Front. Agric. China 2011, 5(3): 356–360
DOI 10.1007/s11703-011-1053-y

RESEARCH ARTICLE

Impact of ozone on quality of strawberry during cold storage

Xiaona ZHANG, Zide ZHANG (✉), Lei WANG, Zhenliang ZHANG, Jing LI, Congzhi ZHAO

College of Food Science and Technology, Agricultural University of Hebei, Baoding 071001, China

Abstract **The postharvest physiology of strawberry was investigated to study the effects of ozone on weight loss rate, ascorbic acid, respiration rate, peroxdase (POD) activity, catalase (CAT) activity, and malondialdehyde (MDA) content during cold storage. The strawberries were treated with ozone of 0 ppm (control), 2 ppm, 4 ppm, and 8 ppm, respectively. The results indicated that the treatment of 4 ppm ozone could inhibited the decrease of ascorbic acid, POD activity, and CAT activity, and reduced weight loss rate and MDA content. The treatment delayed the senescence of strawberry, with a significantly lower respiration rate. Thus, the best concentration of ozone was 4 ppm, and ozone treatment could be a good candidate for maintaining postharvest quality of strawberry and provide a longer storage life.**

Keywords strawberry, ozone, cold storage, quality

Introduction

Strawberry is one of the most popular fruits due to its special taste and medical function (Li et al., 2006; Yang and Kang, 2006; Cong, 2008). However, it is highly perishable and susceptible to microbiological decay during storage (Wills and Kim, 1995; Kim et al., 2010). They have a very short postharvest life, and losses reach 40%. Control of postharvest decay in strawberry fruit has been mostly dependent on the use of fungicides and low temperatures (Washington et al., 1992; Bao and Liu, 2004; Qian et al., 2006). However, because of the negative effects of fungicides on the environment and human health, and the development of fungicide resistance by pathogens (Cao et al., 2010; Gabler et al., 2010), there is an urgent need to seek alternatives.

Ozone is a highly reactive form of oxygen where three molecules are bonded together. Generated electrically on-site where needed, it has a potent antimicrobial activity and other characteristics. Interest in ozone applications for agriculture and food processing has increased in recent years (EPRI Expert Panel, 1997). Ozone has a long history as a water disinfectant in common use for this purpose in many parts of the world. Many aspects of ozone use have been reviewed: (1) water disinfection applications (Nickols and Varas, 1992; White, 1999); (2) food safety and sanitation (Graham et al.. 1997; Kim et al., 1999), (3) chemistry (Razumovski and Zaikov, 1984), and (4) responses of horticultural products to ozone (Forney, 2003). The purpose for this article was to describe experiments of the evaluated ozone applications in packinghouses.

To the best of our knowledge, there are few data regarding the effect of ozone on the postharvest quality aspects of strawberry. Therefore, the objective of this study is to identify the effects of ozone on weight loss, ascorbic acid, respiration rate, POD activity, CAT activity, and MDA content of strawberry.

Materials and methods

Plant materials

Strawberries were obtained from an orchard in Baoding City, Hebei Province, China, and transported to the laboratory. They were graded for uniform size and colour and the absence of physical damage, and then randomly divided into groups for experiments.

Ozone application and experimental design

Strawberries were treated with 0 (control), 2, 4, and 8 ppm ozone for 30 min at 0ºC everyday. The strawberries were placed in plastic bags and ozone was injected, then the bags

Received June 1, 2010; accepted September 9, 2010
Correspondence: Zide ZHANG
E-mail: applezh13@126.com

were immediately sealed and the samples were stored for 30 min at 0ºC. Ozone concentrations were monitored and controlled using ozone analyzers (Model 1180, Dasibi Environmental Corp. Glendale, CA) and a data logger equipped with electronic relays (Model 21X, Campbell Scientific Inc. Logan, UT). Programmed set points in the data logger were used to turn the generators on and off to maintain the desired ozone concentrations. After treatment, all experimental units were stored at 0±1ºC and 90%±5% RH. Ozone was generated by electric discharge from pure oxygen (model SGA01 Pacific Ozone Technology Inc., Brentwood, CA, USA) to avoid the generation of impurities. All treatments were replicated three times as an experimental unit for each parameter studied. Following ozone treatments fruit were stored for 0, 5, 10, 15, and 20 days. At the end of each storage period, measurements were made of weight loss rate, ascorbic acid, respiration rate, POD activity, CAT activity, and MDA content.

