JARQ 60 (4), 307-315 (2026) https://www.jircas.go.jp

Effective Disinfection of *Xanthomonas citri* pv. *citri* on Satsuma Mandarin Fruits Using Gaseous Chlorine Dioxide

Takeo SHIMIZU[1]*, Yuya CHIAKI[1], Takushi YOSHIDA[1] and Nobuyoshi OTA[2]

[1] Division of Fruit Tree and Tea Pest Control Research, Institute for Plant Protection, National Agriculture and Food Research Organization (NARO), Tsukuba, Japan
[2] Department of Business Development, Headquarters, NARO, Tsukuba, Japan

Abstract

Satsuma mandarin (*Citrus unshiu* Marc.) is one of the globally cultivated citrus species. The bacterial pathogen, *Xanthomonas citri* pv. *citri*, which causes citrus canker, is typically managed using sodium hypochlorite-based disinfection in quarantine settings. We assessed whether gaseous chlorine dioxide (ClO_2) could be used for postharvest disinfection of Satsuma mandarins. A disinfection system for this purpose was developed using an 80L plastic container, a gaseous ClO_2-generating reagent, and a gas monitoring device. Under baseline conditions, gaseous ClO_2 concentration increased markedly from 0 to 15 min, then gradually increased to around 60 ppm at 60 min. However, gaseous ClO_2 levels were reduced by absorption or degradation due to contact with the plates and fruit. The system completely inhibited pathogen growth on all test plates and effectively disinfected the fruits after 1 h of exposure, with no significant effect on fruit quality. The disinfection efficacy of gaseous ClO_2 was comparable to that of sodium hypochlorite. The CT (concentration × time) values obtained in this study may serve as a useful parameter for scaling up the system under conditions that balance effective pathogen control with the preservation of fruit quality.

Discipline: Agricultural Environment
Additional key words: citrus canker, quarantine

Introduction

Citrus production is economically important worldwide, and major cultivated citrus species include sweet orange, common mandarin, Satsuma mandarin, grapefruit, lemon, and lime (Agustí et al. 2014). Effective disease management is necessary for stable orchard production. Among the various diseases affecting citrus, citrus canker, caused by *Xanthomonas citri* pv. *citri*, is one of the most destructive. This Gram-negative bacterium produces yellow colonies on nutrient agar and employs both biofilm formation and effector proteins to facilitate infection of host plants. Infected plants exhibit lesions on leaves, young stems, and fruits. This disease reduces both productivity and marketability, and fruit shipment is typically subject to quarantine (Ali et al. 2023). The Florida Fresh Citrus Fruit Shipment Procedures outline the quarantine methods for citrus fruits, which specify that sodium hypochlorite is an approved disinfectant. Under these guidelines, fruits must be thoroughly wetted for at least 2 min with a solution containing 200 ppm sodium hypochlorite (USDA 2024).

Gaseous chlorine dioxide (ClO_2) is a potential candidate for postharvest disinfection. This gas kills microorganisms by destabilizing cell membranes, reacting with amino acids, interrupting protein synthesis, oxidizing DNA, RNA, and proteins, and penetrating bacterial biofilms that form on the surfaces of fruits and vegetables. However, ClO_2 treatment can also affect the surfaces of fresh fruits and vegetables, causing color changes (Sun et al. 2019), thereby reducing marketability.

Gaseous ClO_2 has been investigated for postharvest preservation in various fruits, including blueberries, tomatoes, grapefruit, and tango mandarins (Sun et al. 2014, 2017a, 2017b; Zhong et al. 2021). In blueberries, in vivo experiments showed that a pad containing 0.35 g of ClO_2-generating reagent reduced populations of

*Corresponding author: shimizu.takeo641@naro.go.jp
Received 11 December 2025; accepted 17 February 2026; J-STAGE Advanced Epub 30 July 2026.
https://doi.org/10.6090/jarq.25J16

Escherichia coli (a foodborne pathogenic bacterium) and *Colletotrichum acutatum* (a postharvest fungal pathogen) over 9 d (Sun et al. 2014). In grapefruit, treatment with gaseous ClO_2 at 5-60 mg/L for 24 h reduced populations of *E. coli*, *Penicillium digitatum* (the causal agent of green mold), and *Xanthomonas citri* pv. *citri*. However, prolonged high-dose exposure (49 d) resulted in visible phytotoxic effects, such as peel browning, which reduced fruit quality (Sun et al. 2017b). In cherry and grape tomatoes, *E. coli*, *Alternaria alternata* (a causal agent of black rot on tomatoes and a mycotoxin producer), and *Salmonella enterica* (a foodborne bacterial pathogen) were reduced following ClO_2 treatment at 2-8 ppm for 14 d. Although firmness was maintained, weight loss was observed in treated fruits (Sun et al. 2017b). In tango mandarins, gaseous ClO_2 generated from 2.0 g of a granular mixture inhibited mycelial growth of *Lasiodiplodia theobromae* (the causal agent of stem-end rot) on potato dextrose agar after 24 h. However, 1.5 g of the granular mixture, which generated 39.3 ppm at 2 hours and declined to 0 ppm at 24 hours, was insufficient for complete inhibition of mycelial growth (Zhong et al. 2021).

