Treatment of Cut Vegetables with Aqueous Ozone: Technical Assessment

1007465

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Technical Update, December 2002

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This report describes research sponsored by EPRI and Tennessee Valley Authority.

The report is a corporate document that should be cited in the literature in the following manner:

Treatment of Cut Vegetables with Aqueous Ozone: Technical Assessment, EPRI, Palo Alto, CA, Tennessee Valley Authority, Chattanooga, TN: 2002. 1007465.

REPORT SUMMARY

Background

Since 1981, family owned and operated Strickland Produce Company in Nashville, Tennessee, has packed fresh cut vegetables and lettuce in bags for the ready-to-eat (RTE) market. Most of the produce, including lettuce and cabbage, is trucked from California, sorted, cut, washed, packed in plastic bags and distributed under refrigeration. Flume water, which is used for washing, and transporting the produce through the plant, is recycled in a closed loop.

In the past, Strickland used only chlorine for sanitizing the flume water. Since the chlorine provided antimicrobial activity but did not clean the water, the flume water quickly became discolored, laden with organic residues and needed to be replaced every 2-3 hours. Water costs and wastewater disposal costs are expensive and can often mean the difference between profit and loss in the highly competitive produce business. Also, produce that was treated immediately before the water was replaced ran the risk of contamination form the higher levels of organic compounds in the flume water.

Objectives

Because of the water and wastewater costs and the risk of increased contamination, Strickland Produce was looking for a technology that could provide the antimicrobial protection of chlorine and at the same time clean the flume water as it was recirculated.

Approach

Strickland Produce installed a state-of-the-art water cleaning and ozonation system. To reduce the suspended solids load, the system has a self-cleaning 50-micron “wedge-wire” filter by Ronningen-Petter installed in the 200-gpm flume in front of the water chiller. After the chiller a side stream of 50 gpm is diverted from the flume and ozonated at 50 psig pressure in an Osmonics designed ozonation system. The highly ozonated side stream is then returned to the flume and mixed with the moving flume water. The ozone gas is injected into the side stream with a Mazzei injector followed by a pressurized contactor tank. Before returning the highly ozonated water back to the flume stream, entrapped gases are removed in a GDT centrifugal separator with catalytic destruction of any excess ozone. Thus, ozone is not allowed to escape into the plant environment

Once excess ozone is removed, the cleaned flume water continues through the plant washing cut vegetables. Near the end of the wash cycle, chlorine is added for residual sanitation and antimicrobial protection while the product is being packaged and stored. At the end of the flume the washed products are screened and excess water is removed through centrifugation. Because a small amount of water is lost in the process, necessary fresh water is added to bring the system to capacity and the flume water is recirculated to wash additional vegetables.

Results

A 30-member panel at the Department of Food Science and Technology at the University of Tennessee in Knoxville analyzed refrigerated samples taken from the Strickland operation. The results of the sensory analysis clearly showed the superior quality and longer shelf life of the ozone treated samples, even after 25 days of storage. The reduced use of chlorine in combination with an effective ozone treatment improved the taste and appearance of the fresh-cut produce considerably compared to the use of chlorine alone.

Turbidity analyses of the flume water showed that the ozone treated water stayed clearer over an extended operating time, thus allowing a full day operation without the need for water replacement. Water savings in the order of 60% have been achieved.

Microbiological analysis done by UT scientists confirmed the plate count reduction for aerobic bacteria, which explains the longer shelf life of ozone treated produce.

Conclusions

Once the system was installed and tested, it was found to have several advantages over either chlorine or ozone treatments. These advantages consisted of:

- Improved product appearance and quality
- Enhanced shelf life to 25 days
- Improved cleanliness of the recirculated water in the flume system (no brown off-color, better sanitation, reduced bacterial count in the water)
- Flume water replacement is required only once a day instead of every 2 - 3 hours, reducing water usage and reducing the volume of plant effluent.

EPRI Perspective

EPRI is a leader in the application of ozone in food processing. The treatment of cut vegetables is only one of many ozone research and demonstration programs that range from the treatment of processed meat, poultry and fish to treatment of numerous fresh agricultural products and treatments for reducing microbial activity in stored food products.

Keywords

Fresh-cut vegetables

Ozone

Chlorine

Water

Flume Water

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1
INTRODUCTION

In 2000, the Ozone GRAS Affirmation had not been accepted due to the "Limiting Rule" caused by a ruling on bottled water. Yet, several manufacturers were feeling the pressures for enhanced food safety procedures due to illnesses caused by food-borne microorganisms. To guard against these organisms, greater and greater rates of chlorine were being applied as sanitizers and disinfectants. These high rates resulted in undesirable working conditions due to excessive amounts of chlorine in the air, possible long-term affects on worker health, and food off-flavors and odors caused by intensive chlorine treatments.

