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Chlorine Dioxide Gas Retain Postharvest Quality and Shelf Life of Tomato During Modified Atmosphere Packaging Storage

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ABSTRACT

While surface sterilization can minimize the postharvest loss of fruits and vegetables, it depends on concentration, treatment duration, storage condition, and crops. This study was conducted to investigate the consequences of chlorine dioxide (ClO_2) gas on post-harvest quality and shelf life of tomato fruits during the modified atmosphere packaging storage. Tomato fruits of light red maturity stage were harvested at Gangwon province in the Republic of Korea**.** Fruits were dipped in fungal suspension and, afterward, some of them were sterilized with NaOCl, while others were sterilized with ClO_2 gas. On the final storage day, the 5 ppm ClO_2 gas 12 hours treated tomato fruits showed the least carbon dioxide and ethylene, and the utmost oxygen concentration. The least fresh weight loss, prolonged shelf life and the most suppressed fungal incidence were obtained by the 5 ppm ClO_2 gas 12 hours treatment. As compared to other treatments, the 5 ppm ClO_2 gas 12 hours treatment yielded higher firmness, titratable acidity and vitamin C, and lower soluble solids. Therefore, the 5 ppm ClO_2 gas 12 hours treatment may be useful to prevent fungal incidence as well as to retain the postharvest quality and increase the shelf life of tomato fruits.

Keywords: firmness; fungal incidence; shelf life; vitamin C

INTRODUCTION

Post-harvest quality maintenance is an important aspect for satisfying both the buyer and the consumer. If post-harvest losses minimized the food feasibility will increase to expanding human being, and producing area as well as natural resources will conserves (Kader, 2003). The quality of horticultural crops depends on production, packaging, and environmental condition which lead to physicochemical properties of a product (Giuffrè & Capocasale, 2016). Modified atmosphere packaging (MAP) is needed for perishable crops to retain postharvest quality and shelf life (Islam et al., 2014). But the most important disadvantage of MAP is high microorganism incidence rate because the high humidity in packaging even though applied high permeable packaging materials. The control of microorganism is essential for maintaining the quality of perishable horticultural crops. Nowadays, physical, chemical, and gaseous sterilization treatments are used to maintain the postharvest quality and storability.

Chlorine dioxide (ClO_2) is an effective sanitizer which has biocidal activity and more oxidizing capacity than chlorine, as well as no detectable chemical residues (Chen & Zhu, 2011). ClO_2 gas reduces disease-producing agent of strawberries (Mahmoud, Bhagat, & Linton, 2007). Tomato fruits decay that occurred during cultural practices may prevent by ClO_2 gas (Mahovic, Tenney, & Bartz, 2007).

In cabbage, the 3-minute 100 ppm NaClO treatment significantly was found to reduce the microbial activity; however, the same treatment lasting 10 minutes did not show any significant differences (Rahman, Jin, & Oh, 2010). Although NaOCl is the most widespread disinfection agent, it has limitation against pathogens and generates carcinogenic compounds (Gómez-López, Lannoo, Gil, & Allende, 2014). The effects of ClO_2 gas as a preservative on postharvest physiology and preservation quality of produce is still small in range (Du, Fu, Li, & Xia, 2007). Moreover, to date, ClO_2 gas consequence with MAP treatment on postharvest quality and shelf life of tomato is rare. This study was organized to demonstrate the performance of different concentrations of ClO_2 gas on quality and shelf life of tomato 'Dafnis' at the storage temperature of 5 ˚C.

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MATERIALS AND METHODS

The fungal inoculum was prepared according to the procedure described in Gabler, Smilanick, Mansour, & Karaca (2010). In brief, a *Botrytis cinerea* was isolated from cherry tomato fruits (obtained from plant pathology laboratory at Kangwon National University). At 24 ˚C, it was grown in a medium of potato dextrose agar for two weeks. After removing conidia, sterile distilled water with 0.05 % (W/V) Triton X-100 surfactant was affixed. Cheesecloth was used to pass the conidial suspension. To get the 0.25 absorbance at 425 nm of a spectrophotometer, sterile water was added to the conidial suspension. The conidial suspension was diluted and adjusted to 1×10^6 conidia per mL.

