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Critical Evaluation of the Advantages and the Disadvantages of Using Ozone as a Novel Method of Food Preservation

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Abstract

The food contamination issue needs constant control of food at every steps of food production. Pathogens and spoilage free organisms as well as high quality and safety of products are one of the most important factors in food industry. This may be achieved by many advanced novel technologies. The aim of this work is to review the role, contribution, importance, and impart of ozone as decontaminated agent use to control and eliminate the presence of microorganisms in food products as well to extend their self-life and removed unwanted odours. Many researchers have reported the properties and application of ozone, showing that ozone treatment technologies can be applied to all types of food such as fruits, spices, vegetables, meat, seafood products, and beverages. A compilation of other research works presented in this review work can be a useful tool for establishing appropriate ozone treatment conditions to improved quality and safety of food products. A critical evaluation of the advantages and the disadvantages of ozone in the context of it application in food industry is also highlighted as well.

Keywords: *Ozone, Decontamination, Food Industry, Microorganisms, Quality and Safety*

Introduction

The consortium of microbes, parasites and pests in plant foods, animal's foods, seafood, and other food related products is a big problem to the food industry and the health of the consumers that need to be addressed. These organisms if they are not properly treated and controlled would be sources of spoilage of the foodstuff and foodborne diseases. Therefore, the need for safe, environmentally friendly and effective methods of food preservation is needed to overcome these challenges. The application of ozone as a powerful disinfectant as well as a potent decontaminator in the food processing industry has been well recognised (Tiwari et al. 2010; Brodowska, Nowak & Smiggielski. 2018). This report is to critically evaluate the advantages and the disadvantages of using ozone as a novel method of food preservation.

Research Methodology Approach

Conceptual Frame Work

The food industry is involved extensively in using ozone to enhance the shelf-life and safety of food products and in discovering new uses of the sanitizer. However, the use of ozone in food industry has some advantages and disadvantages.

Research Methodology

The research methodology approach was to critically review the related literature on the advantages and disadvantages of using ozone in the food industry.

Ozone Generation

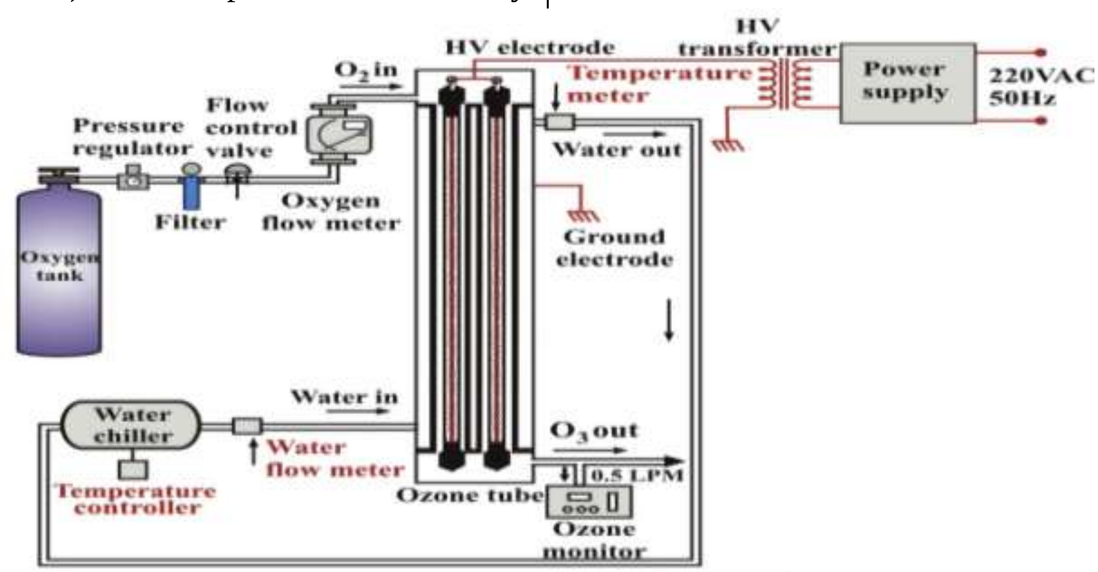

Figure 1: Schematic diagram of the setup for the ozone generator (Jodpimai, et al. 2015)