Utilizing Tailored Collaborative Funds, TVA agreed to support a study whereby ozone was used to wash vegetables and reduce the amount of chlorine necessary for the sanitation of cut vegetables. The project reported herein was a part of this support. In the past three years, the project has become a benchmark study that is often referenced for the use of ozone in cut vegetable processes.

2 BACKGROUND AND LITERATURE REVIEW

A detailed review of EPRI's efforts to develop ozone as an antimicrobial agent for use on food products can be found in *Ozone for Use as an Antimicrobial Agent: Agricultural and Food Processing Technical Assessment*, 1005962. Review for the study reported herein, is a summary and overview of the Technical Assessment, 1005962, plus additional findings since publication of Technical Assessment, 1005962.

EPRI's interest in ozone began with the Food Technology Alliance (FTA) in 1995. Based on the recommendation of FTA members, an Expert Panel was convened. In 1997, ozone brought in contact with food products was declared GRAS (Generally Recognized as Safe). The findings and report issued by the Expert Panel for the GRAS Affirmation have become a landmark piece of scientific literature and the now out-of-date GRAS Affirmation Report volumes are in great demand by researchers, regulatory agencies, and legal firms.

Although the GRAS Affirmation route for clearing the use of various chemicals on food products is an excellent method and is quite trusted in the scientific community, it has never actually satisfied the regulatory requirements for the utilization of ozone on food products. To overcome this problem of the GRAS Affirmation, EPRI at the urging of the Food and Drug Administration, developed a Food Additive Petition requesting the use of ozone as an antimicrobial agent in the processing of food products. Notice of the acceptance of the Food Additive Petition was published in the Federal Register, Vol. 66, No. 123, Tuesday, June 26, 2001/Rules and Regulations and appears as follows: "Part 173-Secondary Direct Food Additives Permitted in Food for Human Consumption". In December 2001, USDA FSIS recognized the Food Additive Petition and agreed to allow the use of ozone as an antimicrobial agent on meat products.

During the period that the GRAS Affirmation was being developed and, subsequently, the Food Additive Petition was being written, strong interest was generated to find additional antimicrobial agents in the war against food-borne pathogens. EPRI, listening to and supporting its customers, conducted numerous studies on the use of ozone as an antimicrobial agent. These studies involved a wide array of food products including meats, grains, soil fumigation, and the washing of fruits and vegetables. All of these studies are reviewed in Technical Assessment, 1005962.

Prior to the publication of Technical Assessment, 1005962, the Strickland Produce project was in development and various ozone treatments were being tested.

3
STRICKLAND PRODUCE COMPANY PROJECT

Background

In the early 1980s, Walter Strickland started his produce packing and packaging service for restaurants. At the outset, his business consisted of the acquisition and handling of premium vegetables for the food service industry. This industry is extremely competitive and without the use of "value added" techniques and the development of niche products, it is a fairly low return industry.

From preparing cut products for institutional use, the process moved to bagged salads. Because fresh produce often contains high levels of microbes and many plant exudates from the product cutting process, it is imperative that the final product be handled in the most sanitary conditions possible. As cut produce volumes increased, it was not uncommon to approach 100 parts per million of chlorine for the vegetable wash water. These chlorine levels sanitized the product but provided a very unsatisfactory work environment causing burning eyes and the smell of chlorine in the plant. Further, resident chlorine was left in the final product and the resulting final product quality was not always acceptable. The experienced reductions in microbial load from chlorine treatments are presented in Figure 3-1.

