Bacteria Efficacy of TetraClean Sanitation Solution™ Treatment of Poultry Products and Process Handling Equipment

Edward F. Askew PhD

Askew Scientific Consulting

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Abstract

The use of ozone to diminish or eliminate of bacteria species that promote a shortened shelf life or that are detrimental to human consumption has been investigated over the last few years on many types of consumables. Foodstuffs as varied as sushi[1], freshly cut salad vegetables[2], and processed or whole carcass poultry[3-7] treated by ozone have been detailed in the literature. In some cases the ozone exposure was in a gas phase, while in others it was dissolved in water before application to the foodstuffs. The efficacy of the ozone was significant on bacteria that were not in a spore phase, but had a cell wall that could be disrupted by the oxidation created by ozone, or hydroxide radicals created by the reaction of ozone with water and the dissolved solids. This study will focus on the bacteria efficacy seen by the topical application of ozone at levels of 2.5 – 5 ppm dissolved gas on processed chicken, chicken tenders, and production trays utilized to transfer the chicken products through the processing plant. Study results show the bacteria concentration arithmetic sum mean value for ozone treatment is one to two orders of magnitude less than the chlorinated treatment water arithmetic sum mean bacteria concentration Comparison of the chlorinated treatment water bacteria geometric mean values to the ozone treatment water geometric mean shows the trend where ozone treatment reduces bacteria at least 1 to 1½ orders of magnitude.

Introduction

Ozone has been recognized as an efficient sanitizer for the production of food products. Certain food products such as salad mixes[2] benefit from the application of ozone for the reduction in spoilage and extension of shelf life. Other food producers such as sushi manufacturers utilize ozone for sanitation of the fish, vegetable, and rice mixture that is used in the production of sushi, along with extension of the shelf life [1].

Poultry processors have combined ozone strengths for product cleaning, surface disinfection, and extension of shelf life to optimize the production of poultry whole carcasses and portions. Ozone has been applied either as a gas[8] or in an aqueous form [3, 4, 6, 7, 9-11].

Detailed studies by the California Energy Commission [11] have shown results in which:

1. Processing chiller bath water with a concentration of 2-4 PPM ozone using ¼ gallon of makeup water remained visibly clear and the microbial counts, aerobic plate count and E. coli, were equivalent to a three stage chlorinated chiller bath.
2. A final rinse of birds emerging from the chiller using available tap water containing 6-8 PPM ozone reduced the bacteria count further.
3. Ozone reactive oxidation of the chicken carcass meat quality was not significant compared to chlorine processing.
4. Sensory evaluation by both expert panels and a- home food service judge the chicken treated with ozone as being equal in quality as chicken processed with chlorine.

This study will focus on the bacteria efficacy seen by the topical application of ozone at levels of 2.5 – 5 ppm dissolved gas on processed chicken, chicken tenders, and production trays utilized to transfer the chicken products through the processing plant. Results will show that implementation of the ozone treatment in the processing line not only produced a final chicken tender product with significantly lower bacteria, but also reduced the residual bacteria deposited by the chicken tenders on the production container/tote. This secondary disinfection of the production container/tote reduces the cross contamination of unprocessed chicken tenders and the overall residual bacteria load seen in the processing line.

A final benefit seen with the use of ozone instead of chlorine is the overall workplace environment improvement due to the reduction or elimination of chronic line worker exposure to chlorinated water. (i.e. respiratory inflammation dermal irritation and drying) [12]. This data was only collected through line worker anecdotal comments and observations made during this study.

Background

Ozone is a triatomic molecule from the electrochemical or photochemical reaction of diatomic oxygen. Ozone is unstable in certain environments such as seen in gaseous environments or aqueous environments with organic or inorganic compounds that go through a reduction/oxidation (redox) reaction. Its formation in an aqueous environment can be prolonged by the use of nanotechnology to produce very small bubbles that do not out gas easily from water.

The reaction of ozone with dissolved solids in water can produce radicals and anions that are the actual efficacy agents. These secondary reaction products can be more effective than ozone in deactivating biological processes. The dissolved inorganic compounds that facilitate the deactivation process or efficacy of ozone have not been investigated. In most cases, the researchers utilized either distilled/deionized water or well water/city drinking water.