Satsuma mandarin (*Citrus unshiu* Marc.) is cultivated in Japan, Spain, Korea, Turkey, Georgia, California (USA), Uruguay, and South Africa (Agustí et al. 2014). In Japan, it is a major citrus crop, well adapted to the Japanese climate. Desirable traits include seedlessness, ease of peeling, early maturation, disease resistance, and high productivity. In addition, new cultivars have been developed through citrus breeding programs to improve fruit quality, fragrance, production stability, and stress resistance (Omura & Shimada 2016). In 1995, the US quarantine authority required Japan to implement quarantine measures against several pests and citrus canker in Satsuma mandarin exports (Katayama et al. 2001). In evaluating the insecticidal efficacy of methyl bromide fumigation as a quarantine treatment, the CT (concentration × time) product was used as a key indicator (Misumi et al. 2001).

Although sodium hypochlorite is currently used in the quarantine treatment of citrus canker on Satsuma mandarins, the development of a new disinfection method may enable more effective disease management while reducing the labor burden on citrus producers. In this study, we evaluated the efficacy of gaseous ClO_2 for disinfection of *X. citri* pv. *citri* on Satsuma mandarin fruit. A disinfection system with real-time monitoring of gaseous ClO_2 concentration was developed, and its efficacy was compared with that of the conventional sodium hypochlorite method. The quality of treated fruits was also assessed.

Materials and methods

1. Fruits

Satsuma mandarin fruits (cultivars: 'Okitsuwase' and 'Aoshima') with no symptoms of citrus canker were harvested by the Division of Citrus Research at the Institute of Fruit Tree and Tea Science, National Agriculture and Food Research Organization (NARO) in Shizuoka Prefecture, Japan. For experiments using 18 fruits per set, 'Okitsuwase' fruits were harvested on 11 November 2024. For experiments using 8 fruits per set, 'Aoshima' fruits were harvested on 16 December 2024. After harvest, the fruits were transported to our laboratory at the Division of Fruit Tree and Tea Pest Control Research at the Institute for Plant Protection, NARO, in Ibaraki Prefecture, Japan. All fruits were stored at 4°C until the experiments were conducted.

2. Preparation of bacterial suspension for inoculation

The rifampicin-resistant strain KC20RR of *Xanthomonas citri* pv. *citri* (Imai et al. 2018) was used to inoculate the fruits. YP medium was prepared by dissolving 0.5 g of yeast extract and 1.0 g of Bacto peptone in 100 mL of distilled water. The bacterium was cultivated on YP agar plates (containing 1.5% agar) supplemented with rifampicin at a final concentration of 100 ppm, and incubated at 25°C for 2 to 3 d. After cultivation, YP medium was added to the plates, and bacterial cells were collected from the surface using a sterile spreading stick. The bacterial suspension was adjusted to an optical density (OD_{660}) of 0.10-0.13 using a Mini photo 518R (TAITEC, Saitama, Japan). The resulting bacterial concentration was confirmed to be $1.0\text{-}4.0 \times 10^{11}$ CFU/mL (data not shown). The suspension was then diluted 1,000-fold in liquid YP medium. Both undiluted and diluted suspensions were used to prepare bacterium-inoculated fruits. Hereafter, "concentrated inoculation" and "diluted inoculation" refer to treatments with suspensions at OD_{660} 0.10-0.13 and 1,000-fold dilution, respectively.

3. Construction of disinfection system with gaseous chlorine dioxide

80L plastic containers were purchased from a hardware store, and a hole was drilled at the center of the lid (Fig. 1A). A silicone tube was inserted into the hole and connected to a D16 PortaSens III portable gas leak detector (Analytical Technology, Inc., Collegeville, PA) to monitor gaseous ClO_2 concentrations. ClO_2 was generated within the container using Panaclean CLP30 (ClO_2)-generating reagent (Iwatani Camborough Co., Ltd., Tokyo, Japan). For each disinfection experiment,

