2

Ozone Treatment: The Green Technology in Food Industry

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ABSTRACT

The food industry has many the environmental challenges in terms of emerging microbial strains, bacteria, viruses and accumulation of toxic chemicals. Ozone (O_3), environmental bluish gas is an extremely potent oxidant, which is effective solution for disinfection, sanitization for various kinds of products. The application of ozone treatment in agro processing has become green technology with increasing acceptance. It can apply in liquid form, gaseous form to sanitize food, food packaging materials, process water and to disinfect equipments. Ozone can be generated by different methods such as ultraviolet radiation method, corona discharge method etc. In this chapter, ozone properties, its generation, antimicrobial power and advantages with application of ozone has covered. Fruits and vegetables treatment with ozone have shown increased shelf-life and many hazardless advantages of the products. Some products preserved with ozone. Anti microbial activity, no residues in foods, assurance about preservation of sensory, nutritional and physicochemical properties of food have made ozone application as a promising technology for all kinds of food products

Keywords: Ozone, Disinfectant, Sanitation, Antimicrobial, Chlorinated water, Ozone generation

2.1 Introduction

Now days, pathogens such as bacteria, viruses and many other microbes on fruits, vegetables and their products are a primary issues related to food-safety. Many thermal unit operations and chemical treatments are applied to minimize these pathogenic microorganisms. However, these technologies, affect the quality of foods. Certain novel techniques like high pressure processing, pulse electric field and many others prevent the food quality losses to certain extents.

Sanitization, aseptic processing, and maintaining hygiene are the key parts to get hazard free safe food products. Generally, sanitization is done with chemical treatments, thermal treatments, which are crucial to maintaining the quality; also it has many drawbacks like residues retentions, nutritional losses and other quality losses. Therefore food industry is in need of green processing technologies in order to meet the consumer expectations. The ozone application in food sector is one of the promising technologies to minimize these kinds of drawbacks. Ozone has shown strong and rapid antimicrobial action against all kinds of spores, fecal and pathogenic microorganisms, and viruses, as compared to chlorine. Ozone use has many advantages and applications, like no chemical residues and natural degradation into oxygen. (Khadre *et al.,* 2001).

Many food disinfectants are available in the market and commercially applied in food sectors like chlorine, Iodophors, Quaternary Ammonium Compounds etc. Every disinfectant has certain disadvantages (Table 1.)

Table 1: Disadvantages of Some Widely used Chemical Disinfectants

Disadvantages of some disinfectants	Chlorine and its compounds	Iodophors	Quaternary Ammonium Compounds
	• Organic matter causes a quick reduction in bactericidal effectiveness. • Effectiveness reduces as pH increases. • Highly dissipates in hot water. • Corrosion to metal . • Affect to skin if contact. • Low shelf life. • Off odor.	• Slow reaction at pH 7.0 above, • Quick vaporizes at 120 ^{O}F. • Less effective against bacterial spores than hypochlorites • Stain some plastics and porous surface • Highly expensive	• Not compatible with hard water and most detergents. • Forms film. • Produces foam in mechanical operations. • Selective in destruction or inhibition of various types of organisms. • Requires higher concentration for better action than chlorine or iodine. • Expensive.

Ozone has a strong oxidant and strong antimicrobial components which destroys 99.9% pest and microorganisms due to its potential oxidizing capacity. Due to oxidation process any pathogens or contaminants can be disinfected or removed. Ozone has shown to be effective over a much wider spectrum effect on the microorganisms than chemicals disinfectants. It is the strongest disinfectant of all, as it applies in water treatment. (Khadre *et al.,* 2001; Kim *et al.,* 1999).

