OZONE TREATMENT ON CUCUMBER AND TOMATO DURING SIMULATED RETAIL STORAGE

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The effect of storage temperature and ozone treatment on post-harvest quality and chilling injury of cucumber and tomato was investigated. Cucumber and tomato were stored together with or without gaseous ozone treatment at 20°C and 14°C for 16 days. Firmness, color, weight loss, DA index and decay percentage of samples were evaluated during storage period. The results showed that the combination of ozone treatment and cold storage could maintain the quality of these horticultural products and decreased the decay incidence. Additionally, this combination also reduced the weight loss of samples during storage. Furthermore, ozone treatment maintained the green skin color of cucumber. No sign of chilling injury occurred during storage at 14°C. Commodities stored with approximately 0.1 ppm gaseous ozone at 14°C retained the firmness compared to other treatments until the end of the experiment. This study suggests that a promising of using gaseous ozone treatment in storage chamber where ethylene-producing and ethylene-sensitive vegetables were stored together.

Keywords: post-harvest, ethylene-sensitive, ethylene producing, vegetables

Introduction

Fruits and vegetables are essential foods for daily healthy diet. Thus, maintaining quality of fruits and vegetables to meet consumers' demand is necessary. The postharvest ripening results in changing the quality of products including nutrition and appearance (Liu, 2014).

Most of horticultural produce are not consumed immediately after harvest. In supply chain, ethylene-sensitive and ethylene-producing commodities are usually stored together. The high ethylene concentration in the storage room accelerates the ripening and senescence that cause postharvest loss of fresh fruits and vegetables (Liu, 2014). Therefore, to extend the shelf-life of ethylene-sensitive vegetables, removing the ethylene from storage room is necessary (Skog and Chu, 2001).

In order to prolong the postharvest life of horticultural products during retail storage, the development of new approaches is in demand. Cold storage is one of the most common applications in postharvest technology (Zhang et al., 2015).

Ozone is widely applied in postharvest management of horticultural commodities for two purposes including ethylene removal and sanitizing, particularly treatment pre-storage or during storage (Paulo et al., 2002). The efficacy of ozone in extending shelf-life and reducing microorganism of fresh products such as apple, pear, broccoli, cucumber and mushroom (Skog and Chu, 2001), fresh melon (Nguyen et al., 2018) was reported.

Cucumber is one of the most important vegetables consumed as fresh or cooked, however, cucumber is highly sensitive to ethylene (Skog and Chu, 2001). Tomato is a climacteric and medium ethylene producing product (Watkins and Nock, 2012). In retail storage, cucumber and tomato are often stored with ethylene producing commodities that makes them deteriorate rapidly. Thus, this work was aimed to evaluate the effect of gaseous ozone treatment on tomato and cucumber during 16 days of storage at 20°C and 14°.

Materials and methods

Materials

Cucumber (*Cucumis sativus* L.) and tomato (*Solanum lycopersicum* L.) were bought from a wholesale fruit and vegetable market. Samples were transported to the laboratory. Vegetables with uniformity of size, shape and freedom from external damage were used for experiment. Cucumber at green stage and tomato at red stage 5 of ripening according to tomato ripeness chart (Postharvest Technology center, UC Davis) were selected. Samples temperature was kept at 20°C or 14°C before ozone treatment.

Ozone was generated by an ozone generator (Neo.Tec XJ-100, China).

Methods

Experimental design

Samples were divided randomly into 4 groups, each group containing 15 cucumbers and 15 tomatoes. The weight of each piece was 81 ± 3g for cucumber and 122 ± 3 g for tomato. Experiment was carried out with 4 storage conditions. Two groups were stored together at 20°C or 14°C, RH 95% for 16 days with gaseous ozone treatment at approximately 0.1ppm. The other two groups were kept at the same temperature without ozone treatment served as control.

Measurements

The measurements were performed according to Nguyen et al. (2020a, 2020b) and Zsom et al. (2020)

Stiffness, surface color, weight loss, decay percentage and DA index were conducted at the initial time (day 0) and at 4, 8, 12 and 16 day.

