AP 817

Overcoming corrugated cardboard acting as a barrier to the effective application of ClO_2 gas to sanitize tomato fruit

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Abstract/Summary

Use of chlorine dioxide gas (ClO_2) as a sanitizing agent of fresh market tomatoes (and other produce) has been effective. In one trial, 1 kg of fruit with fresh wounds inoculated with *Erwinia carotovora* subps. *carotovora* failed to decay after treatment with 2 mg of ClO_2, while untreated fruit had a 100% decay incidence. However, these reports were on fruit treated under laboratory conditions. When similarly treated fruit were randomly distributed among 11.3 kg of fruit in a single corrugated cardboard box, treatment with up to 99 mg of ClO_2 failed to reduce decay incidence below 50%. Cardboard was added to chambers containing a ClO_2 source and a KI solution, and after 2 hrs, titration of both solutions were able to account for only 20% of the ClO_2 added to the system. If the cardboard piece was removed, or replaced with an equal sized piece of polycarbonate, aluminum foil, or the plastic from a drum liner, 80% of the ClO_2 was accountable after 2 h. This suggests cardboard acts as a sink for ClO_2. A scale forced-air system was developed and utilized to re-test applications of ClO_2 on wound-inoculated fruit stored in a cardboard box. Fruit decay was reduced to 0-20%. Although corrugated cardboard will act as an alternate sink and as a barrier to the mass-transfer of ClO_2, use of a delivery system which rapidly moves the ClO_2 to the target location seems to overcome these issues.

This poster is a report on research currently being investigated.

Introduction

Use of dry chlorine dioxide gas (ClO_2) was previously observed to be successful in controlling the establishment of bacterial soft rot in wound-inoculated tomato fruit (Mahovic et al., 2007). The studies performed were carried out in sealed chambers, with only the inoculated fruit to act as a reaction site. This is not a representative model of actual handling situations. After harvest, tomato fruit are run across a sorting/grading line and packed into corrugated cardboard boxes. These boxes are then palletized and moved into a ripening room where they are treated with ethylene gas for up to three days (or more). To better model a real-world application, larger volumes of fruit, stored in close proximity, with a physical barrier to gas movement, also including a competitive sink in the form of corrugated fiberboard, should be treated.

Materials and Methods

Tests based on inoculation and treatment of six fruit (~1 kg) in a 21-L, sealed, aluminum container with a circulation fan were scaled-up to consist of three commercially packed, corrugated cardboard boxes (~33 kg) of green tomatoes in a poly drum liner (208 L) with a fan for circulation. A stock suspension of the bacterial soft-rot (BSR) pathogen *Erwinia carotovora* subsp. *carotovora* was prepared and inoculated to fruit shave-wounded around the equator in five evenly spaced locations, as previously described (Mahovic et al., 2007). After wound-inoculation, the six fruit were randomly placed in a standard corrugated fiberboard shipping box designed to contain 11.34 kg (or about 12.6 L) of fruit, along with enough unwounded fruit to fill the box. The boxes were enclosed in a drum-liner with an electric fan (15.24 cm diameter, 0.26 A) and a number of sachets designed to each produce ~50 mg ClO_2 in two hours, or ~ 44 in 12 h. The sachets were activated and placed in an empty fruit box with the fan, atop the stacked boxes of fruit in the drum liner. The drum liner was filled with air supplied through a rubber tube from a lab air supply to fill the volume of the liner before it was sealed for testing. The number of boxes of fruit and the number of sachets in the drum liner scale-up tests were varied. Tests were performed with one or three boxes of fruit and one to six sachets, over a 2 or 24 h release time frame. Subsequent tests were further altered to remove corrugated cardboard through use of mesh onion bags (Fig. 1) as containment chambers within treatments.

Figure 1. Design of mesh bag inside of poly drum liner tests. For testing, the liner is pulled up and filled with air from a standard lab source, then sealed for treatment.

Figure 2. Forced air treatment system.

