FACT SHEET *D R A F T*

OZONE

Fact Sheet for Food Processors

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1. Why Ozone Processing of Foods?

On June 26, 2001, the U.S. FDA approved ozone, a gas that is strong oxidizing agent capable of acting as a disinfectant[1], as an Antimicrobial Agent for direct contact with foods of all types. This material can control microorganisms of all types without producing halogenated byproducts. Ozone has been used since the early 1900s for controlling microorganisms in potable waters, and its uses have been extended to the treatment of waters used for swimming pools, bottled waters, cooling towers, soft drinks, washing of food processing and handling equipment, etc. Applied in the gas phase, ozone also has found applications in odor and mold control and the storage and packaging of harvested agricultural products and processed foods. Current effective applications for ozone in food processing plants include process water treatment for reuse, for processing and

[1]For this Fact Sheet, the term "disinfectant" will be used as a generic term for any product capable of killing or reducing the number of microorganisms on food products as well as on food preparation surfaces. The specific terms "antimicrobial agent", "sanitizer", and "sterilizer" will be used whenever referencing the numbers of microorganisms removed from a food or food preparation surface.

storage of foods, and for packaging of foods. When applied, ozone decomposes, returning to the oxygen from which it was made, leaving no chemical residues from the Antimicrobial Agent itself on the food products.

2. How Does Ozone Treatment Benefit Consumers?

The primary benefit of ozone in food processing is its ability to control microorganisms of all types, including storage microorganisms. Consequently, the shelf life of many food products can be increased, sometimes by simply washing the foods in water containing ozone (fresh cut salad mixtures, apples for candying, strawberries, blueberries, etc.). Addition of ozone does not add potentially toxic residues to the food products which it contacts. However, because ozone is simultaneously a strong disinfectant as well as a strong oxidant, close attention must be paid during initial testing to guard against the indiscriminate overuse of ozone, which can cause oxidative damage to the food product(s) being treated.

Additional benefits of ozone include less storage of chemicals and pesticides (alternatives to ozone) on-site, lower amounts of chemical residues passed into our ecosystem, and less chloramines in processing plant air for workers to breathe (when chlorine chemicals are used).

3. How Does Ozone Technology Benefit Food Processors?

Since ozone is not classified as a pesticide chemical (it is unstable and cannot be produced at a central manufacturing facility, packaged, stored, and shipped), its use on foods allows microorganism control without the use of chemical pesticides. If chlorine is being used for microorganism control, the use of ozone allows the use of less chlorine – sometimes the total elimination of chlorine – while achieving the same target for microorganism control as previously attained with chlorine. Less chlorine means less equipment maintenance as well as fewer halogenated reaction products. In turn, this can result in cost savings for the user. See the IOA web site for examples of User Success Reports (www.io3a.org).

4. What Is Ozone?

Ozone, O_3, is a gas – the same ozone gas that is generated constantly in the Earth's stratosphere when the Sun's high-energy ultraviolet rays first encounter oxygen that makes up our atmosphere. Some oxygen molecules (O_2) are ruptured, forming single oxygen species that are quite reactive. When such active oxygen species encounter other oxygen molecules, the two species combine to form the very strongly reactive ozone molecule, O_3.

Gaseous ozone is partially soluble in water – its solubility increases as the water temperature decreases. The molecule itself is a very strong oxidizing agent, and this oxidizing power makes it a very strong disinfectant. Ozone's disinfecting action involves the chemical oxidation of cell membranes of microorganisms. When cell walls are ruptured by oxidation, the interiors of the

cells are exposed and the cells are killed. When the cells are killed in this manner, they usually do not regrow or mutate.

Viruses are chemical in structure, not living organisms. When ozone attacks viruses, it does so by rupturing key chemical bonds in their DNA structures. Given sufficient ozone for sufficient time, viruses also are destroyed (inactivated).

Ozone can be applied either as a gas or in aqueous solution. Microbial oxidation and subsequently disinfection can occur in both phases. Reactions of all types occur much more slowly in the gas phase, particularly when the air to which ozone gas is applied is dry. As the relative humidity increases, reaction rates of ozone increase rapidly.

In aqueous solution, reactions of ozone are rapid, and many ozone reaction rates (including disinfection) increase with increasing temperature and pH. The increase in rate of disinfection with increasing pH is opposite to the disinfection performance of aqueous solutions of chlorine, in which the rate of disinfection decreases dramatically as pH increases.

Ozone, being unstable, quickly reverts to the molecular oxygen from which it was made. This reaction occurs more rapidly in water, and more slowly in the gas phase.

