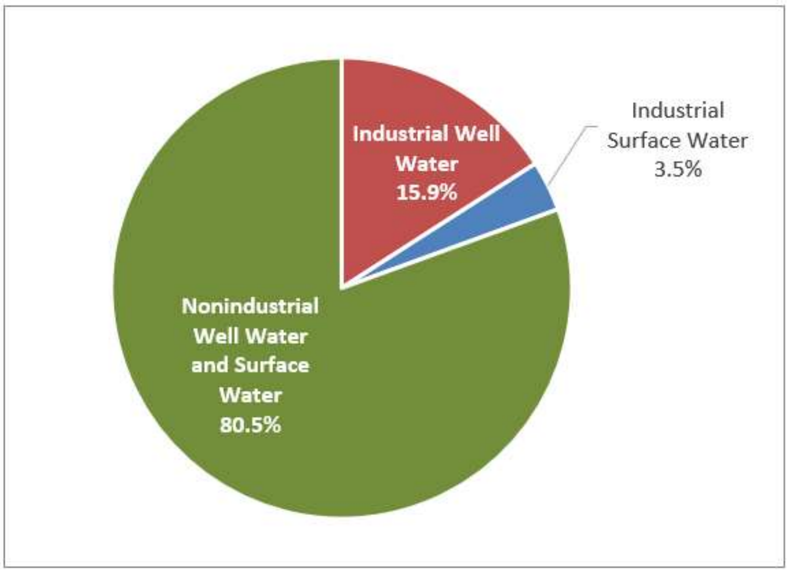
APPENDIX H: Equipment Cleaning and Sanitation Technologies

In Tulare County, many large food processors draw water from their own groundwater wells, while others purchase some or all their water from municipal water utilities. In 2010, the U.S. Geological Survey (USGS)[182] estimated that industrial facilities withdrew an average of 16.07 million gallons of water per day (MGD) from wells in Tulare County and 3.56 MGD from public water supplies for a total of 19.63 MGD industrial water withdrawals.[183] Figure H-1 compares Tulare County's industrial water withdrawals to the county's overall non-irrigation water withdrawals.

Figure H-1: Tulare County Non-Irrigation Water Withdrawals



[182] The U.S. Geological Survey (USGS) estimated self-supplied industrial withdrawals by collecting data from a sample of major industrial facilities, creating water-use coefficients in the form of volume used per employee or per unit of product and using these coefficients to calculate usage for the remaining industrial facilities in the county. Further details, including sample size, were not provided by the USGS, but this estimate is sufficient to justify the need to conserve water in this industry. Industrial withdrawals from public supply were estimated by summing data found in urban water management plans from the top water users in Tulare County. This estimate should be lower than reality because not all municipalities had published urban water management plans.

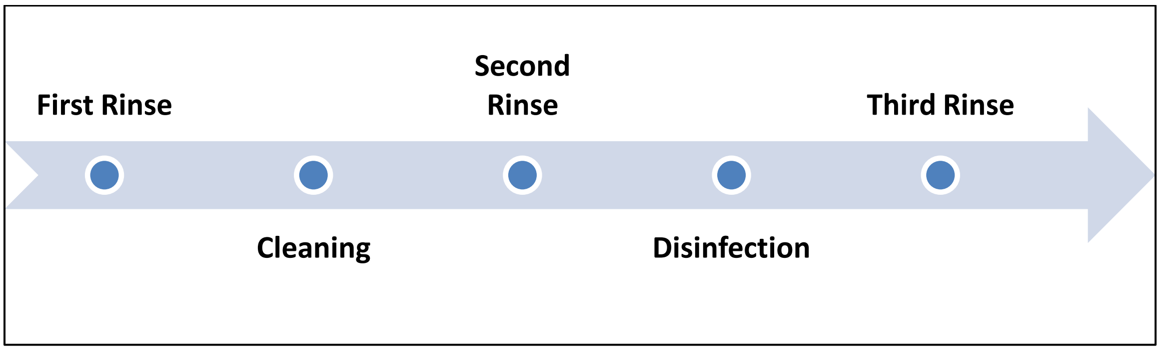
[183] "USGS Water Use in the United States - County data download 2010." *U.S. Geological Survey* website. https://water.usgs.gov/watuse/data/2010/.

