Ozone in Food Processing Applications

Past Experience, Future Potential and Regulatory Issues:

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Abstract

The recent stories of food contamination reported in the media serve to highlight the need for the food industry in the United States to seek better, more effective methods of ensuring the safety of food products. In the vast majority of cases reported, the culprits have been identified as *Escherichia coli*, *Salmonella enteriditis*, *Listeria monocytogenes* and other pathogens found in fruits, meats, shell fish and other foods consumed by the public. The results of these cases of contamination have been serious illnesses and, in some cases, fatalities.

The use of ozone in the processing of foods has recently come to the forefront as a result of the recent approval by the U.S. Food and Drug Administration approving the use of ozone as an anti-microbial agent for food treatment, storage and processing. The FDA approval marks a watershed event for the food industry. Prior to the approval, FDA had approved ozone for use only as a disinfection mechanism for bottled water production and the sterilization of bottled water lines. The recent regulatory breakthrough is a result of efforts made by the Electric Power Research Institute (EPRI) and the panel of technical experts assembled to review and evaluate the efficacy and safety of ozone in food processing.

It is worthy of noting that, the use of ozone in food processing has been allowed and accepted in Japan, Australia, France and other countries for some time. There is a plethora of documentation and supporting literature attesting to the benefits of ozonation as a food product sterilization methodology some of which will be reviewed herein.

The FDA's recent approval serves to provide the basis for expanded use of ozone in food processing with application ranging from produce washing to recycling of poultry wash water to seafood sterilization. A sampling of these applications will be presented in the attached case studies.

The 1997 EPRI Expert Panel Report

This important reference document is organized as follows: An Executive Summary that is followed by chapters dealing with Efficacy of Ozone, Applications of Ozone, Safety Issues and Ozone Toxicology, Nutrient Impacts of Ozone and Summary Options of the Expert Panel. Also within the EPRI document are various appendices containing the qualifications of the experts, abstracts and citations of pertinent articles dealing with the use of ozone in processing and preserving foods. Specific applications are divided into 37 categories including; treatment, disinfection, eggs, fish, fruits, meats, poultry, vegetables, storage, etc.

Introduction

Ozone, first discovered in 1840 (Schonbein), began being utilized as a disinfection agent in
the production of potable water in France in the early 1900's. The majority of early development was limited to Europe where it became more widely used in drinking water treatment. The potential utility of ozone to the food industry lies in the fact that ozone is 52% stronger than chlorine and has been shown to be effective over a much wider spectrum of microorganisms than chlorine and other disinfectants. Complementing the effectiveness, is the fact that ozone, unlike other disinfectants, leaves no chemical residual
and degrades to molecular oxygen upon reaction or natural degradation. The fact that ozone has a relatively short half-life is both an asset and a liability to practitioners. This is particularly true in treatment of drinking water where ozonation is employed to enhance filtration and provide primary disinfection but requires the addition of chlorine as the terminal disinfectant to maintain a residual in the distribution system.

Ozone is effective killing microorganisms through oxidation of their cell membranes and most of the pathogenic, foodborne microbes are susceptible to this oxidizing effect. During food processing operations, surface disinfection of the product (raw or partially processed) is very important. This is supported by the following statistics:

1. An estimated 30% of fresh produce is lost by microbial spoilage from the time of harvest, through handling, storage, processing, transportation, shelving and delivery to the
consumer (Beuchat 1991).

2. The USDA estimates the costs associated with foodborne illness to be in the range of $ 5.5 billion to $ 22 billion per year.

History of Early Ozone Applications in Food Processing:

Some early reported uses of ozone in food processing and preservation have been reported and documented. The examples below represent a sampling of notable cases:

1. Fish and Shellfish Preservation:

Washing of fish with ozonated water extended shelf life for 5 days:

Experiments performed by Violle in 1929 found that ozonated seawater spiked with various strains of bacteria (*B. typhus, B. coli,* etc.) resulted in sterilization that was comparable to what was obtained in fresh water. Further experiments showed that exposure of shellfish to ozonated water did not adversely affect the taste or appearance of the shellfish. Thus, Violle concluded that preozonation of water was suitable treatment for depuration of shellfish. Later work by Salmon and Le Gall (1936) built upon the work of Violle and reported that fresh fish, stored under ozonated ice, were edible for between 12 and 16 days. Fish treated with sterilized ice (presumably hypochlorous acid treated) were inedible after the 12th day and, possibly after the 8th day.

The original work in this area was carried further by others and reportedly resulted in the installation of an ozone system designed to sterilize 2000 kg per day in Le Havre and another facility in Boulogne-sur-Mer for treating a daily output of 6000 kg.

2. Ozone Used in Cold Storage for Meats:

Gaseous ozone was used as a preservation agent in meat and egg storage:

Kuprianoff (1953) reported that the first known use of ozone as a food preservation agent was in Cologne, Germany dating back to 1909. Later industrial applications using gas phase ozone for food preservation were reported in 1924 where Hartman stated that *"in cold storage ozone is successfully used to prevent the growth of fungi" and " eggs have been carried at a relative humidity of 88 and 90 percent and mold developments inhibited with the use of ozone*". Hartman summarized by noting that ozone *"has manifold applications in cold storage and splendid results are being obtained in practice with this reagent every day".*

3. Disinfection and Preservation of Fruits and Vegetables:

One of the earliest reported experiments dealing with preservation of fruits was related to ozonation of bananas (Gane - 1933, 1934, 1935, 1936). Since then, numerous studies have been conducted on a wide variety of fruits and vegetables including carrots, broccoli,
pears, peaches and apples. The vast majority of these studies have reported some degree of shelf life extension and reduction of pathogenic contamination.

