Ozone and UV for Grain Milling Systems

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Final Report, December 2000

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REPORT SUMMARY

Background

Recognizing the current concerns with food safety, First Energy Services and EPRI collaborated in a project to investigate the feasibility of using ozone as a substitute for chlorinated water to control bacteria and mold at the Harvest States Amber Milling facility in Huron, Ohio. Traditionally, chlorinated water is used to control bacterial and mold in grain processing. Since chlorine usage can be costly and because chlorine presents problems in storage and safe handling of chlorine gas, the project participants chose to test the effectiveness of substituting ozone and UV for chlorine in controlling organisms in grain steeping and storage. To conduct this project, RGF Environmental Group designed the system and supplied the equipment.

Objectives

The objectives of this project were:

- Utilize ozone in steeping water for the hydration of wheat to 15% moisture prior to milling to flour
- Reduce microbiological activities in steeped and hydrated wheat
- Reduce micro-organisms in the milling facilities and wheat or flour products treated with ozone and UV

Approach

A plant survey of the existing process at the Huron, Ohio facility was conducted in 1999. In early 2000, a Tailored Collaboration project began with process design, equipment specification and installation performed by RGF. Testing of the ozonation/UV process began in May 2000 and continues to date.

The treatment system used in this study consists of ozone treatment supplemented by photo-ionization (UV), which delivers both ultra-violet light and ozone to create hydroxyl radicals for the control of microorganisms on grain and the processing equipment. The system has three major components:

1. A skid-mounted corona discharge ozonation system with a dry air feed to dissolve ozone in the water used to temper the grain

2. A stainless steel photo-ionization chamber mounted over the grain-mixing auger to supply UV light and UV-generated ozone

3. A generator to supply gaseous ozone in elevated concentrations to the grain storage tempering bin and the roll bin to suppress bacteria and mold growth

More than 1,000 ready-for-shipment flour samples were evaluated to determine the effectiveness of ozone treatment in the wheat grain milling process. Samples were tested for total plate count. To establish the base for comparison, 365 samples were taken from flour processed using traditional chlorinated water disinfection. The remaining 650 samples were taken from flour processed using ozone disinfection. Visual inspections were made to determine the effectiveness of ozone/UV for mold control as compared to the effectiveness of chlorinated water treatment. In addition to the microbial analysis and mold estimation, the study evaluated plant operation, using ozone/UV versus chlorinated water.

Results

Results of data gathered during the project indicate a potential 75 to 80 percent reduction in total plate count when ozone was used in place of the traditional chlorinated water treatment. Although the project did not include mold counts to quantify the effectiveness of ozone versus chlorine in mold abatement, visual inspection of equipment and processing lines indicates a similar reduction of mold growth in equipment. RGF, the equipment supplier, estimates a cost savings of about $40,000 per year using ozonation and UV in place of chlorination. (Electrical costs to operate the ozone system are $0.18 per hour or approximately $1,600 per year, thus this rate of savings would pay out the capital investment in the ozonation and UV equipment in 30 months).

It should be noted that this analysis does not include the potential of additional savings from reduction in equipment maintenance and plant downtime previously required to remove mold from processing lines and equipment, and the costs for reprocessing grain which fails to meet microbial standards.

EPRI Perspective

EPRI’s Agriculture and Food Technology Alliance continues its goal to provide new cross-cutting electrotechnologies to its food and agriculture customers. Through the testing and evaluation of ozone in the food processing industry, and the recognition of ozone’s special abilities toward improving food safety and quality, the future of ozone use in the food industry is expected to expand rapidly.

Key Words

Ozone
UV
Food processing
Grain milling

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Ozone and UV for Grain Milling Systems

SUMMARY
The Electric Power Research Institute and First Energy Services have joined in a Tailored Collaboration Project to investigate the feasibility of using ozone as a substitute for chlorinated water for bacteria and mold control in a wheat processing plant. Microbiological test data of flour samples after milling show that the use of ozone results in a reduction in bacteria of approximately 75-80 percent compared with grain treated with chlorinated water. Visual inspection of equipment and lines indicates a similar reduction in mold growth. RGF Environmental Group provided the engineering design, manufacture, and installation of the ozonation equipment.