Water use for cleaning of facilities and equipment is large as a percentage of total water use within the industrial sector. It is particularly high in food and beverage (F&B) processing where 60 percent or more of process (non-food) water is used for cleaning:[184]

- CIP ("clean in place" systems clean the interior surfaces of process equipment without the need to disassemble the system).
- COP ("clean out of place" systems clean equipment that cannot be cleaned "in place", such as areas where process equipment may need to be disassembled, and/or items that are small, complex, sensitive, or difficult to clean).
- Floors and exterior equipment.
- Lubricating and cleaning conveyors.

The cleaning process can include, but is not limited to, the steps shown in Figure H-2.

Figure H-2: Five Steps of Traditional Industrial Cleaning Processes



1. First Rinse

   This initial rinse is intended to wash away any free particles/chemicals on the surface. Water from the second or third rinse can safely be reused for this step.

2. Cleaning

   The cleaning process removes all visible soil and materials from the surface. It typically involves the use of a caustic and/or corrosive alkaline chemical detergent. Many wastewater treatment facilities require companies to reduce the pH range, chemical oxygen demand (COD), and biological oxygen demand (BOD) of waste streams, which typically requires treatment of the runoff from this step.

3. Second Rinse

184 Blake Schomas, Director of Marketing for Nalco Water, an Ecolab company, in an interview with Debra Schug, Food Engineering, *Reducing water usage in food and beverage processing*, April 18, 2016.

Depending on the nature of the chemicals used for the cleaning step, a secondary rinse may be necessary between cleaning and sanitizing. Rinse water from the third rinse can be reused for this intermediate rinsing step.

4. Disinfection

The process used to sanitize the surface must be an effective disinfectant capable of neutralizing bacteria, viruses, fungus, and many other forms of pathogens.

Thermal sanitation is easy to apply, readily available, and effective over a broad range of microorganisms. However, it is a slow process that is energy intensive, carries employee safety concerns, and can contribute to the degradation of equipment through thermal shock/cycling. Chemical sanitizers typically consist of chlorine, peroxides, or various acids.

5. Third Rinse

For some sanitation chemicals, a third and final rinse is necessary to wash away residual chemicals. This water should be fully sterilized. The FDA maintains a list of sanitizers that do not require rinsing afterward.

Strict cleaning measures are necessary to prevent the contamination of food products. Thorough sanitation of food processing equipment is essential to public health and safety, and food processing facilities feel immense pressure to institute and enforce a strict regime of sanitation procedures. Simultaneously, drought conditions increase the need to conserve water. Food processing facilities can satisfy both pressures by implementing innovative technologies that reduce or eliminate the need for water while maintaining an excellent level of cleanliness.

Many of the traditional cleaning solutions and sanitizers used in the food industry are hazardous to those who use them and those who work around them. Exposure to caustic/corrosive cleaning chemicals can cause skin irritation, rashes, burns, and irritation of the eyes, nose, throat, and lungs.[185] Custodial workers, who frequently encounter cleaning chemicals, are twice as likely to develop asthma compared to other workers.[186] Vegetables have typically been washed with water that contains free chlorine in concentrations less than 30 ppm for several decades, but many researchers have determined that excessive use of chlorine can be harmful due to the formation of carcinogenic disinfection byproducts caused by the reaction of residual chlorine with organic matter.[187]

The five technologies below can replace traditional caustic/corrosive/carcinogenic cleaning chemicals while also decreasing water and energy consumption.

185 Spruce, L. "Back to Basics: Environmental Cleaning Hazards." *AORN Journal*, Vol. 106, No. 5, pp. 424–432. Nov. 2017.

186 "Green Cleaning, Sanitizing, and Disinfecting: A Curriculum for Early Care and Education." *University of California, San Francisco (UCSF) Institute for Health & Aging*. 2013.

187 McDonald, T.A. and H. Komulainen. "Carcinogenicity of the Chlorination Disinfection By-Product MX." *Journal of Environmental Health*, Part C, Vol. 23, No. 2, pp. 163–214. July 2005.

