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Ozone Treatment in Prolongation of Shelf Life of Temperate and Tropical Fruits

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ABSTRACT

In recent years, increasing attention has been focused on the safety of fruits and vegetables, andin particular on the intervention methods to reduce and eliminate human pathogens from fresh produce. Traditional technology utilizes water with or without a sanitizing agent to wash fresh fruits and vegetables. Chlorine is the most widely used sanitizing agent available for fresh produce, but it has a limited effect in killing bacteria on fruit and vegetable surfaces. Research and commercial applications have verified that ozone can replace traditional sanitizing agents and provide other benefits. 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. Ozone is an oxidant/disinfectant that quickly decomposes to diatomic oxygen (O_2), while reacting with targeted organic matter or microorganisms. In the case of fruits and vegetable ozone is used to increase safety of fresh produce and shelf life. Several researches have shown that treatment with ozone appears to have a beneficial effect in extending the store life of fresh non-cut commodities such as broccoli, apple, grapes, oranges, pears, raspberries and strawberries by reducing microbial populations and by oxidation of ethylene.

Key words: *Fruits, Vegetables, Chlorine, Ozone*

INTRODUCTION

Ozone, first discovered in 1840, began being utilized as a disinfection agent in the production of potable water in France in the early 1900s. 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.

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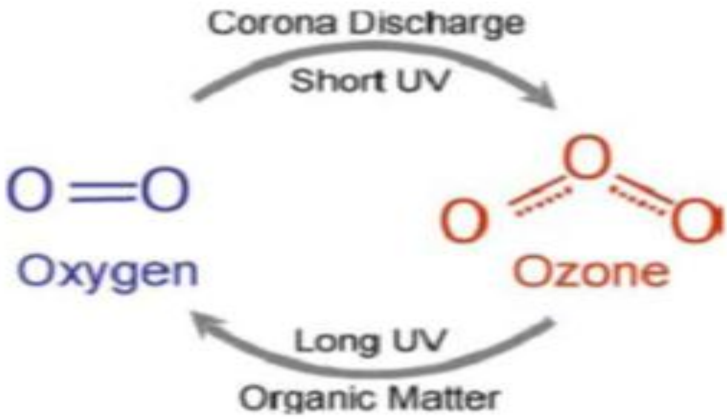
Ozone is effective killing microorganisms through oxidation of their cell membranes and most of the pathogenic, foodborne microbes are susceptible to this oxidizing effect.

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 FORMATION

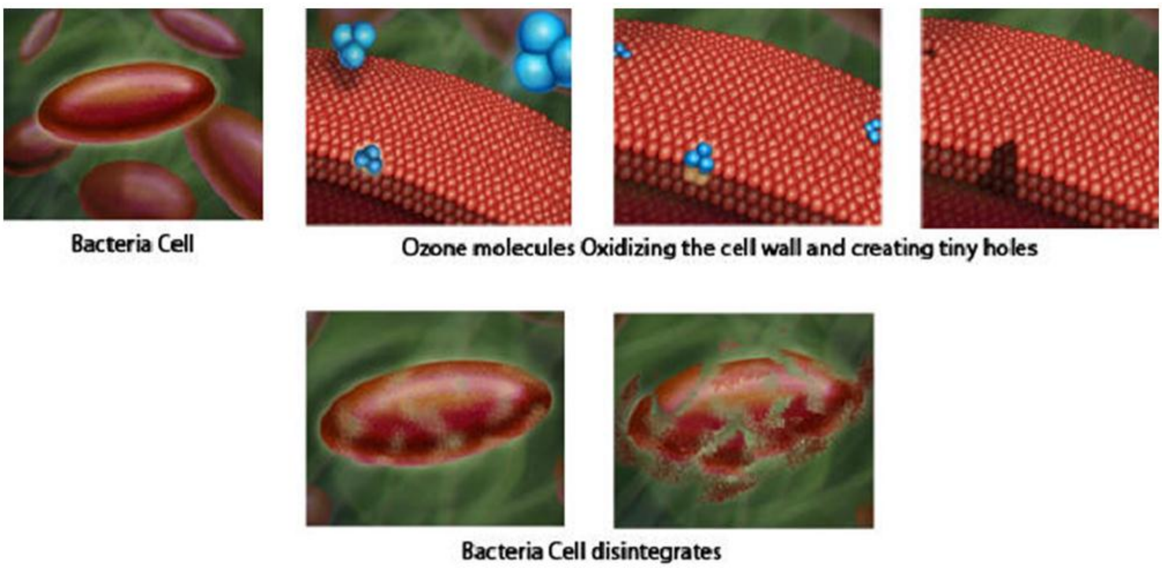
Ozone is naturally generated in the stratosphere, the upper atmospheric layer that protects us from harmful radiation. Gaseous ozone is formed also in the atmosphere during lightning discharges and on the earth's surface by photochemical reactions, UV sterilization lamps, and high voltage electric arcs.



