Antimicrobial Performance of Alkaline Ionic Fluid (GC-100X) and Its Ability To Remove *Escherichia coli* O157:H7 from the Surface of Tomatoes

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**ABSTRACT**

An efficacy test of GC-100X, a noncorrosive alkaline ionic fluid (pH 12) composed of free radicals and supplemented with xylitol, was carried out against six major foodborne pathogens—*Staphylococcus aureus* FRI913, *Salmonella enterica* serovar Enteritidis ATCC 13076, *S. enterica* serovar Typhimurium DT104 Korean isolate, *Vibrio parahaemolyticus* ATCC 17803, *Escherichia coli* O157:H7 ATCC 43894, and *Pseudomonas aeruginosa* KCTC 1637—at three different temperatures (4, 25, and 36°C) with or without organic load (2% yeast extract). Results revealed a more than 4-log₁₀ (CFU/ml) reduction (1.0 × 10⁴ CFU/ml reduction) against all pathogens reacted at 37°C for 3 h in the absence of organic material. GC-100X solution diluted with an equal volume of distilled or standard hard water (300 ppm CaCO₃) showed effective bactericidal activity, particularly against gram-negative bacteria. Washing efficacy of GC-100X solution was compared against *E. coli* O157:H7 on cherry tomato surfaces with those of a commercially used detergent and chlorine water (100 ppm). Viable cell counts of *E. coli* O157:H7 that had penetrated to the cores of tomatoes after sanitizing treatment revealed that GC-100X stock and its 5% diluted solutions had similar washing effects to 100-ppm chlorine water and were more effective than the other kitchen detergent. These results indicate that GC-100X has good bactericidal and sanitizing activities and is useful as a new sanitizer for food safety and kitchen hygiene.

In the past, foodborne outbreaks in Korea were associated with meat and fish contaminated with *Salmonella*, *Staphylococcus aureus*, and *Vibrio parahaemolyticus*. Recently, however, infections related to raw fruits and vegetables have risen (19). Documented illnesses in developed countries also involve various types of fruits and vegetables, including tomatoes, lettuce, alfalfa sprouts, radish sprouts, parsley, scallions, cantaloupe, and berries, as well as unpasteurized apple and orange juices in the United States (4, 9, 10, 12, 14, 29). Microorganisms can occur on raw or minimally processed produce at populations ranging from 10³ to 10⁹ CFU/g through various contamination sources (9, 11, 26). Before harvest, feces, soil, irrigation water, water used to apply fungicides and insecticides, air (dust), animals, insects, and human handling act as sources of contamination, whereas cross-contamination from feces, human handling, harvesting equipment, transport containers, animals, insects, air (dust), water, processing equipment, and ice can occur after harvest. Improper storage, packing, or display temperature, can also occur after harvest and increase microbiological risk (5, 13, 28). Recently, because of changes in food consumption patterns of Koreans, increasing numbers of large-scale restaurants and salad bars can be found. This trend is a warning signal that outbreaks of foodborne illnesses caused by cross-contamination in the United States can also occur in Korea. Therefore, special attention should be given to the safety of raw fruits and vegetables.

Consumers generally wash raw fruits and vegetables with tap water or detergent. Washing produce in water can remove some soil and debris, but this process cannot be relied on to completely remove microorganisms and could result in cross-contamination of food preparation surfaces, utensils, and other food items (9). Detergent, on the other hand, is effective in removing disease-causing microorganisms from the surfaces of raw fruits and vegetables, but at the same time, improper rinsing could cause safety problems or deterioration of sensory qualities in raw produce (9). Chlorine, approved by U.S. Environmental Protection Agency as an effective sanitizer for washing fruits and vegetables, is used at concentrations in the range of 50 to about 200 ppm (8). Although the rapidity and broad spectrum of the antimicrobial activity of chlorine are accepted worldwide (5), it is toxic and can cause safety problems. Therefore, a safe and effective sanitizer for the removal of pathogens on fresh produce is urgently needed. GC-100X, a noncorrosive alkaline ionic fluid (pH 12), is produced by special electrolyzation of sodium chloride solution. It is composed of free radicals (8.8 × 10² relative light units, hydroxyl radicals contained), Na⁺, K⁺, and 0.5% xylitol. It is not supplemented with surfactants. A detailed list of ingredient concentrations is not given, but its shelf life is