In France on year 1886, first time Ozone has been adopted for production of potable water. In ozone treatment, foods to be decontaminated is exposed aqueous and/or gaseous phases of ozone at a constant flow per unit time, constant pressure and particular concentration based on the percentage of contamination. There are many applications such as surface hygiene, plant sanitization, equipment sanitization, waste water treatment, controlling level of chemical oxygen demand (COD) and biological oxygen demand (BOD) (Brooks *et al.,* 1990). Ozone has been used for disinfect the water and remove off odor (Rice, 1999; Muthukumarappan *et al.*, 2000). Utilization of ozone in member countries for a long time has reported by many authors (Guzel-Seydim *et al.,* 2004). In US ozone treatment in the food industry has not been widely used till 1982. In 1982 first time for use of ozone in bottled water the federal agency US FDA approved generally recognized as safe (GRAS) status. Ozone has also been declared as GRAS for use in food processing by the US FDA in 1997 and allowed as an antimicrobial food additive in 2001 (Graham, 1997).

2.2 Ozone Structure and Property

Ozone (O3) is naturally present in the atmosphere in a gaseous form. Lightning or high energy UV radiation responsible for creation of natural Ozone in the atmosphere (Jakob and Hansen, 2005). Ozone is an allotropic form of O2 available in different form and mostly are in chain arrangement. It have molecular weight of 48.

2.3 Ozone: Antimicrobial Action

Ozone has antimicrobial action against bacteria (vegetative and spore), fungi, viruses and other similar microbe (Ligimol *et al.,* 2002). Inactivation of Microorganism by ozone treatment is a complex process. Ozone reacts with microbial constituents like cell walls, cell membranes, endosperm coats, the cytoplasm, viral envelopes and virus capsids (Khadre *et al.,* 2001).

Bacteria - Ozone inactivates both kinds of bacteria. Gram-positive bacteria were less sensitive to ozone than Gram-negative organisms. Ozone at different doses and exposure times showed *E. coli* inactivation *(*Finch *et al)*. High concentrations of airborne ozone have achieved 99% death rates for *E. coli* and S. *aureus* (Kowalski *et al.,* 1998). Moore *et al.* observed inhibitory effect of ozone on *E. coli, Staphylococcus aureus, Serratia liquefa ciells, Listeria innocua* and *Rhodotorula rubra.* Dose of 1.5 ppm ozone in distilled water shown decrease of *Salmonella Enteritidis* population was by 6 log units (Kim *et al.,* 1999).

Fungi - *Candida albicans* and *Zygosaccharomyces bacilli* have considerable reduction by ozoneated water treatment (Restaino *et al.,*1995*)* Kawamura *et al*. found yeasts on ozone treatment shown more sensitive than molds.

Whereas, in the case of *Aspergillus niger* spores, less reduction was noticed. Many organism found inhibitory and Moore *et al.* found that yeast species were more resistant than bacteria towards ozone activity. Beuchat *et al*. (1999) worked and reported the susceptibility of conidia of aflatoxigenic aspergilli to ozone.

Viruses – Naturally ozone acts as a virucidal agent inactivates viruses on short exposure. Viruses with cells are high resistant to ozone compared to purified virus II. Herbold *et al.* have tested flowing water in steady having pH 7 at 20°C to find resistance of viruses and bacteria to ozone. When the ozone demand of the medium is low then low concentration levels ozone and less process times are generally adequate for inactivation of viruses whereas when the ozone demand of the medium is high (e.g., in wastewater), long contact time and high ozone concentration are sufficient to inactivate viruses (Kim *et al.,* 1999).

Protozoa - Ozone is more effective than chlorine against *Cryptosporidium* and *Giardia. Naegleria gruberi* cysts were more resistant than *Giardia muris* to ozone. Korich *et al.* reported that more than

90% reduction in the population of intestinal parasite, *Cryptospordiumparvwn,* within 1 min in ozone demand free water. Ozone is more effective against protozoan parasites in water systems as compare to other chemical disinfectant like chlorine or chlorine dioxide.

2.4 Ozone Production

Many methods are adopted for production of ozone. The corona discharge method uses high-energy electrical field, photochemical method based on ultraviolet radiation and chemical method where oxygen molecules converts into ozone for continuous use. In which photochemical and corona discharge are used commercially (Guzel-Seydim *et al.,* 2004). Ozone production can be done by electrolysis method, phosphorus reactions with water, and radiochemical procedure. However these procedures are in their in the early hours stages of development and not much cost effective.