Tomato fruits (*Solanum lycopersicum* cv. Dafnis) of light red maturity stage were harvested from Gangwon Province of Korea Republic in 2016 and dipped into the conidial suspension for 10 minutes. All tomato fruits were kept in a refrigerator for 2-3 hours to remove the water. Afterward, some tomato fruits were dipped into 150 ppm sodium hypochlorite (NaOCl) and some of them were treated by ClO_2 gas with different doses and different time (1 ppm ClO_2 gas 6 hours, 1 ppm ClO_2 gas 12 hours, 1 ppm ClO_2 gas 24 hours, 5 ppm ClO_2 gas 6 hours, and 5 ppm ClO_2 gas 12 hours), and others were dipped in distilled water, as control. The dipping treated tomatoes water remove as the same way that did after inoculation. ClO_2 gas treated and untreated (control) tomato fruits were packed with 20,000 cc OTR (oxygen transmission rate) film, as a modified atmosphere packaging (MAP). Tomato storage temperature and relative humidity were 5 ˚C and 85 %, respectively (Islam at al., 2014).

A PBI Dan sensor Check Mate 9900 was adjusted to analyze the oxygen and carbon dioxide concentration. Ethylene was examined by a GC 2010 Shimadzu of Wax column. At 127 ˚C, the detector and injector were operated in GC 2010 Shimadzu. The oven of GC 2010 Shimadzu was fixed 50 ˚C. GC 2010 Shimadzu carrier gas (N_2) flow rate was 0.67 mL s^{-1} (Mele, Islam, Baek, & Kang, 2017).

The fresh weight loss of tomato fruits was measured according to Mele, Islam, Baek, & Kang (2017). The scale of 1 to 5 (1 = very bad, 2 = bad, 3 = good, marketable, 4 = very good, and 5 = excellent) was used to observe the visual quality during 5 ˚C storage for 0 - 20 days. To observe the visual quality and fungal incidence of tomato fruits, five-panel members were appointed (Islam et al., 2014). Tomato fruits that were contaminated by fungus were separated and then, calculated fungal incidence percentage.

A Rheo meter (Sun Scientific Co. Ltd., Japan) for firmness, a Refractometer (Atago U.S.A. Inc., U.S.A.) for soluble solids, and a DL 22 Food & Beverage Analyzer (Metter Toledo Ltd., Korea) were used to measure the titratable acidity of tomato fruits. Vitamin C was analyzed by RQflex plus (Merck, Germany) and the result was mentioned as mg/100gFW (Arvanitoyannis, Khah, Christakou, & Bietsos, 2005).

The one-way ANOVA of Duncan's multiple range test (DMRT) was used to data analyze by SPSS V. 16 (SPSS Inc., Chicago, USA).

RESULTS AND DISCUSSION

Tomato fruits in the 5 ppm ClO_2 gas 12 hours treatment showed a significantly lower concentration of carbon dioxide and ethylene and a higher oxygen concentration; however, the control showed the opposite result on the final storage day (Fig. 1). In melon fruits, the control showed higher carbon dioxide and ethylene compared to ClO_2 gas treatment because of the excess metabolic process, thus fruit get ripening (Guo et al., 2013). In the 5 ppm ClO_2 gas 12 hours treatment at 5 ˚C storage, the average oxygen, carbon dioxide, and ethylene concentration were 20.31 %, 0.89 %, and 2.47 μL L^{-1}, respectively. A reduced ethylene production suppressed the color development, ripeness and increased the tomato fruits shelf life. In apricots, the ethylene production was delayed by ClO_2 treatment (Zhong, Wu, B., Wang, Wu, J.-M., & Wei, 2006). Therefore, ClO_2 treatment could be effective to suppress the color development by lowering ethylene production.