INTRODUCTION

Food safety is the most important concern confronting food processors today. This is particularly true in the grain milling industry where incoming grain carries contamination from the field and where the milling process itself creates environments conducive to the growth of mold and bacteria. Traditionally, chlorinated water is used to control bacteria and mold in grain processing. Chlorine, however, frequently carries its own cost concerns as well as problems in storage and the handling of chlorine gas.

This project investigates the feasibility of substituting ozone for chlorine in wheat milling. Ozone has strong antimicrobial qualities and does not leave a residue, as does chlorine. Although ozone has proven effective in disinfecting drinking water and wastewater, its effectiveness for controlling organisms in the food processing industry is just beginning to be recognized. Because of the importance of bacteria and mold control and the problems associated with chlorine, ozone is an excellent candidate for application to grain steeping and storage.

The project is a Tailored Collaboration effort between EPRI and First Energy Services to introduce and evaluate the use of ozone as an antimicrobial agent in grain milling. The other participants in the project are Harvest States Amber Milling of Huron, Ohio, and RGF Environmental Group, West Palm Beach, Florida. Harvest States operates the facility at which the test is being conducted. RGF Environmental Group was selected to design the ozonation system and supply the equipment.

BACKGROUND—GRAIN MILLING

Grain is produced by plants growing in open fields and, as such, arrives at a processing mill carrying some foreign matter in addition to plant leaves, dust, and stalks. The milling process separates the grain from the other material and grinds it into flour. Chlorinated water is used to control bacteria and mold during the process.

The grain milling process

Milling begins with the grain being mechanically separated from stalks and foreign matter. The next step is to increase the moisture content of the grain. This is necessary because hard wheat is too dry to grind into flour. Consequently, water is added to bring the grain's moisture content up from about 12 percent to approximately 15 percent (this latter number varies within the industry). Moisturization is done via automated temper systems, which are large augers that mix and move the grain while a carefully regulated stream of water is added. The test plant has three temper systems.

Chlorine is added to the water to control bacteria and mold which typically are present in the grain. At the test plant, 450 ppm of chlorinated water is applied at a flow rate of four gallons per minute in each temper system, or a total of 12 GPM for the three units together.

The temper systems convey the moistened grain into large concrete tempering tanks or bins, which are approximately 45' high and 8' in diameter. The grain flows continuously, and residence time in the bins is approximately 18 to 24 hours, which allows the water to be absorbed. Next the grain is conveyed through tubes to the wheat rolling mill where the grain is abraded to loosen the bran, which then is separated by sifters and air purifiers. The grinding continues until the grain reaches the proper level of fineness, at which point it is packaged or shipped in bulk.

Tempering auger with UV/Ozone photo-ionization hood mounted

Problems with the current process

- Contamination of grain prior to and during processing
  Wheat and other grains collect dust, insects and other foreign matter—such as insects, soil, and feces—in the fields where they are grown. When the wheat is harvested, inevitably some foreign matter accompanies the grain and plant material. The grain is exposed to additional contamination from bacteria and foreign material through transportation vehicles, storage containers, fertilizers, rain, and moisture in the air. The result is a potentially high level of bacteria and mold on the pre-processed grain surfaces. Further exacerbating the problem is the necessary addition of water to the grain to increase its moisture content, creating warm, moist tempering conditions prior to milling. This moist grain supports growth of mold and bacteria. It is to combat these inherent problems of contamination that grain processors treat the grain with chlorinated water during the tempering process when water is added to the grain to increase its moisture content.

- Effectiveness of chlorine treatment
  Although problems of mold and bacteria in grain are traditionally addressed by the use of chlorinated water, this technique is frequently inadequate for removing these harmful materials. As a result, tempering bins, holding containers, and processing lines become contaminated and have to be cleaned. This requires complete shutdown of the plant and results in production and financial losses.

- Returned shipments
  In addition, elevated bacterial and mold counts sometimes cause final products to fail to meet client microbial standards. Returned shipments can cost up to $5,000 per rail car plus reprocessing costs.

