Proc. Fla. State Hort. Soc. 119:340-342. 2006.

POSTHARVEST TREATMENT OF TOMATO FRUIT WITH CHLORINE DIOXIDE GAS: DOSE AFFECTS FRUIT QUALITY

MICHAEL MAHOVIC[1]*, JERRY A. BARTZ[1],
ADRIAN D. BERRY[2] AND STEVEN A. SARGENT[2]
[1]*University of Florida, IFAS*
Department of Plant Pathology
P.O. Box 110680
Gainesville, FL 32611

[2]*University of Florida, IFAS*
Horticultural Sciences Department
P.O. Box 110690
Gainesville, FL 32611

Additional index words. Lycopersicon esculentum, decay control, phytotoxicity, sanitation

Abstract. **Chlorine dioxide (ClO_2) gas shows potential as a postharvest sanitizing treatment for fresh market tomatoes. Previous tests with ClO_2 applied at 1 to 2 mg·kg^{-1} of tomato resulted in a significant reduction in recoverable bacterial populations and in the incidence of soft rot in inoculated wounds. However, treatment with 88 or 99 mg·kg^{-1} produced bleached and sunken wounds and stem scars, whereas effects of these high treatments on the ripening or other quality factors were not recorded. Here, standard round tomatoes from three commercial harvest/handling steps (field pack of light reds, green fruit post ethylene gas treatment, and green fruit prior to the dump tank at the packinghouse) were exposed to a standard or 10× standard dose of ClO_2 gas for 2 hours and were then ripened at 20°C for up to 6 days to evaluate the effects of an overdose on fruit quality. By the conclusion of the 20-mg treatments, each of the stem scars appeared slightly whiter than those on the untreated controls or those treated with 2-mg. Within 24-h of storage after treatment, the bleached appearance became more evident and had progressed into the pigmented tissues beyond the corky ring around the stem scar. By contrast, stem scars on the 2-mg fruit appeared similar to those on the control fruit. Green fruit not treated with ethylene and then exposed to ClO_2 at 20 mg·kg^{-1} had an accelerated onset of ripening; all other fruit ripened similar to controls. However, the stem scars of fruit from any harvest method treated with 20 mg·kg^{-1} ClO_2 (only) were observed to have whitened immediately following treatment and, by day 6, 28% to 61% of these developed visible fungal growth. By contrast, no other detrimental changes in fruit quality could be attributed to either dose of ClO_2.**

Treatment of fresh market commodities with gaseous sanitizers has been increasingly explored recently, fueled by the growing concern over food safety and the need to identify more effective, easier, and/or less expensive sanitizing agents. Preliminary success in reducing microbial loads with the application of chlorine dioxide (ClO_2) gas has been reported for numerous commodities, including citrus, apples, green peppers, and various berries (Brown and Wardowski, 1984; Du et al., 2003; Han et al., 2001; Sy et al., 2005). The effect of ClO_2 on tomato fruit has also been investigated, suggesting that treatment at 2 mg·kg^{-1} fruit may cause a significant reduction of either decay or human pathogenic bacteria (Bartz et al., 2005; Mahovic et al., 2003). In the same reports, however, it was noted that a much higher dose (about 50× the effective levels reported) could cause phytotoxicity on wounded surfaces of fresh fruit. Phytotoxic or other effects on intact fruit, or on the ripening of immature fruit, were not explored. Also, fruit quality issues may be seen if treated with excess amounts of ClO_2 gas, or by not assuring uniform distribution of the gas in fruit treatment facilities. In this study, we explored the possibility that the reported effective dose of ClO_2 of 2 mg·kg^{-1}, or a dose 10 times greater, as is often investigated by government agencies in the evaluation of new chemical treatments, may negatively affect the quality of fresh market tomato fruit.

This research was supported by a grant from The Florida Tomato Committee We would like to thank ICA Trinova, LLC, Newnan, Georgia, for providing the chemical product necessary for this experiment.

*Corresponding author; e-mail: mmahovic@gmail.com

Materials and Methods

Fruit from three different commercial handling steps were sampled and sorted for defects at the laboratory. Field-packed fruit ('Florida 47') were light red in color. Green fruit ('Soraya') that had been processed at the packinghouse were sampled after 3 d in the ethylene gas room. Additionally, green fruit ('Soraya') were sampled from field bins prior to being processed. The fruit were transported (from Florida west coast production area) to the laboratory where individual fruit were randomly sorted into three, ca. 4 kg (8.8 lb), samples. At this time all fruit were at ca. 23°C in temperature. The samples were placed in one of nine 19-L (5.02-gal) plastic bins (3 treatments × 3 harvest methods). A glass Petri dish was placed in each bin and filled with enough of a dry two-component mixture (kindly donated by the ICA TriNova Corporation, Marietta, Ga.) to produce 2 or 20 mg of ClO_2 gas (in the ratio of 5 mg produced per 1 g of each material [2 g total] used) per kg fruit (0.064 or 0.64 oz ClO_2 per ton of fruit) over the course of 2 h (Linton, 2006). A Lexan lid with an activated circulation fan (12 V, diameter = 46 mm [1.81 in]) was then placed on each bin. Of the total production of ClO_2 that will occur over the 2-h treatment time, 50% is generated within 30 min of combining the components and ca. 90% production occurs after 90 min. Control fruit were treated similarly, except that no gas-producing mixture was enclosed with the fruit. Bins were stored at room temperature (23°C) for the duration of the 2-h treatment. After completion of the treatments, the fruit were removed, placed on trays, and stored at 20°C and 95% relative humidity. Observations of color change, phytotoxicity and decay were made daily.

