Ozone Applications in Catfish Processing

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Abstract

TVA, EPRI, Global Energy Partners, LLC, ClearWater Tech, LLC and Superior Catfish Products (Macon, Mississippi) partnered to conduct research and demonstrate beneficial effects of applying gaseous and aqueous ozone in catfish processing. Utilizing an HDO_3-III skid mounted ozone unit manufactured by ClearWater Tech, LLC, various processing areas in the Superior Fish Products catfish processing plant were evaluated in August 2005 to determine if aqueous ozone could reduce the microbial load in the processing line and on finished product. In the offal room, gaseous ozone was introduced to determine if odors could be reduced while catfish byproducts were being loaded into trucks also located in the in the offal room. The utilization of aqueous ozone as a final rinse for processing equipment was also tested.

All tests were replicated five times and a completely randomized design was used to statistically analyze resulting data. Standard Laboratories, Inc. of Starkville, MS was contracted to conduct all microbial analyses.

It was found that aqueous ozone was very effective in significantly reducing microbial loads on live catfish entering the plant. Finished catfish fillets washed in ozonated water showed significant reductions in total plate counts. Ozonation at the fillet machine could be beneficial. Utilizing aqueous ozone as a final wash after using soap and a chlorine sanitizer was of no benefit and actually removed the residual chlorine and led to

increased plate counts. Gaseous ozone reduced odors in the offal room rapidly and effectively. Utilization of ozone for odor reductions will require ozone monitoring equipment that ensures employee safety.

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INTRODUCTION

Background

Catfish production and processing is a major Agri-Food industry in the Southeast U.S. Alabama, Arkansas, Louisiana and Mississippi are the leading states in both production and processing. Of these four states, Mississippi is the leading producer and processor. This major Agri-Food Industry began in the 1960's and like the poultry industry is becoming a very integrated process. Production costs for the live catfish comprises a major portion of the total production costs. Processing facilities are highly mechanized modern plants with holding facilities, fillet machines, IQF facilities, cold and frozen storage and waste facilities that are capital intensive. Dean and Hanson (1) estimate that a 50,000 pound per day processing facility will realize $0.16/lb profit per pound of product sold. As the industry grows, this margin which barely covers depreciation and interest on investment could shrink even further. Without technology advances that reduce production and processing costs, there will be a general reduction in the number of processors.

Publications and technology transfer materials for both production and processing are readily available from the major land grant universities in the production states. Websites for these publications and technology transfer materials are listed in the Appendix. In addition to production and processing technology transfer materials, NASS (National Agricultural Statistics Service) Http://nass.com provides and updates production volumes annually or more often as new information appears.

The production and processing industries are attaining maturity and margins are often low. There is very little room for mistakes that can lead to either reduced production or quality. Producers are continually seeking ways to reduce production costs (fingerlings, feed and production labor) while processors are concerned about raw product prices (live catfish), labor and processing costs such as packaging materials, cold storage and waste disposal costs. A major concern with processors is food product safety and quality. Food poisoning outbreaks caused by organisms such as E.coli, and/or *Salmonella* can require production stoppages and recalls and can even force an operation into bankruptcy. To ensure that food poisoning outbreaks do not happen, catfish processors are continually looking for new technologies that will safely remove or reduce microbial levels and provide a safe product.

The following terms are included to keep equipment manufacturers, cleaning supply sales personnel, and food safety workers "on the same page". Processing facilities that advertise the use of sanitizing procedures or agents should be certain that their product meets these definitions as the USDA Food Inspection Service is strict about the use of these terms.

S*terilizers, sanitizers and antimicrobial agents* are defined as follows:

- *Sterilize or Sterilizers* – Technologies or techniques that totally remove microorganisms from a food product (e.g. heat, radiation and ultra-high pressure)
- *Sanitize or Sanitizers* - Technologies or techniques that consistently produce at least a five log reduction in microorganism populations in a food product (products that usually
- contain peroxides and/or chlorides and have been proven to provide five log microbe reductions)

- *Antimicrobial Agents* – Technologies or techniques that provide at least a two log reduction in microorganism populations in a food product (e.g. ozone, pressure washing, etc.)