5. How Is Ozone Applied And Controlled?

A. For Treating Water

Food processing plant water can come from various sources – from a municipality, from a well, or from a river, lake or stream. If the water has not been treated, then ozone can be of great assistance. The necessary application rates must be determined according to the impurities present in the influent water. For surface waters ozone can aid the action of flocculating clays as well as chemical compounds. Filtration can be aided by oxidation of dissolved organic compounds, thus increasing filter run times to backwashing. Ozone can serve as a disinfectant as the treated water enters the food processing plant.

Ozone is applied in large scale drinking water plants by means of porous diffusers placed strategically in large concrete contacting tanks. In smaller plants, ozone usually is applied via injectors. Control of ozone addition is by means of appropriate analytical instrumentation that measures ozone levels either in the liquid or gas phases – sometimes in both phases. Application and control of ozone to water is similar regardless of the specific use of the treated water.

B. For Process Water Recycle and Reuse

For proper treatment of process waters for reuse, attention must be paid to the materials now contained by the process waters. The process water to be recycled and reuse should be treated by appropriate procedures involving flocculating agents (as necessary to assist removal of organic

contaminants and colloidal materials), then sedimentation, dissolved air flotation (DAF) and filtration, followed by treatment (with ozone) prior to recycling. A significant advantage of ozone is that it saturates the water being treated with oxygen, giving the ozone-treated water a higher optical transmittance.

C. For Wastewater Treatment and Disposal

Wastewaters from food processing plants usually contain high levels of organic contaminants. These usually are easily biodegradable and as such are amenable to biological wastewater treatment. However, this type of treatment requires rather large land areas and time (~ 30 days or more) for completion. Biological treatment is the least costly method of wastewater treatment, requiring the least amount of added energy from the food processor. When land is not available, or there is insufficient time for bioprocessing, ozone can provide a technology to reduce BOD and COD levels. Ozone has been shown to aid sludge dewatering, thus aiding filtration. Biotreated effluents can be disinfected with ozone, thus avoiding disinfection with chlorine, and also avoiding the formation of chlorinated organics that pass into the environment and enter the food chain.

D. For Washing Foods – Whole or Cut

For this application, water must be very clean and free of organisms. Usually this is not an application for recycled water. However, because of the oxidative properties of ozone, many organic contaminants of food wash waters are destroyed by ozone, allowing the wash water to be used for a longer period of time before disposal. Strickland Foods, for example, washes their fresh cut salad mixes with water containing ozone, and then sends that water to recycle. Meanwhile, the ozone-washed salad mixes then are washed with chlorinated water. Prior to installing ozone, chlorine was the sole disinfectant at this facility. Since installing ozone, both water use and chlorine use have dropped considerably.

E. For Storage of Raw Food Products

Based on prior research, water for this application is treated with ozone to a level appropriate for the specific food. Foods are washed, and then packaged (sometimes allowing exposure to air, others not). Many times, raw food products are stored in an atmosphere containing gaseous ozone. In these cases, it is important to know the concentrations of ozone necessary to protect the food product(s) from damage. Examples: Onion and Potato Storage – see User Success Reports on IOA Web Site (www.io3a.org).

F. For Packaging of Foods

Foods normally are cleaned, then packaged. Chilean grapes, for example, are washed with water containing ozone (to lower contamination effects from *Rhizopus stolonifer*), then packaged in air-breathing plastic bags. Carrots are stored in air-breathing bags in ozone-containing atmospheres. However, when finally packed for distribution, carrots sometimes are packaged in sealed plastic

bags. Specific types of packaging are required for specific foods. When packaging is to be in air-tight sealed plastic bags, ozone treatment can be followed by carbon dioxide and/or nitrogen. Ozone disinfects surface microorganisms, then the inert gases flush away any remaining oxygen that may allow growth of detrimental organisms.

G. For Treating Process Room Air

If workers are not present in a food processing room (rare circumstances – such as a storage room), ozone can be applied throughout the room air to levels that are effective for their intended purposes, but which may exceed federal government regulations for ozone in air (see Item 10). When workers are present, room air should be treated with levels of ozone that are below federal regulations, and these may be too low to accomplish their air-treatment objective. In these cases, contaminated air can be removed from the room, treated with appropriate quantities of ozone, excess ozone destroyed, and the cleaned air then returned to the processing room. Another approach is to mount ozone-generating UV lamps in the processing room ceiling. When turned on, these lamps produce lower concentrations of ozone than by the corona discharge technique used for treating large quantities of water. Since ozone gas is slightly heavier than air, it will fall from the ceiling UV bulbs to the floor of the processing room. Depending on the degree of odors present (ex. a garlic processing room) the odorants normally rise upwards, where they can encounter the descending ozone gas and be destroyed. At 6 feet above floor level, there may be no ozone at all (as measured by a wall-mounted ozone monitor pre-set at just below the appropriate OSHA level).