- Other problems
  Chlorine is a reactive chemical and causes corrosion in metal parts in the mixing and grain transfer equipment. In addition it is a hazardous chemical to store and handle. Furthermore, chlorine chemically reacts with some materials and organics, and the resulting chlorinated compounds sometimes remain in the final product as a contaminant. Some of these compounds, known as trihalomethanes (THMs) have suspected carcinogenic properties.

BACKGROUND—OZONE IN FOOD PROCESSING

Ozone has long been used as an industrial chemical and for water and wastewater treatment. Recently, the food processing industry has begun exploring ways to apply ozone's special abilities toward improving food safety and quality.

Ozone (O_3)is a molecule composed of three oxygen atoms; in contrast ordinary oxygen (O_2) has only two oxygen atoms. Because of its atomic structure, ozone is an unstable gas that quickly decomposes into ordinary oxygen, regardless of whether it is in a gaseous state or dissolved in water. This tendency to naturally decompose makes ozone important as an antimicrobial agent. As ozone changes into oxygen, the extra oxygen atom splits off from each ozone molecule. These free oxygen atoms have two important characteristics: they are toxic to microorganisms, and they oxidize many chemical compounds, usually changing them into nontoxic substances.

Because ozone is a safe, powerful oxidizer, it can be used to control growth of unwanted microorganisms like bacteria and mold in food and beverage plants. In a water solution, ozone can be used to disinfect equipment, process water, and some food products. In gaseous form, ozone can help sanitize and assist in the preservation of some food products as well.

The conventional disinfectant in the food industry is chlorine. Ozone has three obvious advantages over chlorine:

- Efficacy
  Ozone is much more effective than conventional disinfectants against such notorious organisms as *Salmonella, Giardia, E. coli*, and *Cryptosporidium*, so the motivation of the food industry to adopt ozone is great.

- Safety
  Gaseous chlorine and chlorine solutions are dangerous to transport, store, and use. Ozone eliminates each of these problems. Because it is generated on site at the point of application, it does not have to be either transported or stored. While ozone is toxic in high concentrations, it is easier to handle than chlorine and degrades rapidly. As a result, properly designed ozone treatment systems are inherently safer than chlorine systems.

- No byproducts
  Ozone has the ability to eliminate microorganisms without leaving residual chemical byproducts in the food or liquid being treated, or in the processing water or atmosphere in which foods are stored. In contrast, the presence of toxic residues of chlorine and halogenated organic chemicals is a serious problem associated with chlorine disinfection. In fact, the US Environmental Protection Agency (EPA) is proposing regulations that would set lower maximum levels for halogenated organic chemicals in drinking water. Once these regulations have been established by the EPA, the US Food and Drug Administration (FDA) is mandated to adopt these same regulations for food products within one year. Since ozone disinfection does not use chlorine, it does not create halogenated byproducts.

Until recently, the food processing industry limited its use of ozone mainly to the treatment of bottled water and of wastewater because ozone was not approved by the FDA for food applications. In 1997, however, the situation changed. An Expert Panel convened by the Electric Power Research Institute reviewed the history, use, and safety of ozone, and declared ozone to be “Generally Recognized As Safe” (GRAS) as a sanitizer and disinfectant for foods. Because ozone is an effective antimicrobial agent leaving few or no toxic chemical residues or unpleasant tastes or odor in treated food, the GRAS declaration has been a catalyst for the food industry to adopt ozone technology.

Ozone generator cabinet in left center with control system skid on right. Grey boxes on right of control skid are ozone monitoring and metering devices.

DESCRIPTION OF PROJECT

The project tested the effectiveness of ozone as an antimicrobial agent for flour milling. Ozone was used in three ways in the project:

- in steeping water applied to wheat during the flour milling process
- in its gaseous phase in conjunction with UV light and hydroxyl radicals during tempering
- in its gaseous phase as a facility-cleaning agent for further bacteria and mold control

A plant survey and evaluation of the existing process was made in 1999. The project began early in 2000 with process design, equipment specification, and installation performed by RGF. Testing of the ozonation process began in May 2000 and continues at the time this report is being prepared.

