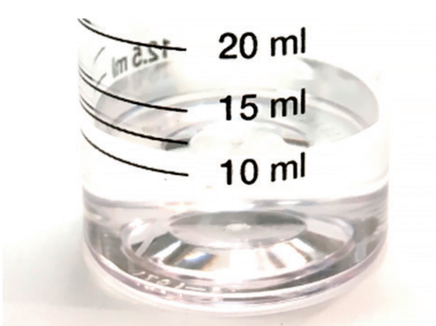
Use test strips or titration as a way to monitor your washing systems at frequent intervals. Monitoring systems for PAA will also interact with hydrogen peroxide, although at a slower rate. For these reasons it is imperative to strictly adhere to the time limits for reading test strips or titrations in order to achieve as accurate a reading as possible. Titration kits rely on the ability of PAA to:

- oxidize iodide to iodine,
- which then reacts with starch,
- resulting in a dark purple to black color,
- and is titrated with sodium thiosulfate to reach a colorless endpoint (Figure 4).

The number of drops needed to create this color change can determine approximate concentration of PAA in the solution. Keep records whenever readings are taken so you can demonstrate proper sanitizer strength in the produce wash water.



Starting PAA solution, typically dark purple to black, that has had reagents added and is ready to be titrated with sodium thiosulfate.



End-point of the PAA titration, a colorless solution. The number of drops of titrant added indicates the concentration of PAA.

Figure 4. Starting and end point colors in the peroxyacetic acid titration method.

Postharvest Washing Recordkeeping

Keeping records to demonstrate proper management of packinghouse water is key. These records should indicate the sanitizer concentration at start-up and at regular intervals dictated by the postharvest water monitoring standard operating procedure (SOP). Corrective actions should also be developed if sanitizer concentrations dip below established minimum concentrations. These typically include adding sanitizer to increase the level to the appropriate concentration and more frequent monitoring to ensure the concentration of sanitizer remains stable. Other pertinent records, such as change schedules for batch or recirculated water based upon turbidity, should also be considered.

Sanitation of Packinghouses

There are numerous sanitizers which can be used for disinfecting food contact surfaces, utensils, packing bins, and other areas in the packinghouse, such as floors, walls, and drains. The Produce Safety Alliance has compiled a list of sanitizers in an Excel file linking EPA labels and the uses for which they are labeled. The list is available at: http://bit.ly/PSA_sanitizer. It is critical to maintain a routine sanitation schedule since microorganisms can easily grow on equipment and other surfaces in the packinghouse and contaminate produce when packed.

There are three critical steps that should be followed when cleaning and disinfecting surfaces:

1. **Clean:** remove dirt and other organic matter with a food grade detergent.

   Thorough cleaning of surfaces with a food grade labeled detergent and potable water must be done prior to sanitizing. Detergents for use in packinghouses should be surfactant-based, which are similar to household detergents used to clean dishes. Detergents are used to reduce the surface tension and improve dirt removal. Removal of organic matter, like food or soil and plant debris, before sanitizing is essential as sanitizers can bind with organic matter thus reducing their effectiveness. Alkaline detergent cleaners are a good choice for soil and wax removal and can be applied with a combination of pressure, mechanical action (such as scrubbing), and exposure time to effectively clean a surface. Acidic cleaners are typically recommended if there will be a need to remove mineral deposits. Sometimes it is necessary to use both an acidic and alkaline cleaner to remove all types of compounds on the fouled surface.

2. **Rinse:** rinse with potable water.

   Rinse thoroughly with potable water to remove both organic matter and residues. Detergent residue is alkaline (pH >7), which can alter the overall pH of the sanitizer solution and reduce its efficacy, so remove it with a rinse step prior to applying the sanitizer. Only potable water should be used in any postharvest water applications, (i.e., rinsing surfaces, making sanitizing solutions, washing and cooling produce, icing, and other applications).

3. **Sanitize:** apply sanitizer.

   When the sanitizer is applied to a clean surface it is able to efficiently disinfect or reduce the number of microorganisms to an acceptable level. Leave sanitized surfaces (of all equipment and surfaces sanitized in the packinghouse) to air dry unless the product label mandates rinsing.

Develop a system to determine when sanitation events should occur. It is important that you establish a master sanitation schedule that dictates when specific areas of the packinghouse are cleaned. As an example, areas such as coolers may only receive weekly or biweekly cleaning rather than the daily cleaning that needs to take place in the primary packing area. In addition to the master sanitation schedule, it is also important to establish Sanitation Standard Operating Procedures, or SSOPs, that very clearly describe how a surface is to be cleaned and sanitized so that any employee is adequately trained and can properly carry out the task.

Critical Parameters for Sanitation

The critical parameters described above for washing are the same when applying these compounds during sanitation. You will want to focus on the following parameters:

- Product has an EPA registration number.
- Labeled (intended) use: food contact surfaces (porous and non-porous) and non-food contact surfaces (walls, drains, ceilings, and floors).
- Minimum and maximum concentration.
- Recommended contact time.

Regularly monitor the sanitizer as described above to ensure the appropriate concentration is being applied. Non-food contact surfaces (e.g., floors, walls) typically can have higher concentrations of sanitizer applied than food contact surfaces.

It is also important to perform visual inspections after cleaning and before a sanitizer is applied to make sure all equipment is clean. Some growers also like to incorporate tools such as Adenosine Triphosphate (ATP) meters to make sure a surface is clean before the sanitizer is applied. ATP is found in all living matter and ATP testing methods rely upon this fact to determine when there is an "above normal" amount of soil or plant material left on a surface.

ATP readings are taken by wiping a surface with a cotton swab. When finished wiping, you place the swab into a plastic sheath and release a solution carrying the enzyme luciferase, which is the same enzyme that causes fireflies to light up. Luciferase interacts with any ATP present on the swab and causes fluorescence. The swab can then be placed into an ATP meter and the relative fluorescence units read. This tool provides a very accurate way to determine if a surface has been adequately cleaned prior to applying a sanitizer. If the reading comes back above a predetermined threshold, clean the surface again and repeat the ATP test. Testing for microbial indicators, such as coliforms, *Escherichia coli*, or *Listeria* species, may also be conducted on a less-frequent basis than ATP testing to document control of microbial targets. These verification checks are becoming increasingly important ways to demonstrate you have a strong sanitation program in your packing facility.

As mentioned, training employees will be key to effective implementation of any sanitation program. Direct observations, where a supervisor directly observes a monitoring or cleaning/sanitation event take place, can help employers understand how well employees adhere to SSOPs. This type of insight will help you develop the most robust program for your operation.

Sanitation Recordkeeping

Keep records to demonstrate that packinghouse sanitation is conducted on a regular basis as delineated in the master sanitation schedule. These records should indicate when cleaning and sanitizing took place, the location, SOP followed, concentration of any sanitizer used, and the name of the person responsible for the procedure. Additional records should be kept describing other verification activities, such as visual inspections, ATP readings after a sanitation event, and any corrective actions that were needed (e.g., recleaning or sanitizing surfaces).

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