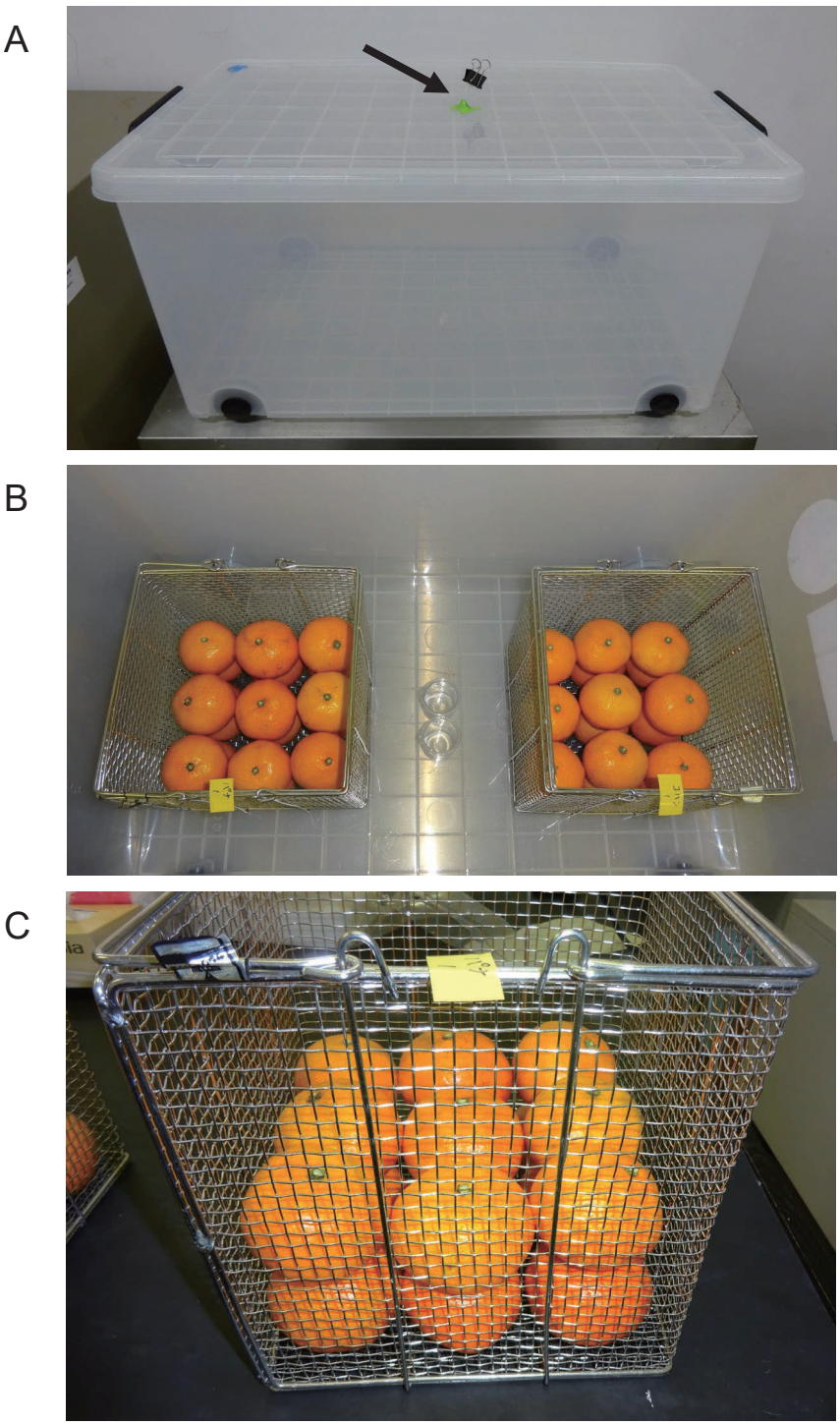


Fig. 1. Construction of the disinfection system using gaseous ClO_2
(A) 80L plastic container used for the disinfection experiments. The black arrow indicates the hole used to connect the container to the D16 PortaSens III portable gas leak detector for monitoring gaseous ClO_2 concentration. (B) Arrangement of the beakers containing the ClO_2-generating reagent and placement of the fruits inside the 80L plastic container. (C) Configuration of 18 fruits: nine fruits were arranged in a 3 × 3 matrix, with two such matrices stacked vertically.

0.1 g of Panaclean CLP30 was mixed with 140 µL of distilled water in a beaker, and two beakers were placed at the center of the container (Fig. 1B). The experiments were performed in triplicate in a room maintained at 25°C using an air conditioner.

4. Plate disinfection

To prepare inoculated plates, 100 µL of the bacterial suspension was spread onto YP agar plates (1.5% agar). The inoculated plates were placed adjacent to the beakers containing Panaclean CLP30 inside the 80L plastic container. Plates were exposed to gaseous ClO_2 for 1 h and then incubated at 25°C for 3 d. Bacterial colonies were then counted following incubation. Each test included six plates: three inoculated with the concentrated suspension and three with the diluted suspension. This procedure was repeated three times, resulting in three replicates of ClO_2 concentration monitoring and bacterial colony enumeration. Statistical analyses were performed as described below.

5. Fruit disinfection

A summary of the experimental conditions for fruit disinfection is presented in Table 1, and the detailed procedures are described below.

Two sets of fruits were placed adjacent to the beakers containing Panaclean CLP30 inside the 80L plastic container as shown in Figure 1B. One set was used to assess bacterial survival, and the other to evaluate fruit quality. For the bacterial survival assessment, the fruits were immersed for 1 min in 2 L of bacterial suspension (prepared as described in Section 2), then air-dried overnight at room temperature on a laboratory bench. For concentrated inoculation experiments, 18 fruits were used per set; for diluted inoculation, 8 fruits were used per set. In the 18-fruit sets, fruits were arranged in a 3 × 3 matrix, with such matrices stacked vertically (Fig. 1C). In the 8-fruit sets, fruits were arranged in a 2 × 2 matrix, also stacked in two layers.

Following 1 hour of exposure to gaseous ClO_2, each set of 18 or 8 fruits was gently hand-washed in 2 or 1 L of distilled water, respectively, to recover surface-associated bacteria. Aliquots of 100 µL and 1,000 µL of the washed solution were plated on YP medium (1.5% agar) supplemented with rifampicin (Wako, Osaka, Japan) at a final concentration of 100 ppm. These plates were incubated at 25°C for 3 d, and bacterial colonies were counted. The total colony-forming units (CFU) recovered from each test were quantified and expressed as $\log_{10}$CFU.

