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# The Use of Ozone in Improvement of Health of Fruits and Vegetables in Foodstuff Industries

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## ABSTRACT

Considering the strategic importance of fruits and vegetables in foodstuff industries and its effects on human beings' heath and the necessity for promotion of food safety of the society, we need an appropriate method for disinfection and more durable preservation of fruits and vegetables. Regarding that old and current methods such as chlorination, etc. are not appropriate methods and, in some respects, have side effects for human being, we decided to study ozonation of fruits and vegetables. In this study, we concluded that Ozone controls microbes and fungi and toxic agents on the surface of fruits and vegetables and leads to their more stable storage, least weight loss, and also most quality preservation which are possible by precise adjustment of amount and appropriate time of ozonation and we can ozonize important and strategic fruits and vegetables with higher quality at standard warehouses.

**KEY WORDS**: the use of ozone, fruits, vegetables, foodstuff industries, storage

## INTRODUCTION

Fresh fruits and vegetables have been increased abundantly in the last two decades. Alongside, incidence of diseases caused by contaminated food and water and chemicals are also on the rise. Waste rate of fresh crops has reached 30 percent in the period between harvest to processed product consumption, some part of which is result of microbial activities in this period. This situation leads to loss of significant resources and decrease of health safety of the society and reminds the necessity of considering transfer of crops by a more appropriate and healthier method. (1)

Considering the ability of ozone in oxidation and disinfection and shelf life of fruits and vegetables, the use of ozone was declared generally safe by FDA in 2009. (9)

Ozone is a form of oxygen which is generally known for its ability in protection of the earth against UV. Having been discovered in 1839, the germicidal properties of ozone were identified. (2)

In this article, we try to specifically examine the effects of ozone on preservation and health of foodstuff and fruits and vegetables.

### Why is Ozone an Appropriate Alternative for Other Antiseptics and/or Disinfectants?

According to the researches of the last decade, gaseous ozone may be a good alternative for chlorines on commercial and industrial scale. Ozone has been entered to the list of GRAS to be used in food industries since 1997. The superiority of ozone over chlorine is its higher oxidation (1.5 times more than chlorine) and its effectiveness on a wider range of microbes. Ozone eliminates bacteria such as Escherichia Coli, Listeria, and other food pathogens much faster than other disinfectants (such as Chlorine), while it leaves behind no chemical residues. (1)

Sodium Hypochlorite is one of the most commonly used disinfectants in packaging industries of fruits and vegetables but its use has decreased and even banned in some European countries because of producing harmful and toxic byproducts such as trihalomathanes (THMs) and haloacetic acids (HAAs) which cause mutants and cancers. (4)

Nowadays, ozone is used abundantly in disinfecting water and foodstuffs. One of the advantages of use of ozone is that its precursor does not produce any harmful compound at the end of washing process and, depending on the type of the product, may be used in gas and liquid forms. (4)

A group of experts of Electric Power Research Institute (EPRI) of USA in 1997 insisted that ozone can be used as a GRAS in disinfecting food, provided that the conditions of Good Manufacturing Practice (GMP) for producing a high quality product are observed. (2)

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Ozone is the more powerful commercial disinfectant whose comparison table with some elements is as follows:

**Table 1**

| Oxidant | Redox (V) |
|---|---|
| **OH** | 2.80 |
| **O** | 2.42 |
| **$O_3$** | 2.07 |
| **HOCl** | 1.49 |
| **$Cl_2$** | 1.36 |
| **$H_2O_2$** | 0.87 |
| **$O_2$** | 0.40 |

In the following, there is the comparison of power of ozone with some disinfectants:

**Table 2**

| Disinfectant | Entero Bacteria | Virus | Bacterial Spores | Amurlde Cysts |
|---|---|---|---|---|
| **$O_4$** | 500 | 5 | 2 | 0.5 |
| **HOCl** | 20 | 1 | 0.05 | 0.05 |
| **OCl** | 0.2 | <0.02 | <0.0005 | 0.003 |
| **$NH_2Cl$** | 0.1 | 0.0005 | 0.001 | 0.02 |

BLC: high voluc – high disinfection power

Ozone is stronger than chlorine to disinfect, and the most important point is that iteliminates all microorganisms with a higher speed without considering their natures which is shown in the table of comparison of ozone, chlorine, and UV:

**Table 3**

Comparing Disinfectants

| | Ozone | LV | Chlore |
|---|---|---|---|
| **F.coli** | Yes | Yes | Yes |
| **Salmonella** | Yes | Yes | Yes |
| **Giardia** | Yes | Yes | Yes |
| **Legionnaire** | Yes | No | No |
| **Crypto-sporidiuln** | Yes | No | No |
| **Virus** | Yes | No | No |
| **Algnes** | Yes | No | No |
| **THM** | Yes | No | Yes |
| **Cancer** | Yes | No | Yes |