Table 1 provides some common technologies that are used to provide measures of food safety in manufacturing processes. Only those technologies that are considered to be even remotely connected to catfish processing are listed along with their classification and comments.

In summarizing Table 1, it can be concluded that there are several technologies capable of reducing microbial levels in catfish processing plants. Once the high capital cost processes such as radiation and ultra-high pressure are discounted, most plant managers will quickly conclude that they are faced with utilizing steam, hot water, high pressure water, detergents and chemicals such as chlorine bleach and peroxide to wash, clean and sanitize processing facilities. After properly cleaning the facilities, employing rinses utilizing chlorinated water or ozonated water may further enhance product safety and shelf life. The effectiveness of these treatments should always be substantiated and followed by a laboratory that utilizes accepted procedures and follows microbial populations in both the plant and on finished products. Most plants have their own laboratory routinely performing tests of facilities and determining the safety of products being shipped. Often an independent laboratory is employed to test in-house procedures and provide backup test results as needed.

The utilization of chlorine in processing plants is common with levels up to over 100ppm found in vegetable processing plants. Chlorine at these levels will provide antimicrobial protection. It will also cause a strong chlorine odor in the plant, employee discomfort (eyes and nose burning) and can cause off-flavors in meat and fish products. These factors coupled with the recent finds of the harmful effects of trihalomethanes, has made high levels of chlorine unpopular in processing plants. In vegetable plants it is often used with ozone treatments to provide residual antimicrobial effects while ozone destroys the microorganisms.

Unfavorable reports about the use of chlorine in food processing have led to a growing number of investigations into the use of ozone in food processing. Most of these investigations are summarized in the *EPRI/Global Ozone Handbook* (2) compiled by Arzbeacher, Parameter and Sopher. Generally, it has been found that the utilization of ozone in food processing systems provides antimicrobial protection and enhances shelf life of treated fresh products.

Table 1. Technologies that may be employed to remove or reduce microbial populations in catfish processing facilities

Technology	Classification	Comments
Heat	Sterilizer, Sanitizer and/or antimicrobial agent	In catfish processing, heat treatments such as hot water or steam are of value only as cleaning agents. Treatment of fresh products is not practical unless the processor is producing a "ready to eat" or RTE product
Radiation	Sterilizer	Excellent method for microbial control but capital costs is prohibitive. Consumer acceptance is usually not a problem. Worker safety could be a problem. May have potential for overseas shipments
Ultra-high Pressure	Sterilizer	Not presently used in fish processing but is being utilized in the poultry industry. Capital costs are very high. Preliminary results are very good and the process should work well on boneless fish parts
Chemical Washes	Usually Sanitizers	Few used in catfish processing but chemicals such as trisodium phosphate have been utilized in poultry processing. Testing will be required to ensure off-flavors are not present.
High Pressure Washes	Usually antimicrobial	Effective method of removing fish residues from concrete and processing equipment. Should always be used in conjunction with an on-site micro laboratory to ensure low microbial counts
Clean Water Rinsing	May or may not be Antimicrobial	Effective but can be expensive due to high water and wastewater costs
Chlorine	Antimicrobial	Effective in reducing microbial levels but can cause an irritating odor if used at high levels. Does provide residual effects but can generate trihalomethanes (THM's)
Ozone	Antimicrobial	Very effective oxidizer of microorganisms and organic compounds. Does not provide residual effects. Usually very few reaction byproducts. Cannot be used in conjunction with heat but does work well as an antimicrobial in ice machines found in fish processing facilities. Ozone may also be used in the future for odor control
UV Light	Antimicrobial	Emerging technology that could be coupled with ozone and water rinses. In the future, this technology could be utilized with existing ozone installations in catfish processing facilities
Soap and Water	Not classified	All of the above technologies will not substitute for Best Management Practices. Facility and equipment washing is always necessary

Silva, Kim, Chen and Gawborisut (3) in a paper presented at Ozone IV, March 2005, Fresno, California, reported less encouraging results after using ozone to treat fish products but indicated there was potential for the use of ozone in ice production and as a cleaning agent.