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about 3 to 4 years because of its stability (GC-100X is effective and stable as long as it maintains pH 12). Its toxicological safety was verified by Korea Testing and Research Institute for Chemical Industry and the Department of Public Health (College of Veterinary Medicine, School of Agricultural Biotechnology, Seoul National University) through acute and subacute toxicological tests (unpublished data). Therefore, our study focused on evaluating the bactericidal efficacy of GC-100X against major foodborne pathogens and its removal of viable E. coli O157:H7, which was inoculated onto the surfaces of cherry tomatoes. GC-100X as a fresh produce sanitizer was also compared with other sanitizers, such as detergent and chlorine, as well as with distilled and tap water.

MATERIALS AND METHODS

Microorganisms. Staphylococcus aureus FRI 913 (staphylococcal enterotoxin A [SEA]+, SEC+, SEE+, and toxic shock syndrome toxin [TSST]-1+), Salmonella enterica serovar Enteritidis ATCC 13076, Salmonella Typhimurium DT104 (bovine fecal isolate resistant to ampicillin, chloramphenicol, streptomycin, sulfonamides, and tetracycline), Vibrioparahaemolyticus ATCC 17803, Escherichia coli O157:H7 ATCC 43894 (shiga-like toxin [SLT] I+ and SLT II+), and Pseudomonas aeruginosa KCTC 1637 were used as foodborne pathogens. They were incubated in nutrient broth (Difco, Sparks, Md.) at 37°C for 24 h, centrifuged at 1,700 rpm for 30 min to obtain the cell pellets, and diluted with phosphate-buffered saline (pH 7.2) or a 40% yeast extract (Difco) solution to the concentration of 5.0 × 10⁸ CFU/ml.

Bactericidal efficacy test and viable cell count. The post-treatment growth method was based on the guidelines of the Department for Environment, Food, and Rural Affairs (United Kingdom), with modifications to the concentration of organic material and treatment duration (2). GC-100X stock solution (Buhmwoo, Seoul, Korea) and its twofold-diluted solutions with distilled water or standard hard water (300 ppm CaCO₃) were tested for their efficacies. Standard hard water was made according to the guideline of the Association of Official Analytical Chemists method (25). Tests were carried out with or without an organic load (2% yeast extract); exposure time to bacteria was 30 min to 3 h. Nine milliliters of the test solution and 1 ml of bacterial culture were mixed to a final bacterial concentration of 5.0 × 10⁸ CFU/ml. For the organic challenge, a bacterial cell suspension was diluted with the same volume of 40% yeast extract (Difco) to the concentration of 5.0 × 10⁸ CFU/ml and then mixed with the test solution as described above to the final concentration of 2% yeast extract. The mixture of solution and bacteria was incubated at three reaction temperatures—4, 25, and 36°C—for 30 min and 3 h. Subsequently, 1 ml of the mixture was diluted with 10 ml of nutrient broth to neutralize the sanitizer, and viable cell count was performed using the conventional plate counting method. Neutralization of the sanitizer was confirmed by pH calculation (decreased to pH 7.3). For the case of V. parahaemolyticus, 3% NaCl was added to plate count agar (Difco). Efficacy was determined as effective when a 4-log₈ CFU/ml reduction of bacteria was achieved after application of the solution.

Viable pathogens treated with GC-100X stock solution at 25°C were counted at 0, 30 s, and 1, 5, 15, and 30 min after treatment to determine the rapidity and effectiveness of the bactericidal activity of GC-100X.

<table>
<thead>
<tr>
<th>Group</th>
<th>Dipped in E. coli O157:H7 solution</th>
<th>Treatment (no. of tomatoes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Yes</td>
<td>GC-100X stock (20)</td>
</tr>
<tr>
<td>B</td>
<td>Yes</td>
<td>GC-100X 5% (20)</td>
</tr>
<tr>
<td>C</td>
<td>Yes</td>
<td>GC-100X 3% (20)</td>
</tr>
<tr>
<td>D</td>
<td>Yes</td>
<td>100 ppm chlorine water (20)</td>
</tr>
<tr>
<td>E</td>
<td>Yes</td>
<td>Kitchen synthetic detergent (20)</td>
</tr>
<tr>
<td>F</td>
<td>Yes</td>
<td>Distilled water (20)</td>
</tr>
<tr>
<td>G</td>
<td>Yes</td>
<td>Sterile tap water (20)</td>
</tr>
<tr>
<td>Positive control</td>
<td>Yes</td>
<td>None (20)</td>
</tr>
<tr>
<td>Negative control</td>
<td>No</td>
<td>None (20)</td>
</tr>
</tbody>
</table>