Table H-1: Technologies for Equipment Cleaning and Sanitation

Candidate Technologies	Applications
Dry Ice Blasting	Waterless clean-in-place system that can rapidly clean nearly any surface; ideal for 'dry' facilities such as bakeries
Biomist	Misted sanitizer that can effectively disinfect nearly any surface; highly effective at disinfecting hard-to reach and water-sensitive surfaces
Electrochemically Activated Solutions	Nontoxic, nonthermal cleaning and sanitizing solutions that can be produced on-site and on-demand
Ultrasound Disinfection	High-powered sound waves might be able to effectively sanitize produce and containers submerged in water
Cold Plasma	Electricity applied to gas surrounding produce and containers creates disinfecting plasma that might be an effective sanitizing agent

Dry Ice Blasting

Dry ice blasting, also known as cryoblasting, refers to blasting surfaces with small pellets of solid carbon dioxide (CO2). Upon impact, the pellets simultaneously evaporate and freeze the substrates on the surface. Cryoblasting exerts mechanical and thermal stresses on substrates that effectively strip the material from said surface[188] (see Figure H-3 below).

Figure H-3: Depiction of the dry ice blasting process

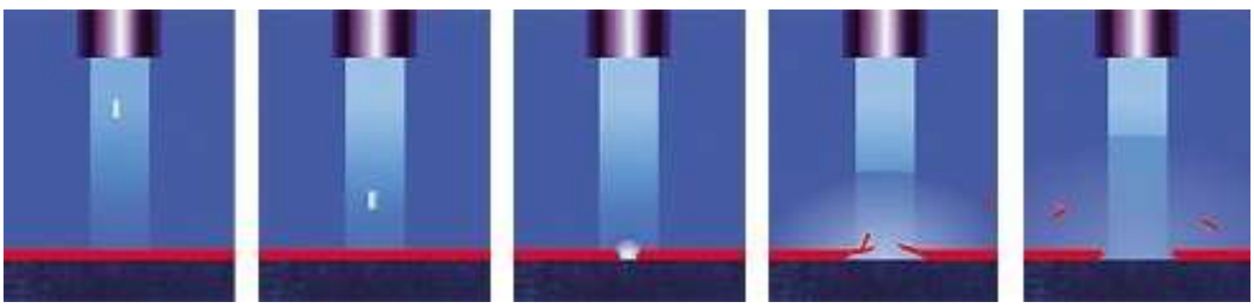


Figure used with permission of Cold Jet.

Because dry ice evaporates upon impact, there is no residual cleaning chemical on equipment surfaces or in cavities of parts, meaning that subsequent clearing or drying of these areas is unnecessary. Dry ice blasters are capable of shooting anything from finely shaved dry ice to larger pellets, which allows the operator to fine-tune the machine to the ideal scrubbing power. This mechanism is ideal for cleaning in place because it can easily scrub hard-to-reach places and doesn't splash liquid. Additionally, there is no drying time delay before the equipment can be put back into production. Dry ice blasting can be implemented with sensitive electronics and applications where water and chemicals could cause considerable damage.

188 Spur, G., E. Uhlmann, and F. Elbing. "Dry-ice blasting for cleaning: process, optimization and application." *Wear*, Vol. 233–235, pp. 402–411. December 1999.

Dry Ice Blasting is not an Effective Sanitizer

Though dry ice blasters are highly efficient at removing built-up residue from all kinds of surfaces and have demonstrated antibacterial properties, they are not considered to be an effective sterilization method for surfaces that contact food products. This is because the process of blasting surfaces can potentially disperse bacteria to nearby surfaces, which increases chances of recontamination.[189] Dry ice blasting alone may be most effective for the removal of dirt, grease, and grime on machines and surfaces that do not come into direct contact with food. For applications within food processing facilities, dry ice blasting can be accompanied by a powerful, invasive disinfectant.[190]

Emissions Associated with Dry Ice Blasting

One concern of cryoblasting is the direct release of CO2 into the atmosphere. The carbon dioxide used to produce pellets is a byproduct that can be captured from ammonia production, oil and gas refineries, and ethanol production. If a carbon sequestration method is developed to divert carbon dioxide from one of these industries for cryoblasting, then there would essentially be no net difference in emissions. In Tulare County, Air Liquide is already capturing and liquefying CO2 from ethanol production.[191] The CO2 currently goes to products such as sparkling mineral water and soda, but could potentially be expanded to accommodate dry ice blasting operations.

Other Factors

Dry ice blasting requires less work for disposal of waste and does not require construction of containment mechanisms, which can further reduce emissions from transportation and treatment processes. A study by the University of Miami found that the use of dry ice blasting would result in fewer carbon dioxide emissions for cleaning a concrete bridge when compared to water jetting or sand blasting.[192] They also determined that dry ice blasting would take 10-20 percent less time than water jetting or sand blasting due to the simpler set up and tear down procedures. Though food processing and cleaning bridges are very different, comparable results are expected regarding the carbon dioxide emissions of cryoblasting.

