Food safety of fruits and vegetables begins with growers following Good Agricultural Practices (GAPs) to reduce the risk of foodborne illness. After harvest, growers should incorporate Good Manufacturing Practices (GMPs) into their protocols, including sanitation principles. For additional guidance on good sanitation practices during production, harvesting, and packaging, review PM 1974C, *On-farm Food Safety: Cleaning and Sanitizing Guide*, which provides an overview of cleaning and sanitizing food contact surfaces and products.

This publication provides additional information about the best post-harvest sanitizing practices for fresh fruits and vegetables. It includes a comparison chart of five commonly used liquid sanitizers, with information on mechanisms for killing pathogenic bacteria, testing methods, recommended concentrations, positive and negative considerations, and product examples.

Guide to Using Liquid Sanitizer Washes with Fruits and Vegetables

Factors that Affect Liquid Sanitizer Wash Effectiveness

- **Water source** should be potable and free from debris, odor, and microorganisms. Water hardness can affect the concentration of the sanitizer. Water hardness is the amount of minerals within the water. (***Soft*** is less than 60 ppm. ***Moderately hard*** is 61-120 ppm. ***Hard*** is 121-180 ppm. ***Very hard*** is more than 180 ppm.) The higher the water hardness concentration, the less effective the sanitizer is on produce as mineral deposits can trap bacteria or bind to the active ingredients that cause bacteria to die. For example, in Ames, Iowa, the water supply ranges from 150-165 ppm, while in Des Moines, Iowa, it ranges from 100-135 ppm. Using this example, Des Moines could use less sanitizer wash to achieve the same sanitizer concentration as Ames.

- **Soil** presence reduces the effectiveness of all types of liquid sanitizers. **Soil binds to the active ingredients within the sanitizer wash and results** in a lower concentration of active ingredients. Removal of as much soil as possible prior to rinsing produce with a sanitizer will maximize the sanitizer's effect.

- **Water temperature** can affect the safety and effectiveness of sanitizer. High temperatures can result in sanitizer vaporization, producing a toxic gas that could be dangerous to human health. Low temperatures can reduce the efficacy in some types of sanitizer, as well as reduce the activity of their active ingredients. It is important to be aware of the appropriate temperature for a specific sanitizer.

- **pH** of the water and product can affect a sanitizer's effectiveness. pH is a measure of the acidity of a concentration and is observed on a scale of 1-14. A pH less than seven is acidic, and a pH greater than seven is basic. As shown in the chart, some sanitizers work best in acidic or neutral pH conditions, while others are not affected by pH. For those affected, water testing is important to ensure that the correct type of sanitizing agent is selected for water conditions to achieve maximum impact and value.

- **Contact time on product** can significantly affect the efficacy of the sanitizer in removing disease-causing microorganisms. It is important to read the manufacturer's instructions on how long and under what conditions contact of the fruits or vegetables with the sanitizer solution is most effective. Temperature and pH affect the rate at which sanitizers can kill microorganisms on the surface. For example, warmer water temperatures, along with a neutral pH in the presence of low organic matter (soil), can reduce contact time for chlorine bleach.

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- **Fruit and vegetable surfaces** affect the ability of sanitizers to penetrate the entire surface. Produce surfaces with crevices and punctures, such as cantaloupe and leafy greens, lower the likelihood that sanitizers will cover all areas. Produce items that are easily bruised or damaged, such as apples and tomatoes, have increased likelihood to harbor microorganisms in damaged areas, thus reducing the likelihood for sanitizer to be effective.

- **Other factors for consideration** include the concentration appropriate to the sanitizer agent of the sanitizer used and mixing multiple sanitizers together. Test strips should be used to ensure that the approved concentration of the sanitizer is being prepared and maintained during usage. Sanitizers should not be mixed unless directions from the manufacturers indicate that it is safe.