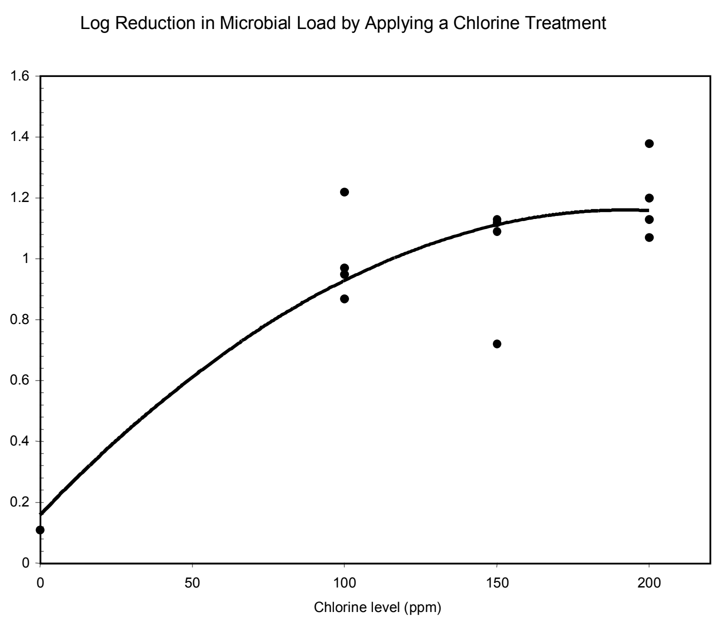

Figure 3-1
Log Reduction in Microbial Load through Increased Chlorine Levels at a Decreasing Rate and Is Not Highly Effective Above 100ppm. (Garcia, 2001)

Initial Experiments with Ozone

To overcome these problems, Walter Strickland approached TVA and through EPRI-TVA collaborative funding, a project was developed to partially treat cut vegetable products with ozonated water. Although ozone is an excellent antimicrobial agent, it cannot be stored and does not have residual antimicrobial powers; thus, chlorine still needs to be introduced into the system to provide a residual antimicrobial treatment. By the same token, clean products treated with low levels of chlorine appear to maintain a very high quality and the chlorine provides a lasting antimicrobial effect. The original system installed at the Strickland facility is shown schematically in Figure 3-2.

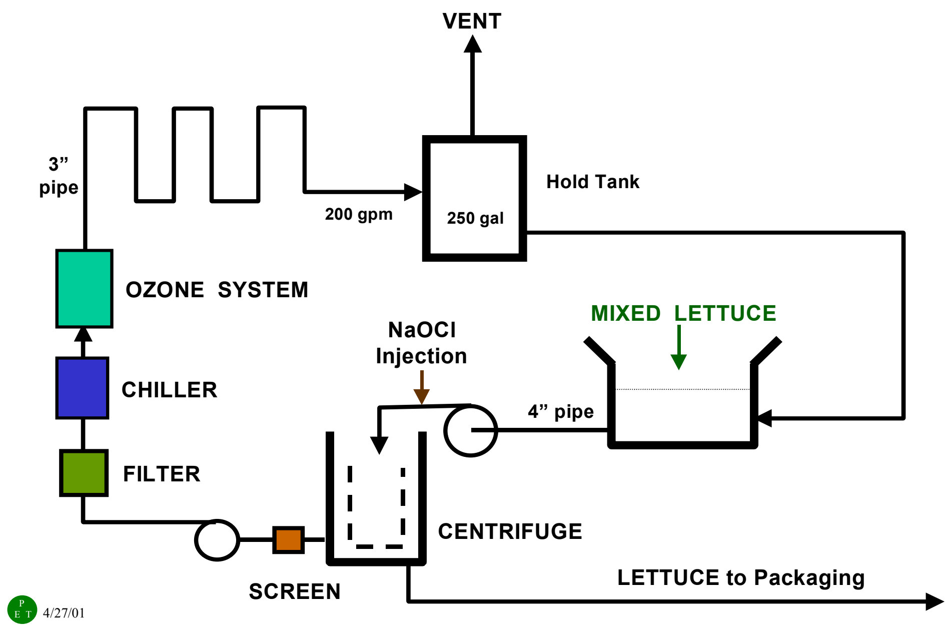

Figure 3-2
Original Ozonation Configuration to Test the Effects of Ozone in the Wash Tanks

From this system the effects of ozone in reducing microbial loads as well as the interaction from using both ozone and chlorine were developed by Garcia (2001). These effects are presented graphically in Figure 3-3 and Figure 3-4. The enhanced microbial log reductions were attributed to the antimicrobial effects of ozone in the wash treatment.

