Comparison of Rinsing and Sanitizing Procedures for Reducing Bacterial Pathogens on Fresh Cantaloupes and Bell Peppers

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ABSTRACT

Increased consumption of fruits and vegetables is linked to health benefits but also to an increase in the number of outbreaks of foodborne illness. To determine the effectiveness of different sanitizing treatments for reducing bacterial pathogens on fresh produce, fresh cantaloupes and bell peppers were harvested and inoculated with suspensions of Salmonella Typhimurium and Escherichia coli O157:H7. The inoculated fruits were treated with water wash alone or were washed and then waxed or rinsed with 200 mg/liter hypochlorite, 10% Ca(OH)2, or 2% lactic acid solutions applied by dipping for 15 s or spraying for 15 s. Preliminary experiments with chlorine treatments indicated that spraying with a 200, 600, or 1,000 mg/liter hypochlorite solution reduced populations of both pathogens by 2.1 to 2.6 and 1.5 to 2.1 log CFU for Salmonella Typhimurium and E. coli O157:H7, respectively. In general, no differences were observed between chlorine solutions without pH adjustment (pH 9.2) and those with pH adjusted to 6.0. When different wash regimes were applied to inoculated cantaloupes or bell peppers, water wash alone produced significantly lower counts of both pathogens on bell peppers in comparison to untreated controls. However, this reduction was not observed on cantaloupes, indicating a possible surface effect. Application of 2% lactic acid by spray was the treatment that resulted in the lowest bacterial counts on both cantaloupes and bell peppers. This treatment did not produce any deleterious change in the sensorial characteristics of the products tested. None of the pathogens studied was able to grow during refrigerated storage (5°C for cantaloupes and 10°C for bell peppers), although numbers close to the detection limit of the counting method were found in randomly tested individual samples at days 14 and 28 of storage, indicating that these pathogens can survive for long periods on the produce surface. These results indicate that selected produce commodities could be sanitized at the packing facility. However, these interventions should not be applied as a replacement for but only as a complement to good hygiene practices.

Recent efforts of government agencies have been aimed at promoting an increase in consumption of these fresh fruits and vegetables (28). Concurrently, these products have been increasingly associated with outbreaks of foodborne illness (23). Outbreaks of foodborne disease associated with fresh and fresh-cut produce were summarized by the U.S. Food and Drug Administration (30). It is clear that Salmonella is commonly associated with produce. Several outbreaks of Salmonella infection have been associated with domestic and imported produce. For imported produce, food safety issues can result in loss of credibility and can affect sales, causing economic losses on one side and shortage of supply on the other. In 1996, a large multistate outbreak caused by Cyclospora cayetanensis affected areas of the United States and Canada (13). Between 1989 and 2001, several outbreaks in the United States were associated with cantaloupes. In most of these outbreaks, the contaminated produce was traced back to Mexican farms (5, 12, 14, 17, 19, 31), resulting in an import alert that is still in place for Mexican melons (31). Castillo et al. (10) studied the prevalence of Salmonella contamination and the presence of Escherichia coli as an indicator of unsanitary operations in cantaloupe farms in Mexico and the United States. In this study, the packing house was identified as the site where most opportunities for bacterial contamination occurred. As a result of information of this type and of outbreak investigations associated with produce operations, the U.S. Food and Drug Administration is now recommending that establishments engaged solely in the harvesting, storage, or distribution of raw agricultural commodities be removed from the exclusion to comply with current good manufacturing practices (32). Another strategy for reducing pathogens during produce packing is produce disinfection. Numerous sanitizers, mainly in aqueous solutions, have been evaluated (11, 21), and hot water treatments have been recommended for cantaloupes and oranges (3, 18). Ukuku and Sapers (27) reported a reduction in the transfer of Salmonella to melon flesh during cutting after application of sanitizing treatments. However, in further studies, Ukuku and Fett (26) found that the level of reduction depended largely on the method of sanitizer application. The rough rind of cantaloupes provides an irregular and hydrophobic surface where bacteria can attach strongly and remain out of the reach of aqueous sanitizers (25). In addition to difficulties associated with intrinsic product

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characteristics, current industry practices such as washing produce in dump tanks may promote pathogen internalization when water temperature is not controlled (7) or cross-contamination when the water is not sanitized appropriately. The objectives of this study were to compare spray and dip treatments with different antimicrobials on the reduction of Salmonella and E. coli O157:H7 inoculated onto fresh cantaloupes and bell peppers and to study the effect of lactic acid sprays on the survival of the pathogens on these commodities during refrigerated storage.