After gaseous ClO_2 treatment, a set of the fruits were stored in a plastic bag at 4°C until the quality experiment was conducted. In the case of the 18 fruits subjected to concentrated inoculation, surface disorders were visually assessed at 3 weeks after treatment. For the 8 fruits subjected to diluted inoculation, surface disorders, soluble solids content (°Brix), and acidity were examined at 2 and 4 weeks after treatment. The Brix and acidity measurements were performed using a PAL-BXIACID1 portable Brix–acidity meter (ATAGO CO., LTD., Tokyo, Japan) according to the manufacturer's instructions.

To evaluate the efficacy of gaseous ClO_2, a positive control experiment was conducted by immersing inoculated fruits in 2 L of sodium hypochlorite solution at a final concentration of 200 ppm for 2 min. As a negative control, inoculated fruits without any disinfection treatment were also prepared. Each group consisted of 18 fruits. The bacterial survival assessment was performed as described above.

Fruit disinfection experiments were performed on 3 December 2024, 23 January 2025, and 4 March 2025. On 3 December 2024, three independent tests were performed using 18 fruits per test, resulting in three sets of data on ClO_2 concentration monitoring, bacterial colony counts, and fruit quality. On 23 January and 4 March 2025, two tests were conducted on each date using 8 fruits per test, resulting in two sets of data per date on ClO_2 concentration monitoring, bacterial colony counts,

Table 1. Summary of experimental conditions for fruit disinfection

Date	Experiment	No. of fruits	Inoculation	No. of tests	Gaseous ClO_2 condition
3 December 2024	Bacterial survival check	18	Concentrated	3	Open triangles in Fig. 2A
	Fruit quality check	18	None	3	
23 January 2025	Bacterial survival check	8	Diluted	2	Open squares in Fig. 2A
	Fruit quality check	8	None	2	
4 March 2025	Bacterial survival check	8	Diluted	2	Open squares in Fig. 2A
	Fruit quality check	8	None	2	

and fruit quality. The fruits treated with diluted inoculum were evaluated for quality at different storage durations. Statistical analyses were performed as described in Section 7.

6. CT product calculation

The CT product, defined as the product of ClO_2 concentration and exposure duration, was calculated using the method of Misumi et al. (2001). The following formula was used:

$$CT = 1/2 \times C_{15} \times 15/60 + 1/2(C_{15}+C_{30}) \times 15/60 + 1/2(C_{30}+C_{60}) \times 30/60$$
$$= 0.25C_{15} + 0.375C_{30} + 0.25C_{60} \text{ (ppm·h)}$$

where C_n represents the gaseous ClO_2 concentration (ppm) at 15, 30, and 60 min.

7. Statistical analyses

All statistical analyses were performed using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria). More precisely, EZR is a modified version of R Commander, enhanced with statistical functions commonly used in biostatistics. For the CT product calculation, bacterial survival assessment under concentrated inoculation, and the measurements of Brix and acidity, the collected data were analyzed using Tukey's test. For the bacterial survival assessment under diluted inoculation, the collected data were analyzed using a t-test.

Results

1. Construction of the gaseous ClO_2 disinfection system

A disinfection system for Satsuma mandarin fruits was constructed with real-time monitoring of gaseous ClO_2 concentration (Fig. 1). In each experiment, gaseous ClO_2 was generated from beakers located at the center of the bottom of an 80L plastic container, and the gas was allowed to diffuse for 1 h. The concentration of ClO_2 was measured over time (Fig. 2A). In experiments using only ClO_2-generating beakers (closed circles in Figure 2A), the ClO_2 concentration increased rapidly from 0 to 15 min and then gradually from 15 to 60 min, reaching approximately 60 ppm. This condition served as the