The lowest fresh weight loss was performed by the 5 ppm ClO_2 gas 12 hours treatment in tomato fruits (Fig. 2). This result is agreed with Du, Fu, Li, & Xia (2007) study that showing the ClO_2 gas treatment had the lowest fresh weight loss in green bell peppers that maintained tissue integrity by reducing the rot and killing bacteria, to further reduce water loss. The fresh weight loss was negligible and it did not exceed the maximum of 0.20 % in tomato fruits in the MAP storage. This result is in similarly reported by Islam et al. (2014) who found that the fresh weight loss of MAP at 5 ˚C in tomato fruits was 0.16 - 0.22 %.

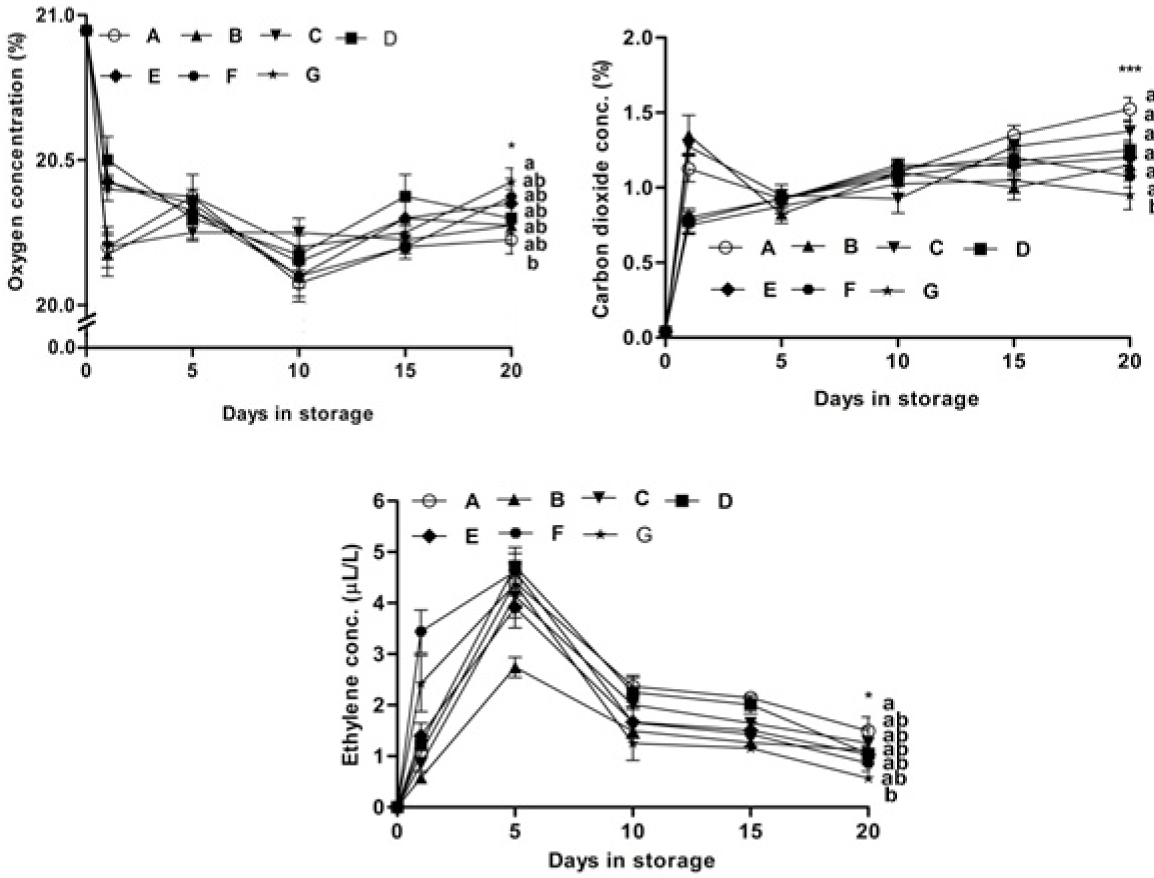
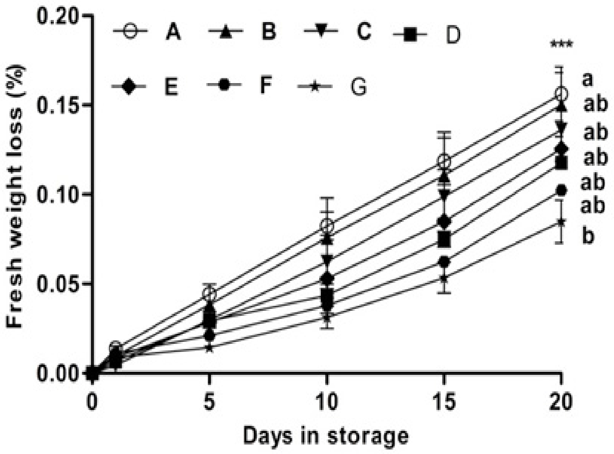