TABLE 1. Groups of tomatoes treated with different solutions

Produce evaluated. Nonoiled and nonwaxed red cherry tomatoes were purchased from a local produce market.

Sanitizers tested. GC-100X stock, 3%, and 5% solutions were tested as fresh produce sanitizers and were compared with chlorinated water (100 ppm free chlorine), commercial kitchen detergent (pH 6 to 7, composed of 17% surfactant, a small amount of natural extracts, and 83% other soluble reagents), distilled water, and sterilized tap water. All test solutions were maintained at 25°C. Detergent was used as a 0.2% diluent according to the manufacturer's recommendation. Free chlorine content was determined using a chlorine test paper (Advantec, Toso Kashiya, Tokyo, Japan). Treated groups and treatment conditions are described in Table 1.

E. coli O157:H7 and sanitizer treatment. E. coli O157:H7 ATCC 43894 was cultured in tryptic soy broth (Difco) for 36 h at 37°C and diluted to 3.0 × 10⁶ CFU/ml using phosphate-buffered saline. The inoculum was maintained at 25°C, and applied to tomatoes within 30 min of preparation. Tomatoes (except the negative control) were submerged in the bacterial suspension for 2 min with continuous agitation and air-dried under a laminar flow hood (Dwyer Instruments, Inc., Michigan City, Ind.) at 15°C for 8 h. Dried tomatoes were randomly divided into eight treatment groups, each containing 20 tomatoes, and treated with 2 liters of each solution using the dipping method at 25°C for 2 min with agitation. Each treated tomato was then packed separately in a Whirl-Pak (Nasco, Fort Atkinson, Wis.) and stored at 15°C until use. Bacterial populations on the surfaces and in the cores of tomatoes were analyzed independently using tomatoes further divided into two groups.

Analysis of bacterial population on the surface of tomatoes. Twenty milliliters of sterile buffered peptone water (BPW; Difco) was added to each Whirl-Pak containing the treated tomato. The tomato was rubbed 50 times by hands. The BPW wash solution was then serially diluted with BPW and analyzed for total number of viable E. coli O157:H7. Viable cell count was carried out using chromocult coliforms agar (CCA; Merck, Darmstadt, Germany). The positive and negative control groups were also counted. After incubation at 37°C for 36 h, two colonies per plate were selected, and O and H antisera (Difco) tests were carried out to identify E. coli O157:H7.

Comparison of CCA with tryptic soy agar. Recovery rate of E. coli O157:H7 on CCA was compared with that on tryptic soy agar (TSA; Difco). Five tomatoes each of the positive control and treatment D (100 ppm chlorine) were washed with BPW and plate-counted on CCA and TSA.
Analysis of bacterial population in the cores of tomatoes. Each sanitizer-treated tomato stored at 15°C for 20 h was placed on a sterilized paper after scrubbing with cotton soaked in 70% ethyl alcohol. The cores of tomatoes were excised to a depth of 0.5 cm using a sterilized scalpel. Each core was weighed and placed in a Whirl-Pak, and 10 ml of sterile BPW was added. The pack was stomached for 40 s and serially diluted for viable cell count as mentioned in the surface bacterial population analysis. Positive and negative controls were also counted. Two colonies per plate were selected, and O and H antisera (Diﬁco) tests were carried out to identify E. coli O157:H7.

To conﬁrm the effectiveness of 70% ethyl alcohol in surface sterilizing, E. coli O157:H7 remaining on the surfaces after chlorine treatment (100 ppm) were plated-counted on CCA with an extra 20 tomatoes (10 for the ethyl alcohol–treated group and 10 for the nontreated group).

