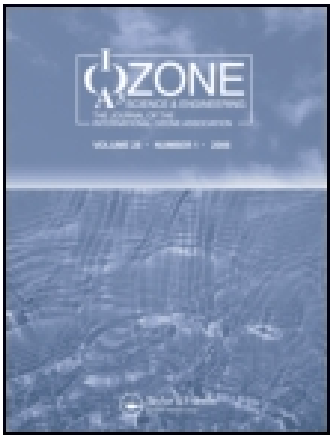

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The Utilization of Ozone for Treating Vegetable Processing Lines

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The Utilization of Ozone for Treating Vegetable Processing Lines

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Adoption of ozone technologies as Food Safety treatments in the Agri-Food Industries today is still being approached with great caution. This paper reviews selected successes in using ozone UV and advanced oxidation to enhance food safety and reduce energy costs in the Agri-Food industry. Included is a preliminary case study of utilizing ozone and chlorination in a FTNON vegetable washing system. Vegetable flotation washing systems such as the FTNON equipment produced by Noord-Oost in the Netherlands have the potential to vigorously wash sand as well as floating particulate from vegetables and fruits. With minor modifications these machines can be adapted to utilize combinations of ozone, UV and chlorination. Preliminary trials indicate plate counts are lowered with the combination treatment. Future data will need to be collected to determine the levels of chlorination required to ensure residual microbial protection without detracting from product taste and quality. When developed, these systems have the potential to enhance food safety, reduce water use and wastewater discharge amounts, reduce electrical demand and increase product shelf life.

Keywords Ozone, Cut Vegetables, Energy Efficiency, Plate Counts, Food Safety, Agri-Food Applications

INTRODUCTION

In 2000 the Ozone GRAS Affirmation had not been accepted due to the "Limiting Rule" caused by a previous 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 employee working conditions due to excessive amounts of chlorine in the air, possible long-term effects on worker health, and food off-flavors and odors caused by these high chlorine treatments.

To overcome these problems, the Food and Drug Administration (FDA) amended the food additive regulations to provide for the safe use of ozone in gaseous and aqueous phases as an antimicrobial agent on food, including meat and poultry (Federal Register, 2001).

Beginning in the early 2000s, the Tennessee Valley Authority (TVA) supported several studies on the use of ozone as a food safety treatment in food processing. A 2002 study known as the Strickland Project reviewed in the next section, utilized ozone and chlorine to reduce microbial levels in cut salads products. Over time it was found that the ozone technologies applied in this study also led to water and energy savings. During the past six years the Strickland project has become a study that is often referenced for the use of ozone in cut vegetable processes. With several recent outbreaks of microbial contamination in cut vegetables and the need to conserve energy increasing, the Strickland study was revisited and energy savings were further quantified. In 2007 the Strickland Processing Plant facility was closed as it was in the path of a major highway expansion. The new owner of the Strickland operation is in the process of opening a new facility and is interested in incorporating some of Strickland's ideas and technologies.

The project reported herein was a TVA supported project initiated as an extension of the Strickland project to study the potential for using ozone, chlorine and possibly UV light in the Food Technology Noord-Oost Nederland B.V. (FTNON) machinery utilized in modern cut vegetable processes.

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BACKGROUND AND STRICKLAND PROJECT REVIEW

With the problems of microorganisms found in products such as spinach, lettuce, peanut butter, cantaloupes and various other food products, it is common to hear statements that indicate research needs to be undertaken to study the problems and develop technologies to ensure that the contamination very seldom or never happens again. Although statements such as this are common, they are an indication of the lack of understanding of the real problems. The research to eliminate these problems for the most part has already been done and at best only needs to be updated and applied utilizing available technologies.

Ensuring that a microorganism won't mutate and a new source of contamination will never take place is not realistic. The effects of Best Management Practices (BMPs), chlorine, ozone, UV and combinations of washes with water, chlorine, ozone, UV and advanced oxidation technologies have been tested and demonstrated. Treatments utilizing chemical sprays and solutions have also been developed. Omitting BMPs is a scenario for disaster and is not excusable. Many combination treatments have been tested and are available for adoption. With BMPs and combination treatments in place, a strong quality control program should keep microbial outbreaks to a minimum.