Industrially ozone is commonly generated by electrical discharge. In this method, dry air or oxygen is passed between two parallel or concentric electrodes that are coated with a dielectric material. Oxygen molecules are broken down to charged oxygen atoms, which recombine to form ozone molecules. Depending on the feed gas, ozone production rate varies from 1–3% (w/w) to 6–16% (w/w) for air and pure oxygen, respectively.

MECHANISM OF MICROBICIDAL ACTION OF OZONE

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.



DISINFECTION AND PRESERVATION OF FRUITS AND VEGETABLES

One of the earliest reported experiments dealing with preservation of fruits was related to ozonation of bananas[5]. 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 ofshelf life extension and reduction of pathogenic contamination.

EXTENSION OF FOOD PRODUCT STORAGE LIFE

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

- Dondo *et al.*[20] reported that ozone treatment during refrigerated storage stabilized the surface bacteria count on beef and reduced that on fish.
- Naitoh *et al.*[13], 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.
- Studies conducted in 1980s, 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.

Application of ozone treatment for shelf life extension of different highly perishable fruits

Apple: Product losses occur all along the production chain. In particular, losses due to post-harvest diseases are costly since these include the cumulative value of growing, harvesting and storing apple fruit. As a general rule, apples can be stored for up to 10 months in cold storage combined with controlled-atmosphere (CA) environment prior to being sold. The most important diseases with economic importance for apples are caused by fungi [e.g. *Pezicula malicorticis* (H. Jacks), *Botrytis cinerea* Pers.: Fr., *Mucor*spp., *Gloeosporium perennans* Zeller & Childs, *Penicillium expansum* (Link), *Phialophora malorum* Kidd & Beaum]. In particular, *P. expansum*is the causal agent of blue-green rot, one of the most economically important post-harvest rots of apples. The fungus is the most important patulin (PAT) producing organism in fruits, especially on pomefruits[2]. PAT is a mycotoxin with genotoxic, neurotoxic, immunotoxic and immunosuppressive effects. Toxic effects caused by PAT are hazards to public health, and its presence has therefore been regulated in different countries. Controlling *P. expansum* development and PAT contamination, to obtain cosmetically perfect produce in conventional apple growing, requires many preventive fungicide treatments. However, the development of resistance to fungicides and the health concerns due to contamination of the environment with pesticides, have resulted in restrictions in the use of these materials, which has resulted in increased research on alternative control measures, including ozone (O_3)[15].

Thaer *et al.*[16], studied fruit of the apple varieties: ‘Royal Gala’, ‘Golden Delicious’ and ‘Fuji’ which were challenged with a patulin-producing *P. expansum*s train and stored at 1 ± 1°C in presence of gaseous ozone at 0.5 µL L-1 for 2 months. During the storage period, fungal populations, the biosynthesis of patulin and the activity of some Pathogenesis Related Proteins (glucanase, peroxidase and phenylalanine ammonia-lyase) were evaluated. Ozone treatment reduced fungal populations and patulin production. The activity of the assayed enzymes was not directly or clearly correlated with the inhibiting effect of ozone. These results indicate that ozone could be used to increase storage duration of apple varieties to maintain their quality.