2.5 Equipment for Ozone Treatment

Generally, ozone may utilize in any aqueous or gaseous phases or in combination of both. Ozone treatment apparatus mainly consists of the gas/pure air, an ozone generator system, an electric power supplier, contactor (water phase ozone), reactor, surplus gas elimination system, and ozone analyzer (Bablon *et al.,*1991). Ozone treatment in the water phase requires similar elements with additional sample pH controller unit (Naito and Sawairi, 2000).

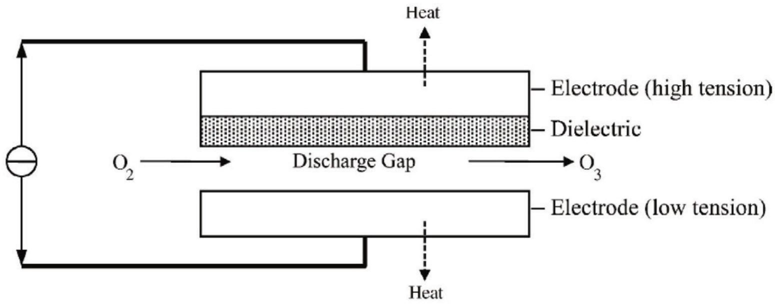

Fig.1: Schematic diagram of Corona Discharge method for ozone generation (Rice *et al.,*1981)

2.6 General Advantages of Ozone Treatment

- Any hazardous chemical residue frees the process.
- Better fumigation than conventional fumigation method.
- Ozone treatment is versatile to all kinds of agro produce foods, meat and sea foods, value added products.
- No adverse effect on texture of fresh & frozen foods.
- Effective in lowering the microbial load leads to enhanced shelf life of produce.
- No adverse effect on sensory and visual quality of the product.
- Non toxic
- Environment friendly and no pollution after treatment (Greene *et al.,* 2012).

2.7 Disadvantages of Ozone Treatment

- Microorganisms sensitivity to ozone differ by several factors like type of product, kind of microorganism, level of contamination, physiological state of the bacterial cells, the physical state of ozone, kind of an organic material.
- Different microorganisms have different resistivity to ozone concentration; therefore effectiveness of dose for particular microorganism is different. (Restaino *et al.,* 1995).
- Higher ozone concentrations may negatively affect food quality preservation.
- High ozone treatment and retaining time may cause reduction of vitamin, polyphenol, and volatile compound.
- Ozone resistant compounds present in water may cause partial oxidation

(Hoign-e, 1998).

- Ozone is unstable in water cause improper ozone concentration doses.
- Ozone treatment cannot be economically feasible to small manufacturer.
- Unawareness about ozone treatment leads to poor acceptability by manufacture and consumers.

2.8 Ozone Application in Food Industry

Ozone technology becomes useful during various unit operations specially used for washing equipment and packaging (Graham 1997). Ozone treatment is widely applied in many food sector. However, an application of ozone use widely depends on the nature, composition, structure of food surface, kind of microbe, end use of product and the degree of final acceptance of microorganisms with food.

A. Fruits & Vegetables Processing

Farm fresh fruits and vegetables are highly prone to contamination by environmental microorganism since from pre harvesting stage. Sivapalasingam *et al, 2004* reported increased food borne disease outbreak linked with minimal processed fruits and vegetable during past decade. Many chemical sanitizers & disinfectants are applied to remove surface contaminations, which leads to safety issues due to residues remain over it. Food industries are now moving to use ozonated water for washing and cleaning agro produces. Kim *et al.* have used ozonated water to wash shredded lettuce and obtained 2- log cfu/g reduction in total plate counts. Ozone efficacy against microbe on surface depends on ozone delivery method. Washing apple with bubbling ozone inactivate *E. coli* O157:H7 on apple surfaces in pre-ozonated water was reported by Achen and Yousef (2001). Ozone treatment on Table grapes increased shelf life due to deactivation of fungi (Sarig *et al.,* 1996).