An illustration of the ozone generator and operation is depicted in **Figure1**. High grade oxygen with a purity of 95% was used as a feed-gas source for ozone production as shown in figure 1. The oxygen is controlled to a pressure of 3.0 bar by a pressure regulator. It is then filtered and the flow rate is measured between 5 and 45 L/min by a flow regulator valve and measured by an oxygen flow meter and finally distributed into the ozone tube. The oxygen in the ozone tube is discharged by a high voltage (HV) power supply and the ozone is generated. It flowed out of the ozone tube and is split with 0.5 L/min going to the ozone monitor. The rest is exhausted to the atmosphere. The ozone capacity is calculated by the following equation: Ozone volume (g/h) = Ozone concentration (g/m^3) × O_2 flow rate (m^3/h) (Jodpimai, Boonduang and Limsuwan, P. 2015)
Ozone has less toxic effects, is less corrosive, its actions are independent on the pH of the products, non-reactive with food products to produce undesirable substances like chlorine and also not reactive when combined with ammonia. The use of ozone has been approved by U.S. Environmental Protection Agency (Mitrol, 2001, in, Pereza, 2007). The use of ozone as a Generally Safe (GRAS) material has been documented (Khadre, et, al., 2001; Kim, et, al., 1999) and ozone is also permitted as a direct food additive for decontamination during storage and processing in food (Rich, 1999; Alexopoulos et, al., 2013).
Ozone has a reduction potential of 2.07 V, and hence is one of the strongest known oxidisers, and is used as a broad-spectrum disinfectant against both Gram-positive and Gram-negative bacteria, bacterial spores, fungi, viruses, and protozoa. Moreover, its breakdown yields oxidative radicals that subsequently give rise to non-toxic oxygen, so it has been permitted for use in food and waste water as a favourable environmentally-friendly sanitiser (Perry and Yousef. 2011; Feng, 2012). Ozone effects cell destruction to foodborne pathogens in the unsaturated lipids in the microbial cell wall of Gram negative bacteria, internal cell enzymes, and genomic materials (Kim *et al.* 2003).The effectiveness of ozone to kill bacteria is due to it oxidative and destructive effect on the cell walls, cytoplasmic membrane and DNA (Alexopoulos *et al*. 2013), another advantage of ozone is due to it higher diffusion potential that facilitate its faster and free diffusion through microbial cells membrane (Cullen, *et al* 2010)
In the food industry, ozone (O_3) is generally formed by electrical discharge or by means of UV light, to substances such as foods to decrease amounts of microbes and/or delay maturing. In food industry, ozone is used in

decontamination of drinking water, sterilisation of process water, washing of fresh foodstuffs, sanitation of food plant equipment and extension of goods shelf life such as fruits, vegetables, meat and seafood products to beverages (Brodowska et al., 2018). It is a strong oxidizing agent with wide variety of antimicrobial action and the capacity to delay ripening in fruits and vegetables by combining with the ethylene that they produce (IFIS. 2009).

The food industry is involved extensively in using ozone to enhance the shelf-life and safety of food products and in discovering new uses of the sanitizer. This concern was just accompanied by a US administrative endorsement of ozone for the safe use, in gaseous and aqueous phases, as microbiocidal agent on food, meat and poultry. Ozone has a strong microbiocidal action against bacteria, fungi, parasites and viruses when these microbes are present in low ozone-demand media. Readily available organic constituents in food, however, compete with microorganisms for applied ozone and thus efficacy of the treatment is minimized. Ozone is suitable for washing and sanitizing solid food with intact and smooth surfaces (e.g., fruits and vegetables) and ozone-sanitized fresh produce has since been introduced in the US market (Kim *et al.* 2003)

