of chlorine - up to 200 parts per million (ppm) have been common. This raised concerns regarding by-product formation, such as trihalomethane (THM), a known carcinogen, formed as the chlorine reacts with organic materials on food surfaces.

In certain instances, i.e., at large growers and packers who are treating tons of produce per hour straight from the field, it may be necessary to apply ozone dosages as high as 2-10 ppm in the process water. Even though the actual amount of ozone necessary to disinfect foods is low, the huge ozone demand created by high organic loads from the farm environment means systems must be designed to counter those loads with enough ozone left over to control microbes and, in some instances, to chemically destroy pesticides.

That ozone is a powerful sanitizer that (even at low doses) is capable of remarkable microbiological control is undisputed. Water treatment professionals, in particular, have become knowledgeable in the technology. Many know what ozone does and how it does it, at least with regard to water treatment applications.

Now, with the approval of ozone for food, these ozone-experienced water treatment professionals have an entirely new market for what is, essentially, an entirely new product, the PurePower point of use (POU) ozone food sanitizing system. Dealers can offer consumers and food service operators alike the ability both to serve safer food *and* to save money by extending the shelf life of produce, fruits, meats and fish.

Events in the food distribution chain can impact food safety.

The potential for the emergence of the POU ozone food sanitizer first became evident when the Electrical Power Research Institute (EPRI) successfully petitioned the FDA in the mid-90s in support of ozone in food processing.

Food safety at the home and restaurant level has become a national priority.

That resulted in a GRAS (Generally Regarded As Safe) status for the technology. The further work by EPRI resulted in the final approval of ozone in food processing.

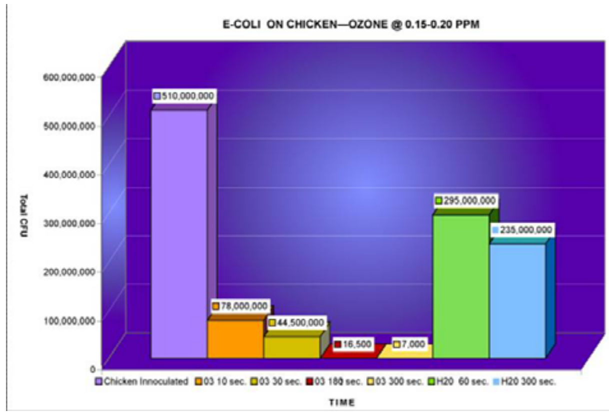
But testing results performed for the benefit of large food processors left a gap in validation of the process for POU customers, such as consumers and food service operators.

Soon after the original GRAS status award in 1997, the author began working with Dr. Joseph Montecalvo, Jr., professor and past chairman of the California Polytechnic University, Department of Food Science & Nutrition and a member of the Technical Advisory Panel of the USDA National Organic Standards Board. Our target was to develop protocols and execute testing of ozone food sanitizing systems for POU applications in the home and in the food service industry.

Dr. Joseph Montecalvo, Jr., California Polytecnic University

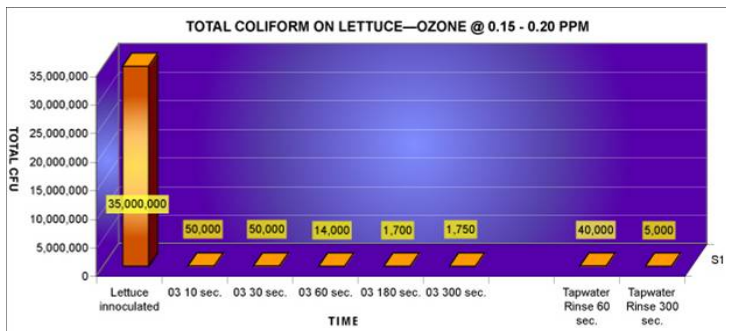
The peer reviewed results of those tests have proven that small, properly designed POU ozone systems, applying dissolved ozone at very low levels and used in conjunction with safe food handling practices, can significantly reduce risk exposure to food borne pathogens.

Research proved that a small ozone system used to rinse a variety of foods was capable of two-to-four log reduction in food pathogens on the surface of food products.

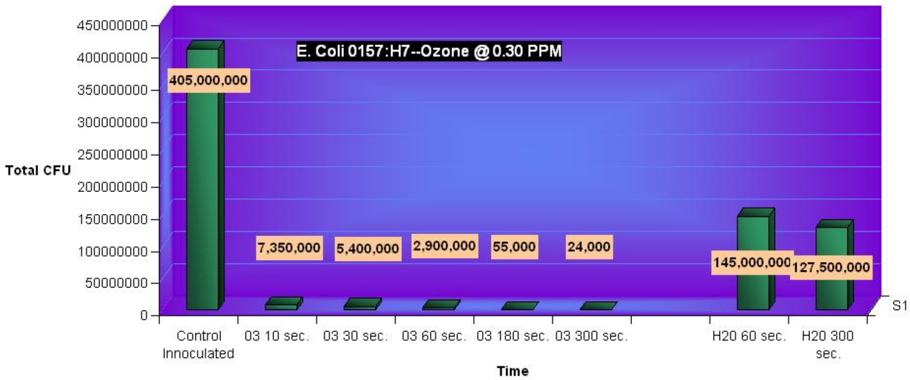


Under the umbrella of a partnership among Dr. Montecalvo's research group, Primus Laboratories in Santa Maria, CA and the author, research was conducted both at Cal Poly and Primus Laboratories in order to determine the sanitizing functionality of ozonated wash waters using PurePower technology.