Project tasks

The project comprises the following steps:

1. Establish baseline microbiological data for the existing steeping process that uses chlorine for disinfection.
2. Select ozone equipment vendor. Purchase and install ozone generation and associated equipment, e.g., UV photo-ionization system, dry air feed system, ozone monitors, ozone destruction unit, and ozone injection system.
3. Begin ozone injection and monitor microorganism levels in steeping water. Adjust system parameters to optimize disinfection and steeping operation.
4. Contingent on time and budget, conduct a preliminary assessment of the potential use of ozone as a gaseous phase sterilizing agent for wheat storage and facility cleaning applications.
5. Develop a final report and technology transfer materials documenting project activities and results.

Dry air feed skid supplies 90 percent pure oxygen to ozone generator

OZONATION AND ASSOCIATED EQUIPMENT USED IN PROJECT

The treatment system used in the study consists of ozone treatment supplemented by photo-ionization, delivering both ultra-violet light and ozone to create hydroxyl radicals for the control of microorganisms, mold, and yeast on the wheat grain and the processing equipment. The system has three major components.

- A skid-mounted corona-discharge ozonation system with a dry air feed to dissolve ozone in the water used to temper the grain.

This system is placed adjacent to the existing water tank. It is sized to provide sufficient ozone for 12 to 15 GPM—4 GPM for each of the three temper systems, even though presently it is used to supply only one tempering auger during the study. The major components of the system include a corona discharge ozone generator with pressure swing adsorption air drying system, venturi mixer, chlorine destruction filter, ozone destruction for ozone off gas, re-circulating stainless steel pump/motor assembly, and pressurized contact vessel. An integrated dual metering system is used to measure and control the levels of dissolved ozone in the water and to measure and control the levels of ozone present in the ambient air.

- A stainless steel photo-ionization chamber mounted over the grain-mixing auger to supply UV light and UV-generated ozone.

The purpose of this combined system is to create hydroxyl radicals to attack the surface of the grain. The ionization hood consists of a series of UV/ozone emitters shrouded for protection in a FDA-approved plasticized shroud targeted on titanium dioxide compound ($Ti\ O_2$). The hoods are hinge-mounted to the top of the existing temper augers and employ a safety system to automatically shut down the lamps if the hood is opened by plant personnel.

- A generator to supply gaseous ozone in elevated concentrations to the grain storage tempering bin and the roll bin to suppress bacteria and mold growth.

A dry air fed corona discharge system generates the ozone gas and delivers it to the application points via Teflon tubing. It too is accompanied by a dual metering system to monitor ozone levels in the bin as well as in ambient air surrounding the bins.

Photo-ionization hood in “off“ position mounted over temper bin. Note UV/ozone emitter tubes and grain being rapidly mixed by the auger.

EVALUATION AND DATA GATHERING PROCESS

To determine the effectiveness of ozone treatment in this wheat grain milling, more than 1,000 samples of flour ready for shipment were evaluated. These samples were tested for total plate count bacteria. To establish a base of comparison, 365 of the samples were taken from flour processed using traditional chlorinated water disinfection. The remaining 650 samples were taken from flour processed using ozone disinfection. Table 1 in the Appendix shows bacteria aerobic plate count prior to ozonation treatment, using the chlorinated water system, while Table 2 shows bacterial counts using the ozonation system.

Because the Harvest States plant doesn’t perform mold counts, visual inspections were used to determine the effectiveness of ozone for mold control in comparison to chlorinated water. In addition to microbial analysis and mold estimation, the study evaluated operation of the plant using ozone versus chlorinated water.

RESULTS

Antimicrobial Action

Data gathered during the project indicate a potential 75 to 80 percent reduction in total plate count bacteria in comparison to conventional treatment with chlorinated water. The average anaerobic plate count (APC) of one group of flour samples from grain treated with chlorinated water average 181,675 cfu/g. In comparison, the average APC for flour from ozone-treated grain is 42,627 cfu/g, a reduction of 77 percent. More recent data on 195 samples of flour processed during late July and August had 75 lots (38%) with APC of less than 10,000 cfu per gram.

