Ozone in Food Industry: A Review

Goswami Ashishgiri[1], Patel Janki[2], Goswami Pooja[3]
[1, 2, 3] Department of Food Processing Technology
[1, 2, 3] College of Food Processing Technology and Bio-energy, Anand Agricultural University, Anand, India

Abstract- *Ozone is a highly reactive form of oxygen, consisting of three oxygen atoms (O3), oxidant/disinfectant that quickly decomposes to diatomic oxygen (O2), while reacting with targeted organic matter or microorganisms. Ozone destroys microorganisms by reacting with oxidizeable cellular components, particularly those containing double bonds, sulfhydryl groups, and phenolic rings. Ozone does not act as a systemic poison to microorganisms, but rather, destroys them by oxidation. Consequently, it is impossible for a microorganism to build up any resistance to oxidation. Today, ozone technology is beginning to be used effectively as an additional point of intervention in the food and beverage industry. Ozone application in food industry such as disinfection and preservation of fruits and vegetables, application on juices, food grain preservation, meat and meat industry and fish industry and use of ozonated water for plant equipment sanitation are discuss in this review. This study also focus on rules and regulation for use of O3.*

Keywords- Ozone, Food, Microbial inactivation, Food industry

I. INTRODUCTION

Ozone is a highly reactive form of oxygen, consisting of three oxygen atoms (O3). It is a potent oxidant/disinfectant that quickly decomposes to diatomic oxygen (O2), while reacting with targeted organic matter or microorganisms. Ozone is naturally generated in the stratosphere, the upper atmospheric layer that protects us from harmful radiation. Gaseous ozone is formed also in the atmosphere during lightning discharges and on the earth's surface by photochemical reactions, UV sterilization lamps, and high voltage electric arcs.

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.

II. COMMERCIAL PRODUCTION OF O3

Ozone is generated naturally from oxygen in the air by electrical discharges such as lightning and by high-energy electromagnetic radiation. However, in order to harness this natural cleaning agent for commercial uses, ozone must be produced on-site when it is needed. It cannot be conveniently purchased. It is generated in small tanks or large robust generators when oxygen (O2) is charged with high voltage electricity. This is because ozone lasts only about 20 to 30 minutes in distilled water at 20˚C, and less time if contaminants are present.

The primary process used commercially today to make ozone is called electrical discharge, or corona discharge. This is the preferred method for the water treatment industry. In this process, a high voltage electrical spark is fired across a gap (like a spark plug) to turn oxygen into ozone. The other products formed in the process must be destroyed through various mechanisms, all of which are done safely and efficiently as part of the ozone generation process.

Mechanism of inactivation microbes using O3:

Ozone destroys microorganisms by reacting with oxidizeable cellular components, particularly those containing double bonds, sulfhydryl groups, and phenolic rings. Therefore, membrane phospholipids, intracellular enzymes, and genomic material are targeted by ozone; these reactions result in cell damage and death of microorganisms. Bacteria which can be inactivated include Salmonella Enteritidis , E.coli O157:H7 , Listeria Monocytogenes , Shigella Dysenteriae Micrococcus Aureus , Clostriduim botulinum , Mycobacterium Tuberculosis, Bacillus Anthracis , Streptococcus sp and molds such as Botrytis , Rhizopus , Penicillium , Aspergillus can be inactivated.

III. APPLICATION IN FOOD INDUSTRY

1. Disinfection and Preservation of Fruits and Vegetables:

Klockow et al. (2009) studied safety and quality assesment of packaged spinach leaves by treating it ozone generated in air and oxygen for 5 min. and stored at room temperature (22°C) and showed the reduction of 3–5 log10 CFU/leaf E. coli O157:H7 populations after 24 hours of storage.

Zambre et al. (2010) examined the redness of Tomato and assessment of ozone treatment for extending shelf life, found Ozone treatment delayed both the development of red colour as well as of rotting Shelf life was enhanced by 12 days when treated tomatoes were stored at 15°C.

Tastee Apple is a privately owned processor of fresh apples, located in Newcomerstown, Ohio. The plant is one of the major packers in the US of caramel apples. The ozone concentration in the flume water is maintained at about 0.05 to 0.15 ppm. To ensure that the maximum amount of ozone in the air does not exceed the OSHA limit of 0.08 to 0.1 ppm, an ozone detection unit is continuously monitoring the amount of ozone in the environment adjacent to the flume.

2. Application on juices

Toree et al.(2011) examined effect of ozone processing on colour rheological properties of apple juice with ozone concentration of 1-4.8% w/w for 1-10 min. mean total colour difference (TCD) value was 30.84 at the highest processing conditions employed i.e. at ozone concentration of 4.8% w/w and processing time of 10 min.

Apart from microbial inactivation, ozone treatment of apple juice also has been reported for destruction of mycotoxins. In fact the efficiency of ozone in mycotoxin degradation is due to the presence of polyketide lactome which makes it highly vulnerable to oxidation.

3. Food grain preservation

Tiwari et al. (2010) showed that ozone is an effective fumigant for insect killing, mycotoxin destruction and microbial inactivation which has a minimal or no effect on grain quality. Studies have demonstrated that ozone which is a natural agent, may offer unique advantages for grain processing along with addressing growing concerns over the use of harmful pesticides.