It can be said that almost in all food industries, ozone is used for sterilization, disinfection and elevating the time of shelf life. Ozone eliminates bacteria, viruses, fungi, and even spores without considering their natures. (3)

***Uses of Gaseou and Dissolved Ozone in Food Industries:***

***1- Disinfection and Storage of Crops***

In the performed studies, sometimes, low density of ozone, about 1 to 0.3 PPM could have slowly but considerably prevented citruses such as oranges and lemons from decay by penicilliumdigitatum P.itaticwn, strawberries by botrytis cinerea and peaches by moniliniafructicola. (2)

Also, it has been observed that ozone completely prevents fungi, the most important post-harvest diseases of grapes, from growth. Fruits such as oranges and lemons can be preserved by gaseous ozone for two months.

A reduction of bacteria has been shown in many other food products such as raw eggs, lettuce, spinach, tomatoes, and blueberries by using ozone system. (6)

The studies performed by Kim et al (1999) showed that lettuce disinfecting and washing by mesophillic and psychrotrophic microorganisms of ozone with the only amount of 1.3 ppm decreases more than 99.9 percent of psychrotrophic bacteria which grow in a temperature between $20^{\circ C}$ to $45^{\circ C}$in five minutes. (5)

Peaches and grapes are the main crops in San Joaquin, California, USA. Fruit decomposition and decay are the main elements. Peach post-harvest losses are great. Post-harvest disease of peaches is very important in California and depends on the weather conditions and touch of this fruit after harvesting. Gray mold is another post-harvest disease of peaches. Use of fungicide, before and after harvesting, has been among the measures of Pest Management Practices Institute. But currently fungi and post-harvest disease control is important.

Problems in relation to using artificial fungicides such as proliferation of strains resistant against pathogens and worries about public and environmental health has increased.

In California, grapes were stored in the refrigerator in a temperature between $0^{\circ C}$ to $1^{\circ C}$ and 90% to 95% humidity for four months, but gray mold was created, the stems turned brown, and the water was lost; all of these were problems.

Meanwhile, it should be noted that crops such as peaches, grapes, mushrooms, apples, oranges, and potatoes must be surely stored in healthy form and without primary decay and ozone must be added to them; otherwise, if there is even the least corruption, fruits will decay very fast due to the strong oxidizing effect of ozone.

Ozone controls the growth of many lya and ferostikla and spores production and causes peaches and grapes stay healthy in 90% humidity. Grapes can be stored for 4 weeks.

Ozone, also, controls growth of fungi in seedless Thompson. Colonies of fungi, yeasts, and bacteria in berries and grapes are controlled when they are exposed to ozone for 20 minutes by ozone generator and their shelf lives increases.

Ozone can be simply used for storage of crops such as potatoes, grains and cereals. For example, the performed researches have shown that gaseous ozone is effective in decreasing the symptoms of Silver Scarf Disease in commercial storage of potatoes and also may have positive effects on seed tubers while it does not have effects the quality of potatoes. (2)

Generally speaking, in storing organic products and their cultivation, ozone is a good alternative for pesticides and antiseptics. (10)

**2- The Effect of Gaseous Ozone on Elimination of Ethylene from Fruit Warehouses:**

Slowdown of ripening process of fruits and vegetables is one of the important effects in cold storage. During the ripening of fruits such as bananas, apples, grapes, citruses, peaches, vegetables, onions, peppers, cucumbers, sour apples, potatoes, squashes, kiwis, watermelons, tomatoes, zucchinis, pears, raspberries, and corns, ethylene gas is released which accelerate the process of fruit ripening. Ozone has a great effect in eliminating ethylene through chemical reactions happening in storage of most of fruits and vegetables. (1)(2)(8)

$$H2C=CH2 + O3 \Leftrightarrow CO2 + H2O$$

In addition to eliminating ethylene, ozone interestingly causes elimination of the smells. (2)

**3- Disinfecting and Washing the Crops**

**Effects of Ozone on Vegetables*:***

Vegetables are rich sources of vitamins such as B, C, A, K and beta-carotene, folic acid, and minerals such as iron, magnesium, calcium, potassium, etc. ensuring food quality and shelf life of vegetables are the most important critical points in production line. (10)

By the same token, considering the environmental and health problems, using chlorine for disinfecting vegetables has been banned by European Union. (11)