Although there is great interest in the use of ozone in catfish processing, there are numerous logistics problems. Equipment manufacturers are cautiously developing packaged systems to introduce ozone into catfish processing plants. This "one size fits all" or that a few standardized ozone systems will work in all types of plants has produced a mixture of results ranging from excellent to terrible. In visiting several catfish processing plants utilizing ozone, it has been observed that installations include improperly sized systems, unmaintained systems, improperly used systems and unsafe systems.

To demonstrate the use of ozone in catfish processing systems, Tedd Battles and David Salladay (later replaced by David Dinse) of TVA contracted with Global Energy Partners, LLC, a subsidiary of EPRI Solutions, Inc., to conduct an onsite demonstration of the use of ozone in a catfish processing plant. The demonstration was conducted at the Superior Fish Products facility in Macon, Mississippi. C&S AgriSystems, Inc. and ClearWater Tech, LLC provided planning, engineering and equipment for the project. Processes studied for this report were: the application of ozone on live fish as they entered the stun chamber, utilizing an ozonated wash on the fillet machines, washing finished fillets in ozonated water, cleaning equipment with ozonated water and demonstrating the effects of ozone to reduce odors in the offal room. The goals of the demonstration were to:

- Measure the effects of ozone as an oxidizing agent to reduce the microbial load brought into the plant by live catfish
- Determine if an ozonated water wash would reduce the microbial load on fillets coming from the fillet machine to the chiller
- Determine if a significant reduction in microbial load could be obtained by washing finished fillets in ozonated water
- Determine if ozone washing of equipment that had previously been cleaned utilizing Best Management Practices could further reduce microbial load
- Qualitatively evaluate the effect of gaseous ozone on air quality in the offal room

PROCEDURES

Preliminary Discussions

Superior Fish Products of Macon, Mississippi (hereafter Superior) has the capacity to process 50,000+ pounds of catfish during a one shift operation. The plant was selected for the demonstration because it is a newer plant that does not yet utilize ozone as an antimicrobial agent. The use of ozone was discussed with Mr. Harvey Nickel and Mr. Fred Johnson, Superior Plant Management, and TVA representatives, Tedd Battles and David Dinse. From these discussions, the following was summarized:

- Could ozone applications reduce microbial load in the processing plant, and at what points?
  - ❖ Incoming catfish
  - ❖ Selected portions of the processing line
  - ❖ Finished fillets
- Would washing equipment with ozonated water after scheduled daily cleaning provide additional protection?

- Could the odors be reduced in the offal room?
- Based on previous studies, it was determined that it would not be necessary to ozonate the IQF line as it would be ozonated if ozone equipment was determined feasible for use in the plant.
- Based on experience in poultry industry studies, it was decided not to ozonate the chiller water because the organic load and sugars in the chiller water could easily dissipate ozone levels. Since water use and wastewater disposal are not a problem at this time, cleaning of the chiller water was left for a future project.
- Superior does not have an on-site laboratory for Quality Control purposes.
- Both the Plant Management and TVA stressed that minimum production disruption would be very desirable.

The Demonstration Plan

Considering the physical layout of the plant and the results of the discussions outlined above with TVA and the Plant Management, plans for the following tests were developed:

1. Test for the possibility to reduce microbial load on incoming live fish
2. Test the potential for using an ozonated water wash on the fillet machine
3. Test for potential reductions in microbial load after washing finished fillets in ozonated water
4. Determine if reductions in microbial load could be obtained by using ozonated water to wash equipment after it had been cleaned by the cleaning crew
5. Test to see if gaseous ozone could be utilized to reduce the odor in the offal room

Materials and Methods

Laboratory Analyses: At the outset of the study it was determined that Standard Laboratories, Inc., Starkville, Mississippi would be contracted to conduct microbial analyses. Mr. Noel Hall, General Manager, Standard Laboratories, assisted with the development of sampling procedures. Surfaces were sampled by utilizing swabs placed in 25ml of buffered water after swabbing the surface. Fillets from both the fillet machine and the final product after the chiller were sampled by bagging whole fillets.