Application of ozone in food grain preservation is mainly due the growing concern over the use of harmful pesticides to kill storage pests. A limited number of studies have been reported on ozone treatment of cereals and cereal-based products as an alternative to chlorine treatment. Use of ozone in a closed sequential batch reactor, would aid in the flour quality improvement.

4. Meat and meat industry and fish industry

Crowe et al. (2012) studied application of ozone spray of 1 mg/L and 1.5 mg/L on the microbial and chemical quality indices of Atlantic salmon fillets inoculated with Listeria innocua as a surrogate species replacing the pathogen Listeria monocytogenes significantly lower the counts ($p \leq 0.05$) than non-ozonated controls on days 0, 3, 6, and 10 of refrigerated storage at 4 °C.

5. Use of ozonated water for plant equipment sanitation

Greene et al. (1993) proposed the effectiveness of ozonated water and chlorinated sanitizer for the disinfection of stainless steel surfaces in dairy and food industry which had been incubated with UHT milk inoculated with either Pseudomonas fluorescens (ATCC 949) and Alcaligenes faecalis (ATCC 337) at 32□C for 4–24 h.

Rules and regulation for use of O3:

1957 - Ozone in the gaseous form was approved for the storage of meat by the USDA.March 12,

1975 - FDA recognized ozone treatment to be a Good Manufacturing Practice (GMP) for the bottled water industry. The minimum ozone treatment for GMP is "0.1 part per million (0.1 mg/l) of ozone in water solution in an enclosed systems for at least 5 minutes."

In June 1997, an Expert Panel of Food Scientists convened by the Electric Power Research Institute concluded the following:

“The available information supports the safety of ozone when used as a food disinfectant or sanitizer, and further, that the available information supports a GRAS classification of ozone as a disinfectant or sanitizer for foods when used at levels and by methods of application consistent with good manufacturing practices”.

FDA Federal Register, June 26, 2001,

The Food and Drug Administration (FDA) is amending 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.

IV. ADVANTAGES

- It only requires oxygen or air for its production.
- It is compatible with organic food processing.
- It can be generated onsite, so no storage is required.
- It leaves no residues in food or water.
- It can be applied in an aqueous or gaseous state.
- It is faster and better at killing microbes than chlorine.
- It is a non-thermal way to control pathogens and microbes in food processing.
- It is a non-chemical alternative for treating water and sanitizing food contact surfaces.
- It saves money because water does not have to be heated.

V. DISADVANTAGES

- It could damage rubber and other polymers used for gaskets and o-rings.
- Its active life in water is less than 30 minutes, so it cannot be stored or moved.
- Like chlorine ozone is not selective. It will oxidize all organic material present. Depending on the soil load, its ability to kill micro-organisms may be restricted. So, when disinfecting water, the water should be pre-filtered before ozonation.

REFERENCES

[1] Anonymous, 2006. Science Tech Enterprenurs. Application of Ozone in Food Industries.

[2] Anonymous, 2012. www.fnbnews.com/Article (accessed April 2012).

[3] Aguirre D.B., Gustao V., and Barbosa C. (2003). Disinfection of selected vegetables under nonthermal treatments: Chlorine Acid citric, ultra-violet light and ozone. Food control. (29) 82-90.

[4] Choia M.R., Liu Q., Lee S. ,Jin H., Ryu S., and Kang D.H. (2012). Inactivationof Escherichia coli O157:H7, Salmonella typhimurium and Listeria monocytogenes in apple juice with gaseous ozone. Food Microbiology (32)191-195.

[5] Crowe K.M., Skonberg D., Bushway Al. and Baxter S. (2012). Application of ozone sprays as a strategy to improve the microbial safety and quality of salmon fillets. Food Control. 25(2) 464-468.

[6] Greene, A. K., Few, B. K., & Serafini, J. C. (1993). Ozonated vs chlorinated sanitization of stainless stell surfaces soiled with milk spoilage organisms. Journal of Dairy Science. 76, 3617–3620.

[7] Klockow P.A. and Keener K.M. (2009) .Safety and quality assessment of packaged spinach treated with a novel ozone-generation system. LWT - Food Science and Technology (42)1047–1053.

[8] Kim J.G., Yousef A.E. and Khadre M. A. (2003).Ozone and its current and future application in the food industry. Advance in Food and Nutrition Research.(45) 167-218.

[9] Ozone in Food Processing Applications. Past Experience, Future Potential and Regulatory Issues: By Zentox Corporation.

[10] Ozone Technologies Group, Inc.Executive Overview of Ozone Sanitation in the Food Industry.

[11] Pascual A., Llorca I., and Canut A. (2007). Use of ozone in food industries for reducing the environmental impact of cleaning and disinfection activities. Trends in food science and technology. (18) S29-S35.

[12] Tiwari B.K., Brennan C.S., Curran T., Gallagher E., Cullen P.J., and O' Donnell C.P. (2010). Application of ozone in grain processing. Journal of Cereal Science. 51(3)248-255.

[13] Zambre S.S., Venkatesh K.V., and Shah N.G. (2010). Tomato redness for assessing ozone treatment to extend the shelf life. Journal of Food Engineering. (96) 463–468.