The reasons for not adopting newer technologies are many and include but are not limited to the following:

- Lack of capital – present systems are not fully depreciated and will not be replaced until depreciated;
- Lack of understanding of the technologies for:
  - Food safety;
  - Energy efficiency
  - Electrical load reductions;
  - Reduced water and wastewater costs;
- Lack of understanding of the seriousness of microbial problems – recalls can spell financial disasters for even large companies;
- Resistance to Change – If it isn't broken, don't fix it;
- Competition between technologies – many chemical suppliers do not support ozone or UV technologies because they fear the loss of chemical sales. Even ozone and UV technologies often compete as well as the competition that exists between various types of ozone and UV systems;
- Insufficient in-house quality control procedures and personnel.

Strickland Project Review

The following is excerpted from the Final Report of the EPRI Strickland Project: *Treatment of Cut Vegetables with Aqueous Ozone: Technical Assessment* (2002). This final report was a compilation of the findings by Drs. Sopher, Graham and Strasser during the project and from data extracted from A. Garcia (2001).

> **This information is included as it served as a starting point for the present project. For a complete discussion of the project see the above cited previously in the final EPRI report no. 1007465. The following are the conclusions from this report.**
>
> With support from TVA, Nashville Electric Service, and EPRI, Strickland Produce 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 was installed in the 200-gpm loop in front of the water chiller. Subsequently, a "slip-stream" of 50 gpm was ozonated at 50 psig pressure in an Osmonics designed system. At Strickland, the ozone gas was 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 of the University of Tennessee (Knoxville, TN) Department of Food Science and Technology 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 as 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 of operation without the need for water replacement. Water savings in the order of 60% were achieved.

Microbiological analysis done by UT scientists confirmed that the plate count reductions explain the longer shelf life of ozone treated produce. The following summarizes the benefits of ozone treatment of cut salads to the food processor and the consumer:

- Improved cleanliness of the re-circulated water in the flume system (no brown off-color, enhanced sanitation, reduced bacterial count in the water);
- Flume water replacement was required only once a day instead of every 2–3 hours, reducing water usage and the volume of plant effluent and thus, reducing wastewater disposal costs;
- Reduced usage of chlorine resulted in a better tasting product with better appearance;
- Reduced chlorine usage provided an enhanced work environment in the processing plant;
- Lower bacterial count on the produce, thus longer shelf life and enhanced food safety.

At the time the conclusions from the Strickland study were drawn in 2002, large outbreaks of *E. coli* contamination in cut salads had not been experienced and the increased need to reduce energy consumption was known but still on the horizon. With several recent outbreaks of microbial contamination in cut vegetables and the need to conserve energy increasing, the Strickland study was revisited and energy savings were further quantified. Results of this quantification were presented at the International Technology Conference and Ozone V Meeting; April 2–4, 2007; Fresno, CA in the paper entitled *Six Years of Ozone Processing of Fresh Cut Salad Mixes,* by Walter Strickland, Charles Sopher, Rip Rice and Tedd Battles. Global Energy Partners (4) recently published this paper.

MATERIALS AND METHODS

For the project presented herein, a two-stage FTNON unit produced by Food Technology Noord-Oost Nederland B.V. was utilized in the project. This unit is a new concept and has considerable potential for washing and removing, dirt, insects and insect fragments. The FTNON machinery is presently utilizing chlorine as an antimicrobial agent. Washed products are collected and transported to centrifugation and bagging. All tests in this study were conducted utilizing the FTNON unit. Figures 1–4 depict various views of the FTNON machinery as supplied by Noord-Oost. The actual plant operation and pictures remain proprietary at the request of the cooperating food processor.

An HDO_3 Clearwater Tech, LLC ozone unit (San Luis Obispo, CA) in Figure 5 was utilized to supply ozone to the FTNON unit. The use of the unit and suggested piping and machine settings were provided by Mr. Cameron Tapp, President, Clearwater Tech, LLC. Mr. Marc DeBrun, Sales Engineer, Clearwater Tech, LLC provided engineering for the project.

Water from the rear of the first FTNON unit was directly piped to the ozone generator and ozonated. The ozonated water was returned to the front of the FTNON unit. It was found that water at the end of the first section

FIGURE 1. Food Technology Noord-Oost Nederland B.V. (FTNON) is a specially developed flotation washing machine for washing products such as fruits, (leaf) vegetables, mushrooms etc. (Photo supplied by Noord-Oost).