---

189 Miller, I. "Final Technical Report: Cold Jet - A Novel Technique for Cleaning and Decontaminating Food Processing Areas, Equipment, Carcasses and Foods." *Microchem Bioscience Limited*, B02006. September 2004.

190 Witte, A.K, M. Bobal, R. David, B. Blättler, D. Schoder, and P. Rossmanith. "Investigation of the potential of dry ice blasting for cleaning and disinfection in the food production environment." *LWT - Food Science Technology*, Vol. 75, pp. 735–741. January 2017.

191 "Food Processing Presents Energy Industry Opportunities in Tulare County, CA," 2015. *Area Development* website: http://www.areadevelopment.com/FoodProcessing/.

192 Millman, L.R. and J. W. Giancaspro. "Environmental Evaluation of Abrasive Blasting with Sand, Water, and Dry Ice." *International Journal of Architecture, Engineering and Construction*, Vol. 1, No. 3, pp. 174–182. September 2012.

Technology Benefits

The primary rinse is usually unnecessary because dry ice blasting removes substantial amounts of soil. Depending on the application, the secondary rinse may also be unnecessary. The cleaning step, which typically uses chemicals diluted in water, uses no water whatsoever. In some scenarios, implementing dry ice cleaning with a no-rinse sanitizer can completely clean and sanitize surfaces while removing four out of five water-based steps from the process. The water savings that can be achieved from this implementation are significant. Additionally, case studies have proven dry ice blasting to be incredibly time efficient, reducing cleaning times by up to 90% when compared to manual cleaning methods. Finally, the simplicity and speed of dry ice blasting can save energy and reduce emissions compared to traditional cleaning technologies.

Biomist

Biomist is a misted alcohol technology developed by Biomist, Inc. for the disinfection of food and food processing surfaces. The Biomist formula is bactericidal, viricidal, and tuberculocidal.[193] The alcohol kills germs on contact and evaporates, leaving surfaces and equipment dry and ready for use. Many studies have demonstrated the efficacy of alcohol as a disinfectant.[194] Biomist is ideal for dry environments (nuts, bakeries, spices, etc.) because it evaporates away with no residue. No wiping or cleaning off is necessary, which helps to eliminate cross-contamination. Biomist can also be applied to sanitize non-washable equipment, electronics, control panels, and other sensitive items because it is non-corrosive. The penetrating mist can spray surfaces up to 15 feet away and can reach into cracks and crevices that are inaccessible to other sanitizing methods. Biomist is an effective solution for disinfecting surfaces that have been treated with dry ice blasting.[195] Biomist avoids flammability by encasing the alcohol vapor in a stream of CO_2 gas, cutting off all oxygen needed for combustion. Consequently, the Biomist formula can be sprayed in places where there is a chance of sparks or open flames.

193 Musgrove, M.T. and J. K. Northcutt. "Evaluation of an Alcohol-based Sanitizer Spray's Bactericidal Effects on Salmonella Inoculated onto Stainless Steel and Shell Egg Processing Equipment." *International Journal of Poultry Science*, Vol. 11, No. 2, pp. 92–95. February 2012.

194 Graziano, M.U., K.U. Graziano, F.M.G. Pinto, C.Q. de M. Bruna, R.Q. de Souza, and C.A. Lascala. "Effectiveness of disinfection with alcohol 70% (w/v) of contaminated surfaces not previously cleaned." *Revista Latino-Americana de Enfermagem*, Vol. 21, No. 2, pp. 618–623. April 2013.