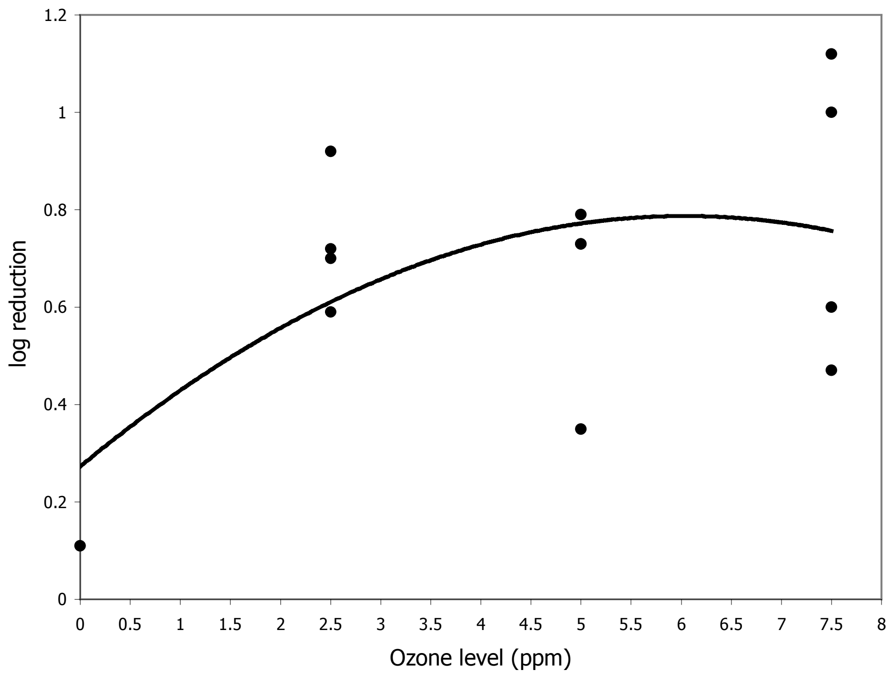

Figure 3-3
Log Reductions in Microbial Load from Ozone Applications to Cut Vegetables (Garcia, 2001)

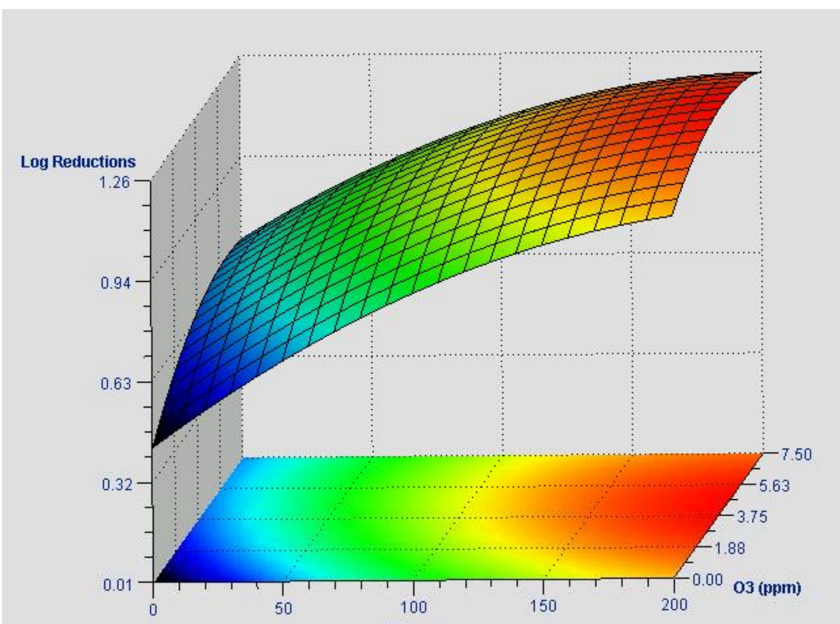

Figure 3-4
Expected Microbial Log Reductions Utilizing Combination Ozone – Chlorine Treatments (Garcia, 2001)

Tests from this initial installation were able to show that fresh-cut salad processed with ozone has the following characteristics:

- Improved flavor
- Enhanced appearance
- Extended shelf life
- Greater protection from the potential of harmful bacteria in the finished product
- Extended water recycling time
- Reduced water usage in the plant
- Reduced effluent burden

In this initial test system, ozone was directly injected into the unpressurized flume water stream (Figure 3-2.) circulating at 800 liters/minute (200 gpm). Holding time was approximately two minutes in a pipe loop and subsequent surge tank. Within the two-minute timeframe dissolution of the ozone into the water was not very effective. Considerable amounts of undissolved ozone escaped at the surge tank and had to be removed before the water was sent to the lettuce pick-up station. Only coarse suspended solids were removed from the loop by a rotary screen having a 2-mm gap. While benefits of this process were appreciable, it was decided that very fine suspended solids needed to be removed before ozone application. In order to improve the dissolution of ozone into the circulated flume water, the vendor recommended that the ozone injection should be done in a pressurized slip stream system with an additional contactor tank. These modifications were considered and an improved system was designed.