FIGURE 2. Food Technology Noord-Oost Nederland B.V. — A closer view of the FTNON unit (Photo supplied by Noord-Oost).

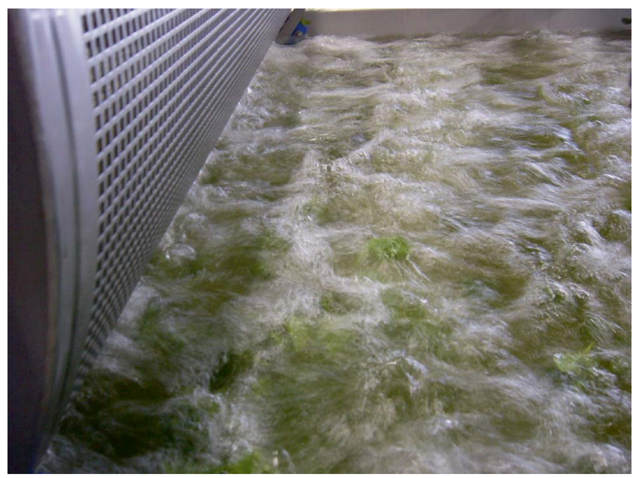

FIGURE 3. Food Technology Noord-Oost Nederland B.V. – As product moves though the FTNON unit, agitation removes non-vegetative materials. Heavier particles such as sand and mineral particles settle and light particles such as insects and insect fragments flow though the rotating drum and are removed in a side stream (Photo supplied by Noord-Oost).

FTNON unit was loaded with product, the return water averaged 0.2–4 ppm ozone. Average ozone residence time was approximately 18 seconds. CT values were not calculated as only total plate counts were measured and specific microorganisms were not isolated. Water temperatures averaged 42 °F.

Under the test conditions, off-gas was monitored with an Aeroqual Series 300 ozone monitor (Fondriest Environmental, OH, USA). Off-gas at the surface of the water in the FTNON was a problem unless product was loaded into the FTNON. Off-gas when the FTNON was loaded was not measurable at greater than six inches from the water surface in the FTNON. Care was taken to ensure the FTNON units were loaded during the test as off-gassing can occur. Figure 6 is provided to illustrate the agitation and turbidity that can occur in the FTNON unit.

Utilizing the Ozonation treatment just described, ozonated test products were treated and submitted to Warner Laboratories, Nashville, TN for microbial analyses. For this project only chopped iceberg lettuce was tested by loading the product into the FTNON unit and ozonated in the first section of the machine. The product was then chlorinated in the second section of the machine. All treatments were replicated five times. This procedure gave a combination treatment of ozone plus chlorine and closely duplicated the Strickland Study except residence time was shorter. Water samples for incoming water quality as well as water quality of the circulating water in the FTNON were collected. During the investigation it was noted that filtration was needed in the ozone circulation system and is recommended for future systems.

FIGURE 4. Food Technology Noord-Oost Nederland B.V. – After product moves under the rotating drum, it is conveyed to a second unit and washed again. Water temperatures are maintained and chlorine levels are checked frequently (Photo supplied by Noord-Oost).

of the FTNON unit could be ozonated with a maximum of 25 ppm ozone in a 20 GPM flow and returned to the front of the FTNON unit where the product is first introduced. The ozone unit utilized was capable of pumping higher rates of water but a 20 GPM flow maximized dissolved ozone. Under static conditions (no chlorine or organic load) in the FTNON water, the ozone would leave the HDO_3 unit at 25 ppm ozone and return to the ozone generator at approximately 15–18 ppm. When the