Results and Discussion

At the conclusion of the 2-h treatment, all fruit treated with 20 mg·kg^{-1} had noticeable bleaching of the stem scars (Fig. 1). By contrast, those untreated or treated with 2 mg·kg^{-1} appeared to be free of surface bleaching or other changes. After 24 h of storage, fruit that previously had visible phytotoxic

Fig. 1. Stem scars of fruit commercially treated with ethylene for 3 d prior to ClO_2 treatment at 20 mg·kg^{-1} (0.64 oz per ton), after storage at 20°C for 4 d (top left) or 6 d (top right). Bottom: fruit that had been commercially treated with ethylene for 3 d, then treated with 0 mg·kg^{-1} ClO_2 (control), after 6 d storage.

effects also developed sunken and desiccated stem scars, with damage expanding beyond the corky ring and under the adjacent cuticle for several mm (<¼ inch); all other fruit remained free of visible phytotoxic effects. The color of the field-packed fruit treated with 2 or 20 mg was similar to the controls and became fully red by the end of the storage period. All 3-d ethylene-treated fruit ripened similarly to controls after ClO_2 treatment, regardless of dose (Fig. 2). Green fruit that were not exposed to ethylene prior to treatment with ClO_2 at 2 mg·kg^{-1} ripened similarly to control fruit; however, onset of ripening occurred earlier in fruit that were treated with ClO_2 at 20 mg·kg^{-1} (Fig. 3). Stress to commodities such as

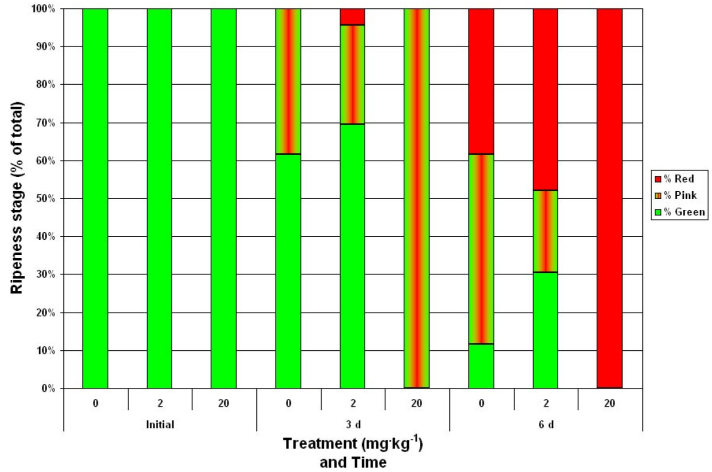

Fig. 3. Ripening rate over 6 d at 20°C of green-harvested tomato fruit sampled from a field-bin on the day of harvest that were treated with ClO_2 at each of three doses (0, 2, or 20 mg·kg^{-1} fruit).

tomato can stimulate the production of ethylene, so an earlier onset of ripening (in fruit that were still green at treatment and not treated with ethylene) is not surprising (Hong and Gross, 1998; Yokotani et al., 2004).

After 6 d of storage, mold began to develop on some fruit. Fruit from each ripeness stage tested had the greatest incidence of mold when treated with ClO_2 at 20 mg·kg^{-1} (Fig. 4). All mold was observed on stem scars (Fig. 1) that were previously noted as damaged due to the ClO_2 treatment. The observed fungi were not identified, but had previously been noted to include common saprophytes of damaged, desiccated, or senescent tomato fruit (Bartz and Mahovic, unpublished). The visible desiccation, sinking, and cracking of the stem scar apparently provided necrotic tissues that were colonized by saprophytes or weakly pathogenic microorganisms.

While ClO_2 gas has promise as a fumigation treatment for sanitation of fresh market tomatoes, and could be applied directly to field-packed fruit, quality issues could arise due to application of excess amounts, or the poor distribution of ClO_2 gas within a container of fruit. The quality problems were as-

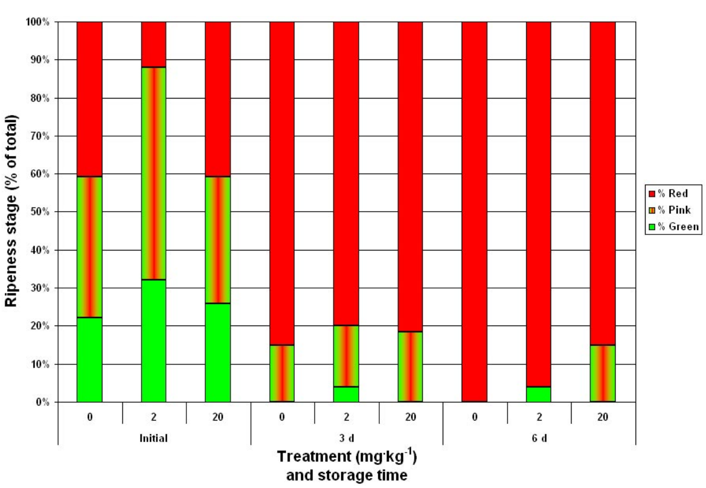

Fig. 2. Ripening rate during storage at 20°C of fruit that were commercially treated with ethylene for 3 d prior to treatment with ClO_2 at each of three doses (0, 2, or 20 mg·kg^{-1} fruit).