Recent Studies of Ozonation in Food Processing:

In spite of past regulatory restriction limiting usage of ozone in the U.S. food processing industry, numerous studies were undertaken to determine the efficacy and economics of ozonation. The examples below serve to illustrate some of these studies and conclusions.

1. Fruits and Vegetables:

Several controlled studies have been reported in the food science literature relating to the evaluation of treatment of fruits and vegetables with ozonated water. Kondo et al (1989) observed greater than 90% reduction of total bacterial counts upon treatment of Chinese cabbages with ozonated water (2.3 mg/L) for 60 minutes.

Treatment of wash water used in processing of carrots has been reported to provide 3 log reduction of bacteria (Williams et al 1995).

Barth et al (1995) evaluated ozone exposure for prevention of fungal decay on thornless blackberries. The fruit was harvested and stored for 12 days at 2 deg. C in 0.0, 0.1 and 0.3 ppm ozone, then evaluated for fungal decay (*Botrytis cinerea),* anthocyanines, color and peroxidase activity. Ozone storage suppressed fungal development for 12 days, while 20%
of control fruits showed decay. The treated fruit did not show observable injury or defects.
Sarig et al (1996) showed that ozone at low dosages (0.1 mg/g fruit) for 20 minutes, reduced the levels of fungi yeasts and bacteria on grapes, but that higher doses caused some fruit damage.

2. Poultry:

The poultry processing industry is a large volume consumer of water. The potential for reuse of poultry processing water represents an attractive economic benefit to the industry. In 1996 the USDA approved the use of ozonation for washing of poultry carcasses (provided that the ozone did not come into direct contact with the product). Studies by Chang and Sheldon (1989) reported that a combination of screening, diatomaceous earth filtration and ozonation yielded the highest quality of water with total microbial loads (total coliforms, *E. coli* and *salmonella* reduced by 99%). A subsequent study, Chang and Sheldon (1989) found no significant differences in measures of carcass quality including skin color, taste or shelf life using recycled, ozone treated water as opposed to fresh makeup water. The investigators further reported that a 2.7 log reduction in of total plate count was observed in the recycled water stream. The results of this study showed that, for a typical broiler processing plant (240,000 broilers/day) the savings resulting from chiller water reuse would equate to 50% reduction in discharges and savings of more than $ 45,000 per year.

3. Extension of Food Product Storage Life:

The following are a sampling of studies directed at application of gaseous ozone in food storage facilities.

A 1980 study (Gabriel'yants') showed that cheese stored with periodic ozonation prevented mold growth for 4 months while controls showed mold growth as soon as 1 month.

Japanese researchers indicated good results in the treatment of grains, flour and raw noodles with ozone with significant reductions in microbial growth.

Dondo et al (1992) reported that ozone treatment during refrigerated storage stabilized the surface bacteria count on beef and reduced that on fish.

Naitoh (1989) showed that ozone treatment inside a confectionery factory reduced airborne microorganisms over a 1 - 1.5 year period, “remarkably” inhibited bacterial growth and extended storage life of the product by 7 days.

4. Ozone Treatment of Dye Wastewater

Several studies have shown ozone and ozone/hydrogen peroxide to be effective in removal
of color resulting from dye processing. Dyes used in food processing are typically easier to
oxidize with ozone since they are organically based compounds.

Discussion of Current and Future Applications

Ozone is by no stretch a panacea or universal solution for all food processing operations. There are a significant number of good, sound applications including; disinfection of food
wash water, wastewater treatment and recycling, treatment of cooling water and process water, and gas phase sterilization of products in storage and transport. Along with these beneficial applications comes some limitations. There are existing restrictions relating to human exposure to ozone (OSHA and EPA) which must be considered. Plant operators seeking to employ ozone will be faced with system design and process operation challenges.

Proliferation of ozone applications in the food industry is assured. As of this writing, the industry is free to start using ozone. Operators wishing to apply ozone are expected to employ Good Manufacturing Practices to protect workers from inadvertent exposure to ozone as well as to avoid overuse of ozone which may cause damage to the food product.

Conclusions

As a result of the recent FDA ruling, it is anticipated that ozone in food processing will be
accelerated due to a number of factors:

1. The use of chlorine by the U.S. food industry is coming under increasing scrutiny by regulators due to toxicity issues and disinfection byproducts (DBPs).

2. Ozone has been proven to produce greater lethality rates for microorganisms than chlorine or other chemical sanitizing agents.

3. The recent surface water rules promulgated by the U.S. EPA relating to chlorine and chlorine derived DBPs will undoubtedly stimulate operators to seek technologies which will assure discharge compliance.

4. The increasing cost of water resources (both makeup and discharge), together with the drive toward more conservation, will stimulate industry to seek treatment methods which allow recycling of product wash water and process water.

5. Advances in ozone generation and applications technologies have continued to make the process more reliable and economical.