Fruit and vegetable shelf life mainly controlled by ethylene content produced during respiration and ripening. High ethylene production leads to more ripening and senescence in fruits and vegetable. Ozone treatment is effective method to control the ripening and senescence by removing ethylene through chemical reaction leads to extended shelf life of fruits & vegetables. The shelf-life of potatoes would be enhanced upto 6 months at temperature range from 6 to 14°C and Relative humidity 93 to 97 per cent with 3 ppm of ozone without affecting the quality. Ozone can also be used for increasing the shelf-life of blackberries, by preventing fungal growth without causing any observed defects, and surface colour of berries for 12 days.

B. Meat and Meat Processing Sector–

Pathogenic microorganisms are highly responsible to cause hazardous contamination to meat and meat products during handling, processing, slaughtering and distribution operations (Zhao *et al*., 2001). During washing of beef carcasses with natural water followed by ozonated water was more effective than that of treatment with trisodium phosphate, acetic acid or a sanitizer. On the contrary, it have been found that treatment with ozone was an improvement over control but it showed no advantage over conventional washing in reducing microorganisms. Carcasses and cut fresh meat decontamination may do with chemical sanitizer but the safety of this method was questionable. Therefore ozone treatment is the best alternative sanitizer against meat and meat product contamination. Many researchers confirmed the applicability of ozone as safe disinfectant for meat industry. Meat and meat product contaminated with faecal materials which may includes pathogens due to improper good handling practices. These faecal contamination and pathogen may removed by antimicrobial ozone treatment.

Greer and Jone studied on impact of ozone application on beef carcass bacterial spoilage, meat quality and carcass trexture. They reported that under ozone atmosphere psychrotrophic bacterial growth was retarded on carcass surfaces. (Greer and Jones, 1989).

C. Dairy Sector

Milk handling equipments and machineries adhered with milk residues and pathogenic bacteria during milk handling and processing which are rigid to remove. Heavy microbial load and milk residues on handling equipments lead to deterioration in quality of milk. Ozone treatment is best substitute solution to chemical based sanitizers to remove these residues and bacteria from surfaces (Guzel- Seydim *et al.,* 2004). Milk product like cheese can be prevented by mould growth and air borne moulds during ripening and storage. Shiler *et al* have also suggested a method of ozonation of cheese for ripening and storage without any harm to cheese and its wrapping materials. Swedish company has developed pasteurization process which included pre-ozonation treatment followed by conventional pasteurization (Pastair 2014). The ozone application has claimed to extension of shelf life with better quality. Dried milk product like milk powder also influenced by ozone treatments in chemical, physical, functional and organoleptic properties. Kurtz *et al*., 1969 reported that skim milk powder have significant sensory score which is prepared under surroundings ozone level of 32 ppb. Also, with wide application of ozone treatment, dairy waste water had effectively treated with ozone treatment to control over pollution in terms of BOD and COD (Laszlo and Jeno, 2016).

D. Grain Industry

Many insects and microbes like mould, fungi, bacterial were grow during storage of grains and which leads to post harvest loss around 3-10 per cent yearly (Jayas 1999). Many techniques are used to reduce the losses but have limitation in terms of adverse effects. Ozone treatment with proper concentration dose will reduce the level of contamination and deterioration of the grains. Vikas Chandra Verma *et al.*, 2018 reported ozone treatment efficiency depends on the kind of nature, processing state and ozonation conditions. Red flour beetle, maize weevil and larvae Indian meal moth had evaluated for effect of ozone fumigation in corn grain. He reported at lower dose mortality (77–99.9%) of insect depends upon the insect species. No effect on germination of grain was found even ozone level was controlled below 0.98 mg/g of grains per min. Germination rate of corn seed had found higher when treated with ozone for short term (Violleau *et al.,* 2008).

Wheat grain treated with ozone earlier than processing was studied to improved flour quality and safety (Yvin *et al.,* 2001). Three days ozone treatment showed 92–100% mortality of Sitophilus zeamais (Motsch.), Tribolium castaneum, adult red flour beetle, larval moth and Plodia interpunctella. Also, the level of contamination of fungus Aspergillus parasiticus Speare on surface was reduced 63%. The additional advanteage of ozone treatment is ozone dispose rapidly to molecular oxygen with no any chemical residue and hence proved as an effective technology for grain protection without affecting its quality. (Pawar *et al.,* 2015).