Fig 1. The oxygen, carbon dioxide and ethylene concentration in packages of tomato fruits that treated with different sterilization methods [**A**: Control, **B**: 150 ppm NaOCl 10 minutes, **C**: 1 ppm ClO_2 gas 6 hours, **D**: 1 ppm ClO_2 gas 12 hours, **E**: 1 ppm ClO_2 gas 24 hours, **F**: 5 ppm ClO_2 gas 6 hours and **G**: 5 ppm ClO_2 gas 12 hours] during 5 ˚C MAP storage

The visible quality was the highest in the 5 ppm ClO_2 gas 12 hours treatment and the control was the lowest in tomato fruits (Fig. 2). ClO_2 gas is effective in terms of retaining the visual quality of strawberry (Mahmoud, Bhagat, & Linton, 2007) and tomato fruits (Trinetta, Morgan, & Linton, 2010). In addition, the 5 ppm ClO_2 gas 12 hours treatment in tomato fruits holds the extended shelf life due to maintaining their marketable visual quality (≥ 3) and freshness by reducing fungal rot. Visual quality and freshness retain in tomato fruits by reducing respiration and ethylene production. Shelf life increased in ClO_2 gas treated strawberry fruits by reducing microorganism contamination (Han, Selby, Schultze, Nelson, & Linton, 2004) and, in tomato fruits, the risk of microbial activity was reduced (Trinetta, Morgan, & Linton, 2010). The shelf life of the control, 150 ppm NaOCl, 1 ppm ClO_2 gas 6 hours, 1 ppm ClO_2 gas 12 hours, 1 ppm ClO_2 gas 24 hours, 5 ppm ClO_2 gas 6 hours, and 5 ppm ClO_2 gas 12 hours -treated tomatoes amounted to 14, 15, 16, 17, 18, 19, and 20 days at 5 ˚C, respectively (Fig. 2).

The 5 ppm ClO_2 gas 12 hours treatment showed a lower fungal incidence than other treatments (Table 1). It is reported that ClO_2 gas is effective to control post-harvest fungi by the kinetics of strawberry (Mahmoud, Bhagat, & Linton, 2007) and tomato fruits (Trinetta, Morgan, & Linton, 2010). The highest firmness was obtained in the 5 ppm ClO_2 gas 12 hours treatment of tomato fruits, and it may happen due to turgor and reduce ethylene production that decreased during ripening; however, ClO_2 gas can retard turgor. In pears, ClO_2 maintained firmness by protecting the fruit cell wall from disassembles that contribute to textural changes and softening during ripening (Chen & Zhu, 2011). Moreover, softening mainly happens due to chemical degradation in the cell wall ingredients by ethylene (Hertog, Nicholson, & Jeffery, 2004). Soluble solids were increased on the final storage day as compared to the harvest time in tomato fruits. In addition, the 5 ppm ClO_2 gas 12 hours treatment in tomato fruits showed a lower concentration of soluble solids as compared to other treatments including control. In green bell pepper, ClO_2 gas treatment did not show any significant differences in soluble solids and titratable acidity (Du, Fu, Li, & Xia, 2007). In the 5 ppm ClO_2 gas 12 hours treatment of tomato fruits showed the highest titratable acidity and vitamin C among the treatments. In apricots (Zhong, Wu, B., Wang, Wu, J.-M., & Wei, 2006) and pears (Chen & Zhu, 2011), titratable acidity and vitamin C were also higher in ClO_2 treatment and it may happen due to reducing fungal or bacterial decay that helps to reduce the vitamin C oxidization as compared to the control, i.e. infected ones.