- *Stiffness.* Samples firmness was estimated using the acoustic vibration method and expressed as the parameter Stiffness (S, $g^{2/3}s^{-2}$). Stiffness of the samples was determined at 3 points on the exterior circumference of each fruit, using a table top acoustic firmness instrument of type AWETA AFS DTF V0.0.0.105 (AWETA, Nootdorp, The Netherlands) (Nguyen et al., 2020a).

- *Surface color.* Samples skin color was measured with a portable Minolta Chroma Meter CR-400 (Minolta Corporation, Osaka, Japan). Standard CIE L*, a* and b* color characteristics were determined at 3 points of each fruit. The hue angle value was calculated as arctangent of b*/a* (Nguyen et al., 2020a).

- *Weight loss.* Weight loss was determined by weighing the samples at the beginning of the experiment and each interval with a balance (Sartorius, Germany). Results were expressed as percentage loss of initial readings according to Nguyen et al. (2020b).

- *Decay percentage.* Decay was evaluated as mold growth occured on stem or surface of tomato and on the skin of cucumber. Decay percentage was calculated as the number of decayed samples divided by initial number of samples within a group multiplied by 100 (Baranyai et al., 2020).

- *DA index.* DA (or ΔA) index® of cucumber was measured by a FRM01-F type Vis/NIR DA-meter® (Sintéleia s.r.l., Italy) at three points on cucumber skin to evaluate the changes of surface color related chlorophyll content during storage. The value of DA-index® varying from 0 to 5 is proportional to the amount of active chlorophyll existing in the sample (Zsom et al., 2020).

Statistical analysis. Data were collected and visualized on charts using Microsoft® Excel® (version 16.45). All data were analyzed using analysis of variance (ANOVA) via SPSS version 11.0.1 (SPSS Inc, USA). Significant differences were determined using $p < 0.05$ The results were reported as means with standard deviations

Results and discussion

Weight loss

Figure 1 showed the results of weight loss during 16 days of storage. The control samples at 20 °C were kept only till the 12th day due to decay. The weight loss of vegetables increased over storage period but at different rate. Cold temperature decreased the weight loss of all samples. Vegetables stored at 14 °C had lower values in weight loss compared to samples stored at 20 ºC. The control sample kept at 20 ºC without ozone treatment had the highest values in weight loss for both cucumber and tomato. Gaseous ozone treatment could decrease the weight loss for cucumber, however, no significant difference was observed at the end of measurement for both cucumber and tomato.

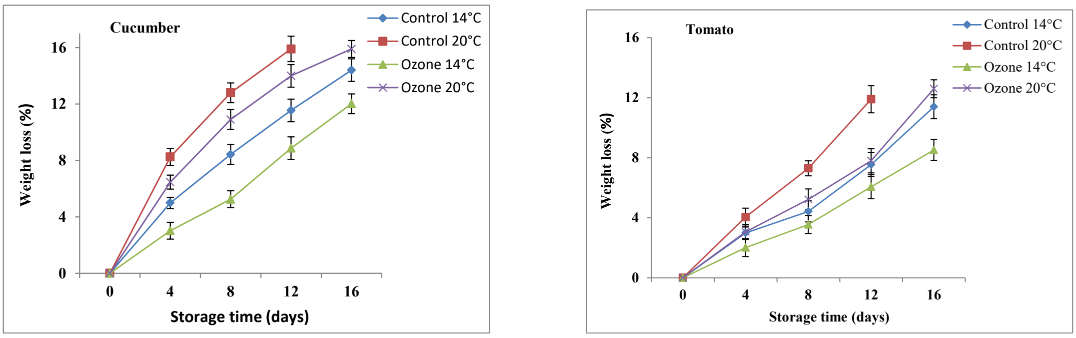

Figure 1. Effect of storage conditions on weight loss of vegetables. Data are presented with mean ± standard deviation.

The combination of storage at 14 ºC and gaseous ozone treatment was effective in reducing the weight loss of vegetables. It could be that cold temperature caused lower respiration rate and decelerated the metabolism than higher one. Moreover, ozone treatment also had effect in removing the ethylene in the storage chamber. This could delay the senescence of vegetables. There was no visible chilling injuries on the skin of ozone treated vegetables was observed over storage.