Figure 3. Treatment vs. a competitive sink. Fruit treated with corrugated fiberboard, used as a competitive sink or barrier to air flow for ClO_2 (before or after fruit added to chamber).

A model trial system replicating a barrier to movement was also explored. Wound-inoculated fruit were placed in a 20 L aluminum pressure cooker, with one treatment consisting of six fruit in a loosely closed brown paper grocer's bag. In the same chamber, an equal number of fruit were placed atop the bag. The second chamber contained six fruit only, with no bag. A sachet that generated 0.75 mg of ClO_2 over a 2-h time frame was placed in each chamber by taping to the inside of the chamber lid. A set of similarly wounded and inoculated fruit was run as a comparative control. Based on current flume handling recommendations (Mahovic et al., 2002) these fruit were treated in a water bath containing 100 mg L^{-1} HOCl for 2 minutes and set aside for observation. Another set of fruit were wounded and inoculated, and then set aside for observation, as a non-treated positive control.

Another set of fruit were tested in the 208-L poly drum liner with a model forced-air system designed to overcome slow mass-transfer (Fig 2). A six-inch electric fan was sealed into a hole cut into the handle side of a single corrugated cardboard box, with air-flow being pulled out of the box. Vent holes in the box were sealed on the sides, allowing air to enter the box only at the far end from the fan, when the lid was in place. The box was filled with green to pink fruit, including six that were wound-inoculated. A source of ClO_2 was placed next to the vent opening outside of the far end of the box and the entire system was sealed in a drum liner for two hours; enough time for the sachet to produce 4.4 mg / kg (~50 mg/2 hr) of ClO_2. Fruit were removed and placed in storage for observation and decay development.

Finally, pieces of corrugated fiberboard were placed in a 21-L chamber with wound-inoculated fruit. The first treatment included the fiberboard from one box body (~650 g, no lid material) and as much fruit as the chamber would hold (almost all of the fruit from one 11.3 kg box), including six wounded and inoculated fruit, randomly dispersed among the other fruit (Fig 3). A treatment with the same volume of fruit and the same number of wounded and inoculated fruit was also conducted, with only one piece of fiberboard among the fruit (20 g). The third treatment was composed of the same volume of fruit but with no fiberboard.

Results

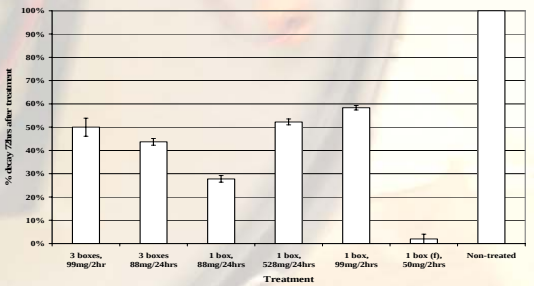

Figure 4. Fruit in boxes treated in a drum liner. Efficacy of ClO_2 gas as a curative agent of 1 kg wounded green fruit inoculated with 8 log_{10} cfu/ml *E. carotovora* subsp. *carotovora* during storage in corrugated cardboard boxes filled with 11 kg fruit (total). Test denoted (f) was a forced air system. Inoculated fruit were recovered after treatment and stored at room temperature on a tray in a loosely sealed plastic bag, to maintain R.H, for observation. Decay represents % of total inoculated wounds with decay 72 hrs after completion of treatment; positive controls = 24 hrs. ($P < 0.001$)

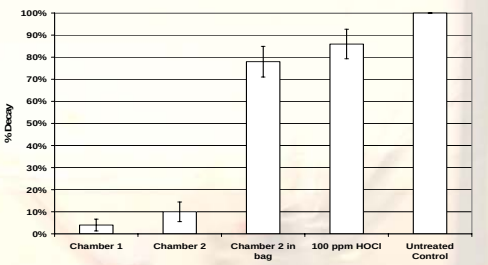

Figure 5. Fruit treated in 21 L chamber, with or without brown paper bags. Observable decay, as a percent of total, in wounded fruit inoculated with 8 log_{10} cfu/ml *E.c.c.,* five days after a 2-h treatment with 0.75 mg ClO_2 in a sealed 21 L pressure cooker. Chamber 1 contained only fruit (1 kg) and a treatment sachet; chamber 2 contained 1 kg of fruit in a loosely closed brown paper bag and 1 kg of fruit resting on top of the brown paper bag. Results are a compilation of two trials. Untreated controls reached 100% decay within 24 h. ($P < 0.05$)