Improved Ozone System

In the spring of 2001, a new water cleaning and ozonation system was installed with assistance from TVA, Nashville Electric Service and EPRI. In order to reduce the suspended solids load, a self-cleaning 50-micron Ronninger-Petter “wedge-wire” filter was installed in the 800 liters/minute loop right after the coarse (2 mm) rotary prescreen. The schematic for the total system is presented in Figure 3-5 and the Ronninger-Petter DCF filter as installed is shown in Figure 3-6.

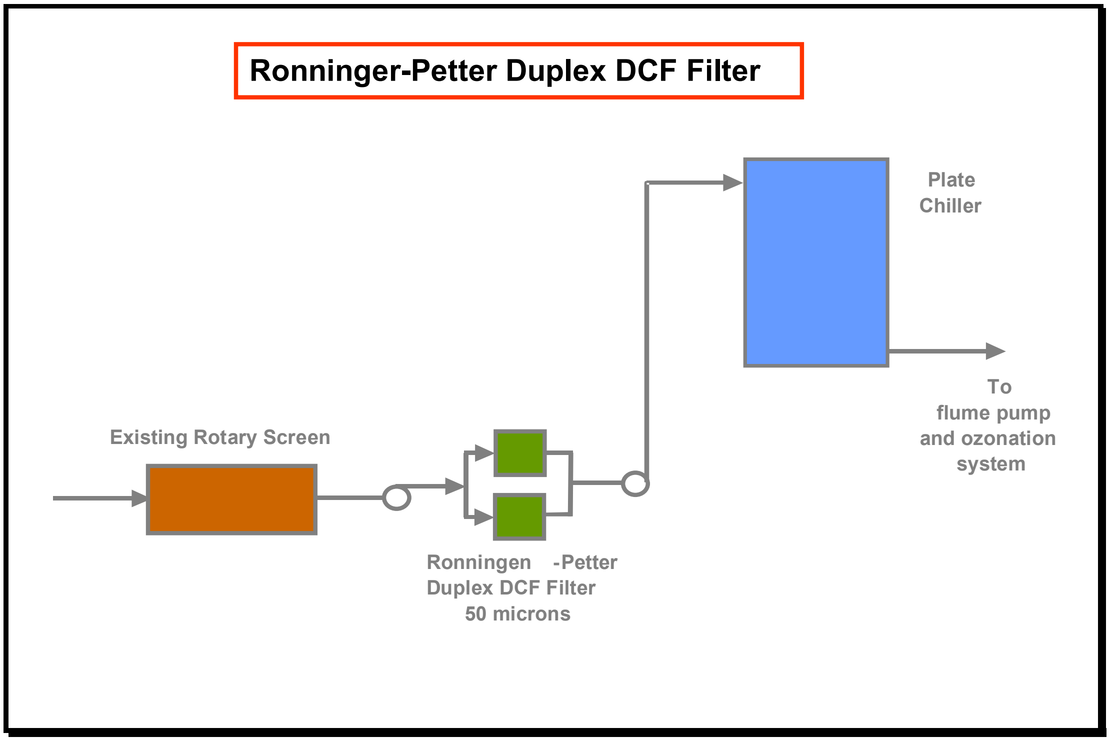

Figure 3-5
Modified Water Filtration System Utilizing the Ronniger-Petter Duplex DCF Filter

Figure 3-6
The Ronninger-Petter Duplex DCF Filter

The R-P filter removes fine vegetative particles in a continuous unattended process. After the filter, the water is pumped to a chiller where it is cooled to 5 ºC. One side benefit of the filter is the increase in the performance of the chiller, due to elimination of the possibility of clogging of the nozzles, which spray the water on to the heat exchanger plates.

To address the problems of ozone off-gassing into the plant and the dissolution of ozone into the wash water, the ozone injection system was modified such that a "slip-stream" of 200 liters/minute was taken out of the flume by a high pressure pump and ozone was injected at 350 kPa (50 psig) pressure using a Mazzei injector in an Osmonics-designed system. After the Mazzei injector, water entered into a pressurized contactor tank. Before introducing the highly ozonated water back into the rest of the flume stream, any entrapped gases are removed in a GDT centrifugal separator with catalytic destruction of any excess ozone. No ozone is allowed to escape into the plant environment, as required by EPA and OSHA regulations.

Once the off gassing phase is completed the ozonated water is used as a cut vegetable wash. From the ozone wash the vegetables are pumped to the centrifuge and chlorine added. From the centrifuge excess water is pumped back to the system and final washed vegetable products are moved to packaging. The overall system is shown in Figure 3-7., and the ozonation units are depicted in Figure 3-8.