Ozone is an oxidizing compound and strong disinfectant which effects a wide range of microorganisms in various PH (12) and decreases the microbial loads of vegetables and fruits while preserves their freshness and colors. (13)

Although ozone is one of the most valuable disinfectants and preservatives and keeps well the quality of fruits and vegetables, it significantly decreases natural aroma. (15)

In disinfecting lettuce and other vegetables and fruits, containing vitamin C, by perchlorate and ozone, the amount of vitamin C should decrease considerably due to oxidation but experiments do not confirm such result, because disinfectants control ascorbic acid oxidase at first and ozone effectively prevents decrease of vitamin C; therefore, ozone is more appropriate for maintaining nutritional value and amount of vitamin C. (16 & 17)

Figure 3, Article 3

Ozone causes longer shelf life of vegetables by preserving their nutritional value and minimal changes in their quality and decreasing microbial load.

In storage of fruits, grapes in particular, using ozone with density of 2500 and 5000 controls maximum gray mold and decreases decay and is has better effects on preserving fruits and grapes in long term and with a lower dose, and with a dose of 4 to 7 micrograms decreases the rate of vitamin C reduction and causes longer shelf life and better quality.

Washing fruits and vegetables, either by immersion or with showers, is an appropriate way to preserve them and control microbial corruption. Ozone has particularly bactericidal effect on E.coli (an important microbe which is food health control index). (1) & (2)

**4- The Effects of Ozone on Elimination of Antipests and Pesticides Residues on Crops**

In a study by Ong et al on apples, it was found that ozone with the density of 0.25 ppm may decrease the remaining amount of three insecticides Azinphos-methyl (Guthion$^{R}$), Captan (Orthocide Captan$^{R}$) and Formetanate Hydrochloride (Carzol$^{R}$) on fruits up to respectively 75%, 72%, and 46%. In this study, washing by ozone had considerable effect on the remaining amount of insecticideon the surface of processed apples and water employed in washing apples. (2)

Pistachio is one of the valuable products with high nutritional and economic value but it quickly get infected by Aflatoxin produced by toxigenic and food contaminating fungi including three main groups of Aspergillus, Fusarium, and Penicillium. At least 18 structures have been identified for Aflatoxin that in most cases are produced by Aspergillus Flavus and Aspergillus Porteuson crops. Aflatoxins are resistant to heat up to 150 degrees for one hour. Humidity may increase production of Aflatoxin; therefore, transfer for dry and in low humidity is appropriate. According to the studies, ozone dissolved in water can decrease Aflatoxin of pistachios. Ozone performance for decreasing Aflatoxintakes place on the pistachios with shell (without the soft outer skin) because the outer soft skin prevents the effects of ozone on pistachios. Reduction in Aflatoxin in pistachios without the outer soft skin occurs with minimum 4 ppm in 6 hours or 8 ppm in 2 hours and leads to persistence and health of pistachio. Aflatoxin of pistachio can be decreased by ozone with the aforesaid amount.

**5- The Use of Ozone in Disinfecting Equipment and Water of Process of Food Processing**

Ozone can be used as an alternative for disinfecting and elimination of microorganisms. (2)

Ozone is used as a powerful disinfectant for machinery, equipment, and surfaces.

**Conclusion:**

As the study of performed experiments in the field of disinfecting foodstuff suggests that water alone is not able to eliminate microorganisms of fruits and vegetables surfaces and it also has been found that ozone with a high capacity of disinfecting, leads to increasing the life of fruits and also control of smell and because it controls microbes causes the fruits and vegetables to be fresh and clean. The results obtained in this field show that ozonation can be a safe method to create a sterile environment which leaves behind no pollutions in the environment and has no threat for food products. Therefore, it can guarantee safety and health of foodstuff and crops and also have effects on costs and efficiency. Basically, ozone is not a toxic gas and, contrary to chloric compounds, does not accumulate in fatty tissue of the body and does not have chronic effects, so it is a safe gas. Authorities also have declared that its use in food products and crops is harmless and can be an appropriate alternative for sodium hypochlorite which is banned in many countries because of its harmful compounds. Regarding its safety and oxidizing and disinfecting properties, the considerations in respect of time and dose of contact to products or personnel must be observed and people must use safety equipment while working with it.

Studies show that ozone with an appropriate density has an important role in maintaining quality of fruits and vegetables and its density and effective time is significant in elimination of any harmful factors (18 & 14). By observing the above principles, we can enjoy the less decay, less vitamins reduction, less weight loss, and most maintenance of nutrients of fruits and vegetables and most storage life with least quality reduction.

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