Peach: Internal breakdown and fruit decay are the main causes of peach postharvest losses. Brown rot, caused by *Monilinia fructicola* (G. Wint.) Honey, is the most important postharvest disease of stone fruit in California. Depending on weather conditions and postharvest handling, other high-incidence postharvest diseases of stone fruit are gray mold, caused by *Botrytis cinerea* Pers. Fr., Mucor and Rhizopus rots, caused by *Mucor piriformis* E. Fischer and *Rhizopus stolonifer* (Ehrenb.) Lind, respectively, and blue mold, caused by *Penicillium expansum* Link. Integrated pest management practices including the use of both pre-harvest and postharvest fungicides are currently required to effectively control postharvest diseases. Problems associated with the use of synthetic fungicides such as the proliferation of resistant strains of the pathogens or concerns about public health and environmental contamination have increased the need for development of alternative treatments.

Continuous ozone exposure at 0.3 ppm (v/v) (US-OSHA Threshold Limit Value for short term exposure) inhibited aerial mycelial growth and sporulation on 'Elegant Lady' peaches wound inoculated with *Monilinia fructicola*, *Botrytis cinerea*, *Mucor piriformis*, or *Penicillium expansum* and stored for 4 weeks at 5 °C and 90% relative humidity (RH). Aerial growth and sporulation, however, resumed afterward in ambient atmospheres.

Watermelon: Minimal processing for "fresh produce" has been rapidly developed on the world. In fruit and vegetable industry, minimally processed fruits are products that maintain their attributes and quality similar to those of fresh products. In tropical countries, fruit fresh-cut has been a highly consumed product, ozone was used in watermelon fresh-cut processing as an antimicrobial agent.

An Experiment was conducted by Man *et al.*[10], in which Ozone flux was directly blown into the package containing watermelon fresh-cut. The ozone concentration in the blowing flux was 4.2mg/dm^3 (30^{0}C, 1atm). Four samples T1, T2, T3 and C1 were examined. The blowing time of samples T1, T2 and T3 was 1, 2 and 3 minutes, respectively. C1 was the control sample – without ozone treatment. All samples were then stored at 4^{0}C for 6 days. The microbiological characteristics of the watermelon fresh-cut are presented in Figure 1 and 2. It can be noted that ozone blowing into the package containing watermelon fresh-cut decreased the number of microbial cells in the product. The longer the treatment time, the lower the number of bacteria, yeasts and molds in the product. In addition, during the storage, the growth of bacteria, yeasts and molds in samples T1, T2 and T3 was slower than that in control sample C1.

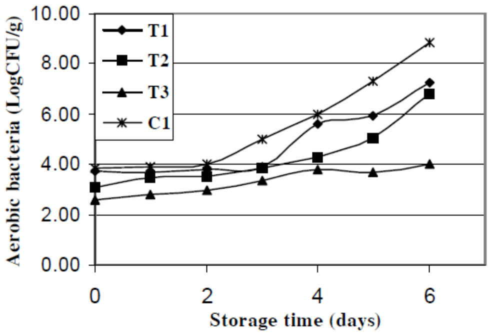


Figure 1. Bacterial growth in the watermelon fresh-cut during the storage at 4^{o}C. Treatment time of T1, T2 and T3 samples was 1, 2 and 3 minutes, respectively. C1 was the control sample.

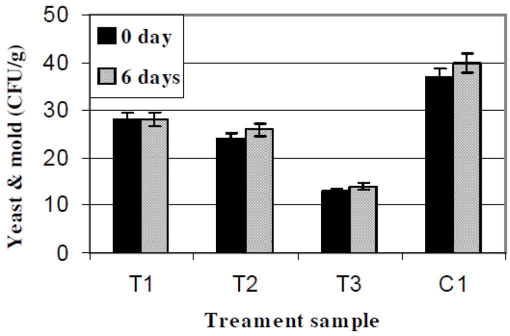


Figure 2. Yeast and mold quantification in the watermelon fresh-cut after 0 day - storage and 6 day - storage at 4^{o}C. Treatment time of T1, T2 and T3 samples was 1, 2 and 3 minutes, respectively. C1 was the control sample.

