Basics of Ozone Applications for Postharvest Treatment of Fruits and Vegetables

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In the search for effective disinfectant treatments for fresh vegetables and fruits, the postharvest handling industry often operates within areas of regulatory uncertainty. Some produce handlers and processors use ozone for water sanitation, cold room air treatment, and other postharvest applications. For applications to whole or peeled produce, handlers and processors are relying on the self-affirmation that ozone has achieved Generally Recognized As Safe (GRAS) status as a food processing aide. Recent expert advisory panel recommendations have made this determination (Graham 1997), but, to date, the U.S. Food and Drug Administration (FDA) has not released an official determination on these materials. Unlike chlorine gas, calcium hypochlorite, and sodium hypochlorite, no postharvest uses of ozone in contact with produce are currently registered by the U.S. Environmental Protection Agency (EPA) or California Department of Pesticide Registration (DPR).

A conference on “Ozone for Processing Fresh-Cut Fruit and Vegetables” was held in April, 1998 in Salinas, CA and was very well attended by a diversity of fruit and vegetable shippers and processors. Their interest was very much reflective of the broad appeal of ozone as an alternative or supplementary postharvest sanitation and disinfection tool.

Ozone(O_3)
Ozone is a strong, naturally-occurring oxidizing agent with a long history of safe use in disinfection of municipal water, process water, bottled drinking water, and swimming pools. More recent applications include treatment of wastewater, dairy and swine effluent, cooling towers, hospital water systems and equipment, aquariums and aquaculture, water theme parks, and public and in-home spas.

In clean, potable water that is free of organic debris and soil particulates, ozone is a highly effective sanitizer at concentrations of 0.5 to 2 ppm. Ozone is almost insoluble in water (0.00003g/100mL at 20°C [68°F] and effective dispersal is essential for antimicrobial activity. Ozone's disinfectant activity is unaffected at a water pH from 6 to 8.5. Ozone is highly corrosive to equipment and lethal to humans with prolonged exposure at concentrations above 4 ppm. Ozone is readily detectable by human smell at 0.01 to 0.04 ppm. OSHA limits of exposure specify a 0.1ppm threshold for continuous exposure during an 8-hr period and 0.3ppm for a 15-min period. At 1 ppm ozone has a pungent disagreeable odor and is irritating to eyes and throat. The need for off-gas containment in an open process line would have to be carefully evaluated for each planned use but current experience would not forecast a serious problem for line workers. Effective but safe concentrations are difficult to maintain in process water because automated detection systems have not been highly reliable.

Past research is often difficult to evaluate and reproduce due to uncertainty of reported concentrations of delivered ozone in the experimental or commercial system. Newer electrode probes that measure oxidation reduction potential (ORP) of the water or colorimetric kits are being used to monitor ozone concentrations more accurately but problems in practical application still exist. Ozone is also highly unstable in water and decomposes to oxygen in a very short time (less than half the activity remains after 20 minutes). In process water with suspended soil and organic matter, the half-life of ozone activity may be less than one minute. Lower water temperatures extend the half-life of ozone. Maintaining effective concentrations for microbial disinfection by using remote ozone generation and injection into a centralized water system, as is done with chlorine and chlorine dioxide, has proved difficult. With increased practical use in postharvest handling of fresh vegetables and fruits these obstacles will very likely be overcome.

In some applications, a reduced (lower than if used as the sole oxidizing agent) amount of hypochlorite or other more stable disinfectant is added to water to provide a residual effect downstream of the primary ozone injection.

How is ozone formed ?
In nature, ozone is formed by UV irradiation (185nm)from the sun and during lightening discharge. *Commercially,* UV-based generators pass ambient air (20% O_2) across an UV light source, typically less than 210nm. These systems have a lower cost but also have a more limited output than corona discharge systems. Corona discharge generators pass dry O_2 enriched air across a high electric voltage (>5,000 V) or corona; similar to a spark plug. Excess O_3 not dispersed in water must be captured and destroyed to prevent corrosion and personal injury. One method of destruction is by UV light at a longer wavelength, 254nm, combined with the use of a catalytic agent.

How does water quality impact effectiveness?
Dissolved and suspended organic and inorganic substances react quickly with ozone and interfere with a desired antimicrobial action. Similar to chlorine, water quality has an important impact on "ozone demand" and stability in water. In particular, dissolved iron, manganese, copper, nickel, hydrogen sulfide, and ammonia will increase the concentration and contact time needed for maximum lethality to microorganisms. High suspended solids (or insufficient contact time in flumes or drench tanks) are often cited as the responsible factor for lower than expected reductions in viable microbial counts from treated water, often no more than a 10 fold (1 log) decrease. In filtered systems, a 3-4 log reduction may be expected.

How is ozone applied to water ?
The ozone generator supply line interfaces with the process water supply or return line at a Venturi-type injection dispersor unit. Adequate mixing and sensitive process monitoring are essential for uniform treatment with the low concentrations applied to water for postharvest uses.

How does ozone compare to chlorine ?
Ozone is reported to have 1.5 times the oxidizing potential of chlorine and 3,000 times the potential of

hypochlorous acid (HOCl). Contact times for antimicrobial action are typically 4-5 times less than chlorine. Ozone rapidly attacks bacterial cell walls and is more effective against the thick-walled spores of plant pathogens and animal parasites than chlorine, at practical and safe concentrations.

Total operating costs are reported to be $1,000 per lb. of O_3. Ozone generation requires approximately 5 times more energy input than Cl_2 but 25 times less than ClO_2.

Ozone for other postharvest uses ?

Ozone has been evaluated for postharvest disease control and other storage uses for many years. Some commercial use has occurred with a few commodities such as apples, cherries, carrots, onions, and potatoes. There is increasing interest and empirical activity in the evaluation of ozone for a diversity of water treatment and air treatment uses in postharvest quality management. Examples include ethylene degradation (within a confined reactor), odor elimination for mixed storage, disinfection of humidification systems (including retail super markets), fungal spore elimination in storage room aerosols, and treatment of superficial mold after long-distance shipping of onions. Both effective disease control and phyotoxicity of ozonated air on certain cultivars was reported for table grapes and carrots (bleaching). Ozone treatment has been reported to induce natural plant defense response compounds thought to be involved in postharvest disease resistance.

Additional research is needed to define the potential and limits of effective use of ozone for postharvest treatment of whole and minimally-processed vegetables and fruits.

The recent expert panel recommendation to the FDA supporting GRAS classification of ozone as a disinfectant for foods has opened the door for the produce industry to establish independent affirmation of safety when applied in a manner consistent with good manufacturing practices. When using ozone for produce contact, a copy of the public disclosure of the expert panel (Graham 1997) must be available on-site for an inspector requesting the authority upon which GRAS classification is presumed.

Refenences

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Partial Listing of Ozone Generator Providers

AgTech International	760.480.4488
Cyclopss	801.972.9090
Del Industries	800.676.1335
Novazone	510.454.0303
Oxion,Inc.	800.552.0617

See also Postharvest Chlorination Basics
DANR Publication #8003
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