# IOA-PAG USER SUCCESS REPORTS– COMMERCIAL APPLICATIONS OF OZONE IN AGRI-FOODS

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## ABSTRACT

The IOA/PAG Agri-Food Task Force (the AFTF) has developed a format for reporting user success experiences with ozone in the Agri-Foods sectors. Six User Success Reports (USRs) have been reviewed and approved by the AFTF, and these have been posted on the IOA web sites. Strikingly, one major benefit provided by ozone is a significant savings in costs to the user by replacement of other technologies that either cost more than ozone processes or that are more complicated or result in maintenance or product quality problems. Additional benefits include the expected extensions of shelf-life, reductions in spoilage, and improvements in product quality.

## KEY WORDS

Ozone, Case Studies, Fresh-Cut Salad Mixtures, Chiller Water at Cooked Food Packaging Plant, Spray Bar System at a Garlic Processing Plant, Apple Washing, Strawberries and Toppings, Onion Treatment and Storage, Potato Treatment and Storage, Treatment of Grain and Milled Flours, Improving Fish Quality, User Success Reports

## BACKGROUND

Prior to U.S. FDA approval in 2001 of ozone as an antimicrobial agent for direct contact with foods of all types (U.S. FDA, 2001), very few detailed case studies documenting more than anecdotal successes with ozone were available. Most of those available reports were not sufficiently comprehensive to be classified as complete Case Studies.

What constitutes a complete Case Study? Most scientists agree that the major characteristics of a Case Study should be conducted with the inclusion of at least the following major items:

- Conducted under controlled conditions
- Conducted in sufficient detail for review
- Written up and reported in detail
- Peer reviewed

Who are the peer reviewers for these Case Studies? Experts in the area of the study (food, agriculture, etc.) and ozone technologies. For the studies discussed in this paper, expertise for reviewing User Success Reports (Case Studies) is being provided by members of the IOA/PAG Agri-Food Task Force (the AFTF). This Task Force was formed in August 2003, at the IOA's 16th Ozone World Congress, in Las Vegas, NV. Over 100 task force members, located the world over, include experts in agriculture, food science, food processing, as well as ozone.

A major objective of the AFTF is to assemble and review case studies (USER SUCCESS REPORTS = USRs) of successful applications of ozone in the food and agriculture sectors. Approved USRs are posted on the IOA web sites – with links to original articles, where appropriate.

## FORMAT OF USER SUCCESS REPORTS

A formatting guideline for USRs, developed by and agreed to by task force members, contains the following items:

- Title of Case Study (USR)
- Abstract
- Description of Problem
- Description of Plant or Process
- Details of Ozone System and Application
- Case Study (USR) Information
    - Cost savings / Return on Investment (ROI)
    - Shelf-life extension
    - Reduction in spoilage
    - Improvement in product quality
    - Other synergies/additional benefits
- Employee Health & Safety Issues
- Submitter – Job title – contact details
- Reference – original article(s)
- Disclaimer

## AGRI-FOOD USRS APPROVED AND POSTED ON IOA WEB SITE

### Aqueous Ozone

The following USRs can be viewed on the IOA/PAG web site (www.io3a.org – click on Ozone User Success Reports, then click on any asterisked food application):

The following User Success Reports are nearing the final stages of approval by task force members. Each involves the use of ozone in the aqueous phase.

## Washing Fresh-Cut Salad Mixtures

Considerable water is used by fresh-cut salad producers and packagers to wash dirt, sand, and other soiling materials from the leafy raw materials. When the wash water becomes cloudy, or if microbial loads become "too high", the water is discharged. Prior to the approval of ozone by the U.S. FDA, fresh-cut salad producers were using chlorinated water (200 mg/L of chlorine).

With the aid of an EPRI (Electric Power Research Institute) grant, Strickland Produce Co., Nashville, TN, a southeastern USA fresh-cut salad mix and cut fruit producer replaced chlorinated water for rinsing with 0.5-1.5 mg/L ozone in rinse water, then followed the initial ozone/water rinse with a second rinse containing 100 mg/L of residual chlorine (less than the 200 mg/L that had been used before in the primary rinse bath). The following benefits of the combined ozonation-chlorination treatment have been reported (Garcia, 2001; Graham, 2002):

- Same log-reductions of microorganisms as when using chlorine-only washing
- Shelf-life of the product has been increased from 16 to 25 days
- Rinse water % transmission now averages 75%, vs 50% by the former process
- 50-60% less fresh water usage is now required, saving considerable cost
- Chlorine use has decreased
- Less wastewater effluent now must be discharged, due to increased water recycle.

Figure 1. Rinsing of fresh-cut produce at Strickland Produce Company (Graham, 2002).

At this meeting, Mr. Walter Strickland will present an update of Six Years of Ozone Processing of Fresh Cut Salad Mixtures (Strickland et al., 2007).