A proposed reaction mechanism for ozone with dissolved inorganic solids is illustrated in Figure 1. The secondary products are intermediates that may actually be the main biocide compounds.

$$O_3 + \text{Inorganic Dissolved Solids} \longrightarrow OH\cdot \text{ or } H_2O_2/HO_2\cdot$$

Figure 1: Ozone Reaction with Dissolved Inorganic Solids

The interaction of organic chemical compounds that may be present on either vegetable, fish, or poultry products with ozone was investigated in some detail for various microorganisms [13]. Soluble starch and bovine serum albumin were used to simulate organic compounds that would be found on the surface of treated food products.

The molecular structures of these two compounds are illustrated in Figure 2. As was expected, the starch molecule is fairly robust and resists oxidation by ozone or it secondary products, while the complex organic structure of bovine serum albumin has many sites that would consume the ozone/secondary products and prevent the disinfection efficacy from being applied to microorganisms on the food products.

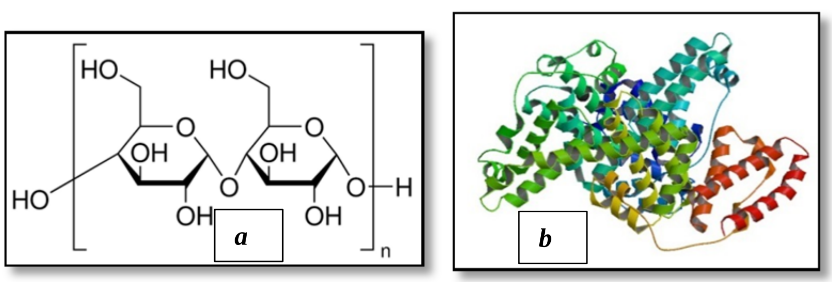

Figure 2(a, b): Starch and BSA Molecular Structure

What can be determined from the literature review is that for commercial poultry processing:

1. Inorganic dissolved solids should be limited in the ozone process water to reduce the secondary product formation.
2. Dissolved organic compounds with a robust structure, such as starch, will resist oxidation by ozone and as such will not interfere with its biocide efficacy.
3. Organic compounds found on meat surfaces, such as bovine serum albumin, will require an additional ozone dose rate to have the desired biocide efficacy. But, will not interfere significantly with ozone biocide efficacy.

4. Organic compounds found on meat surfaces will prevent deep penetration of the ozone aqueous solution and as such crevices found on meat surfaces will not be as efficiently disinfected with ozone.

Study Design

The TetraClean™ ozone generator system was installed at the chicken tender processing facility in an area that was near the chicken tender processing line and did not interfere with either the normal plant operation or any regulatory requirements from the USDA. A schematic of the TetraClean™ system used in this study is illustrated in Figure 3 below.