E. Dry Foods

Dry foods like dehydrated vegetables, spices, powders get contaminated by various pathogens, yeast, mould due to mishandling and packaging. Dry foods are hygroscopic in nature and high potential to contaminate due to increased water activity. Efficacy of ozone treatment on dry food mostly depends on surface properties of products, ozone dose, reaction rate, temperature, humidity in the environment and water activity of the product (Kim *et al.,* 2003). Aflatoxin as most toxic substance is commonly found in dry foods. Detoxification of aflatoxin by ozone treatment has reported (Akbas and Ozdemir, 2006).

Cereal flour and ground pepper had achieved microbicidal effect when treatment with high ozone concentration and long exposure duration (Naitoh *et al.,* 1989). Naitoh *et al.,* have obtained 1 to 3 logs reduction in count of *Bacillus* and *Micrococcus* of cereal grains, peas, beans and spices on treatment with < 50mg/L ozone. In general, high exposure time and low treatment temperature resulted in high microbicidal activity in dry food products. Ozone concentration of < 5 ppm can be used effectively without oxidative changes in lipid containing foods. Ozone decreased essential oil content in some spices, thereby having a negative impact on sensory quali ties. Galdun *et al.* tested the effect of ozone on garlic during long-term cold storage.

F. Packaging Material and Food Contact Surfaces

Packaging materials usually contain many microbial contaminants. Many sterility treatments are utilized to obtain contaminant free packaging materials including hydrogen peroxide (H_2O_2), other sanitizers, thermal treatment like heat, hot air, pressurized steam, Ultra violate radiation (Gardner and Shama, 1998). Sterilization of packaging materials by H_2O_2 has several disadvantages like retention of residue after treatment (Yokoyama, 1990). Ozone applied in gaseous and aqueous states has been explored for surface sterility of packaging materials and tools (Pascual *et al*., 2007). Bacterial biofilms of *Pseudomonas fluorescence* and dried films of *B. subtilis* spores on surface of multi laminated aseptic food packaging can be tested with help of ozone treatment (Khadre and Yousef, 2001a). Multilaminated packaging sterility was achieved when treated with 5.9 µg/ml aqueous ozone for 1 min. Oak barrels used for aging wine were disinfected when treated with ozone. Spoilage yeast has been proven to control over fungus (Day, 2004). Many studies showed ozone treatment inactivate *P. fluorescence* biofilms on stainless steel.

G. Miscellaneous Applications

Ozone has been proven to best alternative of chemicals for disinfection and sterilization of water used by food industry for processing. Ozone has capability of destroying chlorine by-products, chemicals and organic compounds in the water without leaving any hazardous residues. Depending on the source application of ozone ranges from 0.5 to 5 ppm with less than 5 min contact time. Ozone can also be used to remove many minerals like manganese, iron, sulphur etc. Ozone treatment helps in control taste and odour of water. Ozone treatment ensures continuous availability water with high quality and free from toxic chemicals for the industry. Sander has worked on quality deterioration of fruit juices and liquid dairy products treated with ozone showed positive results. Moore *et al* have recommended ozone as an effective terminal disinfectant, if applied after adequate cleaning. Ozone was found to be effective on airborne microorganisms in different air disinfecting systems.

Ozone treatments on waste water have shown best results in terms of control over BOD, COD and other solid residues. It has been used to disinfect, to remove turbidity, colour, odour and to reduce the organic loads of wastewater. Ozone can be used for recycling of water in other industries, particularly in food sector.

2.9 Conclusions

Sanitization and safety process during food processing become important step that ensures diffusion, inactivation of hidden and entrapped pathogens. Ozone efficiency, retention time and spontaneous decomposition to nontoxic products (i.e., O_2) make this ozone a viable disinfectant for ensuring the safety and quality of food products. Ozone application has wide scope in food industry. In modern years processor and consumer became food process literate and have changed their perception about ozone treated foods.