Weight loss rate determination

Using an analytical balance (Sartorius BP 210 S, Goettingen, Germany), we determined the weight of 10 strawberries. The weight was registered. The weight loss rate was calculated using the following formula:

Weight loss rate = (The weight of fruit before storage – the weight of fruit during storage)/The weight of fruit before storage × 100%.

Ascorbic acid determination

The ascorbic acid was measured by 2, 6-dichlorophenolindophenol titration (GB/T 6195-1986, Code of National Standard of China). Briefly, tissue (50 g) from six fruits was immediately homogenized in 50 mL of 0.02 g/mL oxalic acid solution and then centrifuged at 15000×g at 4ºC for 15 min. Afterwards, 10 mL of supernatant was titrated to a permanent pink colour by 0.1% 2, 6-dichlorophenolindophenol titration. Ascorbic acid concentration was calculated according to the titration volume of 2, 6-dichlorophenolindophenol and expressed as mg/100g fresh weight.

Respiration rate determination

Respiration rate was measured by sealing each jar, and sampling the headspace (0.5 mL) using gas-tight glass syringes (Precision Sampling Corp., Baton Rouge, LA). Gas samples were analyzed using a gas chromatograph with a thermal conductivity detector (Fisher Gas Partitioner, model 1200, Fisher Scientific, Springfield, NJ).

Peroxidase (POD) activity

Peroxidase (POD) activity was determined by measuring the increase in absorption at 470 nm according to Kalir et al. (1984) with modification. The reaction was carried out at 25ºC for 20 min in a 3 mL reaction mixture containing 0.02 mL tissue extract, 50 mmol/L sodium phosphate buffer (pH 7.0), and guaiacol 20 mmol/L. The reaction was initiated by the addition of 20 μL H_2O_2. One unit of POD was defined as the amount of enzyme that caused a 1.0 increase of A_{470} per min under the assay condition. Each experiment was repeated three times.

Catalase (CAT) activity

Catalase (CAT) activity was determined by monitoring the decomposition of H_2O_2 at 240 nm following the method of Aebi (1984). The reaction mixture contained 1.7 mL 50 mmol/L sodium phosphate buffer (pH 7.0), 1 mL double distilled water and 0.2 mL tissue extract. The reaction was initiated by adding 0.1 mL 100 mmol/L H_2O_2. One unit of catalase was defined as the amount of enzyme which caused a 0.01 decrease of A_{240} per min at 25ºC.

Malondialdehyde (MDA) content

MDA (malondialdehyde) content was determined with thiobarbituric acid reaction (Zhao et al., 1994). In brief, 0.25 g of tissue was homogenized in 5 mL of 0.1% (w/v) trichloroacetic acid. The homogenate was spun at 10000×g for 5 min. To a 1-mL aliquot of the supernatant, 4 mL of 20% (w/v) trichloroacetic acid containing 0.5% (w/v) thiobarbituric acid was added. The mixture was heated at 95ºC for 15 min and cooled immediately, and the absorption of the supernatant was read at 450, 532, and 600 nm, respectively.

$$\text{MDA content } (\mu\text{mol/gFW}) = 6.45\,(OD_{532} - OD_{600}) - 0.56\,OD_{450}.$$

Statistical analysis

The SPSS 11.5 for Windows (Chicago, Illinois, USA) was used for the analysis of data. All results were treated for multiple comparisons by analysis of variance with least significant difference (LSD) between means determined at 5% level.

Results and discussion

Effect of ozone treatment on the weight loss rate

Figure 1 shows the weight loss of ozone treated strawberries measured at the end of the storage periods for samples stored for 20 days at low temperature. The weight loss increased with the storage periods for strawberry samples. On the 10th day of storage, the weight loss of control reached 5.60%; however, the weight losses in 2 ppm, 4 ppm, and 8 ppm ozone treatments were 3.41%, 2.14%, and 2.84%, respectively, which were lower ($P < 0.01$) than those in the control and the weight loss in 4 ppm ozone treatment was lower ($P < 0.05$)

than 2 ppm or 8 ppm ozone treatments. However, there was no marked effect between 2 ppm ozone treatment and 4 ppm ozone treatment on weight loss. According to Kays (1991), water loss of more than 4%–6% (of the total fresh weight) resulted in visible wilting or wrinkling of the surface of most commodities. These results suggested that the optimal concentration of ozone treatment was 4 ppm.