Statistical analyses. Paired t test and one-way analysis of variance by ranks were performed on the data with Statistical Analysis Systems, Inc., software (Proc ANOVA, version 8, SAS Institute, Cary, N.C.). Comparison data of the recovery rates between CCA and TSA were subjected to paired t tests, and the mean population of E. coli O157:H7 on the surface and inside the tomatoes was subjected to an analysis of variance and Duncan’s multiple range test to determine the signiﬁcant differences (P < 0.05) among the sanitizers.

RESULTS

Efficacy test. Results of efﬁcacy tests conducted at three different temperatures with or without an organic challenge are shown in Table 2. Efficacy of GC-100X against foodborne pathogens decreased when organic material was added; that is, the total number of pathogens was reduced by 4 log_{10} CFU/ml in the absence of organic material. Higher efﬁcacy was shown at higher (36°C) than at low (4°C) reaction temperatures, even when GC-100X was diluted with an equal volume of standard hard water. GC-100X is more effective against V. parahaemolyticus than other organisms tested in this study: the number of V. parahaemolyticus effectively decreased when diluted with distilled water and loaded with organic material (2% yeast extract) at 36°C. Viable cell counts of pathogens treated with GC-100X stock solution at 25°C revealed that all tested gram-negative bacteria were eradicated within 30 s. On the other hand, S. aureus was not killed completely within 30 min, and more than 30 min was required to reduce the number of S. aureus by 4 log_{10} CFU/ml. These results indicate that the efﬁcacy of GC-100X increased as temperature increased, and it was more effective against gram-negative bacteria, including V. parahaemolyticus, Salmonella Enteritidis, Salmonella Typhimurium, P. aeruginosa, and E. coli O157:H7 than S. aureus. When organic material was added, the efﬁcacy of GC-100X decreased signiﬁcantly.

Comparison of CCA with TSA. To analyze the adequacy of CCA in recovering stressed E. coli O157:H7, viable cell counts of TSA and CCA were compared, and the result of a paired t test showed no signiﬁcant difference between the two counts (P > 0.05) (Table 3).

Analysis of bacterial population on the surface of tomatoes. E. coli O157:H7 was not detected in the negative control, and 6.25 ± 0.86 log_{10} CFU/cm² was counted in the positive control. Viable cell counts of E. coli O157:H7 on the surface of tomatoes after sanitizer treatment are shown in Figure 1. No differences were observed in the sanitizing effectiveness of 100-ppm chlorine water (treatment D), GC-100X stock solution (A), GC-100X 5% solution (B), GC-100X 3% solution (C), and detergent (E) (P > 0.05; Fig. 1). However, the washing activities of treatments A to E were much higher than those of treatments F (distilled water) and G (tap water), between which, treatment F was more effective in reducing the pathogen count on the surface of tomatoes than treatment G (P < 0.05).

Analysis of bacterial population in the core of tomatoes. E. coli O157:H7 was not detected in the negative control, and 5.50 ± 0.22 log_{10} CFU/g was counted in the positive control. The 70% ethyl alcohol treatment revealed a 4.35-log_{10} CFU/cm² reduction (5.38 ± 0.38 and 1.03 ± 0.82 log_{10} CFU/cm² for nonalcohol treatment and alcohol treatment groups, respectively). Viable cell counts of E. coli O157:H7 in the core of tomatoes after sanitizer treatment are shown in Figure 2. No differences were observed in the sanitizing effectiveness of treatments A, B, and D (P > 0.05). Treatment C, on the other hand, was not as effective as the above three treatments in preventing the penetration of E. coli O157:H7 into the core tissues but showed higher effectiveness than treatments E, F, and G (P < 0.05). No statistical difference was observed between the sanitizing activities of treatments E and F, and that of treatment G was the lowest among all treatments (P < 0.05).

Analysis of total bacterial population. To compare the treatment efﬁcacy for overall assessment, viable cell counts of E. coli O157:H7 on the surface of tomatoes and of that in the core of tomatoes were expressed in one graph (Fig. 3, CFU/tomato). The sum of E. coli O157:H7 recovered from two parts of tomatoes does not represent the accurate number of E. coli O157:H7 existing on and in tomatoes because the viable counts were performed at different times (8 h after sanitizer treatment for the surface versus 20 h for the core). Nevertheless, Figure 3 shows the relative amounts of E. coli O157:H7 in two areas and the effectiveness of sanitizers compared with the positive control.