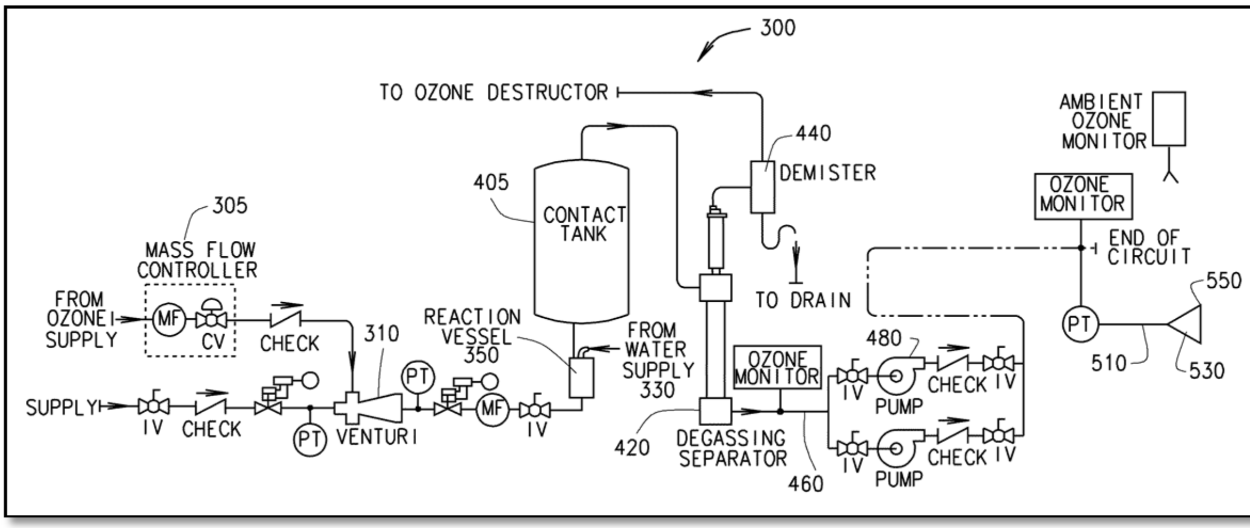

Figure 3: Schematic of TetraClean™ Ozone Generator

Figure 4 outlines the location of the ozone treatment discharges in the chicken tender process line. Figure 5 illustrates the main chicken tender feed line.

Spray bars and spray nozzles were utilized at key areas to treat the chicken tenders and the process line totes utilized at the facility. There were 7 ozone spray bar locations along the main processing line, another ozone source to the Acufeeder and a spray bar on the Marel Line.

Bacteria sampling swabs were taken of the treated chicken tenders at the end of the main process line and the process line totes. These swabs were then analyzed for active bacteria via approved USDA and AOAC testing requirements.

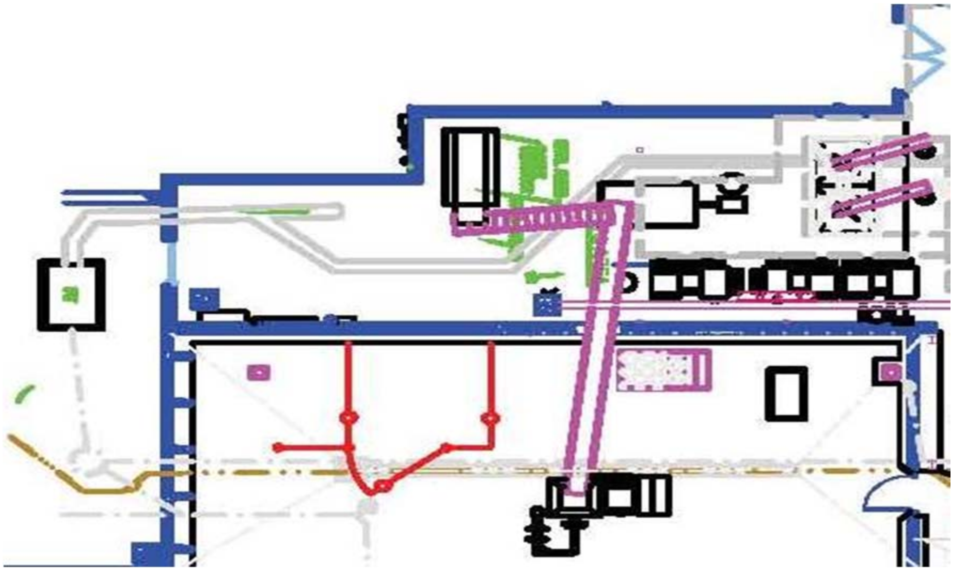

Figure 4: Ozone Treatment Poultry Tender Process Line

Figure 5:Chicken Tender Process Line

Figures 6-8 below illustrate the main process line and the Acufeeder ozone application set up. Figure 8 shows the Acufeeder in action. Notice the puff of water coming out of the nozzle. This will be important to the test to keep this sanitary for each tender.