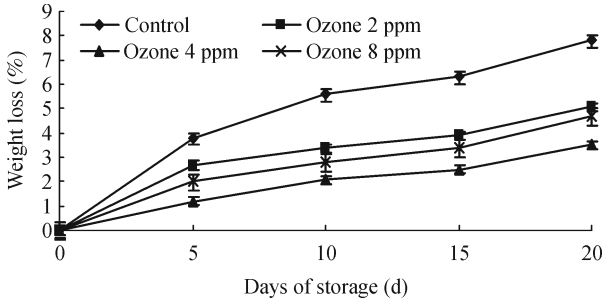

Figure 1 Effects of ozone treatments on weight loss of strawberries.

Effect of ozone treatment on the ascorbic acid

Variations in ascorbic acid values during storage are shown in Fig. 2. Ascorbic acid values decreased continuously during low temperature storage. On the 10th day of storage, ascorbic acid values of control only reached 46.21 mg/100g, reserving rate was 68.76% and fruit quality began dropping. Ascorbic acid in 2 ppm, 4 ppm, and 8 ppm ozone treatments were 58.32 mg/100g, 59.65 mg/100g, and 57.94 mg/100g, respectively, reserving rate was 87.32%, 88.37%, and 85.84%, with fruit still keeping in preferable quality, and the ascorbic acid in these treatments was higher ($P < 0.01$) than that in the control. Accordingly, the 4 ppm ozone treatment was used as the most preferred concentration in all other treatments.

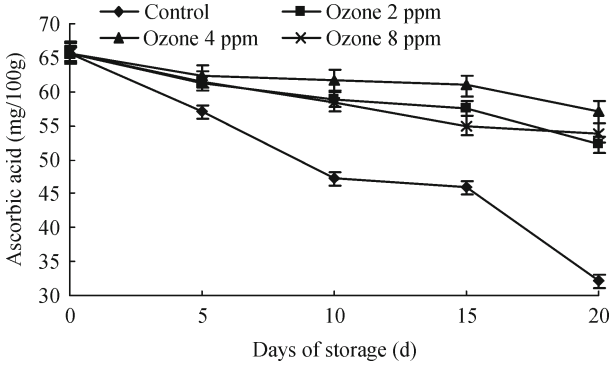

Figure 2 Effects of ozone on ascorbic acid of strawberries.

Effect of ozone treatment on the respiration rate

Variations in respiration rate during storage are depicted in Fig. 3. The respiration rate declined initially, and then rose steadily during low temperature storage. On the 15th day of storage, the respiration rate of control just had 43.20 $mLCO_2$/kg/h FW; however, it declined quickly when treated with 2 ppm, 4 ppm, and 8 ppm ozone respectively, reaching 40.10 $mLCO_2$/kg/h FW, 30.23 $mLCO_2$/kg/h FW, and 38.45 $mLCO_2$/kg/h FW, which were lower ($P < 0.05$) than that in the control. Compared with control storage, ozone treatments can better restrain the respiration rate of strawberries, and then extend its shelf life. 4 ppm ozone treatment was used as the preferred concentration in all the other treatments.

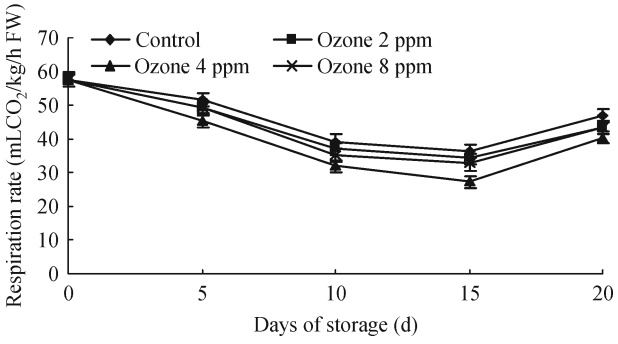

Figure 3 Effects of ozone treatments on respiration rate of strawberries.

Effect of ozone treatment on POD activity

Changes in POD activity of strawberries during storage are shown in Fig. 4. POD activity rose initially, and then declined steadily during low temperature storage. On the 5th day of storage, the POD activity of the control reached its peak value (50.126 ΔOD_{470}/min/g FW). POD activity of 2 ppm, 4 ppm, and 8 ppm ozone treatments reached their peak value (respectively 61.874 ΔOD_{470}/min/g FW, 53.298 ΔOD_{470}/min/g FW, and 65.326 ΔOD_{470}/min/g FW) which were higher ($P < 0.05$) than that in the control, indicating that 4 ppm ozone treatment could better inhibit the decrease of POD activity. These results proved that different concentrations of ozone treatment could delay the manifestation of the peak and restrain the decrease of POD activity during storage anaphase.