Although, the project did not include mold counts to quantify the effectiveness of ozone over chlorine in mold abatement, visual inspection of equipment and lines by plant staff indicates a similar reduction of mold growth in the equipment.

Economic analysis

According to RGF, the company supplying ozonation and UV equipment for the project, there is a cost savings of about $40,000 per year by using ozonation and UV in place of chlorination. (Electrical costs to operate the ozone system are $0.18 per hour or approximately $1,600 per year.) This rate of savings would pay out the capital investment in the ozonation and UV equipment in 30 months.

This analysis does not include potential additional savings from some reduction in maintenance and plant downtime previously needed to remove mold from lines and equipment, and costs for reprocessing grain failing to meet microbial standards.

OTHER ISSUES

Safety

The levels of ozone in the work place at the points of application are monitored by ambient ozone monitors designed to effect complete system shutdown where excess levels of ozone are sensed.

Equipment compatibility

The ozone system is located on the top floor of the flour mill near the existing chlorine tank. The ozone gas and water plumbing go to the floor below where the grain processing and storage equipment are located. The ozonation system is completely independent of the plant chlorine system so the plant still has access to this method of sanitation.

NEXT STEPS

Testing of the ozone system at the Harvest States plant continues. One of the areas being investigated in the efficacy of ozonation for a range of aerobic plate count bacteria levels in the incoming grain.

The future of ozone in the food industry is expected to expand rapidly with anticipated FDA and USDA approvals for ozone contact with food products.

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APPENDIX

Table 1: Bacteria Aerobic Plate Count (cfu/g) Prior to Ozonation Treatment.
March and April 2000

SAMPLE	APC 1	APC 2	APC 3	APC 4	APC 5
1	79000	350000	180000	62000	73000
2	57000	37000	40000	58000	53000
3	100000	350000	260000	110000	24000
4	100000	100000	110000	61000	85000
5	540000	730000	1000000	1000000	33000
6	100000	100000	47000	210000	36000
7	39000	16000	12000	260000	29000
8	320000	380000	200000	170000	51000
9	230000	280000	350000	240000	31000
10	240000	190000	210000	>2500000	23000
11	31000	18000	55000	55000	31000
12	52000	30000	32000	39000	66000
13	25000	25000	23000	25000	29000
14	36000	23000	25000	18000	27000
15	310000	240000	190000	180000	24000
16	>2500000	220000	180000	190000	22000
17	260000	190000	290000	210000	28000
18	300000	250000	220000	270000	26000
19	>2500000	330000	280000	170000	20000
20	180000	86000	320000	260000	28000
21	210000	220000	210000	240000	23000
22	220000	320000	450000	480000	39000
23	250000	430000	360000	360000	44000
24	19000	24000	21000	22000	29000
25	650000	390000	520000	560000	54000
26	310000	230000	210000	220000	36000
27	>2500000	1100000	>2500000	>2500000	13000
28	570000	440000	490000	>2500000	>2500000
29	>2500000	280000	>2500000	>2500000	>2500000
30	320000	270000	320000	>2500000	19000

SAMPLE	APC 1	APC 2	APC 3	APC 4	APC 5
31	190000	>2500000	240000	260000	27000
32	4200	2200	3500	7800	36000
33	2700	2200	3900	4500	6800
34	6600	2300	12000	6700	12000
35	9200	5300	21000	60000	11000
36	14000	10000	3800	81000	8900
37	8800	9100	5200	5900	5300
38	320000	5200	10000	56000	54000
39	100000	65000	110000	78000	6200
40	510000	410000	510000	1300000	32000
41	25000	56000	55000	25000	55000
42	74000	72000	82000	13000	11000
43	8600	85000	100000	13000	55000
44	5600	82000	5600	96000	44000
45	13000	5800	3600	4900	12000
46	37000	9300	11000	6800	7800
47	69000	7800	4900	5200	5300
48	49000	66000	70000	62000	67000
49	64000	69000	73000	78000	11000
50	210000	38000	230000	34000	49000
51	210000	23000	38000	110000	19000
52	42000	42000	90000	56000	12000
53	33000	8500	9300	11000	9500
54	82000	57000	69000	52000	5000
55	44000	6600	6700	5300	8300
56	52000	48000	42000	8500	8200
57	70000	44000	100000	420000	85000
58	4800	5200	6100	6600	45000
59	48000	64000	230000	160000	10000
60	21000	31000	93000	48000	19000
61	180000	200000	75000	81000	73000
62	1600000	1600000	>2500000	>2500000	>2500000
63	6200	>2500000	33000	390000	26000