Figure 6: Chicken Tender as They Come Off the Deboning Line

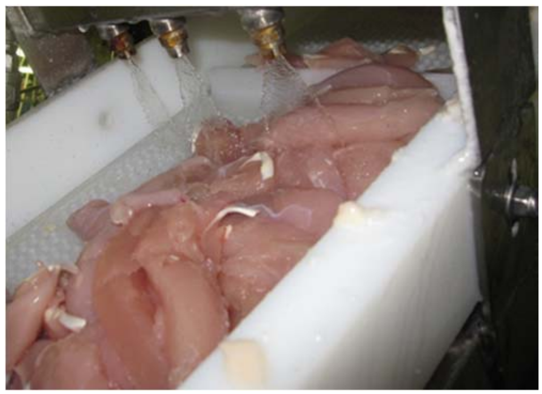

Figure 7: Ozone Spray Bar on Chicken Tender Line

Figure 8: Acufeeder and Close-up of Ozone Spray

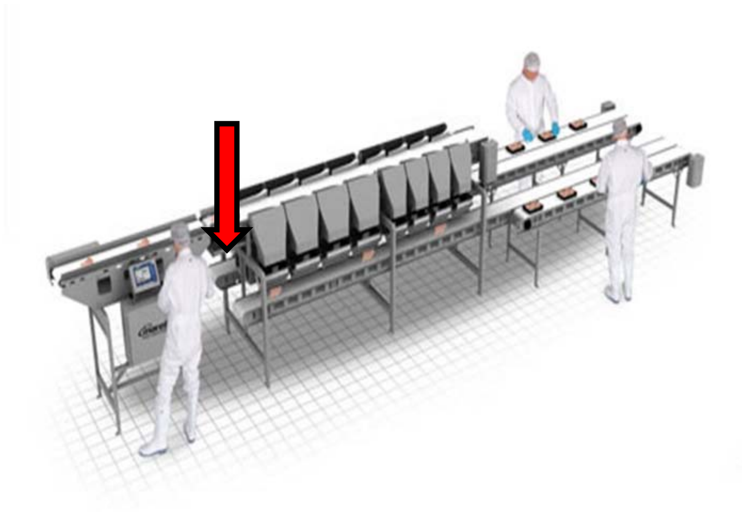

Figure 9: Marel Line Ozone Spray Bar

Figure 9 illustrates the Marel Line for the end-of-service packing of the chicken tenders. The addition of an ozone spray bar at this point will provide additional long-term bacteria treatment of the package chicken tender product and also a shelf life extension as seen in studies with sushi and vegetable food products[1, 2]

Results and Discussion

Summary results from the first 90 days are detailed in Figures 10-12 below. The key points that can be obtained from the study results are:

1. Figure 10 summarizes the 90 day application period in which chlorinated water was compared to water containing ozone. The dramatic drop-off rate in bacteria is evident when the ozone process was started. The slight increases seen for the chicken totes at days 40 and 70 are due shift operations modifying the ozone application rate. Once the ozone application rate was reestablished to the study parameters, the bacteria count returned to a lower level. This variation in data was included in the study as an outlier test was not conducted to eliminate this variable data.
2. Figure 11 summarizes the arithmetic sum mean and the maximum value in the data set. What can be seen is that the bacteria concentration mean value for ozone treatment is one to two orders of magnitude less than the chlorinated treatment water mean bacteria concentration. But to confirm this observation with such a wide variation in the maximum data versus the arithmetic sum mean, the geometric mean was charted in Figure 12.
3. The geometric mean is arithmetic function that utilizes the root of the product of the experimental values and as such normalizes out broad data range values as seen in the arithmetic sum mean. Comparison of the chlorinated treatment water bacteria values to the ozone treatment water still shows the trend where ozone treatment reduces bacteria at least 1 to 1½ orders of magnitude.