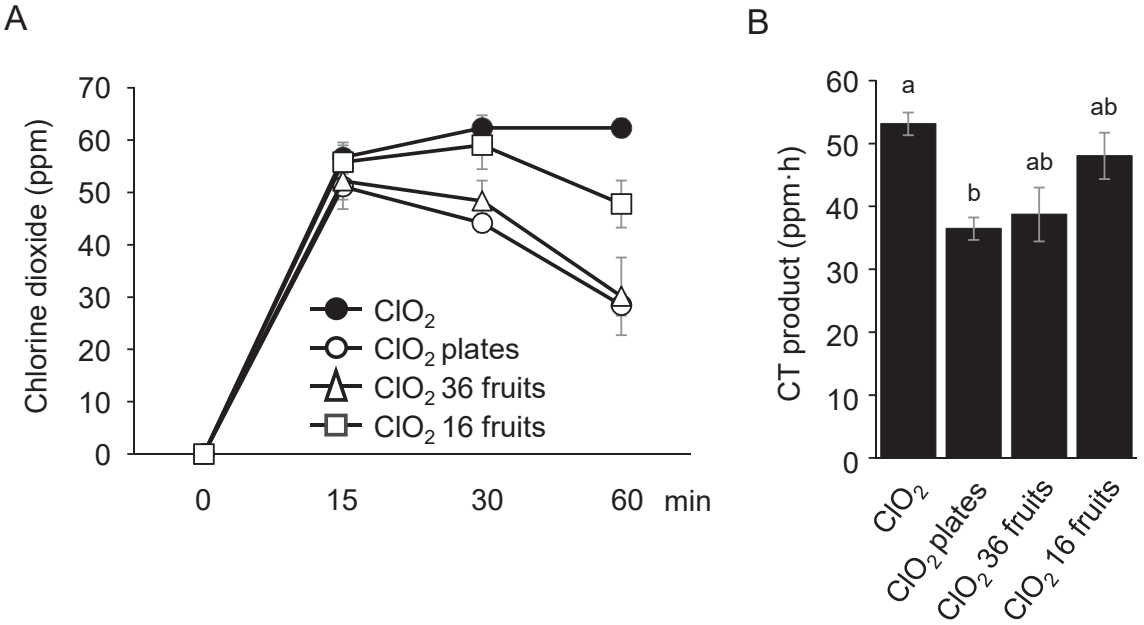


Fig. 2. Operating conditions for the gaseous ClO_2 disinfection system

(A) Monitoring of gaseous ClO_2 concentration in the container. Closed circles: three replicates of the experiment using only ClO_2-generating beakers. Open circles: three replicates using ClO_2-generating beakers and bacterium-inoculated plates. Open triangles: three replicates using ClO_2-generating beakers and 36 fruits. Open squares: four replicates using ClO_2-generating beakers and 16 fruits. (B) CT values calculated from the data shown in panel (A). Different letters indicate statistically significant differences based on Tukey's test ($P < 0.05$).

baseline for the constructed disinfection system. In contrast, when inoculated plates or fruits were placed in the box (open circles, triangles, and squares in Figure 2A), ClO_2 concentrations decreased after 15 min. Corresponding CT values showed significant differences between the condition using only the ClO_2-generating beakers and that with the inoculated plates (Fig. 2B).

2. Disinfection of inoculated plates

To evaluate the efficiency of gaseous ClO_2 in the disinfection system, *X. citri* pv. *citri*, the causal agent of citrus canker, was inoculated onto YP agar plates and exposed to gaseous ClO_2 in the container. Under the conditions represented by the open circles in Figure 2A, the growth of the pathogen was completely inhibited on all tested plates (Fig. 3).

3. Disinfection of the inoculated fruit

Satsuma mandarin fruits inoculated with the pathogen were exposed to gaseous ClO_2 under the conditions represented by the open triangles and squares in Figure 2A. In the negative control experiments (without ClO_2 treatment), pathogen populations of 7.69 or 4.06 $\log_{10}$ CFU were recovered from fruits subjected to concentrated or diluted inoculation, respectively (Fig. 4), indicating that the washing and recovery procedures were effective. In fruits subjected to concentrated inoculation, bacterial populations of 5.48 or 5.00 $\log_{10}$ CFU were recovered following treatment with sodium hypochlorite and gaseous ClO_2, respectively. Although there was no significant difference between the two disinfection treatments, both values were significantly lower than the bacterial population observed in the untreated control. Furthermore, in fruits subjected to diluted inoculation, bacterial growth was completely suppressed following gaseous ClO_2 treatment.

4. Fruit quality

To investigate the effect of gaseous ClO_2 on fruit quality, surface disorders, soluble solids content (°Brix), and acidity were examined in fruits treated under the disinfection conditions represented by the open triangles and squares in Figure 2A. No surface disorders were observed in any treated fruits, regardless of storage duration (Fig. 5A, B). Similarly, °Brix values remained unchanged across all treatment conditions and time periods. Acidity was also unaffected, except in one test conducted on 23 January 2025, in which slight variation was observed (Fig. 5C). These results indicate that the disinfection conditions used in this study did not cause any significant deterioration in fruit quality over a 4-week storage period.