2.10 References

Achen, M. and Yousef, A.E. 2001. Efficacy of ozone against Escherichia coli O157:H7 on apples. Journal of Food Science, 66, 1380-1384.

Akbas, M. and Ozdemir, M. 2006. Effect of different ozone treatments on aflatoxin degradation and physicochemical properties of pistachios. Journal of the Science of Food and Agriculture. 86, 2099-2104.

Brodowska, A. J., Smigielski, K., Nowak, A., Brodowska, K., Catthoor, R. and Czyzowska, A. 2014. The impact of ozone treatment on changes in biologically active substances of cardamom seeds. J. Food Sci. 79(9): C1649–1655.

Beuchat L R, 1991. Surface disinfection of raw produce, Dairy Food Environ Sanitation, 12,6.

Brooks, G. M. and Pierce, S. W. 1990. Ozone applications for commercial catfish processing. Paper presented at 15th Annual Tropical and Subtropical Fisheries Technological Conference of the Americas, December 2-5, Orlando, Florida.

Day, C. 2004. Developments in the management of Brettannomycess. Wine Industry Journal. 19, 18-19.

Finch G R, Smith D W & Stiles M E, 1988. Dose-response of *E. coli* in ozone demand-free phosphate buffer, Water Res, 22 , 1563.

Galdun T I, Postol A Y & Lukovnikova G A, 1984. Changes in the carbohydrated comples of garlic during long tcrm cold storage with ozonization and ionization treatments, Tovarovedenie, 17, 43.

Gardner, D.W.M., and Shama, G. 1998. The kinetics of Bacillus subtilis spore inactivation on filter paper by u.v. light and u.v. light in combination with hydrogen peroxide. Journal of Applied Microbiology, 84, 633-641.

Guzel-Seydim, Z. B. et al., 2004. Use of ozone in the food industry. Lebensm.-Wiss. u.-Technol. 37, 453–460.

Graham, D. M., 1997. Use of ozone for food processing. Food Technology, 6 (51), 72-75.

Greer, G.G. and Jones, S.D.M. 1989. Effects of ozone on beef carcass shrinkage, muscle quality and bacterial spoilage, Can Inst Food Sci Technol J, 22: 156–60.

Greene A K, Few B K & Serafini J C, 1993. A comparison of ozonation and chlorinating for the disinfection of stainless steel surfaces, J Dairy Science, 76, 3617.

Greer, G.G. and Jones, S.D.M. 1989. Effects of ozone on beef carcass shrinkage, muscle quality and bacterial spoilage, Can Inst Food Sci Technol J, 22: 156–60.

Guzel-Seydim Z B, Greene A K and Seydim A C. 2004. Use of ozone in the food industry. LWT - Food Science and Technology, 37 453–460.

Hoigné, J., and Bader, H. Ozonation of water. 1975. Role of hydroxyl radicals as oxidizing intermediates. Science (Washington, DC, United States) 190, 782-784.

Herbold K, Flehmig B and Botzenhart K, 1989. Comparison of ozone inactivation in flowing water of Hepatitis A virus poliovirus I and indicator organisms, Appl Environ Microbiol, 55, 2949.

Jayas, D.S. 1999. Grain preservation: researchers aim to decrease waste by improving storage techniques, Resource, 7: 7–8.

Jakob SJ and Hansen F. 2005. New Chemical and Biochemical Hurdles. In Emerging technologies for Food Technology. Edited by Sun, D. Elsivier Ltd., 387-418.

Khadre M A, Yousef A E and Kim J G, 2001. Microbiological aspects of ozone applications in food: a review. Journal of Food Science, 66, 1242–1252.

Kim, J.G., Yousef, A.E., and Chism, G.W. 1999. Use of ozone to inactivate microorganisms on lettuce. Journal of Food Safety, 19, 17-34.

Kells, S.A., Mason, L.J., Maier, D.E. and Woloshuk, C.P. 2001. Efficacy and fumigation characteristics of ozone in stored maize, J of Stored Products Research, 37: 371–82.

Kowalski W J, Bahnfleth W P and Whittam T S, 1998. Bactericidal effects of high air-borne ozone concentrations on E. coli and Staphylococcus aureus, Ozone Sci Engineering, 20, 205.