Live Fish Ozonation and Sampling: Live fish from the conveyor going to the plant were randomly selected and swabbed on both sides for microbial samples. A manifold was then placed over the conveyor. Ozonated water at 4.5 ppm ozone was passed over the fish for 10 seconds and five fish selected at random were swabbed for microbe samples.

Ozonation at the Fillet Machine: Although the fillet machine is operated with running water directed around the fillets, it is still a portion of the operation that can contain high amounts of fecal matter from ruptured intestines and is an area that contributes a high microbial load to the total microbial load of the plant.

Fillets from the fillet line were randomly selected and bagged for microbial analyses. Ozonated water (4.5 ppm ozone) was then directed on the fish moving thorough the line and random

samples were taken for microbial comparison with the untreated samples. All microbial load reductions at the fillet machines will provide cleaner chiller water and a lower microbial load on the fish products.

Ozone treatment of the Final Fillets from the Chiller: Applying ozonated water to fillets from the chiller presented a problem because the fillets from the chiller are dumped on the final grading belt in small piles of about 3-5 lbs These piles do not allow for the fillets to come in contact with the ozonated water. To overcome this problem, a tote was cleaned and rinsed with ozonated water and the fillets were rinsed under a stream of ozonated water from the ozone generator. All fillets were given a 10 second wash in ozonated water at 22-25psi. An ozone level of 4.5ppm was used.

Washing of Equipment after Daily Cleaning: Mr. Fred Johnson of Superior requested ozone be tested as a final rinse for equipment cleaned after each daily production cycle. Three areas of production were chosen for the test: cutting boards, final sorting conveyor and fillet sorter for the final product. Each area was swabbed after cleaning and then rinsed 10 seconds with ozonated water at 5.0ppm ozone and swab samples were again taken. The cleaning operation utilizes a soap that contains chlorine and also uses a final "sanitizing" rinse that contains chlorine. Residual chlorine is present in the plant and on the equipment after cleaning. For this reason, unpredictable results were expected. For each treatment on each piece of equipment, five samples were taken.

All aqueous ozonation treatments were made utilizing an HDO_3-III ozonation system from Clearwater Tech, LLC. An oxygen generator in conjunction with the system was utilized as an oxygen source. Untreated well water was utilized as the water source.

Ozonation of the Offal Room: Treatment of this room was a simple demonstration of how ozone can destroy odors. The oxygen generator utilized for aqueous ozone was switched to an air dryer and gaseous ozone was piped into the offal room utilizing tygon tubing. The generator was operated for two 15 minute periods. The ozone level in the room was checked using a hand held aeroQUAL Ozone Meter, series 300. Levels were watched very carefully to ensure 0.045ppm ozone in the air was not exceeded.

ANALYSES AND INTERPRETATIONS

Statistical Analyses and Interpretations

For all laboratory analyses, five samples were taken on both untreated and treated (ozonated) samples. Each experiment was analyzed utilizing a two factor analysis of variance (Anova) without replication. An F test was utilized to determine statistical significance.

Table 2. Live Catfish - Unwashed vs Washed with 4.5ppm Ozonated Water in Feed Conveyor

Total Plate Counts from Swabbed Fish

Unwashed	Washed
75000	2100
41000	1800
20000	650
35000	300
15000	700

ANOVA: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	5	186000	37200	559200000
Column 2	5	5550	1110	623000

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3256220250	1	3256220250	11.633035	0.009213	5.317645
Within Groups	2239292000	8	279911500			
Total	5495512250	9				

Washing the catfish in the conveyor before the fish enter the stun chamber significantly reduced the microbial load going to the plant. For Superior to utilize this technique, it is suggested that the present wash lines over the conveyor be charged with ozonated water. To ensure that off-gassing does not cause worker safety problems with high levels of ozone in the air from the water, ozone monitors should be installed over the conveyor and in locations occupied by plant workers. Because the conveyor is subject to stopping, ozonation and water flow should be stopped when the conveyor stops. Since the Study herein performed only one test at one ozone concentration, further testing is required to develop the exact ozone level needed and the wash time necessary to ensure a reduced microbial load. This testing can be completed whenever an ozone generator is installed in the plant.