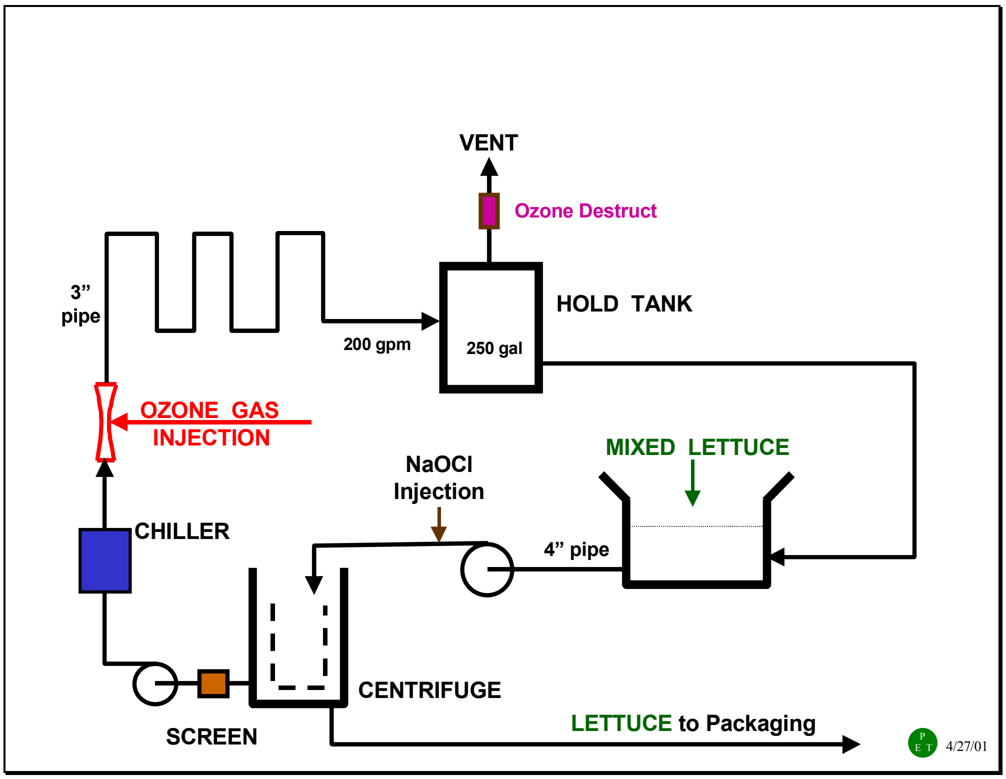

Figure 3-7
Schematic of the Final Test System

Figure 3-8
Ozone Generation Equipment

Figure 3-9
The GDT Unit

Once the equipment was assembled and tested the system operated satisfactorily. Although the final chlorine levels used by Strickland Produce are of a proprietary nature three significant events were noted:

- Factory air quality was enhanced
- Shelf life was increased
- Product flavor is enhanced

In subsequent discussions with Mr. Strickland, it was found that chlorine levels are regulated depending on the microbial load of the fresh product. With the ozone technology installed, final levels never approach the levels experienced before the ozonation equipment was installed.

The final product is very attractive and is well received by the industry. A typical packaged product unit is shown in Figure 3-10.

Figure 3-10
Strickland Supreme Salad

Product Quality

During the course of the study, Garcia (2001) conducted several product and system evaluations at the Strickland Plant as the availability of the ozonation equipment provided an opportunity to enhance his thesis research. Sensory panels were used to evaluate products treated with chlorine, ozone and chlorine-ozone combinations. All data were statistically analyzed and differences in consumer preference were observed. Figure 3-11 summarizes Mr. Garcia's findings.