Effect of ozone treatment on CAT activity

Changes in CAT activity of strawberries are shown in Fig. 5. The CAT activity rose initially, and then declined steadily with time during low temperature storage. The CAT activity of the control slowly increased in the first 5 days. On the 5th day of storage, it reached its peak value 2.56 ($0.01\Delta OD_{240}$/min/g FW). Compared with the control, the CAT activity in ozone treatments kept a higher level during the storage life, and simultaneously delayed the peak value. In 2 ppm, 4 ppm, and 8 ppm ozone treatments, The CAT activity reached their peak value of 3.15 ($0.01\Delta OD_{240}$/min/gFW), 3.49 ($0.01\Delta OD_{240}$/min/g FW), and 3.47 ($0.01\Delta OD_{240}$/min/g FW) respectively, lower ($P < 0.01$) than that in the control. It is demonstrated that the different concentrations of ozone

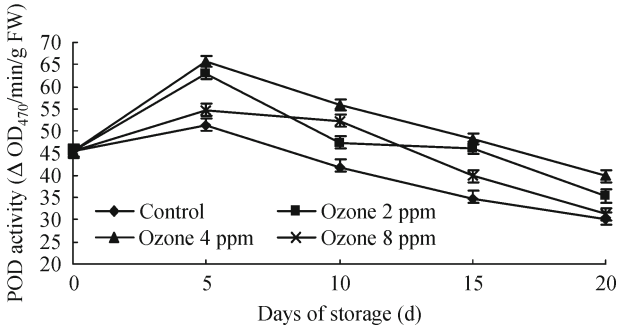

Figure 4 Effects of ozone treatments on POD activity of strawberries.

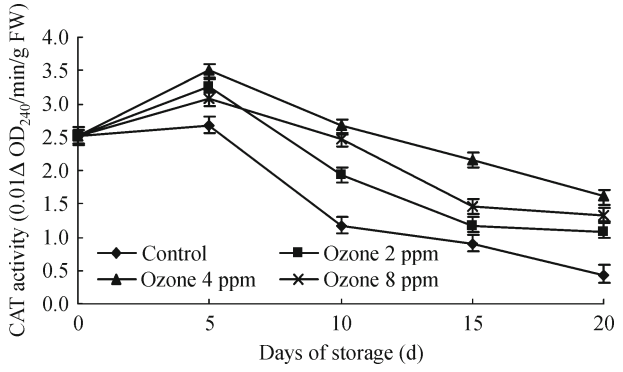

Figure 5 Effects of ozone treatments on CAT activity of strawberries.

treatment could effectively delay the manifestation of the peak and inhibit the decreasing of CAT activity at subsequent storage. These results suggested that the optimal concentration of ozone treatment is 4 ppm.

Effect of ozone treatments on MDA content

MDA content of strawberries gradually increased over the 20-day storage period (Fig. 6). On the 10th day of storage, the MDA content of ozone treatments was lower ($P < 0.01$) than that of the control, and the MDA content of 4 ppm ozone treatment was lower ($P < 0.05$) than that of 2 ppm or 8 ppm ozone treatment; however, no significant difference between 2 ppm ozone treatment and 8 ppm ozone treatment was found. It is demonstrated that different concentrations of ozone treatment could effectively inhibit the accumulation of MDA content, with the optimal effect of 4 ppm ozone treatment among them.

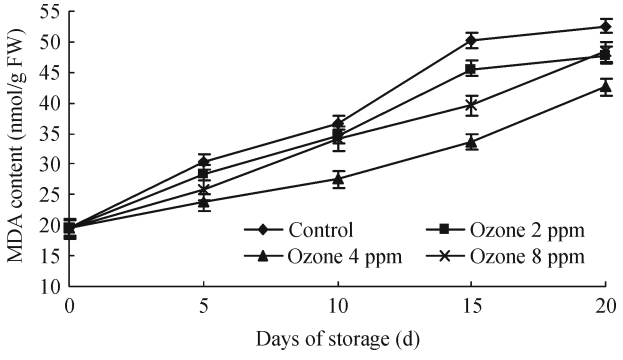

Figure 6 Effects of ozone on MDA activity of strawberries.