Source: Man *et al.*[10], experiment conducted on prolongation of watermelon fresh-cut shelf life by ozone treatment.

Strawberry: Strawberry is one of the most delicate and perishable fruit, being susceptible to mechanical injury, physiological deterioration, water loss, and decay caused by fungi, mainly gray mold rot caused by *B. cinerea.* Thus, effective postharvest procedures are required to prevent deterioration during strawberry packing. The effect of ozone treatment on the postharvest quality was evaluated[3], strawberry fruits were stored at 2^0C in an atmosphere containing ozone (0.35ppm). after 3 days at 2^0C, fruits were moved to 20^0C to mimic retail conditions. Ozone treatment was effective in preventing fungal decay in strawberries after 4 days at 20^0C.

Mango: Mango fruit (*Mangifera indica* L.) is an economically important fruit in the tropics. However, as a fleshy fruit, the losses resulting in senescence, desiccation, physiological disorders, mechanical injuries and microbial spoilage can occur at any point from harvest to utilization. The total postharvest loss of mango was found as much as 34% due to improper handling and storage. Recently, ozone applications on postharvest commodities, including mango fruit were reported to be an effective method in delaying ripening, reducing microbial contamination and improving fruit quality during storage. Treatment with ozone can extend the shelf life of mangoes by reducing microbial populations and by oxidizing ethylene to retard ripening.

In a study conducted by Tran *et al.*[17], mango fruits were fumigated with ozone at the concentrations of 2 $\mu L\ L^{-1}$ for 20 min and 10 $\mu L\ L^{-1}$ for 10 min on arrival and after 3 days of storage and were compared to untreated fruit. Fruits were stored in ambient temperature (25 ºC) to determine the effects of ozone on mango quality. Ozone at 10 $\mu L\ L^{-1}$ significantly decreased the respiration rate at day 4 and day 6 compared with the control. After treatment, ethylene production was reduced in treated fruit, but at day 4 and day 6, the higher ethylene production was detected in ozone treatments. The lower L* and b* values in mango peel were found in 10 $\mu L\ L^{-1}$ ozone at day 4. In the pulp, both ozone concentrations decreased the a* values and increased the hue angle values at day 6. Ozone at 10 $\mu L\ L^{-1}$ reduced the weight loss of mango at day 6. However, no significant differences were detected in the fruit firmness, soluble solid content and titratable acidity among treatments.

Banana: Ozone can be used to destroy the active substance produced by ripe bananas, which otherwise accelerates the ripening of green fruit in the same space[5].. studied the effect of ozone on bananas, the fruit was submitted to atmospheres containing different amounts of ozone, namely 40 parts per million, 25-30 parts, 5-7 parts and 1.5 parts per million and the amount of CO_2 given off was noted. In the first case the rate of CO_2 production was raised considerably and injury to the peel was evident after 6 days, in the second, though CO_2 production was only slightly higher than in air, peel injury was noticeable after 8 days. Ripening was definitely delayed as compared with control conditions. With 5-7 parts per million there was no significant change in the rate of respiration or of ripening. With 1.5 parts per million neither ripening nor CO_2output was affected, but slight injury occurred after 10 days.

CONCLUSION

Ozone is by no stretch a universal solution for all food processing operations. There are a significant number of good, sound applications including; disinfection of food wash water. 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).Ozone has been proven to produce greater lethality rates for microorganisms than chlorine or other chemical sanitizing agents. The increasing cost of water resources, together with the drive toward more conservation, will stimulate industry to seek treatment methods which allow recycling of product wash water and process water. Ozone is effective against various kinds of microorganisms on fruits and vegetables. Promising results have been revealed in solving the problems of the food industry like mycotoxin and pesticide residues by ozone application.

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