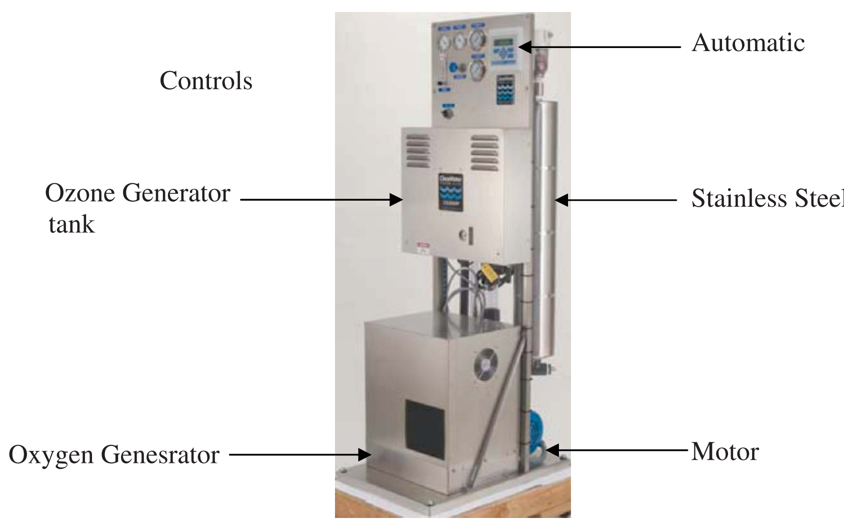

FIGURE 5. An HDO_3 Clearwater Tech equipment unit with an ozone generator, motor and water pump, stainless steel tank and associated equipment to force ozone into the water, an oxygen generator and automatic controls (Photo supplied by Clearwater Tech, LLC).

FIGURE 6. Food Technology Noord-Oost Nederland B.V. – Because the FTNON unit provides a large amount of agitation, ozone off-gassing was measured in and around the unit utilizing an Aeroqual Series 300 ozone monitor (Photo supplied by Noord-Oost).

RESULTS

The following conditions were present during the processing of chopped lettuce.

- Water temperature 41 °F;
- Ozone input 6.9–7.2 ppm;
- Ozone levels returning to the ozone generator 0.79–0.81 ppm;
- Chlorine levels in the second FTNON unit were 60 ppm at the start of the experimental run;
- pH: 6.9;
- Water flow in the slip stream 20 Gpm.

Lettuce heads were chopped and put into the FTNON. The first section of the FTNON was ozonated and the second section was chlorinated. Samples were taken on the raw product, the ozone-washed product and on the final washed product that had been treated with both ozone followed by chlorine.

The analysis of the sample information in Table 1 indicated the treatments of ozone followed by chlorine significantly reduced plate counts at the 0.005 level of probability. This reduction took place even though the raw product had much higher than expected microbial levels. On the average, plate counts were reduced from 672,000 to 10,600.

The studies with this unit were interesting as this type of equipment will become more common and will need to be modified to handle new organisms. From the present study, it was found that the Strickland Studies could be substantiated. In future research studies the following is recommended:

- Separating the two units to utilize ozone followed by chlorine;

TABLE 1. Chopped Iceberg Lettuce Microbial Count Data and Associated ANOVA Tables

Chopped Iceberg Lettuce – Plate Counts

Raw product	Ozone washed FTNON Unit	Ozone + Chlorine FTNON Unit
460000	74000	2600
1300000	100000	2600
280000	62000	22000
1080000	56000	14000
240000	47000	11800

ANOVA Single Factor Iceberg Lettuce
Summary

Groups	Count	Sum	Average	Variance
Raw Product	5	3360000	672000	2.37E + 11
Ozonated	5	339000	67800	4.2E + 08
Ozone + chlorine	5	53000	10600	67740000

ANOVA

Source of Variation	SS	df	MS	F	*P*-value	F crit
Between Groups	1.34E + 12	2	6.71E + 11	8.499498	0.005021	3.88529031
Within Groups	9.48E + 11	12	7.9E + 10			
Total	2.29E + 12	14				

- If ozone is used, a small filter system would be advantageous to filter the water returning to the ozone unit. This filter and ozonation unit should reduce the water use by 50–65%;
- With water reductions will come reduced chilling costs ands reduced wastewater fees;
- The ozone residence time needs to be optimized to ensure maximum microbial kill;
- The speed, pressures and throughput of the FTNON may need to be maximized for ozone/chlorine treatments;
- Off-gassing will need to be addressed;
- Pre-washing may become a necessary step;
- The addition of a UV unit at the end of the ozonation step may further reduce microbial levels and UV will also destroy ozone off-gas. This treatment was not tested.