Stiffness

Changes of firmness were shown in Figure 2. As can be observed, the firmness of vegetables decreased during 16 days of storage. Samples kept at 14ºC with presence of ozrone were firmer than others. The vegetables treated with gaseous ozone at 20 ºC were firmer than control samples stored at 14ºC, but there was no significant was found till the end of experiment for cucumber and tomato. Vegetables treated with gaseous ozone 14ºC had the highest values in firmness compared to that of other treatments.

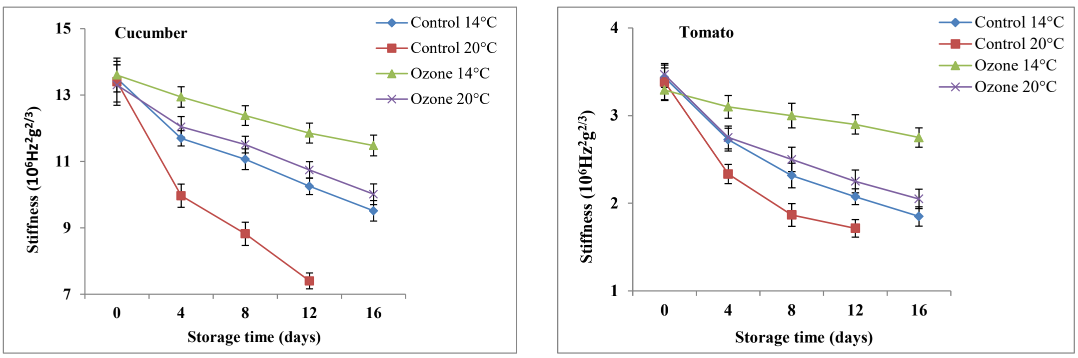

Figure 2. Effect of storage conditions on stiffness of vegetables. Data are presented with mean ± standard deviation.

Softening of horticultural products is due to biochemical processes during ripening (Ali et al., 2010). Cold storage or ozone treatment alone was not strong effect in delay the ripening. The combination between cold temperature and ozone could delay the softening of commodities.

Surface color

Figure 3 showed the effect of treatments on skin color of vegetables. A significant change was observed in hue angle over storage period. There was a dramatic decline in hue angle value for control cucumber at 20 ºC. The skin color of cucumber turned from green to yellow rapidly over storage at 20 ºC. While the cucumber treated with gaseous ozone at 14 ºC were still green until the end of measurement. It was probably that cucumber is highly sensitive to ethylene, thus, the senescence of cucumber occurred promptly when the ethylene in the chamber increased (Al-Juhaimi et al., 2012). Ozone slowed the color change of cucumber skin over the storage. It could be explained that effectiveness of ozone in removing ethylene in the chamber, thus ethylene did not exert its action in ripening (Skog and Chu, 2001).

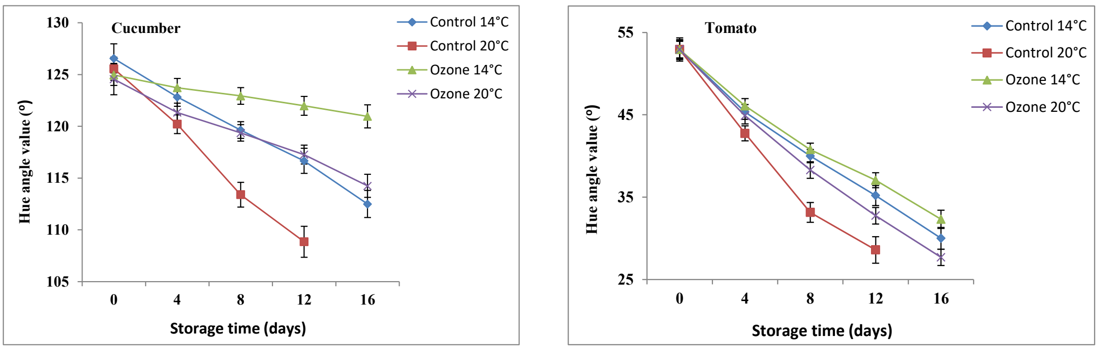

Figure 3. Effect of storage conditions on surface color of vegetables. Data are presented with mean ± standard deviation.

While the hue color of the tomato decreased dramatically during storage. The control tomato at 20 ºC had the lowest value in hue angle. There was no significant difference in hue angle value between cold storage alone and cold storage with ozone treatment in case of tomato.