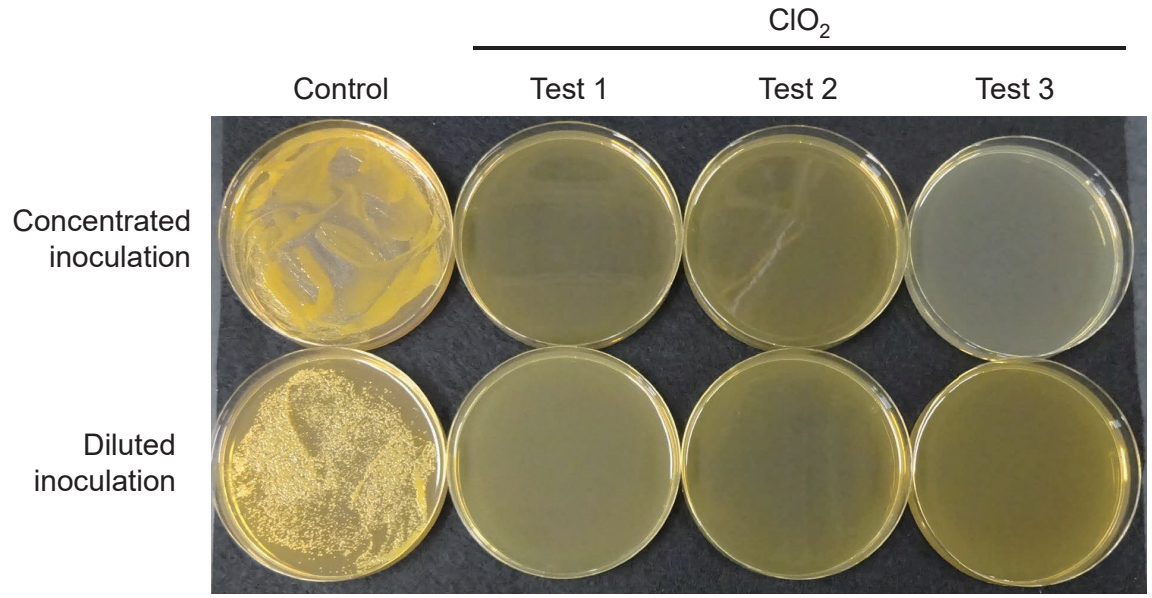


Fig. 3. Disinfection of *Xanthomonas citri* pv. *citri* inoculated onto plates under the conditions represented by the open circles in Fig. 2A

Representative results are presented. 'Control' indicates the negative control condition with no gaseous ClO_2 treatment. Bacterial growth was completely inhibited on all plates treated with gaseous ClO_2 disinfection.

Discussion

Citrus is one of the economically important crops globally, and Satsuma mandarin is a major citrus species cultivated in several countries, including Japan (Omura & Shimada 2016). In the international trade of citrus fruits, citrus canker, caused by *X. citri* pv. *citri*, is a regulated quarantine pathogen, and sodium hypochlorite is an approved disinfectant for postharvest treatment (USDA 2024). In this study, the potential of gaseous ClO_2 as an alternative disinfectant for Satsuma mandarin fruits was evaluated and compared with sodium hypochlorite solution.

A disinfection system for Satsuma mandarin fruits was successfully constructed using a ClO_2-generating reagent and a gas concentration monitoring device (Fig. 1). In contrast to previous studies (Sun et al. 2014, 2017a, 2017b; Zhong et al. 2021), in which disinfection times ranged from several hours to several d, the system developed in this study achieved effective disinfection of *X. citri* pv. *citri* on fruit surfaces within 1 h without causing significant deterioration in fruit quality (Figs. 4, 5). Although high concentrations or prolonged exposure to sanitizing agents can enhance pathogen inactivation, they can also adversely affect fruit quality (Sun et al. 2017b). For example, in grapefruit, high ClO_2 dosage and extended exposure caused phytotoxic peel browning, reducing visual quality. In Satsuma mandarin, high ClO_2 dosages applied over a short duration were effective in balancing disinfection efficacy and preservation of fruit quality.

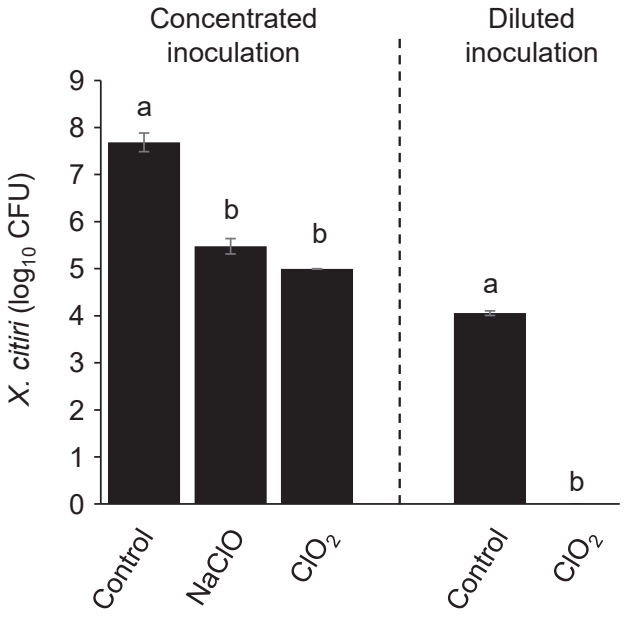


Fig. 4. Disinfection of *Xanthomonas citri* pv. *citri* inoculated onto fruits under the conditions represented by the open triangles and squares in Fig. 2A

A summary of the experimental conditions is given in Table 1. For the concentrated inoculation, three replicates (totaling 54 fruits) were subjected to statistical analysis (Tukey's test). For the diluted inoculation, four replicates (totaling 32 fruits) were subjected to statistical analysis (t-test). Different letters indicate statistically significant differences ($P < 0.05$). Control, no ClO_2 treatment (negative control); NaClO, disinfection with sodium hypochlorite solution; ClO_2, disinfection with gaseous ClO_2.