WATER ISSUES

Water use issues are facing the cut vegetable industry. Water costs are increasing and wastewater BOD penalties are becoming very high. To squarely face these issues, the industry must curtail water use or introduce technologies that utilize the recirculation of water. Curtailing water use is an easy step to undertake in a plant that may tend to "waste" water. Most of these steps have already been taken and very few plants today can be accused of inefficient water use. Water recirculation and in-plant water treatment are more complicated but if utilized can be extremely rewarding. The main tools for recirculation and use are utilizing water for successively less stringent uses. For example, very clean final rinse water can be captured and used for rinses of lesser importance until the last use may be something as simple as washing sidewalks or pallet boxes. Filtration is a second method to reduce water use. Numerous filters and membranes are available for this purpose. Often a simple filter can reduce particulate to a wastewater plant.

In-house water treatment is also a feasible option. This treatment can be accomplished in two ways. In-plant water can be treated with an antimicrobial such as ozone, UV light or advanced oxidation. Unless wastewater penalties are very high, this type of treatment can be expensive and the penalties will probably be the most cost effective method of wastewater disposal. A second method of in-house treatment is the use of the green technologies in the processes. Green technologies are ozone, UV light, advances oxidation, heat, chilling and ultra-high pressure. All of these technologies are virtually residue free and kill microbes without harmful byproducts. In cut vegetable processes the only green technologies that are available are chilling, ozone, UV light and advanced oxidation.

Based on the Strickland project, water use and subsequent wastewater flows were cut by an estimated 65%. Chilling cost for the in-house wash water was also reduced considerably but never substantiated in actual dollars or electrical use. In the current project attempts were made to follow the BOD levels of water after the chlorine and ozone treatments. Insufficient numbers of samples were taken and only generalities can be addressed from the study.

At the outset of the lettuce run the BOD level of the water in the FTNON was 5 mg/L. At the end of the lettuce run the ozone unit was stopped and a water sample was taken. The BOD level was 20 mg/L. If the ozone unit had continued to run the BOD levels would have dropped back from the maximum during the lettuce run. This was not done to avoid off-gassing in the plant. In a properly designed system that kept off-gas to a minimum, the BOD levels could have been reduced prior to another run or the water in the FTNON being sent to wastewater. At the end of the lettuce run the chlorinated water in the second part of the FTNON was at 8 mg/L BOD and 20 ppm chlorine. An automatic chlorine regulation would have been beneficial and may have led to further reductions in microbial levels.

Although incomplete, this small test does demonstrate that ozone will reduce BOD and potential BOD penalties. In a non-experimental system with proper off-gas measures, the BOD to the wastewater facility could be greatly reduced. This area needs further study but is an excellent starting point to reduce water use and BOD levels. Based on the Strickland work and additional studies by the authors, a 40–60 % reduction in wastewater quantities and at least a 30% reduction in BOD levels can be expected. These expectations need to be substantiated.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions were drawn from the experiences and data in the previous sections. Production lines utilizing the FTNON equipment should be thoroughly investigated as methods of using ozone in tandem with a final chlorine rinse.

Items to consider for further research are:

- Pressure and feed rates on the FTNON units;
- Pre-wash methodologies need to be in place to wash dirt from incoming crops;
- Be certain that residence time for the product in the units to ensure the CT (concentration times time) values for the antimicrobial agents are not compromised (i.e., is the product in contact with ozone and then chlorine for sufficient time to ensure maximum microbial kill);
- Off-gassing of ozone and to a small extent chlorine, will need to be handled to reduce the problems;

- Filters may need to be added to ozone units to remove particulate and extend the life of the ozone units;
- Employee education will be essential to avoid off-gas exposure and keep chlorine from the ozonated water.

Water issues will need to be faced in the near future. Water costs, wastewater (sewer) fees and BOD penalties will soon become much more important to plant profit and loss. Potential steps to conserve water and reduce wastewater costs will include:

- Filtration and ozonation of water and waste streams to provide water reuse;
- Pretreatment of wastewater streams to reduce BOD levels;
- Pre-cleaning of incoming product to ensure clean products are going to production;
- Incentives for clean raw products delivered to the plant.

Through proper handling and ozonation of processing lines a plant could expect very safe food products and 35–65% savings in water use depending on the products being processed. These savings will not be easy to implement and thus, detailed plans and quality control measures for water use will need to be in place. Technologies are available but may need to be customized for specific operations.

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