* *Sanitizer effectiveness depends on the properties of the sanitizer wash under these conditions. Some are more robust under different factors.*

Sanitizer Comparison Chart

CATEGORY	MECHANISM for KILLING BACTERIA	TESTING	CONCENTRATION	POSITIVES	NEGATIVES	PRODUCTS
Chlorine based *Bleach is packaged in varying strengths so it is important to use the appropriate amount to obtain end concentration.*	• Alters cellular metabolism and destroys the cell wall → Upsets the chemical balance and denatures structure proteins • Decreases the nutrient uptake • Decreases oxygen uptake and other respiration functions	• Test strips, kits, and testing	**Produce:** • 100-200 ppm • 200 ppm = 2 table-spoons of 6% hypo chlorite (household bleach) per gallon in warm water (75-120°F) **Surface:** • Typically 50-100 ppm	• Easy to prepare • Strong stability • Fast acting • Shown effective on vegetative cells • Inexpensive	• pH control: 6-8.5 • Temperature: below 46°F not effective • Must treat water prior to release • Highly corrosive to metals • Soil binds the free chlorine so must refresh frequently • Can form gas (poor penetration) and can cause health issues • Water hardness: > 500 ppm not effective	✓ Unscented regular strength bleach (6%) • Sanova™ (acidified sodium chlorine
Chlorine dioxide	• Disrupts protein synthesis	• Test strips, kits, and machines	• Less than 3 ppm in liquid form	• Wide range of pHs • Highly soluble in water • Does not ionize in water so effective over long processing times	• Must have a water rinse after application • Can cause quality defects if exposed too long	• Zep Dominion™
Organic acids • acetic acid (vinegar) • citric acid • lactic acid	• Denature proteins (including enzymes) • Inhibit energy production • Degrade outer membrane structure • Disrupt osmotic pressure, which causes cell lysis	• Test the active ingredient • Specific product test	• Vinegars contain less than 8% acetic acid • 8% vinegar with a ratio of 1 part vinegar to 3 parts water • Follow manufacturers' recommendations	• Typically more natural ingredients • Noncorrosive to stainless steel • No staining or odor properties • Works rapidly	• Work best in acid conditions • Limited kill potential against yeast and molds and gram positives	✓ Vinegar at less than 8% acetic acid from an organic source • Veggixide® (citric/ lactic acid) • PRO-SAN© LC • FIT (citric acid, grapefruit seed, ethanol)

Sanitizer Comparison Chart

CATEGORY	MECHANISM for KILLING BACTERIA	TESTING	CONCENTRATION	POSITIVES	NEGATIVES	PRODUCTS
Hydrogen peroxide	• Disrupts osmotic pressure, which causes cell wall damage	• Test strips, kits, and machines	• Food grade hydrogen peroxide 1-5%; 3% most common • Follow manufacturers' recommendations	• Easy to prepare • Easily broken down in water • Fast acting • Highly effective against spores • Available in liquid or gas forms • Inexpensive	• Allergic reactions • Irritant in vapor form • Storage is important (sunlight and temperature sensitive, which affects sanitizer shelf life) • Not stable in water → concentration decreases rapidly	✓ Food grade hydrogen peroxide
Peroxyacetic acid/peracetic acid	• Denature proteins and lipids (disorganize the membrane) • Oxidize outer cell membrane • Disrupt balance of electrons in cell, which cause microbe function to be inactive • Swelling effect if it's combined with hydrogen ions (burst)	• Test strips, kits, and machines	• Follow manufacturers' recommendations	• Effective against bacterial spores • Wider range for pH (5-9) • Apply in cool or warm water • Noncorrosive • Tolerant of organic matter	• Pungent odor • Corrosive to skin • Become corrosive in high temperatures • Lose effectiveness in presence of metals (copper, mild steels, brass)	✓ Tsunami 100® (hydrogen peroxide/peroxy-acetic acid) • StorOx 2.0 (hydrogen peroxide/ peroxyacetic acid) • SaniDate 12.0 (peroxyacetic acid) • StorOx (hydrogen peroxide/peracetic acid)

✓*Approved for usage on certified organic produce/products*

RESOURCE

For additional guidance on good sanitation practices during production, harvesting, and packaging, review PM 1974, an Iowa State University Extension and Outreach publication series on GAPs available for free download at https://store.extension.iastate.edu.

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