In a previous study (Shiotani et al. 2009), *X. citri* pv. *citri* was not detected by PCR in aqueous sonicates from 3,491 mature, asymptomatic fruit harvested from severely diseased Satsuma mandarin trees growing in Japan. The study also demonstrated that the bacterium was found only in three of 14 lesions and the bacterial population was lower than 3 x 10^3 CFU per lesion even in Satsuma mandarin fruits with canker lesions elicited by the inoculation after the fruits had been discarded over 100 d in a navel orange orchard. Therefore, it is unlikely that healthy, asymptomatic Satsuma mandarin fruits harbor detectable populations of *X. citri* pv. *citri*. In this study, two inoculation conditions were examined (Fig. 4). In the concentrated inoculation experiment, 7.69 $\log_{10}$ CFU of the pathogen were recovered from healthy fruits without disinfection, whereas gaseous ClO_2 treatment reduced the population to 5.00 $\log_{10}$ CFU. In the diluted inoculation experiment, 4.06 $\log_{10}$ CFU were recovered from untreated healthy fruits, but no viable bacteria were detected following ClO_2 treatment, indicating complete disinfection even in areas of fruit-to-fruit contact when the surface population is below approximately 4.06 $\log_{10}$ CFU. These results suggest that the disinfection system is effective for treating marketable healthy Satsuma mandarin fruits. Gaseous ClO_2 has been reported to penetrate bacterial biofilms on fruit surfaces (Sun et al. 2019). Since biofilm formation is necessary for the virulence and survival of *X. citri* pv. *citri* (Ali et al. 2023), it is likely that gaseous ClO_2 treatment interferes with biofilm integrity and pathogen viability on fruit surfaces.

Sodium hypochlorite is currently used for postharvest disinfection in citrus quarantine. This study demonstrates that the efficacy of gaseous ClO_2 is comparable to that of sodium hypochlorite against *X. citri* pv. *citri* on Satsuma mandarin fruits (Fig. 4). Furthermore, in disinfected fruits, physiological disorders such as peel pitting, postharvest diseases such as green mold that limit long-term storage, and changes in Brix and acidity were not observed under the experimental conditions (Fig. 5). However, gaseous ClO_2 was degraded

or absorbed by the presence of plates and fruits in the plastic box (Fig. 2A), indicating that the materials present can affect the concentration and persistence of gaseous ClO_2 produced in the box. For practical application in commercial production, methods compatible with large-scale fruit treatment will be required. The CT values calculated in this study (Fig. 2B) may serve as useful parameters for scaling the system under conditions that balance pathogen control and fruit quality preservation. The development of an effective disinfection strategy using gaseous ClO_2 may contribute to improved postharvest management and enhanced production of Satsuma mandarins.

Acknowledgements

We would like to express our gratitude to Dr. Masatoshi Mochizuki for his assistance with harvesting Satsuma mandarins. We also extend our thanks to Dr. Hiroshi Shiotani for providing the strain KC20RR of