Table1: Showing the application of ozone in different food products

Types of Pathogen	Food	Treatment Time (m)	Ozone Conc.	Pathogen Reduction	References
L. innocua	Red bell pepper	3	2.0 ppm	2.8log/g	Alexander, et al., (2011)
Mesophiles	strawberries	3	2.0ppm	2.3log/g	Alexander, et al., (2011)
Coliforms	watercress	3	2.0ppm	1.7log/g	Alexander, et al., (2011)
Eurotium spp	cereals	120	300umol	100%	Babu &singleton.(2011)
Fungi	Paddy rice	10	40mg/l	99.95%	Beber-Rodrigues.(2015)
Total Count	Fish muscle	30240	0.3g/l	< 6 log/g	Bono & Badalucco (2012)
Mesophiles	lettuce	30	0.5mg/l	3.09log/g	Alexopoulos et al., (2013)
Mesophile	Bell pepper	30	0.5mg/l	3.27log/g	Alexopoulos et al., (2013)
Coliforms	Ball pepper	30	0.5mg/l	3.66l0g/g	Alexopoulos et a l., (2013)
Yeasts/Molds	lettuces	30	0.5mg/l	2.14log/g	Alexopoulos et al., (2013)

T. Castaneum	maize	60@20 °C	50ppm	95%	Pereira et al., (2008)
Aflatoxins1,G1	Peanut meals	1	25mg	100%	Dwarakanath et al., (1968)
L .monocytogene	Food-cont surface	2880	$1.07 mg/m^{-3}$	$5\text{-}6 log/m^{-3}$	De candia et al., (2015)

Application of ozone in fruits and vegetables

Vegetables are good for the diet of humans especially the fresh-cut ones and recently the their consumption has been on increase but, slightly treated foods such as vegetables have been implicated with severe outbreaks of food borne disease caused by microbial contamination in the field or after harvest (Aytal, et al., 2010; McEvoy, et al., 2009 in, Alexopoulos. 2013).

Fruits and vegetables frequently have a wide range of bacterial and fungal flora which is commonly involved in food-borne spoilage. Since fruits and vegetables are mostly consumed raw or minimally-processed example ready-to-eat salads, microbiological safety becomes a vital concern to reduce threats to customers (Sago et al, 2003; alexander, et al., 2011).

Alexander et. al. (2011) reported that ozone concentration has an effect on microbial load reduction in fruit and vegetables. They found out that ozone was useful in aqueous solution for decreasing bacterial loads in fruits and vegetables, its efficacy was dependent on the mixture of microbe/food and ozonised water-washings at the highest concentration of 3ppm were more active than ordinary water-washings. Using mixture of ozone and water usually had further decrease of 0.5–1.0 log-cycles and can be reflected as an acceptable decontaminator for contaminated fruits and vegetables. (Tzortzakis *et al.* 2007) reported that exposing tomato fruit (*Lycopersicon esculentum* L. cv. Carousel) for six days to ozone dose ranging between 0.005 (controls) and 1.0 μmol mol−1 at 13 °C and 95% relative humidity improves the Levels of soluble sugars, firmness, weight loss, antioxidant status, ethylene production, vitamin C and total phenolic content were not affected and were maintained compared to the control. This shows that ozone is an effective preservative that slow down the ripening mechanisms and maintain the organoleptic properties of fruits and vegetables.

Ali et al (2013) report that papaya treated with ozone have maintained good firmness than the control one, they subjected papaya fruits to different treatment and kept it for ten days and found out that treated papaya were firmer than the control ones. Ozone react quickly with ethylene and remove it from the fruit which slows down the ripening process of some fruit during storage.

Ali et al (2013) evaluated the antioxidant activity of ozone-treated papaya fruit and untreated fruit and found out that newly collected papaya fruit that were exposed constantly to ozone decontamination (0, 1.5, 2.5, 3.5 and 5 ppm) for four days prior to room storage at 25 ± 3 °C and 70 ± 5% relative humidity (RH) for up to 14 days. The fruit exposed to 2.5 ppm ozone had higher levels of total soluble solids (25.0%), ascorbic acid content (12.4%), β-carotene content (19.6%), lycopene content (52.1%), and antioxidant activity (30.9%), and also reduced weight loss (11.5%) at day 10 compared to the control. The sensory characteristics of papaya treated with 2.5 ppm ozone were higher in sweetness and general acceptability. These outcomes support the use of ozone as a non-heat and safe food preservation method for papaya which can profit both the farmers and customers.