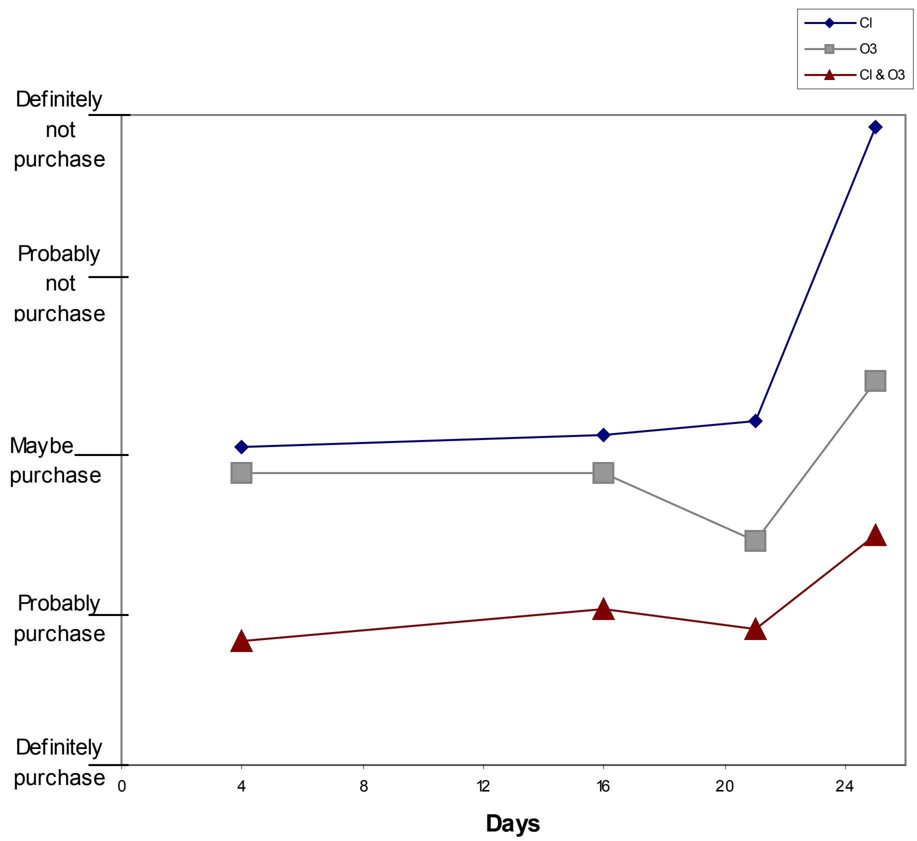

Figure 3-11
Consumer Panel Acceptance of Products Treated with Chlorine, Ozone and Chlorine – Ozone Combinations (Garcia, 2001)

From Figure 3-11, it was concluded that there are definite differences in product quality from antimicrobial treatments with chlorine, ozone and the chlorine – ozone combination. For 21 days after treatment, the antimicrobial effects and consumer panel acceptance are treatment specific but fairly stable across all the 21 day period. Consumer preference for the ozone treated products and the chlorine - ozone treatments were attributed to less chlorine odor in the product. After 21 days, all of the samples were deteriorating but most panelists would probably purchase the product treated with the combination chlorine – ozone treatment. Purchase of ready-to-eat salads treated with ozone was marginal for ozone at 25 days, and panelists would definitely not purchase chlorine treated salad.

Consumer acceptance and shelf life extension are major considerations in delivering produce to consumers and food service companies. Consumer acceptance of ready-to-eat salads increases sales and product turnover in the sales outlet. Enhanced shelf life reduces spoilage costs to the public and private food preparation industry. Five days of extended shelf life is often the difference between profit and loss for the food service industry. Garcia (2001) found shelf life extensions of from 16 to 25 days of the three antimicrobial treatments studied (Figure 3-12).