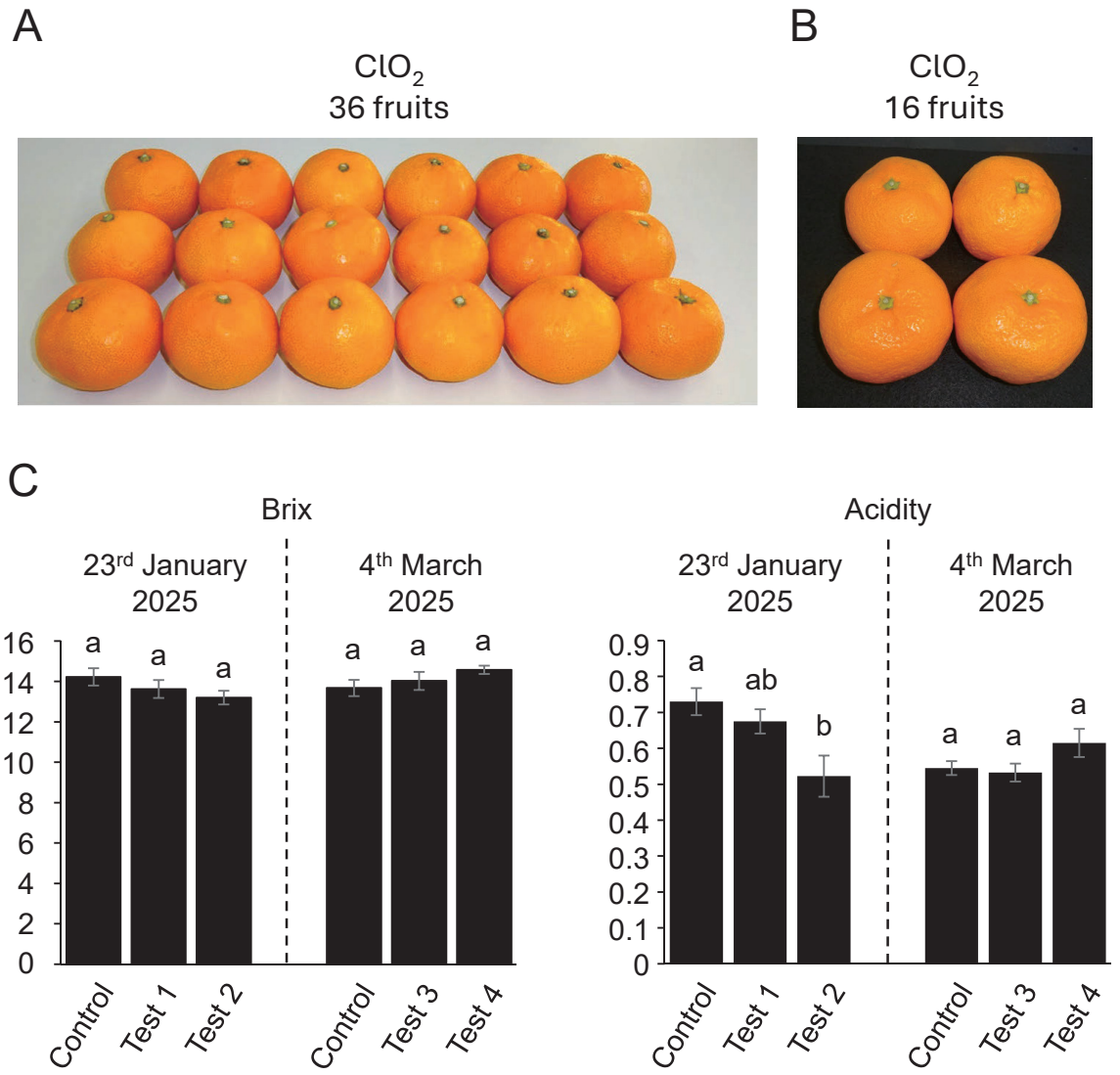


Fig. 5. Quality of fruits following gaseous ClO_2 disinfection

(A) Representative images of fruits at 3 weeks after treatment under the conditions shown by the open triangles in Figure 2A. No surface disorders were observed in 54 fruits examined across three tests. (B) Representative images of fruits at 4 weeks after treatment under the conditions shown by the open squares in Figure 2A. No surface disorders were observed in 16 fruits examined across four tests. (C) Brix and acidity measurements of fruits at 4 weeks after treatment (the same conditions as in panel B). Control, fruits without gaseous ClO_2 disinfection (negative control). In each test, 4 fruits were used. Different letters indicate statistically significant differences based on Tukey's test ($P < 0.05$).

Xanthomonas citri pv. *citri*. This study was conducted as part of a research project demonstrating phytosanitary measures for citrus exports, commissioned by the Ministry of Agriculture, Forestry and Fisheries of Japan.

References

Agustí, M. et al. (2014) Citrus production. In Dixon, G. R., & Aldous, D. E. (eds.), Horticulture: *Plants for people and places, volume 1*, Springer Dordrecht, pp. 159-195. https://doi.org/10.1007/978-94-017-8578-5.

Ali, S. et al. (2023) Citrus canker: A persistent threat to the worldwide citrus industry—An analysis. *Agronomy*, **13**, 1112. https://doi.org/10.3390/agronomy13041112.

Imai, K. et al. (2018) Susceptibility of *Citrus junos* 'Yamane' and 'Kaname No. 2' fruits to *Xanthomonas citri* pv. *citri*. *Bull. NARO, Fruit Tree and Tea Sci*., **2**, 1-7. https://agriknowledge.affrc.go.jp/RN/2010923410.pdf.

Katayama, M. et al. (2001) Mortality tests for Kanzawa spider mite, six-spotted mite, tropical citrus aphid and citrus psylla on Satsuma mandarins by methyl bromide fumigation. *Res. Bull. Pl. Prot. Japan*, **37**, 27-33. https://ndlsearch.ndl.go.jp/books/R000000004-I5876477.

Misumi, T. et al. (2001) CT product and its variation in varieties of commodities fumigated with methyl bromide. *Res. Bull. Pl. Prot. Japan*, **37**, 9-17. https://www.maff.go.jp/pps/j/guidance/r_bulletin/pdf/rb037-002.pdf.

Omura, M. & Shimada, T. (2016) Citrus breeding, genetics and genomics in Japan. *Breed. Sci*., **66**, 3-17. https://doi.org/10.1270/jsbbs.66.3.

Shiotani, H. et al. (2009) Survival and dispersal of *Xanthomonas citri* pv. *citri* from infected Satsuma mandarin fruit. *Crop Prot*., **28**, 19-23. https://doi.org/10.1016/j.cropro.2008.08.002.

Sun, X. et al. (2014) Antimicrobial activity of controlled-release chlorine dioxide gas on fresh blueberries. *J. Food Prot*., **77**, 1127-1132. https://doi.org/10.4315/0362-028X.JFP-13-554.

Sun, X. et al. (2017a) The effect of controlled-release chlorine dioxide on the preservation of grapefruit. *Hortscience*., **52**, 122-126. https://doi.org/10.21273/HORTSCI11363-16.

Sun, X. et al. (2017b) Effect of controlled-release chlorine dioxide on the quality and safety of cherry/grape tomatoes. *Food Control*., **82**, 26-30. https://doi.org/10.1016/j.foodcont.2017.06.021.

Sun, X. et al. (2019) Applications of gaseous chlorine dioxide on postharvest handling and storage of fruits and vegetables – A review. *Food Control*., **95**, 18-26. https://doi.org/10.1016/j.foodcont.2018.07.044.

USDA, APHIS, PPQ, Florida Citrus Health Response Program (2024) *Florida fresh citrus fruit shipment procedures effective September 1, 2024 Version 9.0*. https://ccmedia.fdacs.gov/content/download/81739/file/florida-fresh-citrus-fruit-shipment-procedures.pdf.

Zhong, T. et al. (2021) The potential of gaseous chlorine dioxide for the control of citrus postharvest stem-end rot caused by *Lasiodiplodia theobromae*. *Plant Dis*., **105**, 3426-3432. https://doi.org/10.1094/PDIS-02-20-0407-RE.