195 Cook, R. "Biomist Misted Alcohol Disinfectant Technology Discussion." August 16, 2017.

Figure H-4: Biomist SS20 system

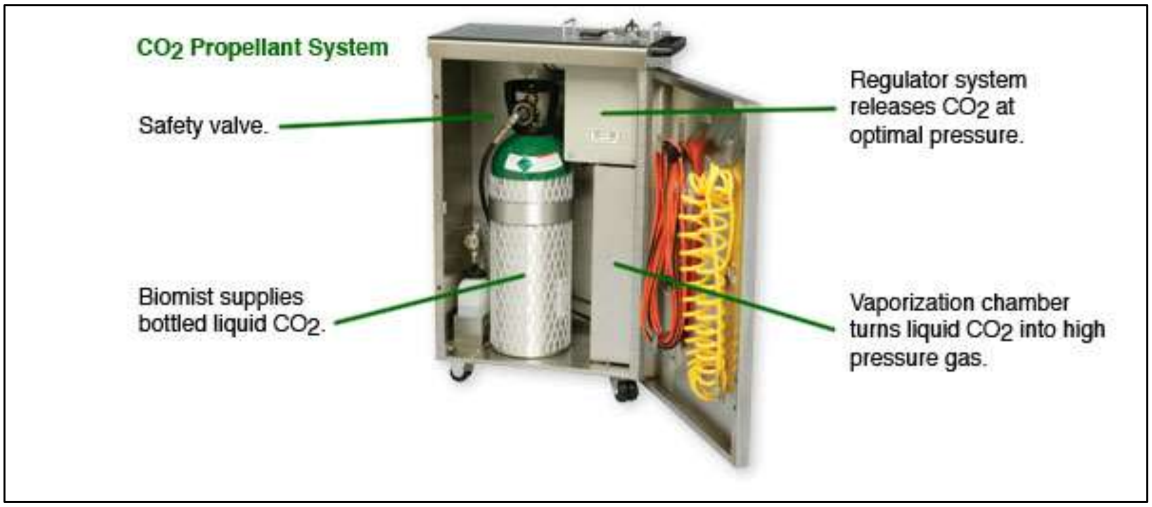


Figure courtesy of Biomist, Inc.

Technology Benefits

Biomist technology saves money through reduced down-time for machinery, eliminating the need for clean-up and disposal, and reduced chemical expenses. The system requires a canister of liquid CO2, which is provided by Biomist. Biomist saves water by eliminating the need for a final rinse and because the misting process uses less water than a foam or disinfecting rinse.

Electrochemically Activated Solutions

Electrochemical activated water (ECA) can be used as a substitute to conventional clean-in-place systems and has been successfully implemented in beverage, meat/protein, grains, starch, condiments/seasonings, and liquid foods.[196] It uses water, table salt (NaCl), and electricity to create two solutions: one for cleaning and one for sanitizing. There are no additional chemicals or hot water involved, and its footprint and operational costs are reduced compared to traditional methods. Both chemicals are skin-safe and present little to no danger to workers. ECA sanitizers can be applied to food products without affecting their appearance, taste, or smell.[197] Because the ingredients of ECA are salt and water, it can even integrate as an ingredient in sauces/condiments.[198]

196 Bramsen, P. “Klarion ECA Technology Discussion.” September 7, 2017.

197 Wang, X., A. Demirci, and V. M. Puri. “Electrolyzed Oxidizing Water for Food and Equipment Decontamination,” in Handbook of Hygiene Control in the Food Industry. *Elsevier*, 2016, pp. 503–520.

198 “Benefits of ECA.” *ECA Consortium*. http://ecaconsortium.com/benefits-of-eca.html.

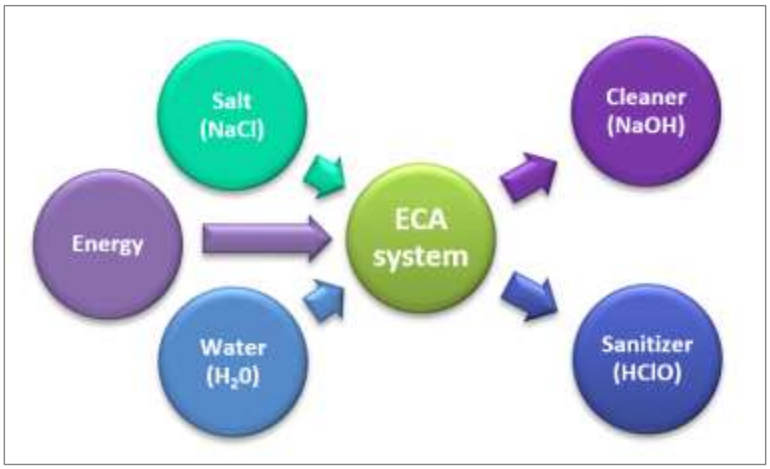
Electrochemical Activation Process

ECA systems are composed of an anode and a cathode, which produce two separate cleaning products.