The results of ΔA index of cucumber were shown in Figure 4. The ΔA index of all samples decreased over storage but at different rates.

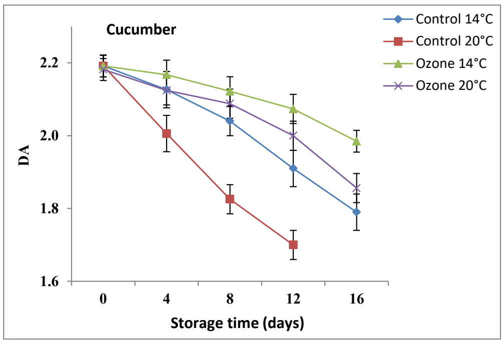

Figure 4. Effect of storage conditions on DA index of cucumber. Data are presented with mean ± standard deviation.

The decline of chlorophyll content relates to ripening during storage (Bron et al., 2004). The control cucumber at 20 °C had the lowest value in ΔA index. The results indicated a significant loss in chlorophyll content because the control cucumber was at senescence stage. Cold storage with presence of ozone could delay the chlorophyll loss over storage.

Figure 5 showed that ozone treated groups were less decay than control groups. The fungal growth often occurred on the surface of cucumber and on the stem of tomato. The result indicated that ozone had effect in decreasing the rot percentage over storage due to effectiveness of ozone treatment. Application of ozone in storage chamber could remove ethylene (Skog and Chu, 2001) and inhibit growth of microbial pathogens on the fruit surface and in the chamber (Crisosto et al., 1993; Guzel-Seydim et al., 2004).

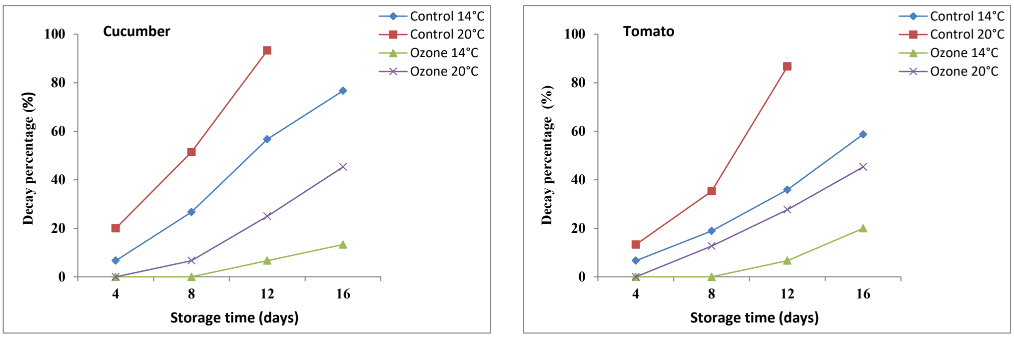

Figure 5. Effect of storage conditions on decay percentage of vegetables. Data are presented with mean

The early sign of microbial development appeared at the 4th day for control vegetables at 20°C and 14°C, whereas the decay occurred at 8th day for ozone treated group at 20 °C. While samples treated with gaseous ozone at 14°C had decay at 12th of storage. The susceptibility of cucumber and tomato also depended on temperature. When produce reached advancing ripening stage, the samples had more decay. This study found that the combination of gaseous ozone treatment and cold storage was effective in inhibiting fungal growth for up to 16 days.

The result of this work was in agreement with reports for peach, table grapes (Palou et al., 2002) and for date fruits (Habibi Najafi et al., 2009).

Conclusion

The presented work showed that gaseous ozone treatment during cold storage could maintain the quality of cucumber and tomato. Application of approximately 0.1 ppm ozone retained the firmness, decreased the weight loss of vegetables over the storage period. Moreover, ozone slowed the yellowing of cucumber throughout 16 days of storage at 14°C. Additionally, decay percentage of vegetables also declined when they were stored in the presence of gaseous ozone. The results of this study found that gaseous ozone has potential application in postharvest treatment, particularly in distribution chain, when the ethylene-sensitive horticultural products were stored together with ethylene-producing commodities. Further study about an optimization of storage conditions for produce in retail chain should be carried out.

Acknowledgments

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