## Chiller Water at Cooked Food Packaging Plant

In this plant, bean dip, salsa, etc., are cooked, packaged in 5-8 lb lots in plastic bags, then chilled in a 5,000 gallon chiller tank, prior to crating and shipping. Prior to adoption of ozone, water in the chiller tank was drained every 1-7 days (due to contamination caused by spillage on the outside of the bags). The new chiller tank water treatment involves addition of 1.15 mg/L of ozone to tank water (replacing chlorine). Ozone-treated chiller tank water now is used for up to 6 months before drainage and replacement is required.

After its initial success with ozone in one process line, the company now has installed ozone systems in three of its packaging plants at a total cost of $70,000 (installed). Ozone has been reported by plant officials to save $10,600/yr in makeup water and maintenance costs over the prior water treatment system. This plant will receive an $11,000 grant from its city for water savings, which total more than 1 million gal/yr.

## Spray Bar System at a Garlic Processing Plant

This plant processes whole, peeled garlic, garlic purées and jalapeño pepper products, and a spray bar is a key item of processing equipment for rinsing of the garlic cloves. Prior to adopting ozone, sodium hypochlorite (NaOCl at 100-125 ppm) was used to maintain cleanliness of the spray bar rinse system. However, NaOCl caused many problems that have been overcome by changing to ozone:

1. NaOCl caused rapid pitting of the stainless steel rollers – this led to higher maintenance costs.
2. High TDS (total dissolved solids) from NaOCl treatment plugged the spray bars, corroding the feed pump and plumbing.
3. NaOCl was leaving a residual in the wastewater pond, which is located directly over a source water aquifer.
4. Granular activated carbon (GAC) scrubbing of air was required, to remove and destroy odors from 100-125 ppm NaOCl solutions.
5. NaOCl reacts with some organics, causing a strong ammonia odor, and has the potential for imparting a hypochlorite (or reaction product) residual on the plant product.
6. The NaOCl itself cost the plant $3,000/year
7. Maintenance costs for the system were $500 - $600/month.

Ozonation equipment installed included the following items:

- 20 g/h, variable output Corona Discharge generator (ClearWater Tech – HDO3)
- 15 SCFH oxygen generator, capable of 90%+ purity and -100 ˚ F dew point
- 1 hp, stainless steel booster pump; Kynar® injector; Back-flow prevention (J-break)
- Stainless steel contact vessel + vent valve
- Fully integrated dissolved ozone monitor
- Full instrumentation; System draws 1 kW/hour of electrical energy.

A 4-20 mA signal from the integrated dissolved ozone monitor controls output from the ozone generator. The system also includes a 10 gpm wash down wand and ambient ozone monitor to ensure safety of workers. Source water comes from a deep well on the property, and is fed directly to the HDO3 system at 20 psi. The HDO3 unit adds 1.3 ppm dissolved ozone to the water, which is fed directly to the spray bar at 13 gpm @ 20 psi. Spray heads on the spray bar were increased in size to accommodate the lower psi of the ozone system.

### Results – Attainment of Microbiological Goals

The ozone system produced an overall 20-30% reduction in aerobic plate counts (APCs) (checked twice/month). This percentage reduction is not a full log. Both hypochlorite and ozone reduce the plate count levels from about 100,000/mL to 5,000/mL. The plant's requirement is plate count results below 10,000/mL. Thus, ozone (at 1.15 mg/L in spray water) is as efficient as hypochlorite (at 100-125 ppm) in the old process.

### Results – Equipment and Maintenance

Maintenance costs have been reduced and pitting of the stainless steel rollers has been eliminated. Spray bar plugging (formerly caused by the high TDS of sodium hypochlorite) and corrosion have been eliminated. This saves the plant $500-$600/month in materials and maintenance costs. The air scrubbing system has been shut down completely, saving approx. $150/month in additional operating and maintenance costs.

Annual maintenance costs for the ozonation system are estimated at about $450, less than the maintenance costs for one month with the former hypochlorite system.

### Results – Wastewater Effects

Wastewater from the spray bar system now contains less than 1 ppm of sodium hypochlorite (too low to produce a residual in the wastewater pond).

### Results – Improved Product Quality

Because of the replacement by ozone, there is no potential for hypochlorite-derived chemical residuals on the plant garlic product.

### Results – Improved Process Reliability

The company reports more consistent sanitation results from ozone, with reduced system maintenance requirements.

### Results – Easier Product Marketing

The current product now is easier to be certified as "organic" per the USDA/NOP (National Organic Program) Final Rule, Subsection 205.605, using ozone, which is an allowed ingredient used in or on an organic product (garlic coming to the plant from the field).