**MATERIALS AND METHODS**

**Product selection and transportation.** On the day before treatments were applied, cantaloupes (Cucumis melo L. var. Reticulatus Naud.) and bell peppers (Capsicum annuum L.) were harvested from a cantaloupe farm and a produce farm, respectively, in Jalisco State, Mexico, placed in cardboard boxes, and immediately transported to the laboratory without any previous treatment or wash. To prevent any effect of cold shock of the fruit surface on the performance of the antimicrobials, the fruits were transported without refrigeration. The maximum time between produce collection and arrival at the laboratory was 5 h. The cantaloupes and bell peppers then were placed on a counter at room temperature (ca. 20°C) to be inoculated and treated on the next day. The average time between collection and inoculation of produce was 18 h, and there were no visible differences between the melons immediately after harvesting and after overnight storage at room temperature.

**Bacterial cultures.** Rifampin-resistant mutants derived from parent strains of Salmonella serovar Typhimurium ATCC 13311 and E. coli O157:H7 were used as marker organisms on inoculated melons. The bacteria were maintained on tryptic soy agar slants at 4°C until use. Before inoculating onto melons, the cultures were grown in tryptic soy broth (TSB; Difco, Becton Dickinson, Sparks, Md.) at 35°C for 12 to 14 h. Rifampin resistance was confirmed by streaking each culture onto separate plates of lactose sulfite phenol red rifampin agar (LSRP), which contains 100 μg/ml rifampin and was developed for differential enumeration of rifampin-resistant Salmonella and E. coli (8). Plates were incubated at 35°C for 24 h. Characteristic colonies were transferred to TSB, incubated at 35°C for 12 h, and then transferred to individual flasks containing 1 liter of sterile TSB and incubated at 35°C for 18 h.

**Inoculation of cantaloupes.** The contents of the 1-liter flasks with cultures of Salmonella Typhimurium or E. coli O157:H7 were poured into a sanitized polyethylene tub containing 8 liters of sterile 0.1% peptone water and mixed to produce a suspension containing ca. 8.0 log CFU/ml for each marker strain. Cantaloupes were inoculated in groups of six melons and peppers were inoculated in groups of 12 by submerging each melon or pepper in the bacterial suspension and gently rotating the fruit with a sterile glass rod to ensure coverage of the complete surface. Each fruit was kept in contact with the bacterial suspension for 1 min and then removed from the tub and allowed to drain for 10 min on a sanitized plastic rack. The inoculated fruits were then randomly assigned to groups of 6 for cantaloupes or 12 for bell peppers, and each group was assigned to one treatment.

**Effect of pH and concentration on the ability of chlorine to reduce pathogens on cantaloupes.** Appropriate amounts of 5.6% commercial sodium hypochlorite (Chlorox) were diluted in distilled water to obtain final hypochlorite concentrations of 200, 600, and 1,000 mg/liter. The amount of free chlorine present in the solution was verified using a chlorine test kit (Hach Company, Loveland, Colo.). These solutions were separated into two batches: the pH in one batch was adjusted to 6.0 with hydrochloric acid, but the other batch was not adjusted and had an average pH of 9.2. These solutions were used for spraying inoculated melons using a handwash and sanitizing procedure consisting of an initial water washing (WW) step followed by chlorine spray. WW was done with a hand-held, noncorrosive polyethylene compressed-air sprayer (10.56 liters; Universal-Gerwin, Saranac, Mich.) used to apply tap water to the surface of the melons for 90 s at 69 kPa. The total water volume applied by this procedure was 1.5 liters. The chlorine treatment was applied by spraying a total volume of 250 ml of the corresponding hypochlorite solution onto two melons at a time with an insulated hand-held, noncorrosive polyethylene compressed-air sprayer (10.56 liters; Universal-Gerwin) calibrated to deliver 250 ml in 15 s. The melons were rotated manually while being sprayed to obtain an even distribution of the solution over the melon surface. After spraying with the corresponding solution, the melons were drained for 10 min in sanitized plastic baskets. Rind samples were then collected for microbiological analysis.

**Comparison of sanitizers and treatment methods.** Cantaloupes and bell peppers were inoculated, prepared, and separated into treatment groups. Each cantaloupe group was assigned to one of the following treatments: no treatment (control), WW, WW followed by washing, WW followed by dipping in a solution containing 200 mg/liter sodium hypochlorite, WW followed by spraying with 200 mg/liter sodium hypochlorite, WW followed by dipping in 10% calcium hydroxide, WW followed by spraying with 10% calcium hydroxide, WW followed by dipping in 2% L-lactic acid at 55 to 60°C, and WW followed by spraying with 2% L-lactic acid at 55 to 60°C. For bell peppers, the same treatments were applied with the exception of dipping or spraying with chlorine solution.