After observing the process used to stun the fish, it was concluded that a wash after the stun box would be more effective than before the stun equipment. This wash would be effective in removing fecal materials that are released when the fish are stunned; thus microbial levels in the plant should be reduced.

Table 3. Fillets from the Fillet Machine - Unwashed vs. Rinsed with 4.5ppm Ozonated Water

Total Plate Counts from Fillets

Unwashed	Rinsed
6000	3600
8500	3200
5700	7000
3200	2800
8500	2000

ANOVA: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	5	31900	6380	4927000
Column 2	5	18600	3720	3712000

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	17689000	1	17689000	4.09515	0.077618	5.317645
Within Groups	34556000	8	4319500			
Total	52245000	9				

Although the ozone wash reduced the plate counts at the fillet machine, the reduction was not significant at the 5% level of probability. It was significant at the 10% level (i.e. expect microbial reductions nine out of ten times). Because the test fell in this probability range, it is expected that higher rates or a longer exposure to ozonated water would result in statistically significant measurements at the 5% probability level of the effects of ozone at the fillet machine. Care should be taken to avoid worker exposure to ozone off-gassed from the washing treatment at the fillet machine. If ozonated water is used at this point, an air sensor that is capable of reducing the water flow or automatically shutting off the ozone generator needs to be installed to ensure worker safety.

If ozone is planned for use in the plant, then ozonation of the fillet machine would be recommended. Without the addition of ozone in the plant, increasing the wash water flow at the fillet machine should be considered as a large amount of fecal matter from damaged intestines, blood and blood sugars are released in the filleting process. These products all add to the microbial load and can continue through to the end of the processing line.

Table 4. Fish Fillets from Chiller - Unwashed vs Washed 10 Seconds in 4.5ppm Ozonated Water

Total Plate Counts

Unwashed	Washed
37000	8600
55000	13000
37000	10000
43000	10000
72000	16000

ANOVA: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	5	244000	48800	222200000
Column 2	5	57600	11520	8852000

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3474496000	1	3474496000	30.07544622	0.000584611	5.317645
Within Groups	924208000	8	115526000			
Total	4398704000	9				

The ozonation of the catfish fillets at this point in the process provided highly significant reductions in microbial loads. The average plate counts dropped from 48,800 to 11,520. The standard deviations for the total plate counts within the groups were reduced from 14,906 to 2,975 with the ozonated water treatments.

Installing ozonation at this point in the process line will take planning and innovation as the fish product comes from the chiller in a pile on a flat belt that is not slotted and would not allow for the ozonated water to come in contact with all surfaces of the fillets. It is suggested that the treatment needs to utilize some type of slotted or perforated belt contained in a water bath that is charged with ozone. After going through the water bath the fillets need to go to the sorter with a minimum of handling. Overflow from the water bath could be returned to the chiller to reduce load in the chiller water. Excess water containing ozone could be piped to the offal room and utilized to flush the drains and partially keep the odor reduced in the area. A water bath conveyor situation is suggested as it can be covered and to prevent off-gassing to the work area if high levels of ozone are utilized.

Because the action of ozone in the water bath will be very rapid, the bath can be fairly short in length but should provide excellent microbial control. This suggestion should be seriously considered by catfish processors. In developing the system, processors could also consider

perforated belts and sprays from both sides. This technique can lead to off-gassing and worker safety problems and may require a hood to remove off-gasses.

Cutting Boards - Sanitized by Cleaning Crew Compared to Sanitized and Rinsed with a 5.0ppm Ozonated Water: Washing the cutting boards with ozonated water actually increased the microbial load on the boards. The cutting boards are washed each day with foaming soap and a sanitizer. Both the soap and the sanitizer contain chlorine. Washing the boards with ozonated water after using the soap and sanitizer removes the residual chlorine and provides a medium for microbe growth. The present sanitation techniques for the daily cleaning of the cutting boards should be continued. If ozonated water is made available in the plant, beneficial effects of ozone could probably be measured if equipment rinses are utilized during break and lunch periods. Ozonation during these times works well as it doesn't leave a residue and processing can restart as needed.