DISCUSSION

Evaluation revealed that GC-100X stock solution has good bactericidal efﬁcacy against major foodborne pathogens at three reaction temperatures. As the temperature increased, the efﬁcacy of GC-100X was also enhanced, showing prominent activity against gram-negative bacteria. On the other hand, with S. aureus, GC-100X was not as effective as with gram-negative bacteria, possibly because of the thickness of the peptidoglycan layer, which can prevent the penetration of GC-100X through the bacterial cell wall. Under organic challenge, GC-100X was effective only against V. parahaemolyticus among the gram-negative bacteria, which indicates that GC-100X functions more effectively in the absence of organic materials.

Furthermore, V. parahaemolyticus’s greater suscep-
<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Condition(^a)</th>
<th>Staphylococcus aureus</th>
<th>V. parahaemolyticus</th>
<th>Salmonella serotype</th>
<th>E. coli O157:H7</th>
<th>Pseudomonas aeruginosa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 min</td>
<td>3 h</td>
<td>30 min</td>
<td>3 h</td>
<td>30 min</td>
<td>3 h</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>3.4 ± 0.03</td>
<td>4.3 ± 0.04</td>
<td>5.5 ± 0.01</td>
<td>5.8 ± 0.00</td>
<td>4.4 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>3.2 ± 0.02</td>
<td>3.7 ± 0.02</td>
<td>5.4 ± 0.02</td>
<td>5.5 ± 0.01</td>
<td>4.4 ± 0.04</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>3.0 ± 0.05</td>
<td>3.4 ± 0.04</td>
<td>4.6 ± 0.01</td>
<td>4.6 ± 0.01</td>
<td>3.9 ± 0.01</td>
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<tr>
<td></td>
<td>D</td>
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<td>Below 4</td>
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<td>Below 4</td>
</tr>
<tr>
<td>25</td>
<td>A</td>
<td>3.6 ± 0.02</td>
<td>4.8 ± 0.03</td>
<td>7.6 ± 0.00</td>
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<td>7.6 ± 0.00</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>3.4 ± 0.03</td>
<td>4.5 ± 0.02</td>
<td>7.6 ± 0.06</td>
<td>7.6 ± 0.00</td>
<td>7.6 ± 0.00</td>
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<tr>
<td></td>
<td>C</td>
<td>3.0 ± 0.02</td>
<td>3.8 ± 0.03</td>
<td>5.7 ± 0.03</td>
<td>5.8 ± 0.03</td>
<td>5.2 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>D</td>
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<td>Below 4</td>
<td>Below 4</td>
<td>Below 4</td>
<td>Below 4</td>
</tr>
<tr>
<td>36</td>
<td>A</td>
<td>4.8 ± 0.02</td>
<td>5.2 ± 0.00</td>
<td>7.6 ± 0.00</td>
<td>7.6 ± 0.00</td>
<td>7.6 ± 0.00</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>4.6 ± 0.01</td>
<td>5.1 ± 0.01</td>
<td>7.6 ± 0.00</td>
<td>7.6 ± 0.00</td>
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</tr>
<tr>
<td></td>
<td>C</td>
<td>4.3 ± 0.02</td>
<td>4.5 ± 0.01</td>
<td>5.9 ± 0.02</td>
<td>6.2 ± 0.02</td>
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</tr>
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<td>Below 4</td>
<td>Below 4</td>
<td>Below 4</td>
<td>Below 4</td>
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</tr>
</tbody>
</table>

\(^a\) Bacterial reduction counts (mean ± SD) over 4 log\textsubscript{10} CFU/ml were regarded as effective.

\(^b\) A, GC-100X stock solution; B, twofold-diluted solution of GC-100X with distilled water; C, twofold-diluted solution of GC-100X with standard hard water (CaCO\textsubscript{3} 300 ppm); D, 2% yeast extract was added to GC-100X stock and twofold-diluted solutions with distilled water or standard hard water.

\(^c\) Only GC-100X stock solution added with 2% yeast extract was effective (4.5 ± 0.01).