Table 2: Bacteria Aerobic Plate Count (cfu/g) After Ozonation Treatment. May-July

SAMPLE	APC 1	APC 2	APC 3	APC 4	APC 5
1	4500	4700	5200	5500	4800
2	46000	37000	49000	49000	7600
3	3600	7200	8600	7700	5600
4	7800	6200	6800	5900	48000
5	51000	62000	47000	11000	25000
6	240000	300000	320000	68000	610000
7	1100	32000	22000	7400	46000
8	13000	16000	5700	5600	6100
9	33000	14000	40000	5800	25000
10	42000	30000	45000	52000	8300
11	1300	5200	4400	12000	9300
12	4900	9800	39000	5800	3100
13	21000	10000	9300	2700	38000
14	12000	10000	45000	10000	43000
15	190000	52000	230000	180000	180000
16	270000	310000	44000	250000	270000
17	31000	6100	20000	4300	25000
18	22000	23000	12000	3900	29000
19	520000	55000	110000	83000	72000
20	12000	46000	37000	230000	48000
21	37000	35000	36000	500000	9600
22	36000	48000	4900	70000	19000
23	84000	38000	260000	97000	79000
24	63000	70000	110000	83000	66000
25	19000	26000	19000	24000	22000
26	21000	23000	2200	170000	25000
27	64000	5600	82000	43000	4100
28	4300	6200	7800	5000	6400
29	10000	4300	3700	5200	8000
30	200000	210000	170000	250000	170000
31	250000	23000	210000	200000	16000
32	59000	200000	240000	20000	220000
33	39000	88000	450000	27000	23000

SAMPLE	APC 1	APC 2	APC 3	APC 4	APC 5
34	430000	39000	160000	270000	180000
35	29000	230000	210000	160000	220000
36	22000	21000	24000	23000	42000
37	21000	31000	26000	310000	21000
38	4800	26000	24000	26000	24000
39	26000	2400	4500	1700	26000
40	13000	9600	9200	10000	8800
41	440000	270000	260000	540000	220000
42	280000	210000	280000	360000	340000
43	220000	29000	21000	260000	22000
44	20000	27000	72000	42000	210000
45	23000	22000	24000	25000	26000
46	7600	2600	31000	5200	4100
47	470000	210000	240000	440000	850000
48	230000	240000	240000	260000	440000
49	160000	120000	73000	87000	96000
50	22000	5000	13000	7000	21000
51	26000	5600	41000	54000	35000
52	7300	9100	8300	2700	30000
53	12000	22000	15000	5300	28000
54	23000	19000	21000	16000	16000
55	27000	3500	2400	4500	2600
56	4600	9200	10000	12000	7700
57	4200	2200	3200	1900	3600
58	210000	24000	220000	180000	26000
59	23000	17000	16000	19000	20000
60	23000	19000	22000	21000	16000
61	4000	5000	2800	3100	4200
62	31000	6000	6100	18000	31000
63	5300	4000	20000	8500	14000
64	15000	31000	8600	7200	26000
65	31000	32000	33000	51000	8100
66	4100	17000	31000	7100	4100
67	26000	29000	19000	29000	12000

SAMPLE	APC 1	APC 2	APC 3	APC 4	APC 5
68	36000	11000	44000	84000	7400
69	36000	3900	3300	2400	5600
70	9600	15000	6800	12000	3500
71	21000	23000	2600	160000	21000
72	240000	360000	260000	230000	260000
73	31000	38000	57000	23000	28000
74	25000	36000	38000	49000	46000
75	21000	26000	16000	26000	8500
76	5200	3500	6700	2600	2900
77	100000	100000	20000	93000	
78	1600	7100	7400	2100	
79	3200	1900	1300	5000	
80	100000	83000	81000	70000	