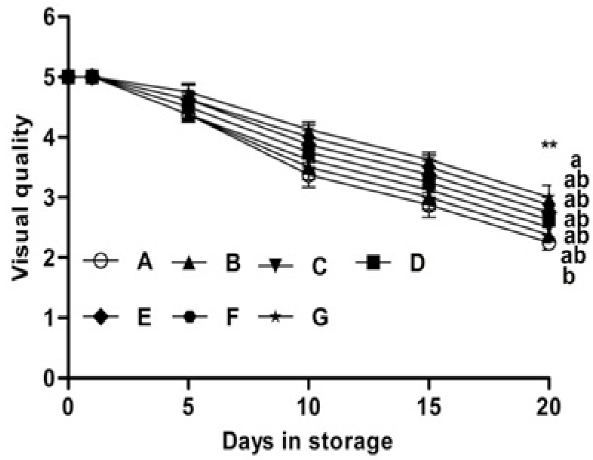


Fig 2. The fresh weight loss and visual quality of tomato fruits that treated with different sterilization methods [**A**: Control, **B**: 150 ppm NaOCl 10 minutes, **C**: 1 ppm ClO_2 gas 6 hours, **D**: 1 ppm ClO_2 gas 12 hours, **E**: 1 ppm ClO_2 gas 24 hours, **F**: 5 ppm ClO_2 gas 6 hours and **G**: 5 ppm ClO_2 gas 12 hours] during 5 ˚C MAP storage. The visual quality observed on the scale 1-5 (5: excellent, 4: very good, 3: good, marketable, 2: bad and 1: waste) during at 5 ˚C storage

Table 1. The fungal incidence, firmness, soluble solids, titratable acidity and vitamin C of tomato fruits at harvesting time and at 5 ˚C MAP storage on the final storage day (20th storage day)

	Fungal incidence (%)	**Firmness (N)**	**Soluble solids (°Brix)**	**Acidity (% citric acid)**	**Vitamin C (mg/100gFW)**
Harvesting time	00 ± 00	13.54 ± 0.55	3.15 ± 0.49	0.51 ± 0.17	18.02 ± 0.48
Control	87.50a^{z}	5.71b	4.46a	0.29b	6.88b
150 ppm NaOCl 10 minutes	25.00b	7.16ab	4.25ab	0.35ab	9.20ab
1 ppm ClO_2 gas 6 hours	62.50ab	7.63ab	4.20ab	0.32ab	7.70ab
1 ppm ClO_2 gas 12 hours	50.00ab	7.68ab	4.05ab	0.36ab	7.60ab
1 ppm ClO_2 gas 24 hours	37.50ab	8.09ab	3.93ab	0.38ab	8.20ab
5 ppm ClO_2 gas 6 hours	25.00b	8.44a	4.08ab	0.37ab	8.35ab
5 ppm ClO_2 gas 12 hours	18.75b	9.32a	3.84b	0.41a	9.82b
P value	**	***	*	*	**

Remarks: $^{Z)}$ Mean separation of columns by Duncan's multiple range tests (DMRT) (n=10). *, **, ***; significant at p≤0.05, 0.01 and 0.001, respectively of Duncan's multiple range tests (DMRT)

CONCLUSION AND SUGGESTION

In this experiment, we analyzed the effect of surface sterilization with different concentrations of ClO_2 gas and a different time with MAP storage on the quality and shelf life of tomato fruits. In the 5 ppm ClO_2 gas 12 hours treatment, respiration, and ethylene production were suppressed. Moreover, the results of our study demonstrate that the 5 ppm ClO_2 gas 12 hours treatment prolongs the shelf life, retains the firmness, and suppresses the fungal incidence in tomato fruits meant for long storage and were maintaining their quality is essential.

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