As background for the study, it was recognized that ozone itself is a highly reactive oxidizing agent with broad germicidal activity. It has been used both in Europe and in the US as an alternative to chlorine for disinfecting water. Chemically, ozone is 52 percent greater in oxidation potential than chlorine as well as 3,200 times faster. It acts

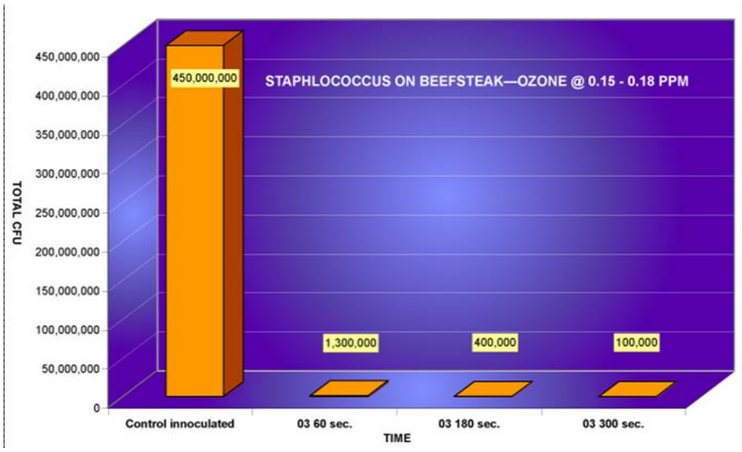


over a broader spectrum of microorganisms than does chlorine



and other commonly used sanitizing agents.

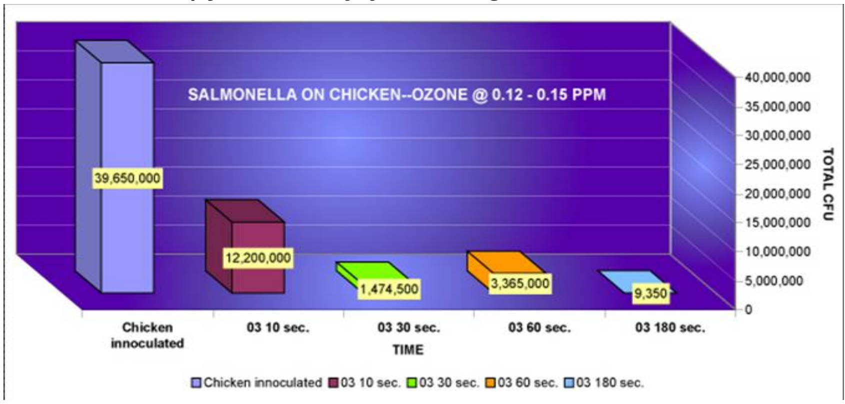
Next to fluorine, ozone is the most powerful oxidizing agent available. Because of its high oxidation capacity, the cell membrane of microorganisms is oxidized and ruptured, (lyced) thereby causing microbial cell destruction. This study focused upon determining the susceptibility of food pathogens to low levels of ozonated water (0.12 – 0.30 ppm) in an effort to determine the efficacy of ozonated water at those levels in food pathogen reduction. All microbiological food pathogen study was conducted at the microbiological



research laboratory at a leading food safety research facility in California under the direct control of a registered microbiologist.

Experimental approaches

Pure cultures of *E. coli, E. coli 0157:H7, Listeria monocytogenes, Staphylococcus aureus, Coliforms, Campylobacter jejuni, Shigella and*



Salmonella were purchased from the American Culture Collection and grown in broth cultures and enumerated. Fresh samples of chicken, beef and lettuce were inoculated individually for each microorganism creating two populations of sixteen food samples for each food pathogen tested. A one-hour equilibration period at room temperature prior to treatment with ozonated water was maintained for all food samples. Using the small ozone system, each freshly inoculated food product was immersed in a continuously ozonated bath of municipal water (filtered through a one-micron absolute carbon filter, prior to ozonation). Dissolved ozone levels reached a maximum of 0.3 ppm, as measured by the indigo thiosulfonate spectrophotometric methodology. Food products were then immersed for different immersion times (i.e. 10, 30, 60, 180 and 300 seconds) in order to determine the optimum immersion time required for maximum microbial cell destruction.