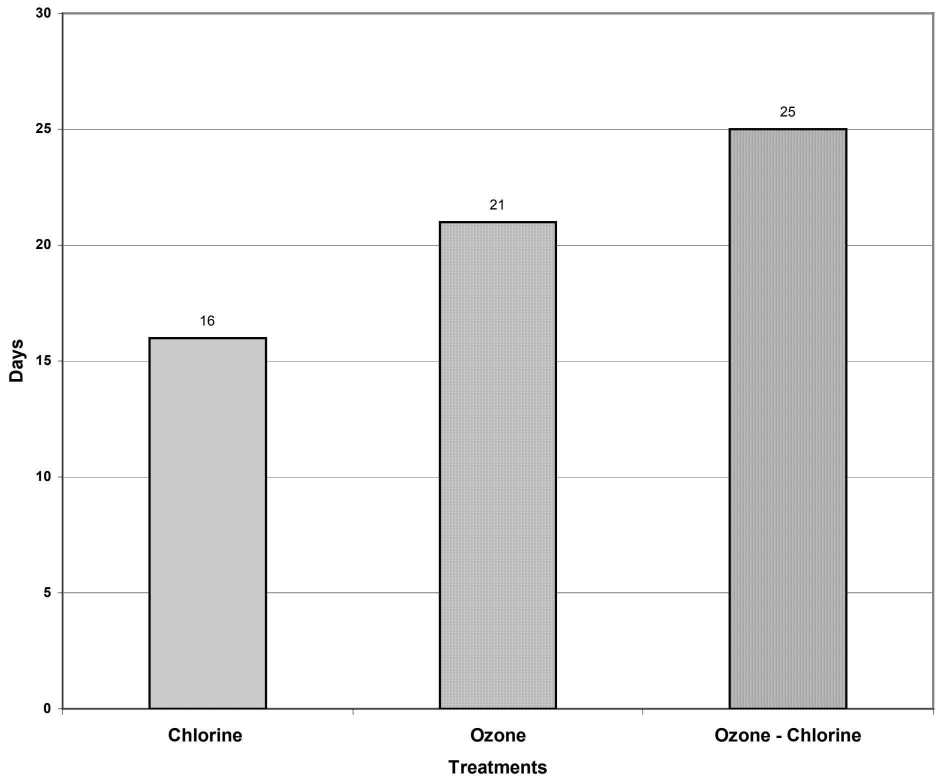

Figure 3-12
Expected Shelf-life for Chlorine, Ozone and Chlorine – Ozone Treatments of Ready-to-eat Salads (Garcia, 2001)

Water Use and Water Quality

A key to a successful and profitable operation for ready to eat salad operations is controlling the quantity and quality of what is often termed the wash or rinse water. Preliminary ozone studies showed that the quality (turbidity) of the rinse water seemed to improve with the chlorine -ozone antimicrobial wash/rinse treatment. After installation of the final filtration and ozonation equipment there was a marked improvement in the rinse water over time and the wash/rinse water could be used for a longer time period.

The magnitude of the water savings is variable and dependent on the cleanliness of the fresh products being used. Generally up to five hours of use could be obtained by recirculating the wash/rinse water when the chlorine – ozone combination was used. With the chlorine treatment alone, turbidity often increased after one hour and water changes were necessary. Garcia (2001) investigated the water quality but could not quantify the savings from the ozone treatments. Strickland Produce reports them as significant and only long-term plant operations will provide actual quantification of reduced water use and wastewater charges.

4 CONCLUSIONS

With support from TVA, Nashville Electric Service, and EPRI, Strickland installed a state-of-the-art water cleaning and ozonation system. To help reduce the suspended solids load, a Ronningen-Petter self-cleaning 50-micron “wedge-wire” filter has been installed in the 200-gpm loop in front of the water chiller. Subsequently, a “slip-stream” of 50 gpm is being ozonated at 50 psig pressure in an Osmonics designed system. At Strickland, the ozone gas is injected into the water stream with a Mazzei injector followed by a pressurized contactor tank. Before returning the highly ozonated water back to the flume stream, entrapped gases are removed in a GDT centrifugal separator with catalytic destruction of any excess ozone. Thus, as required by EPA and OSHA, no ozone is allowed to escape into the plant environment

A 30-member panel at the Department of Food Science and Technology at the University of Tennessee in Knoxville analyzed refrigerated samples taken from the Strickland operation. The results of the sensory analysis clearly showed the superior quality and longer shelf life of the ozone treated samples, even after 25 days of storage. The reduced use of chlorine in combination with an effective ozone treatment improved the taste and appearance of the fresh-cut produce considerably compared to the use of chlorine alone.

Turbidity analyses of the flume water showed that the ozone treated water stayed clearer over an extended operating time, thus allowing a full day operation without the need for water replacement. Water savings in the order of 60% have been achieved.

Microbiological analysis done by UT scientists confirmed the plate count reduction for aerobic bacteria, which explains the longer shelf life of ozone treated produce.

Following is a summary of the benefits of ozone treatment of lettuce to the food processor and the consumer:

- Improved cleanliness of the re-circulated water in the flume system (no brown off-color, better sanitation, reduced bacterial count in the water)
- Flume water replacement is required only once a day instead of every 2 - 3 hours, reducing water usage and the volume of plant effluent
- Reduced usage of chlorine results in a better tasting produce with better appearance
- Lower bacterial count on the produce, thus longer shelf life and better assurance of food safety

As an overall assessment of the technology, it can be concluded that the process works well and is an excellent addition to the ozone technologies developed by EPRI in conjunction with TVA.

5
REFERENCES

The literature search and the background for this publication utilizes the two references cited below. Both of these references contain extensive references lists.

EPRI. 2001. The Use of Ozone as an Antimicrobial Agent: Agricultural and Food Processing Technical Assessment, EPRI, Palo Alto, CA: 2001. 1005962

Garcia, A. G. 2001. The Microbiological Effect of Ozone and Chlorine Treatments on Minimally Processed Lettuce. Masters Thesis, University of Tennessee.

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