Grading Conveyor Underside – Santized vs Sanitized and Rinsed with 5.0ppm Ozonated Water: Results from this analysis are inconclusive because the variance was too high to make statistical measurements. The underside of the belt contained food grade lubricants and some of the swabs were very high in lubricants and fish products from processing. Other swabs were from clean surfaces and reflected low plate counts. It is recommended that present practices be continued but attention may be needed in cleaning the underside of the conveyor.

Sorting Conveyor - Sanitized vs. Sanitized and Rinsed with 5.0ppm Ozonated Water: This test did show a reduction in microbe levels but the results were inconclusive because the variance was high and statistical significance was not obtained. Care should be taken to move flipper arms on sorting conveyors and clean under them during the daily cleaning.

***Odor Reduction in the Offal Room*:** Air quality modification with ozone is an emerging technology that has tremendous promise. With this promise will come equipment that can perform the following functions:

- Oxidize air pollutants
- Ensure worker safety with ozone levels of less than 0.05ppm ozone in the workplace

The test conducted in the offal room was a simple olfactory test conducted by selected Superior employees and all concluded that odors were reduced. While the test was being conducted, an aeroQUAL unit was utilized to monitor ozone levels. The ozone in the offal room reached 0.045 ppm within 15 minutes and would have climbed much higher if the ozone generator had not been stopped. The test was successful since it showed that ozone released into the room will quickly reduce the fish odors.

For processors wishing to ozonate an Offal Room, any of the approaches below can be taken:

1. UV lights can be installed to provide ozone at low levels and provide continuous air cleaning
2. Small ozone generator(s) can be mounted in the ceiling and utilized to reduce the odor levels

3. If ozone is utilized in the plant, it may be possible to take a small side stream to treat the air in the offal room.

Warning – Regardless of the method adopted, the following must be included:

- **Monitors must be in place to turn off the ozone if it is above 0.045ppm when personnel are present**
- **If higher levels are allowed, personnel must not be present and ozone levels must have dissipated before the room is opened**
- **If the room is allowed to have high levels of ozone, particular attention should be paid to oxidizing rubber items (tires) and air handling equipment**

These warnings are provided because many individuals utilize ozone under the principal that if a little does a little good - a lot must do a lot of good. In ozone technology, the proper amount works very well. Lesser and higher amounts should be avoided.

CONCLUSIONS AND RECOMMENDATIONS

General Conclusions

Based on the tests conducted at the Superior Fish Products plant in Macon, Mississippi, the following was concluded:

- Ozonated water rinses and washes can provide statistically significant reductions in microbe levels in catfish processing plants
- Gaseous ozone can be employed to reduce odors and create a more pleasant work-place environment
- Ozone rinses utilized in conjunction with sanitizers and soaps containing chlorine can actually remove the chlorine and reduce the residual effect of soaps and sanitizers

Future Recommendations and Considerations

In developing future growth plans and processes, the following may be considered:

- Ozonation of fish being hauled to the plant
- Ozone washes of the fish trucks transporting fish to the plant
- Utilizing a daily clean-up for four to six hours each day and run two eight hour shifts with a pressure washing followed by an ozone wash between shifts. (This is an excellent method of spreading depreciation)
- Utilize ozone for drain cleaning and waste conveyor cleaning
- Consider covering the lagoon system and utilizing anaerobic digestion to produce methane that can be utilized to heat water

REFERENCES

1. Dean, S. and Hanson, T., *Catfish Processing Economics* (Mississippi State University, Extension Service, Food & Fiber Center, Mississippi State, MS, 2001).
2. *2004 EPRI/Global Ozone Handbook: Agriculture and Food Industries* (Global Energy Partners, LLC, 2004) 1282-2-04.
3. Silva, J., Kim, T., Chen, C. and Gawborisut, S., *Applications of Ozone in Processing and Storage of Catfish and Poultry* (Mississippi State University, Mississippi State, MS, 2005).

APPENDIX

Alabama Cooperative Extension Service: http://www.aces.edu/

Arkansas Cooperative Extension Service: www.uaex.edu/

Mississippi State University Extension Service: http://msucares.com

MSUcares: Aquaculutre: Catfish. Mississippi State University Extension Service. http://msucares.com/aquaculture/catfish/index.html