### Results – Cost Savings / Return on Investment

Prior to installing ozone, chemical costs for NaOCl totaled $3,000 annually. Maintenance costs for the hypochlorite system were $500-$600 per month (average $550/mo), and the air scrubbing system cost $150/month to operate. These costs ($700/mo = $8,400 annually, plus $3,000 for the NaOCl = $11,400) were eliminated when the ozonation system was installed.

The ozonation system cost $16,500, plus $2,500 for installation (total = $19,000). First year savings to the plant totaled $11,400. On this basis, the return on investment is estimated to be about 17 months.

### Results – Employee Health and Safety

By its nature, garlic processing requires a good deal of ventilation to protect the plant workers. Garlic odors react rapidly with ozone in the ambient air. Since garlic odor levels in the plant are quite high, any stray ozone is quickly quenched. Nevertheless, a wall-mounted ambient ozone monitor checks to ensure that ambient ozone levels, if any, are far below OSHA requirements.

### Results – Additional Plant Management Comments

Plant management is so pleased with the replacement of hypochlorite with ozone, that they plan to use the ozone system for equipment wash down and hard surface cleaning (a 10 gpm spray wand is in place). Ozone also is being considered for spray bar rinsing in the jalapeño pepper processing line and for garlic purée processing.

## Strawberries and Toppings

A California strawberry packager also makes strawberry toppings for nationwide distribution. Since June 1998, this firm has been washing incoming strawberries with water containing an average of 2.7 mg/L of ozone. This new washing process controls *E. coli*, coliforms, standard plate counts (SPC), and yeasts and molds, thus prolonging the shelf-life of the berries. Typical performance data are: SPC organisms – 17,767 lowered to 987/mL; Yeast/mold lowered – 56,500 to 1,304.

## AGRI-FOOD USRs – GASEOUS OZONE

The following User Success Reports have been reviewed approval by task force members and have been posted on the IOA/PAG web site (www.io3a.org). Each involves the use of ozone in the gaseous phase.

### Storage of Harvested Onions

A West Coast onion grower tested ozone on part of his 2003 crop. Bulk storage of onions increases problems caused by storage diseases, especially "neck rot" (explained below). If storing onions in ozone-containing air can mitigate the effects of storage diseases, considerable savings can accrue to the onion farmer.

"Neck Rot" is caused by a fungus that spreads quickly from onion to onion, regardless of whether the onions are stored in boxes, bags or piled atop each other. The fungus takes hold primarily at the neck of the onion, therefore the name, neck rot. Onions surrounding a source onion and stored normally (without ozone) quickly become soft and rotten.

The West coast onion grower found that although ozone did nothing to control neck rot in source onions, after ozone treatment and storage, the onions surrounding source onions were not infected.

### Expectations For the 2003 Crop – Without Ozone Treatment and Storage

Some 240,000 bags of onions from the 2003 crop were stored in a single shed; 158,500 bags of these came from a single field. About 30% of the 158,500 bags were contaminated with decay and neck rot. Without ozone treatment, only 20-30% of these contaminated bags were expected to result in marketable onions, at best. At worst, the entire stored volume of onions might have been lost had nothing been done to change the expected outcome (ozone was applied).

### The Ozone Treatment and Storage Approach

Figure 2 shows a schematic diagram of the initial treatment of washed onions being exposed to about 300 ppm in a specially hooded conveyer belt (the O3Co O3Zone Tunnel – Figure 3) for 15-30 seconds. Then, after the ozone-exposed onions had been placed in storage, a second, prolonged exposure to ozone (1~2.5 ppm) over the several months of storage was conducted using the same ozonation unit initially connected to the O3Zone Tunnel.

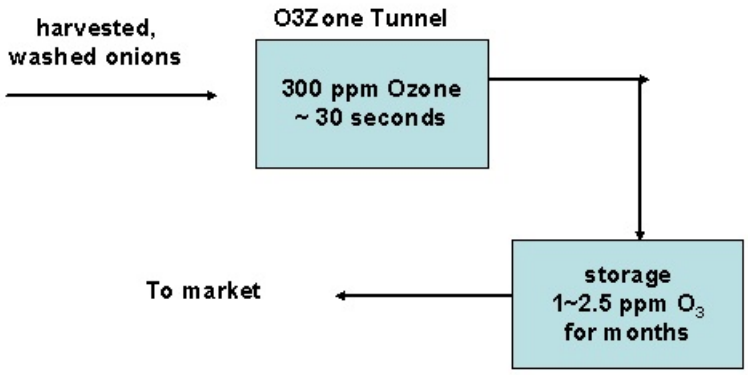


**Figure 2. Schematic diagram of gas phase ozone treatment and storage process.**

Figure 3. The O3Co O3Zone Tunnel.

Ozone is generated by corona discharge from ambient air dried to - 65˚F dew point – 60 g/h (3 lbs/day), and is produced at about 1.7 % by weight.