For all experimental runs, controls were used which consisted of each inoculated food sample receiving a water wash only for the same immersion time. Following

Laboratory studies of ozone rinsed foods proved pathogen reduction results.

ozonation or water wash treatments, residual pathogen levels were determined by standard microbiological direct swab or Stomacher® sample preparation. Enumeration of bacterial numbers was conducted by using specific FDA-AOAC methods for each pathogen according to Bacteriological Analytical Manual (BAM), 8th edition published by AOAC

Results

The results of this study show that a four-log reduction (measured in colony forming units or cfu per gram of food tested) in *E. coli* on the surface of fresh chicken from 5.1 X 10^8 cfu/gm to 1.65 X 10^4 cfu/gm cfu/gm. For total coliforms, a four-log reduction (from *3.5 X* 10^7 to 1.7 X 10^3) was observed on fresh romaine lettuce after 180 seconds of immersion in ozonated tap water. A two-to-three log reduction in *Listeria monocyto genes* (from 8.5 X 10 cfu/gm to 2.2 X 10^5 cfu/gm) was found after 180 seconds of immersion in ozonated water.

Little changes were observed in all cases for the control water wash, generally less than 0.5 log reduction.

A consistent three-log reduction in *Staphylococcus aureus* was observed on beef (sirloin steak) after 180 seconds of ozonated water immersion. A four-log reduction was found with *E. coli 0157:H7* on romaine lettuce after 180 seconds of ozonated water immersion treatment. Additionally, a four-log reduction was observed for *Campylobacter jejuni* on chicken (i.e., 1 X 10^8 cfu/gm to 1.25 X 10^4 cfu/gm). A slightly less than four-log reduction was found after 180 seconds of immersion for *Shigella* on romaine lettuce and a four-log reduction in *Salmonella* was observed (3.9 X10^7 cfu/gm to 4.1 X 10^3 cfu/gm).

The results show that at dissolved ozone levels of 0.3ppm and immersion times of 180 seconds, major reductions in surface food pathogens were consistently observed.

Conclusions

The results from this study allow for the following conclusions:

1. Use of the small POU system, as designed, confidently reduced food borne pathogens from the surfaces of fresh food products tested.

2. Overall, two-to-four log reductions were found for all eight food pathogens tested.

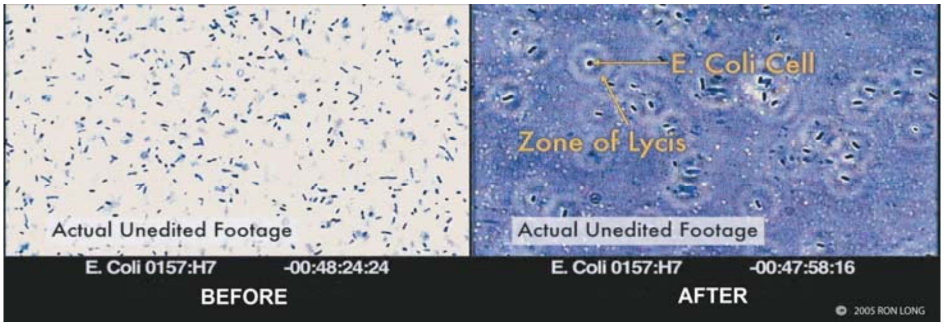
3. To achieve optimum results, the immersion time of the food product with hand massaging (vigorous rubbing of the food surface to assure contact) in the ozonated water was found to be three-to-five minutes for dissolved ozone levels of up to 0.3 ppm, even though ozone levels as low as 0.12 and immersion times as brief as 10 seconds produced significant results on some pathogen species.

4. The results further indicate that increasing the dissolved ozone levels results in greater reduction in bacterial numbers. Therefore, this may suggest that increasing the ozone levels above 0.3 ppm may reduce the contact time of the food product in the ozonated water. Further studies will be conducted in order to prove this concept.

5. In all cases, water washing of the food products tested did not significantly contribute to food pathogen reduction. In nearly all cases, less than a one-log cycle reduction was observed.

6. Use of a properly designed small ozone system may offer both the consumer and the food service operator an effective means of reducing the risk of food born pathogen levels in foods when coupled with safe food handling and application of Good Manufacturing Practices.

Ground-breaking real time video



Groundbreaking real time video shows ozone disrupting or lycing, the cellular wall of E. coli 0157:H7. The rings around the bacterium cells are the cytoplasm spilling out as the ozone breaks down the walls. The number of bacteria in the before shot are more than 100 million times the amount of cfu's encountered under "normal" contamination conditions.

In a recent second ground-breaking study, Dr. Montecalvo's team, together with the author, produced the first ever microscopic video capture of the real time destruction of the dangerous food–borne pathogen *E. coli 0157:H7* utilizing POU ozone food sanitation technology. The new video shows