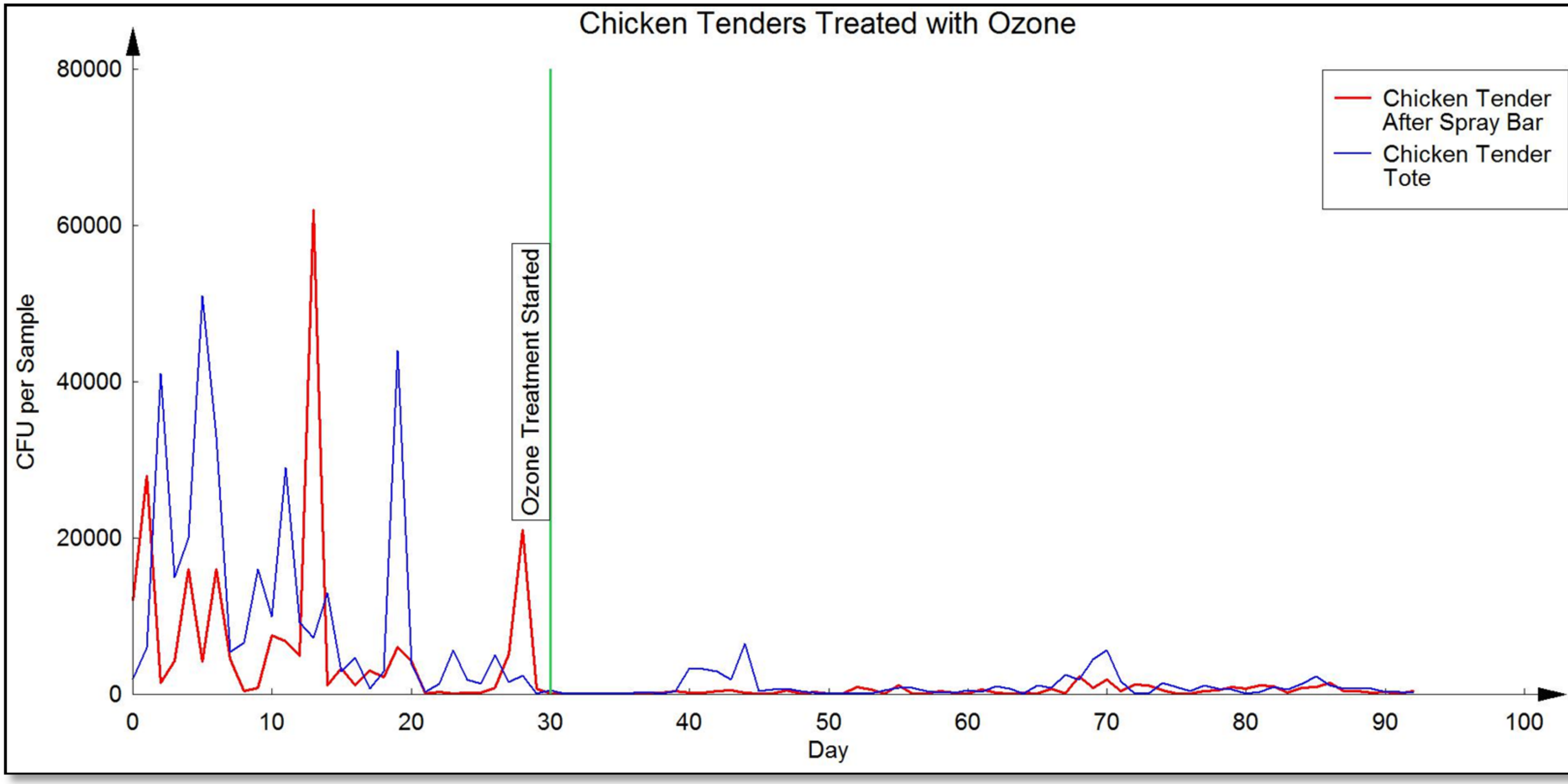

Figure 10: Chlorinated Water vs. TetraClean™ Ozone Water Bacteria Efficacy Timeline