\(^d\) GC-100X stock solution and twofold-diluted solution with distilled water, into both of which the organic material was added, were effective (4.5 ± 0.01 and 4.3 ± 0.03, respectively).
TABLE 3. Viable cell counts of E. coli O157:H7 cultured on tryptic soy agar (TSA) or chromocult coliforms agar (CCA)

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD (log_{10} CFU/cm²)</th>
<th>No treatment</th>
<th>Chlorine treatment (100 ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TSA</td>
<td>CCA</td>
<td>TSA</td>
</tr>
<tr>
<td></td>
<td>6.27 ± 0.65</td>
<td>6.26 ± 0.61</td>
<td>4.81 ± 0.18</td>
</tr>
</tbody>
</table>

bility to stresses, including dryness and sunlight, compared to other bacteria could explain the prominent bactericidal effect observed against this bacterium (15). According to the results of viable cell counts on the surface of tomatoes, washing fresh produce with sanitizers such as chlorine water, GC-100X, and detergent effectively reduced the number of pathogens attached to fruits and vegetables. However, surface-washing activity alone was not sufficient for determining the effectiveness of sanitizers because pathogens attached on the surface of tomatoes might have penetrated into the cores (30). Therefore, we determined the number of E. coli O157:H7 found in the tomato cores, and results revealed that both GC-100X solution and 100-ppm chlorinated water effectively prevented E. coli O157:H7 survival in the cores of tomatoes, whereas detergent could not. These findings might be attributable to the antimicrobial activities of GC-100X and 100-ppm chlorine water remaining on the surfaces or diffused into tomato cores that is not found in detergent (data not shown).

Because officially approved methods for analyzing the effectiveness of fresh produce sanitizer were not available (3, 9), we applied the dipping inoculation method (3, 4, 9). However, with this method, inoculating the exact amount of pathogens is difficult, thus resulting in low reproducibility. In spite of this handicap, the method was still more suitable than spot inoculation for our experimental design because, in spot inoculation, the inoculation sites are arti-

Beuchat et al. suggested that the total number of E. coli O157:H7 recovered from tomatoes significantly decreased after a 24-h drying period because of desiccation stress (4). However, in our study, no significant difference was found between the total numbers of pathogens recovered after 1- and 8-h drying periods (data not shown). These contrary results could be due to the differences in tomato quality and drying temperature: 15°C in our study versus 22°C in the method of Beuchat et al.

According to studies on the development of media for detecting stressed bacterial cells, selective media might inhibit the repairing of injured cells, thereby exaggerating the effectiveness of the sanitizer (6, 22). On the one hand, comparison of selective and nonselective media, together with the thin layer method, showed different results in the recovery of injured cells, depending on the stress factors and researchers (1, 4, 16–18, 20–24, 27). Therefore, the effectiveness of a medium should be confirmed prior to use (6). Although CCA has not been studied previously as a selective medium for recovering stressed E. coli O157:H7 (7), it is different from other selective media in that it contains peptone, pyruvate, sorbitol, and phosphate buffer, which allow the growth of coliforms in even sublethally damaged cells (16). However, CCA is not selective for only E. coli
O157:H7. Klebsiella, Enterobacter, and Citrobacter also have the same chromogenic pattern as E. coli O157:H7, thus causing some confusion. Nevertheless, because these pathogens were not detected in the negative control, CCA was used to recover the stressed E. coli O157:H7.

At low concentrations of GC-100X solution, such as 3 and 5%, at which little bactericidal activity occurs (data not shown), a high washing effect was observed, indicating that the sanitizing activity of GC-100X is more effective than the bactericidal activity. This result also implies that GC-100X might be effective as a fresh produce sanitizer against S. aureus, which showed relatively greater resistance to GC-100X in the bactericidal efficacy test. For further evaluation of practical GC-100X use, a cocktail of E. coli O157:H7 clinical isolates and horse serum albumin as an inoculum carrier can be used.

Sanitizing activities of GC-100X stock and 5% solutions were as effective as 100-ppm chlorine water in removing E. coli O157:H7 from the surfaces of tomatoes. Furthermore, GC-100X stock and 5% solutions effectively prevented the survival of E. coli O157:H7 in tomatoes, and there was no change in tomato appearance or flavor. Therefore, GC-100X can be used as a safe sanitizer for food and kitchen hygiene.

ACKNOWLEDGMENT

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REFERENCES