Conclusions

According to the results obtained in the study, the different concentrations of ozone treatment could be used to maintain the quality of strawberry. The most effective ozone treatment was at 4 ppm which could inhibit the decrease of ascorbic acid, POD activity, and CAT activity, reducing the weight loss rate and MDA content, and simultaneously delaying the senescence of strawberry and significantly lowering the respiration rate. Thus, 4 ppm was the best concentration of ozone as a good candidate for maintaining postharvest quality of strawberry and providing a longer storage life.

References

Aebi H (1984). Catalase *in vitro*. Methods Enzymol, 105: 121–126

Bao Q B, Liu J W (2004). Effects of pre-cooling conditions on qualities of strawberry with different maturity levels. Food Science and Technology, 8: 77–81

Cao S F, Hu Z C, Pang B (2010). Optimization of postharvest ultrasonic treatment of strawberry fruit. Postharvest Biology and Technology, 55(3): 150–153

Cong J M (2008). Research of application of nisin in preservation of strawberry. Food and Machinery, 24(2): 131–133 (in Chinese)

EPRI (Electric Power Research Institute) (1997). "expert panel" U.S. Food and Drug Administration, 1997. Substances generally recognized as safe, proposed rule. Federal Register, 62(74): 18937–18964

Forney C F (2003). Postharvest response of horticultural products to ozone In: Hodges D M, ed. Postharvest Oxidative Stress in Horticultural Crops. Binghamton: Food Products Press, 13–53

Gabler F M, Smilanick J L, Mansour M F, Karaca H (2010). Influence of fumigation with high concentrations of ozone gas on postharvest gray mold and fungicide residues on table grapes. Postharvest Biology and Technology, 55(2): 85–90

Graham D M, Pariza M, Glaze W H, Newell G W, Erdman J W, Borzelleca J F (1997). Use of ozone for food preservation. Food Technol, 51(6): 72–76

Kalir A, Ornri G, Poljakoff-Mayber A (1984). Peroxidase and catalase activity in leaves of *Halimione portulacoides* exposed to salinity. Physiologia Plantarum, 62(2): 238–244

Kays S J (1991). Postharvest Physiology of Perishable Plant Products. New York: Van Nostrand Reinhold

Kim J Y, Kim H J, Lim G O, Jang S A, Song K B (2010). The effects of aqueous chlorine dioxide or fumaric acid treatment combined with UV-C on postharvest quality of 'Maehyangs' strawberries. Postharvest Biology Technology, 56(3): 254–256.

Kim J G, Yousef A E, Dave S (1999). Application of ozone for enhancing the microbiological safety and quality of foods: a review. J Food Protect, 62(1): 1071–1087

Li X Z, Zheng T S, Zhang X M (2006). Study on effect of 1-MCP of different concentrations on fresh-keeping of strawberry fruit. Food Science, 27: 513–516

Nickols D, Varas A J (1992). Ozonation. In: Bryant E A, Fulton G P, Budd G C, eds. Disinfection Alternatives for Safe Drinking Water. New York: Van Nostrand Reinhold, 197–258

Qian Y M, Gao L P, Zhang Y Q, Gao G Z, Xu D C, Yuan W F, Guo Z H (2006). Effects of low temperature treatment on postharvest strawberry fruit quality. Journal of Anhui Agricultural University, 33(2): 268–271 (in Chinese)

Razumovski S D, Zaikov G E (1984). Ozone and Its Reactions with Organic Compounds. Amsterdam: Elsevier Science

Washington W S, Shanmuganathan N, Forbes C (1992). Fungicidal control of strawberry fruit rots, and field occurrence of resistance of botrytis cinerea to iprodione, benomyl and dichlouanid. Crop Prot, 11 (4): 355–360

White G C (1999). Ozone in: Handbook of Chlorination and Alternative Disinfectants. 4th ed. New York: Van Nostrand Reinhold, 1203–1261

Wills R B H, Kim G H (1995). Effect of ethylene on postharvest life of strawberries. Postharvest Biology and Technology, 6(3): 249–255

Yang Y H, Kang Z L (2006). Effect of chitosan and vitamine C mixture on strawberry fresh-keeping. Acta Agriculturae Boreali-occidentalis Sinica, 15(2): 131–133 (in Chinese)

Zhao S J, Xu C C, Zou Q, Meng Q W (1994). Improvements of the method for measurement of malondialdehyde in plant tissue. Plant Physiology Communications, 30: 207–210