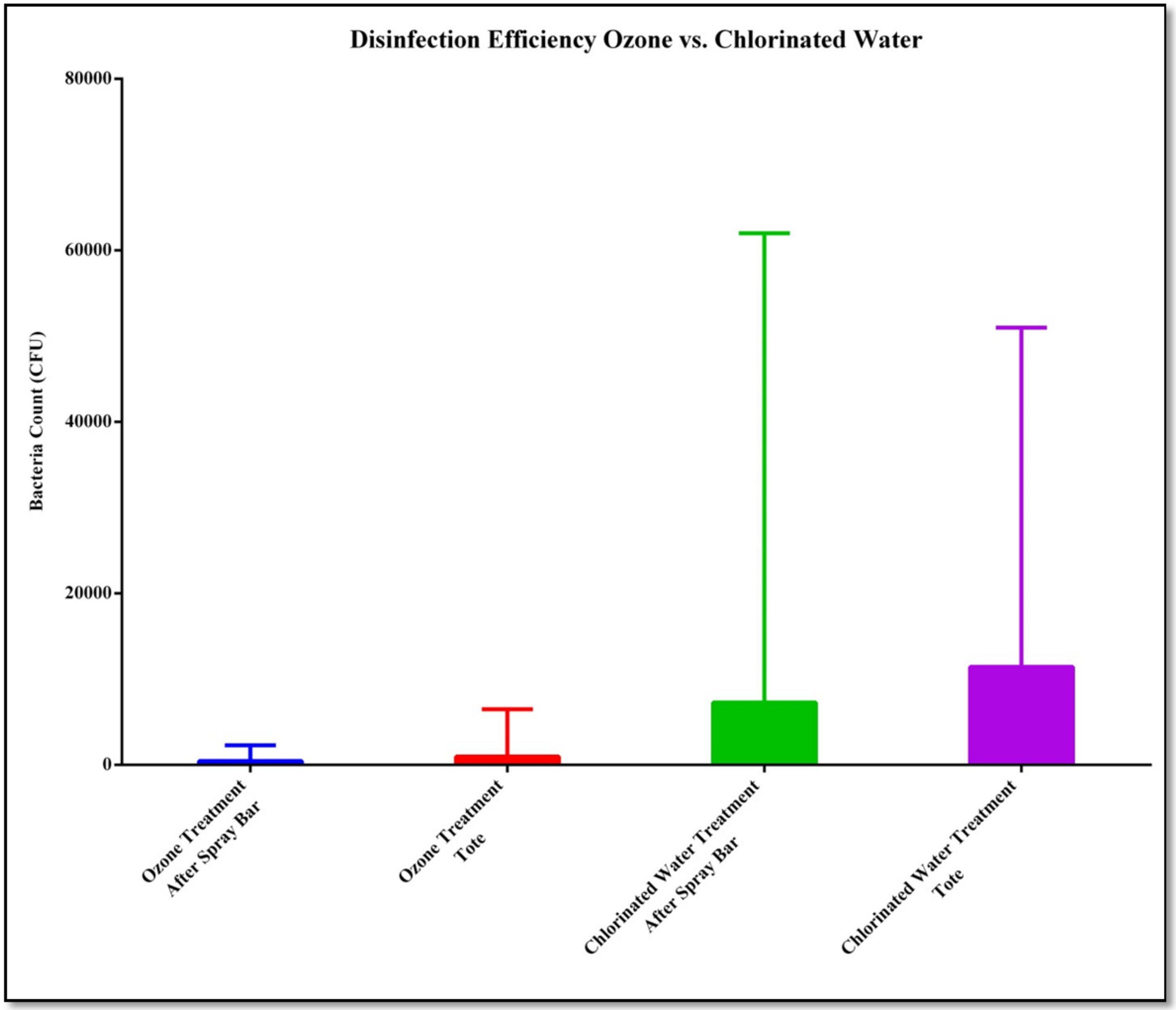

Figure 11: Chlorinated Water vs. TetraClean™ Ozone Water Bacteria Efficacy (Mean and Maximum Value)