In blueberries processing for instance, 1mg/L of ozone in aqueous solution was used during in-line dispensing which caused a population decrease greater than 2.0 log cfug^{-1} in inoculated field culture of both *Enterobacter agglomerans* and *pseudomonas fluorescens* while the decrease observed on inoculated berries with 100mg/L chlorine caused a reduction in the two culture of less than 1.0 logcfug^{-1} (Crowe, Bushway & Davis-Dentici. 2012). This shows that ozone is more effective than chlorine even at low concentration.

Application of Ozone in Grain Processing

Babu and Singleton (2011) reported that fungi surviving in low moisture environments were more resistant to heat treatment such as *Eurotium sp* found in grain, ozonation of grain will reduce the spoilage by these organisms and also ozone encourages oxidative stress which seems to reduce the formation of spores. Using 300µmol ozone for 2hr was required for complete destruction of these organisms. Beber-Rodrigues (2015) has shown that treating paddy rice with (0.1g/l) of ozone for ten minutes successfully reduced (90.40%) from (5.5 to 4.4 log), increasing the concentration to 20mg/l and 40mg/l gave a reduction of (99.95%) from (5.5 to 2.2log) and (2.1 log cfu/g) there was also reduction of moisture contents and water activity from 12.03 to 11.34%, a_w: 0.67 to 0.61. this indicates that ozone is a powerful sanitizer and preservatives of cereals.

Application of Ozone in Sea Food

Sea foods are mostly harvested from sea water that is heavily contaminated by a lot of pathogens and salt tolerant organisms. These foods would spoil quickly after the harvest if they are not well preserved and also becomes a potential source of foodborne diseases. Bono and Badallucco (2012) compared the samples of fish muscle treated with 0.3g/l of ozone and modified atmosphere packaging (MAP) kept at 1^0C for three weeks and sample of (MAP) kept in air, they observed that the ozonised sample of (MAP) has slowed down the growth of bacteria significantly in fish muscles for ten days below 6.0 $logcfug^{-1}$. The chemical parameters of both samples of ozonated MAP and MAP remain significantly lower than the traditional method. This implies that ozone is a powerful preservative and good sanitizer for sea foods.

Disadvantages of Ozone

Ozone is a good sanitizer in food industry and water treatment process. However, there are some limitations in its use for example, the concentration of ozone in water most not be more than 2.0 part per million which could cause a characteristics sign of irritation, noxious, and permanent damage to human health results from the remaining excess undissolved gas if inhaled (khadre, et al., 2001; Pascual, et al., 2007; Alexopoulos, et al., 2013). Ozone is an unstable gas that decomposes back to oxygen atom spontaneously therefore; it cannot be stored for longer period (Tiwari, et al., 2010)

Decomposition of ozone is related to the pH of the medium, temperature, and presence of ozone-consuming materials. Ozone-consuming materials present in apple juice reduced the amount of ozone applied and decreased the amount available to inactivate target pathogens (Choi. 2012) and applying ozone at higher doses to decontaminate foods could alter the sensory quality of the food and ozone is not always effective, sometimes, it may stimulate oxidative spoilage in foods (Cullen et al., 2010). Surface oxidation, colour change, off-odour, could occur in many solid food application such as meat, from excessive use of ozone (Khadre, *et al.,* 2001, in Cullen et al., 2010). Using a moderate concentration of ozone in some slightly processed foods could enhance browning reaction (Perera, 2007).

Alexander et. al, (2011) studied the interaction effects of using ozone and blanching on watercress, strawberries and red pepper and they observed that no any interaction effects occurred on the microbial reduction than the main effect of using the individual method alone. This indicates that ozone has no synergy with blanching.

Conclusion

The presence of consortium of unwanted microbes in our food and food products can alter the organoleptic and sensory characteristics of these commodities. Therefore, using ozone as a novel method of food preservation can overcome some or most of these challenges by destroying them and hence extending the shelf life. From this report, it has shown that using ozone at different concentration as reviewed**.** Demonstrated that it has wide application in foods processing industry because it is safe, less toxic, strong oxidizing agents that is effective against gram positive and gram negative bacteria, parasites, fungi, pest and viruses that are normally implicated in foodborne diseases and food spoilage. However, there are some limitation in its uses, at higher concentration for example, ozone changes the quality of foods, toxic to human health if inhaled, unstable that always need to be generated on-site and in slightly processed foods it facilitate browning reaction. With all these, ozone is still a promising technology in food processing industry.

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