The cathode splits water (H20) into hydrogen (H2) and hydroxide (OH-). The hydroxide combines with sodium to produce sodium hydroxide (NaOH). This chemical is a mild alkaline anti-oxidizing detergent that is effective at lifting dirt and emulsifying grease. This solution can be used for cleaning fruits and vegetables, effectively removing dirt and potentially even pesticides.[199] It can also be used as the cleaning chemical for equipment and surfaces.

The anode splits water (H20) into oxygen (O2) and hydrogen (H+). These molecules recombine with free chlorine ions, resulting in a nontoxic, non-corrosive hypochlorous acid (HClO). This solution is safe enough to be used as a sanitizing agent for medical procedures to fight infection and is highly effective at killing microbes.

Figure H-5: Electrochemical Activation Process



The transformation of the ECA solution is not permanent. After the solution has been recovered and mixed, the chemical species present will spontaneously shift from this thermodynamically unstable condition to a stable non-active form. The non-active form can be disposed of without treatment with no adverse effects on the downstream effluent environment. The way in which these chemicals are applied to surfaces and machinery will depend on the individual facility. They can be used with a bucket and rag, in a spray bottle, combined with a surfactant and applied as a foam, or implemented into an automated CIP system.

199 "Electrolyzed Water." *ECA-Water*. http://www.toxicfreecleaning.com/eca-water.

Technology Benefits

The implementation of ECA cleaning systems in industrial facilities can save time, effort, and resources. Water can be saved because the ECA systems can be more effective than traditional chemicals, therefore requiring fewer passes or less immersion. Additionally, because the cleaner and sanitizer are compatible, no rinse is required between these steps. Increased employee satisfaction can result from the lack of corrosive, hot, or otherwise dangerous chemicals. The ECA Consortium estimates that ECA technology, when compared to traditional CIP systems, will save water (60%), cleaning cycle time (70%), chemical expenses (90%) and energy (98%).

Ultrasound Disinfection

High Power Ultrasound (HPU) refers to soundwaves generated at high power and low frequencies (20 to 100 kHz). Several studies have shown HPU to be an effective antimicrobial agent with potential use for disinfecting produce and food containers.[200] Sound waves are generally considered safe, non-toxic, and environmentally friendly.

During ultrasound applications, thousands of microbubbles are generated in liquid surrounding the produce. The gas within the microbubble is heated to a high temperature (up to 5500 C) and pressure (up to 50,000 kiloPascal),[201] with fluctuations occurring in microseconds. When the bubbles collapse, the generated shockwaves are strong enough to shear and break the cell wall and membrane structures of pathogens.[202] This process is called cavitation.

The components of the microbial cells are disrupted by the transfer of kinetic energy generated by ultrasound waves. This energy can disintegrate solids and remove layers of material from surfaces and porous interior structures, kill microorganisms, and prevent undesirable materials from adhering to solid surfaces.[203]

Furthermore, the localized temperature increase within a collapsing bubble generates primary hydroxyl radicals. Ultrasonic applications accelerated single electron transfers, which results in hydrogen atoms and hydroxyl radicals recombining to form hydrogen peroxide (H2O2), which

200 Sango, D.M., D. Abela, A. McElhatton, and V. P. Valdramidis. "Assisted ultrasound applications for the production of safe foods." *Journal of Applied Microbiology*, Vol. 116, No. 5, pp. 1067–1083. May 2014.

201 Kilopascal (kPa) is a "unit of pressure and stress … of one newton per square metre, or, in SI base units, one kilogram per metre per second squared. This unit is inconveniently small for many purposes, and the kilopascal (kPa) of 1,000 newtons per square metre is more commonly used. For example, standard atmospheric pressure (or 1 atm) is defined as 101.325 kPa." Source: Encyclopedia Britannica. https://www.britannica.com/science/pascal-unit-of-energy-measurement#ref187919.

202 Bilek, S.E. and F. Turantaş. "Decontamination efficiency of high power ultrasound in the fruit and vegetable industry, a review." *International Journal of Food Microbiology*, Vol. 166, No. 1, pp. 155–162. August 2013.