### Benefits of Ozone Treatment and Storage

Had the contents of the storage shed not been treated with ozone and had the crop been lost to mold/fungus growth during storage, the LOSS in marketable onions would have amounted to ca $750,000. If only the single field lot been lost to rot, the crop value would have been ca $300,000. Without ozone treatment, only some 30% of the 158,000 bags (47,550 bags) of onions were expected

to be marketable. Instead, ozone treatment resulted in an additional 55,500 bags of onions being marketable at an additional income of $166,500.

The capital cost of the O3Co Ozone Tunnel was $116,000, including ozone generation and control equipment. Operating costs are low. One lb of ozone requires 10 to 15 kWh for its production. The O3Zone Tunnel unit produces ca 3 lbs of ozone per day. At $0.10/kWh x 15 kWh x 24 h x 3 lbs/day, this equates to $108/day = ca $20,000 over 6 months. Total ozone cost = $138,000.

The extra income ($166,500) from this one crop alone more than paid for the ozonation equipment and its operating cost, and is now being used on subsequent crops of stored onions.

### Potato Treatment and Storage

Two potato growers reported information on the use of the O3Zone Tunnel to treat and store potatoes by techniques similar to those used for onion storage. Washed potatoes are exposed to 300 ppm ozone in O3Zone Tunnel (15-30 sec). Once in storage, ozone levels are maintained at 1~2.5 ppm for months. Ozone treatment and storage was found to eliminate the spread of "pink rot", caused by mold species.

The O3Zone Tunnel cost $116,000 – Potato savings for Grower #1 were $306,000 for his single crop. Potato savings for Grower #2 (in a different part of the country) were $240,000.

### Ozone Treatment of Grain and Milled Flour

A Midwestern flour milling company evaluated ozone (with assistance of a grant from EPRI) to provide an alternative antimicrobial agent to its former use of chlorine. The objectives of the study were to reduce microbial counts of flour and reduce levels of *E. coli*, using a system able to apply the antimicrobial agent in a continuous, automatic application with on-line electronic controls.

The system selected was provided by RGF Industries, and involves UV lights capable of generating both the biocidal wavelength (254 nm) and the ozone-generating wavelength (185 nm). Figure 4 (a) shows the UV-Ozone hood system. Figure 4 (b) shows the system with the hood opened and showing how the flour being processed is circulated and exposed to both ozone and UV radiation.

### Results – Old Treatment (Chlorination) vs New Treatment (UV/Ozone)

Base line microbial counts on chlorinated flour from 58 carloads showed an average APC (aerobic plate count) of 109,000 to 224,000/g. On flour from 84 carloads of UV/ozone-treated flour, the average APC was 26,000 to 77,000/g. Two more recent tests (UV/ozone-treated flour) showed zero APC counts.


Figure 4a. UV/Ozone hood

Figure 4b. UV/Ozone hood – opened

## USER SUCCESS REPORTS IN PROCESS

Several additional USRs are "in process" and are expected to be ready shortly to submit to members of the Agri-Food Task Force for review and approval. These include :

Ozone for Fresh Cut Salads, Vegetables and Fruit – Strickland Produce, Nashville, TN
Ozone Packaging of Fresh Fish – Fresher Than Fresh, Gastonia, NC
Ozone Uses at Cakebread Cellars – Cakebread Cellars, Rutherford, CA
Ozone for Ready-to-Eat Meats – Silver Star Meats, Pennsylvania

In addition, several USRs are in the initial stages of preparation, including Plumrose Meats, Baloian Farms, Sierra Nevada Brewery, and several others.

Other candidate commercially successful applications for ozone will be welcomed for entry into the IOA/PAG USR review process for eventual approval and posting on the IOA/PAG web site. Please contact me with questions and initial submissions.

## SUMMARY

Although only a few complete case studies existed when the IOA/PAG User Success Report project was initiated in 2003, those available showed significant benefits of ozone treatment. In most cases, ozone is providing cost savings to users, in addition to the anticipated increased shelf-lives, reduction in spoilage and improved product qualities. Users of ozone systems also report greater protection of health and safety of plant workers (compared to technologies replaced by ozone).

IOA's Agri-Food Task Force has posted six User Success Reports on the IOA web site. These posted USRs include onion and potato storage, grain milling, food processing plant chiller water, and a garlic processing plant spray bar rinse system.

Four additional USRs are close to being ready to submit to the Task Force Members for review, and three more are in the initial stages. Additional submissions are welcomed at any time.

There is plenty of room on the IOA Task Forces for interested parties to participate and help promote the uses of ozone in the Ag-Food sectors. Come join the IOA and work with us!! The Agri-Food Task Force meets twice each year, usually just preceding a significant ozone meeting. The most recent meeting was Sunday, April 1, 2007, and the next Task Force meeting will be held in August 2007, in Los Angeles, on the occasion of the joint IOA/IUVA World Congress.

## REFERENCES


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