Still another approach is to install an ozone generator in ceiling corners and have each generator fitted with a timer. During times of human occupancy, the ozone generators are turned off. When the plant closes for the night, the timers automatically turn on the ozone generators, and then turn them off an hour or so prior to human occupancy. Gaseous ozone usually dissipates within an hour. To be sure there is no ozone above federal levels when workers return; a fan can be turned on a few minutes before workers return to exhaust the last traces of ozone from the processing room. This approach is not practical for heavy odors, or odors that develop quickly during processing. For mild odors, this procedure is a simple solution. This treatment also can greatly reduce the level of airborne mold in process room air.

Another application for ozone is in controlled atmosphere rooms in which stone fruit or apples typically are stored. These are large rooms used to preserve fruit harvested in summer/fall so they can be sold during winter/spring, after summer stocks are gone and prices are higher. In these storage rooms, negative pressures are used, along with nitrogen gas flooding, cold temperatures (35°F) plus a slight residual of ozone for mold and mildew control.

H. For Plant Washdown and Cleaning

Many ozone equipment suppliers offer specially designed “ozone-wash carts” that are portable and produce a pressurized water stream that contains a few parts per million of ozone dissolved in

water. The solution is under pressure, thus the aqueous stream can perform the normal water washdown functions. However, because of the presence of dissolved ozone, wherever the aqueous spray contacts a surface, microorganisms on that surface will be attacked by ozone.

A special modification of this application for ozone is the washing of workers' boots and waterproof aprons, when leaving the processing room for the day. Boots are hung on special racks outside the food processing room, and these are rinsed with ozone-containing water from the portable ozone-water-washer.

Ozone washes can replace Best Management Practice washing procedures that utilize strong sanitizers. They are usually used when a quick washdown is needed during break periods and shift changes. The ozonated water does not adversely affect products left in conveyors and on cutting tables. These same products sprayed with chlorine- and/or peroxide-containing sanitizers would need to be discarded. Ozone washes can clean many food and container surfaces; however, they do not provide residual microbial protection.

6. Can Ozone Be Used For Processing All Foods?

Yes. Ozone is approved as an Antimicrobial Agent for direct contact with all foods. However, attention must be paid to applying only the minimum amounts of ozone necessary to accomplish its intended purpose(s). Excessive application of ozone may damage the foods being treated, and doses that are too low may not provide the needed microbial protection.

7. Can Ozone Damage Food Products?

Yes. Because ozone is a strong oxidizing agent that also acts as a strong disinfectant, it is important prior to use to determine appropriate ozone application dosages and times of treatment for each intended use. In the fruit and carbonated drink industries, over-treatment with ozone can produce clear and watery-tasting juice products – because all the juice flavor and color is removed.

8. What Is The Shelf-Life Of An Ozone-Treated Product?

The shelf-life of an ozone-treated food product varies with the food and its prior processing. Under proper ozone treatment conditions, usually shelf-life can be increased 15-35%. Because ozone does not provide residual protection, it is necessary that ozone-treated foods be stored in environments that are as clean as practicable at the proper temperatures.

9. What is the Commercial Availability of Ozone?

Ozone as a gas or in solution is not an item of commerce, because of its unstable nature. However, equipment to generate, contact, monitor, and control ozone has been used to treat water commercially for over 100 years. Many other commercial applications of ozone now

abound, and equipment to generate ozone in food processing plants is readily available. Two types of ozone generators are available for food processors – corona discharge and ultraviolet radiation (185 nm). Corona discharge is a process by which electrical energy is passed between two closely positioned electrodes, thus creating a continuous silent electrical discharge – which generates ozone in the gas phase. For UV radiation, high energy UV rays pass through surrounding air, generating ozone, but in much smaller amounts and concentrations than can be generated by corona discharge. For small quantities in gas phase applications, ozone generated by UV radiation is effective and at lower costs than by corona discharge ozone generation.

Of interest to food processors is the fact that while there are many commercial suppliers of ozone generating and application/control equipment, there are fewer suppliers of integrated systems. Ozone equipment suppliers are thorough at making dependable ozonation equipment, and tend to focus on specific niches in the food processing markets. However, many suppliers are not yet so familiar with food processing applications for ozone.

10. What Are The Federal Regulations Concerning Exposure To Ozone in a Food Processing Plant?

Although ozone levels in air are regulated by the U.S. EPA, the U.S. FDA and the OSHA, only the OSHA regulations apply to food processing plants. The OSHA Permissible Exposure Level (PEL) for workers exposed to ozone is 0.10 ppm, time-weighted average over an 8-hour working day, five days per week. OSHA also has established a Short-Term Exposure Level (STEL) of 0.30 ppm, over a 15-minute time period, not to be exceeded more than twice daily.