203 Jiranek, V., P. Grbin, A. Yap, M. Barnes, and D. Bates. "High power ultrasonics as a novel tool offering new opportunities for managing wine microbiology." *Biotechnology Letters*, Vol. 30, No. 1, pp. 1–6. November 2007.

has important bactericidal properties. The hydroxyl radical is also able to react with the sugar-phosphate backbone of DNA, which results in the breakage of microbial DNA.[204]

HPU treatment (patented as Sonoxide) has been used in over 600 applications worldwide for controlling bacteria and algae in industrial water systems. In addition, HPU has been used in the wine industry since 2006 for the removal of microbiological contaminants and tartrate build-up from wine barrels. The Tom Beard barrel washer operates by filling wine barrels with water and sonicating the interior for 5-12 minutes.[205]

A key factor inhibiting the adoption of HPU disinfecting is the lack of case-studies and proofs-of-concept in a real industrial environment. Much more research and testing is necessary to prove whether ultrasound can be an effective replacement for traditional disinfection methods. There presently are no companies that currently offer ready-to-go technology for the disinfection of produce via ultrasound treatments. One organic lettuce packaging facility (Earthbound, in California) successfully implemented ultrasonic cleaning in their facility,[206] and the University of Patras in Greece determined that ultrasound can disinfect lettuce and strawberries to a level comparable to chlorine and hydrogen peroxide without affecting the product in any way.[207]

Technology Benefits

Though ultrasound disinfection technology is not developed enough for full-scale implementation, it certainly appears to have potential to reduce the amount of water necessary to disinfect produce.

Cold Plasma

Cold plasma decontamination is a promising nonthermal microbial inactivation method. It involves the application of electricity to a gas, creating ions, radiation, and excited molecules that can eliminate pathogens without affecting the product. Cold plasma would serve as an excellent substitute for traditional disinfection methods because it is highly energy efficient and significantly reduces the use of water during product disinfection. Furthermore, cold

204 Bilek, S.E. and F. Turantaş. "Decontamination efficiency of high power ultrasound in the fruit and vegetable industry, a review." *International Journal of Food Microbiology*, Vol. 166, No. 1, pp. 155–162. August 2013.

205 Jiranek, V., P. Grbin, A. Yap, M. Barnes, and D. Bates. "High power ultrasonics as a novel tool offering new opportunities for managing wine microbiology." *Biotechnology Letters*, Vol. 30, No. 1, pp. 1–6. November 2007.

206 "Sound Barrier: Can High-Power Ultrasound Protect Produce from Pathogens? *Scientific American*." https://www.scientificamerican.com/article/ultrasound-to-protect-produce-from-pathogens.

207 Birmpa, A., V. Sfika, and A. Vantarakis. "Ultraviolet light and Ultrasound as non-thermal treatments for the inactivation of microorganisms in fresh ready-to-eat foods." *International Journal of Food Microbiology*, Vol. 167, No. 1, pp. 96–102. October 2013.

plasma treatment is nontoxic, has a wide range of applications, and can disinfect food very quickly.[208]

Cold plasma sterilization treatments involve passing an electric current through a gas that surrounds whatever produce item is to be sanitized. The gas could be air, argon, nitrogen, oxygen, helium, or some mixture thereof. When electricity flows through the gas, the impact of electrons can generate reactive chemicals that will interact with and deactivate pathogens. After the cold plasma treatment, the gases will almost entirely return to a nonreactive state. The electrical charge itself may also affect microorganisms. Though the exact mechanisms have not completely been determined, cold plasma treatment has been demonstrated through multiple experiments to be highly effective at removing biofilms from produce and other surfaces.[209]

In general, the application of cold plasma has a negligible effect on the product matrix, neither altering the sensory qualities of the food nor leaving any form of residue. Furthermore, cold plasma could be applied to both solid and liquid products. However, the process does require additional safety measures to protect against high voltage.

Cold plasma is a dry technology that utilizes non-reactive, non-polluting gases and minimal electricity. It does not result in any liquid waste stream, therefore requires no sewage disposal. Cold plasma technology has a significant potential for commercial-scale adoption.

Technology Benefits

Cold plasma treatment virtually eliminates the need for water during the disinfection stage. Furthermore, it is highly energy efficient, can be applied to a wide range of food products, and is highly effective at removing biofilms.

208 Patil, S., P. Bourke, and P. J. Cullen. “Principles of Nonthermal Plasma Decontamination.” “Cold Plasma in Food and Agriculture.” *Elsevier*, 2016, pp. 143–177.

209 Pankaj, S.K., et al., “Applications of cold plasma technology in food packaging,” *Trends in Food Science and Technology*, Vol. 35, No. 1, pp. 5–17. January 2014.