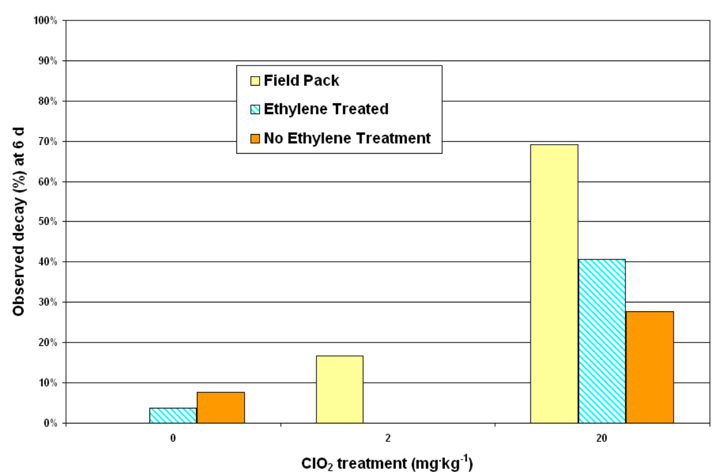

Fig. 4. Incidence of decay observed on tomato stem scars, after storage for 6 d at 20°C following ClO_2 treatment. Ethylene treated fruit were stored in a commercial packinghouse ethylene chamber for 3 d prior to experimental treatments.

sociated with moist areas on the fruit, such as the stem scar and corky areas. Previously, phytotoxicity was found at wound sites on fruit treated with excessive amounts. However, in previous studies and as described here, the ClO_2 gas had no apparent effect on the overall color or smoothness (no pitting was observed) of treated fruit. Thus, the waxy cuticle on the fruit surface appeared to prevent the gas from contacting epidermal cells. A proper dose-response should be evaluated, reported, and observed for any commercial applications. Different fruits and vegetables may have different levels of susceptibility to the bleaching and desiccating effects of ClO_2, therefore the commodity in question should also be similarly tested prior to any commercial treatment.

Literature Cited

Bartz, J. A., M. Mahovic, and J. D. Tenny. 2005. Chlorine dioxide as a postharvest sanitizer: Reversible and irreversible sinks. Phytopathology S7 (Abstr.).

Brown, G. E. and W. F. Wardowski. 1984. Use of chlorine and chlorine dioxide in Florida citrus packinghouses to reduce inoculum of decay pathogens. Proc. Fla. State Hort. Soc. 97:97-100.

DU, J., Y. Han, and R. H. Linton. 2003. Efficacy of chlorine dioxide gas in reducing *Escherichia coli* O157:H7 on apple surfaces. Food Microbiol. 20:583-591.

Han, Y., J. D. Floros, R. H. Linton, S. S. Nielsen, and P. E. Nelson. 2001. Response surface modeling for the inactivation of *Escherichia coli* O157: H7 on green peppers (*Capsicum annuum* L.) by chlorine dioxide gas treatments. J. Food Prot. 64:1128-1133.

Hong, J. H. and K. C. Gross. 1998. Surface sterilization of whole tomato fruit with sodium hypochlorite influences subsequent postharvest behavior of fresh-cut slices. Postharvest Biol. Technol. 13:51-58.

Linton, R. H., Y. Han, T. L. Selby, and P. E. Nelson. 2006. Gas-/vapor-phase sanitation (decontamination) treatments, pp. 401-435. In G. M. Sapers, J. R. Gorny, and A. E. Yousef, (eds.). Microbiology of fruits and vegetables. CRC Press, Boca Raton, FL.

Mahovic, M., J. A. Bartz, and J. D. Tenny. 2003. Use of chlorine dioxide gas in the treatment of tomato fruit for bacterial soft rot. Phytopathology S56 (Abstr).

Sy, K. V., K. H. McWatters, and L. R. Beuchat. 2005. Efficacy of gaseous chlorine dioxide as a sanitizer for killing *Salmonella*, yeasts, and molds on blueberries, strawberries, and raspberries. J. Food Prot. 68:1165-1175.

Yokotani, N., S. Tamura, R. Nakano, A. Inaba, W. B. McGlasson, and Y. Kubo. 2004. Comparison of ethylene- and wound-induced responses in fruit of wild-type, *rin* and *nor* tomatoes. Postharvest Biol. Tech. 32:247-252.