Kurtz F E, Tamsma A, Selman R L and Pallansch M J. 1969. Effect of pollution of air with ozone on flavor of spray-dried milks, Journal of Dairy Science, 52 158–161.

Ligimol James, A K Puniya, V Mishra and Kishan Singh. 2002. Journal of Scientific & Industrial Research,- Vol. 61, 504-509.

Laszlo Varga and Jeno Szigeti, 2016. Use of ozone in the dairy industry: A review.International Journal of Dairy Technology, 69(2), 157-168.

Mahapatra, A., Muthukumarappan, K., and Julson, J. 2005. Applications of ozone, bacteriocins, and irradiation in food processing: A review. Critical Reviews in Food Science and Nutrition. 45, 447- 461.

Moore G, Griffith C and Peters A. 2000. Bactericidal properties of ozone and its potential application as a terminal disinfectant. Journal of Food Protection, 63, 1100–1106.

Patil S and Bourke P. Ozone processing of fluid foods. 2012. In Novel Thermal and Non-Thermal Technologies for Fluid Foods, 225–261.

Pastair, Cold pasteurization: what could be more natural? [Internet document] URL http://qb.se/cmarter/files/20120330-OZ7Z-4PBZVCSC.PDF. Accessed 07/12/2014

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.

Pawar S.G., Pardeshi I.L., Bajad V.V., Surpam T.B. and Rokde H.N. Ozone: 2015. A New Controlled Strategy for Stored Grain, Journal of Grain Processing and Storage, Vol 2.1 , 01-10.

Restaino L, Frampton E W, Hemphill J B & Palnikar P, 1995. Efficacy of ozonated water against various food-related microorganisms, Appl Environ Microbiol, 61, 3471.

Rice, R. G., Robson, C. M., Miller, G. W., & Hill, A. G. 1981. Uses of ozone in drinking water treatment. Journal of the American Water Works Association, 73(1), 44–57.

Rojek U Hill A & Griffiths M, 1995. Preservation of milk by hyperbaric ozone processing, J Dairy Sci, 78, 125.

Shiler G G, Eliseeva N N and Chebotarev L N. 1978. Use of ozone and ultra-violet radiation for the inactivation of mould spores. Proceedings of the 20th International Dairy Congress, E 616.

Selma, M.V., Beltran, D., Allende, A., Chacon-Vera, E., and Gil, M.I. 2007. Elimination by ozone of Shigella sonnei in shredded lettuce and water. Food Microbiology, 24, 492-499.

Sivapalasingam, S., Friedman, C.R., Cohen, L., and Tauxe, R.V. 2004. Fresh produce: a growing cause of outbreaks of foodborne illness in the United States, Journal of Food Protection, 67, 2342-2353.

Sarig, P., Zahavi, T., Zutkhi, Y., Yannai, S., Lisker, N., and Ben-Arie, R. 1996. Ozone for control of post- harvest decay of table grapes caused by Rhizopus stolonifer. Physiological and Molecular Plant Pathology , 48, 403-415.

Verma V. C., 2018. Applications and Investigations of Ozone in Cereal Grain Storage and Processing: Benefits and Potential Drawbacks, International Journal of Current Microbiology and Applied Sciences Special Issue-7: 5034-5041.

Violleau, F., Hadjeba, K., Albet, J., Cazalis, R., and Surel, O. 2008. Effect of oxidative treatment on corn seed germination kinetics, Ozone, Sci and Engineering, 30: 418–22.

Yokoyama, M. 1990. Aseptic packaged foods. In Food Packaging. Kadoya, T. (ed) Chapter 12, p.213-228. Academic Press Inc., New York.

Zhao, C., Ge, B., De Villena, J., Sudler, R., Yeh, E., Zhao, S., White, D.G., Wagner, D. and Meng, J. 2001. Prevalence of Campylobacter spp., Escherichia coli, and Salmonella serovars in retail chicken , turkey , pork, and beef from the Greater Washington, D.C. area. Applied and Environmental Microbiology, 67, 5431-5436, 2001.