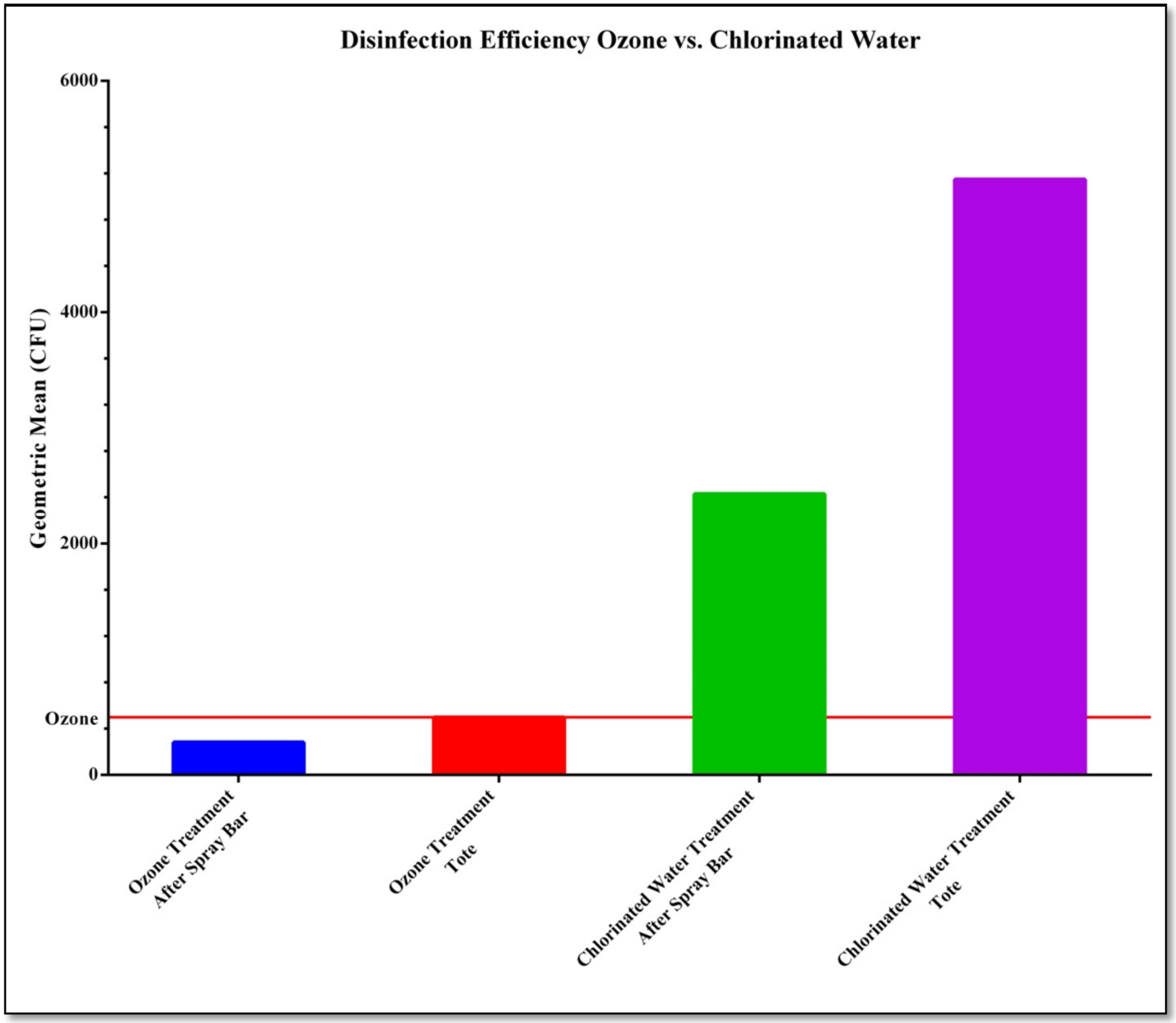

Figure 12: Chlorinated Water vs. TetraClean™ Ozone Water Bacteria Efficacy (Geometric Mean Value)

Conclusion

The study on the bacteria efficacy seen by the topical application of ozone at levels of 1% to 2% dissolved gas on processed chicken, chicken tenders, and production trays utilized to transfer the chicken products through the processing plant has provided the following results:

1. For the 90-day application period in which chlorinated water was compared to water containing ozone:
    a. The dramatic drop-off rate in bacteria is evident when the ozone process was started.
    b. The slight increases seen for the chicken totes at days 40 and 70 are due shift operations modifying the ozone application rate.
    c. Once the ozone application rate was reestablished to the study parameters, the bacteria count returned to a lower level.
2. The arithmetic sum mean and the maximum value for the 90-day study showed:
    a. The bacteria concentration arithmetic sum mean value for ozone treatment is one to two orders of magnitude less than the chlorinated treatment water arithmetic sum mean bacteria concentration.
    b. To confirm this observation with such a wide variation in the maximum data versus the arithmetic sum mean, the geometric mean was determined.
3. The geometric mean is arithmetic function that utilizes the root of the product of the experimental values and as such normalizes out broad data range values as seen in the arithmetic sum mean.
    a. Comparison of the chlorinated treatment water bacteria geometric mean values to the ozone treatment water geometric mean still shows the trend where ozone treatment reduces bacteria at least 1 to 1½ orders of magnitude.

Longer term testing showed the use of TetraClean™ after 2 years continues to keep microbial counts below 100 cfu on average for a chicken processor. The micro levels prior to using TetraClean™ ranged from 60,000 to 100,000 with spikes over 1 million cfu. The design with repeat spray through the sorting and handling to packaging has proven to be a superior product and a money making proposition for the customer.

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