11. What Functional Properties Does Ozone Impart to Foods?

Ozone is a strong oxidant and as such would be expected to cause alterations in nutrient levels in foods if high concentrations are used for extended periods. However, ozone does not penetrate deeply into foods, and any impact on nutrient content is limited to nutrients on the surfaces of foods. As stated by Dr. John W. Erdman, Jr., in reviewing "Nutrient Impact" (of Ozone on Foods) in the 1997 *EPRI Expert Panel Report: Evaluation of the History and Safety of Ozone in Processing Food for Human Consumption*, "it appears that under properly-controlled preservation conditions, ozone causes only minor losses of nutrient content, lower than some other processes commonly in use."

12. How Are Ozone-Processed Foods Stored?

Foods processed by ozone are stored in the same manner as normally processed foods. The only difference is that if the use of ozone provides an extension of shelf-life, then perhaps special care in packaging and storage is appropriate, to realize the commercial benefits of that additional shelf-life. A caution also is warranted to avoid the over-use of ozone when treating. Ozone-treated products should be handled carefully and not abused. They can be recontaminated very easily.

13. Is Ozone Equipment Safe To Operate?

Yes, provided that appropriate ozone monitors and controls are designed into the ozonation system at the beginning and the equipment is operated according to manufacturers' recommendations. The key is to avoid exposure of plant personnel to ozone in excess of the OSHA PEL and STEL regulations. Ozone is not a systemic poison (as is chlorine gas). Nevertheless, ozone is a strong oxidant, and high levels can damage lung tissues if breathed over long periods of time. Modern day ozonation systems for food processing are (or should be) designed so that in the event of an ozone monitor reading an ozone level in excess of the OSHA PEL, an alarm sounds, and the monitor can even stop the flow of electric power to the ozone generator(s), thus ceasing the production of ozone. The odor of ozone at levels near or greater than the STEL is pronounced and noticed quickly by workers.

14. How Economical Is Ozone Processing?

Economics associated with ozone are variable. Ozone generating equipment costs are higher than equipment for some applications of other Antimicrobial Agents. However, process cost benefits from the use of ozone are high. See any of the User Success Reports posted on the IOA web site. The driving force behind each of these USRs is money savings for the ozone user over costs prior to adopting ozone. For example – savings in onion and potato crop loses by preventing the spread of fungal diseases gives the user more product to sell. For a food packaging user, ozone allows better chiller water cleanup and less water use. For a garlic processor, ozone allowed elimination of sodium hypochlorite, with its attendant maintenance and chemicals expenditures, including storage and handling, plus the ever-present safety hazards. And for all ozone-treated foods reported, a higher quality product is provided than before ozone was employed.

15. What Regulatory Approvals Are Required For An Ozone-Processed Product?

The U.S. FDA has approved ozone as an ***Antimicrobial Agent*** for Direct Contact With Foods of all types (*Federal Register* 66(123):33829-33830, June 26, 2001.). The USDA also has approved ozone for contact with meats and poultry (Dec. 21, 2001), but requests a case-by-case submission of proposed application of ozone for its permission to use. In the early 1980s, the FDA approved ozone as a ***disinfectant*** for bottled water and as a ***sanitizer*** for bottled water processing lines. However, approval for use in bottled water was coupled with the statement that "all other food applications for ozone must be approved by means of a food additive petition.

Approval of ozone as an ***Antimicrobial Agent*** means that ozone can provide at least two-logs of inactivation of microorganisms. For ozone to be *called* a ***sanitizer***, it must be capable of providing five-logs of microbial inactivation when applied on specific foods. For ozone to be *approved* by FDA as a ***sanitizer*** in food processing plants, a Food Additive petition must be filed. Processors are free to declare ozone sanitizer treatment as GRAS (Generally Recognized As Safe)

and submit such GRAS Affirmations to the FDA. This approach is not usually looked upon with favor by food processors, although it is often used by the pharmaceutical industry.

If food products are to be treated with ozone (as an Antimicrobial Agent) but are to be marketed and used as nutraceuticals or pharmaceuticals, the processor is advised to contact FDA to determine whether such uses for ozone-treated products are allowed under current FDA drug regulations or whether a special application for approval of use must be submitted.

16. Are Testing Facilities Available for Product Development Before Venturing Into Ozone Processing?

Yes. A potential user of ozone can contact one of several consultants or academic institutions who have experience in treating foods with ozone and can advise whether existing data are sufficient to design an ozone processing system. Most likely the recommendation will be to do some testing at the food processing plant itself. A few suppliers of ozone equipment now have sufficient experience with installations of their equipment at food processing facilities to be able to advise the prospective ozone user and to conduct a product development program. ClearWater Tech, Novazone, Praxair, Del Ozone, and Pacific Ozone are among those firms having on-site testing facilities for demonstrating ozone equipment to prospective users.

For Additional Information, Contact:

The International Ozone Association, Pan American Group, Scottsdale, AZ;
www.io3a.org

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