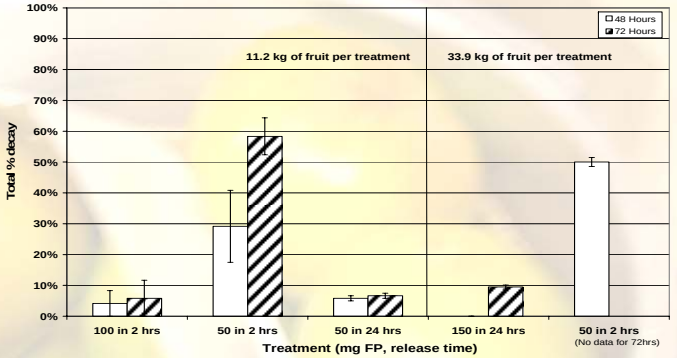

Figure 6. Fruit in Mesh bags treated in a drum liner. Efficacy of ClO_2 gas as a cleansing agent of 1 kg wounded green fruit, inoculated with 8 log_{10} cfu/ml *E. carotovora* subsp. *carotovora,* and treated in mesh bags (11 kg fruit ea) stored in 208.2 L drum liner for treatment. Liners contained 1, 2 or 3 stacked bags, with a fan for air circulation and sachets as a source of ClO_2 gas placed on the top bag. Treatments consisted of 1 to 3 sachets, each producing ~50 mg of ClO_2 gas over 2 or 24 hrs. After treatment, inoculated fruit were recovered and stored at room temperature on a tray in a loosely sealed plastic bag, to maintain RH, for observation.

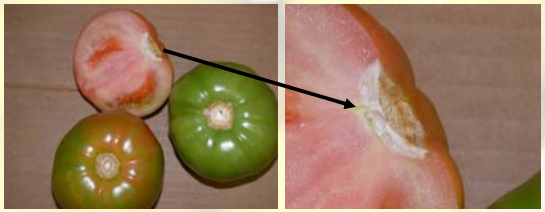

Figure 7. Observable Phytotoxicity. Phytotoxic effects of high dose ClO_2 gas (88 mg / 2 hrs) treatments on tomato fruit with cross-section from damaged stem scar, showing the penetrating desiccation effects (white tissue) beneath the corky ring tissue of the stem scar.

Conclusions and Discussion

Previous studies have shown that ClO_2 can cleanse fruit of recent infections of *E. carotovora* subsp. *carotovora*. With the addition of corrugated cardboard, or the storage of fruit in a low mass-transfer situation (i.e., stagnant air), applied ClO_2 may either not physically reach points of infection, or may react with competitive sinks, such as corrugated cardboard packing materials.

At the highest treatment level in this study (88 mg applied to 1 or 2 kg of fruit in 2 h), stem scars became cracked, sunken in, and bleached (Fig 7). Phytotoxicity at the stem scar expanded beyond the corky ring tissue to also apparently include tissues under the cuticle.

While increased doses of ClO_2 may overcome competitive sinks or barriers to mass-transfer, care must be taken to avoid excessive dosing which may lead to detrimental results. Further investigation to the action of ClO_2 at different doses and against competitive sinks are warranted.

Citations

Mahovic, M. J., Sargent, S. A., and Bartz, J. A. Guide to identifying and controlling postharvest tomato diseases in Florida. March 2002. September 2003.

Mahovic, M. J., J. D. Tenney, and J. A. Bartz. 2007. Applications of chlorine dioxide gas for control of bacterial soft rot in tomatoes. Plant Dis. **91**:0000-0000.

Acknowledgements

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