WW and chlorine spray treatments were applied as described above. Waxing was achieved by spreading 10 ml of vegetable wax (CER-LP, Dequive Co., Colima, Mexico) with a new paint brush. Sprays with Ca(OH)₂ (J. T. Baker, Mallinckrodt Baker Inc., Phillipsburg, N.J.) and lactic acid (Purac Inc., Arlington Heights, Ill.) were delivered using the same type of polyethylene compressed-air sprayer as used for the chlorine treatments that also was calibrated to deliver 250 ml of solution in 15 s. A different sprayer was used for each sanitizing solution. Dip treatments consisted of submerging each melon in 2 liters of the corresponding sanitizer for 15 s and gently rotating the melons with a sterile glass rod to ensure contact of the entire surface with the sanitizing solution. After treatment, all melons were placed in sanitized plastic baskets and allowed to drain for 10 min. Solutions for either spray or dip treatment of melons were prepared immediately before use. Ca(OH)₂ was prepared at a concentration of 10% in sterile distilled water. The final pH of this solution was 12.0, and the temperature at the time of treatment was 30°C. The lactic acid solution was prepared by diluting enough 88% L-lactic acid in sterile distilled water at 60°C to obtain a 2% solution (pH 2.1). The sprayer containing lactic acid solution was allowed to cool so that the temperature of the solution at the time of treatment was 55°C. Except for the lactic acid, no temperature adjustments were made to the sanitizers; room temperature ranged between 25 and 28°C. All experiments were repeated twice to minimize the effect of any variation in the bacterial populations.

**Pathogen survival after lactic acid spray.** Lactic acid treatment was selected for studying the effect of a decontamination
TABLE 1. Counts of Salmonella Typhimurium and E. coli O157:H7 on whole cantaloupes after treatment with solutions containing different concentrations of sodium hypochlorite with or without adjusting the pH to 6.0

<table>
<thead>
<tr>
<th>pH of solution</th>
<th>Free chlorine (mg/liter)</th>
<th>Salmonella Typhimurium</th>
<th>E. coli O157:H7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean ± SD count</td>
<td>Estimated reduction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(log CFU/cm²)</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0</td>
<td>3.9 ± 0.4 A</td>
<td>NA</td>
</tr>
<tr>
<td>6.0</td>
<td>200</td>
<td>1.8 ± 0.3 b</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>600</td>
<td>1.2 ± 0.8 bc</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>1,000</td>
<td>1.0 ± 0.7 c</td>
<td>2.9</td>
</tr>
<tr>
<td>9.2</td>
<td>200</td>
<td>1.3 ± 0.8 bc</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>600</td>
<td>&lt;0.5 ± 0.2 d</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>1,000</td>
<td>0.6 ± 0.4 CD</td>
<td>3.3</td>
</tr>
</tbody>
</table>

a The pH was adjusted with 0.1 N hydrochloric acid. Within columns and treatment groups, means followed by the same letter are not significantly different (P > 0.05).

b Log reduction was estimated by subtracting the mean count (log CFU per square centimeter) on melons for each treatment group from the mean count on control melons. NA, not applicable.

c Control melons were washed with only tap water.

step during postharvest processing of melons on the survival of Salmonella Typhimurium and E. coli O157:H7 on the fruit surface during refrigerated storage. Incubated melons or peppers were separated into two groups and assigned to WW only or WW followed by lactic acid spray. All fruits were placed in separate plastic boxes and stored at 4°C (melons) or 10°C (bell peppers). On the same day of treatment (time 0) and at 7-day intervals, six melons or 12 peppers were randomly separated from each group, and samples were taken for enumeration of rifampin-resistant Salmonella and E. coli O157:H7. Noninoculated fruits were subjected to the same treatments and storage conditions and were used for subjective sensory evaluations.

Sampling and microbiological examination. Rind samples were collected by cutting a 10-cm² outline area of fruit epidermis with a sterile borer (approximately 2 to 3 mm deep) and excising the surface sample at a depth of 2 mm or less with a sterile scalpel and forceps. In all experiments, three samples (30 cm² total area) of rind were collected before inoculation to make sure that no rifampin-resistant microorganisms were attached to the cantaloupe surface. Sampling for postinoculation microbiological analysis was achieved by excising three rind samples from melons subjected to each treatment. Each set of three samples was placed in a stomacher bag with 100 ml of sterile 0.1% peptone water and pummeled for 1 min with a Stomacher 400 (Tekmar Co., Cincinnati, Ohio).

Counts of rifampin-resistant Salmonella Typhimurium and E. coli O157:H7 were determined by plating appropriate dilutions of the composite samples onto LSPR plates, which were incubated at 35°C for 24 h. Differential colonies counts were then made for each pathogen. No enrichment or most-probable-number methods were used for samples with counts below the detection limit of the counting method because the inoculum concentration was relatively high to allow measurement of the bacterial reduction, and near total elimination of bacteria was not expected. Treatment comparisons could not be made if different counting methods had been used. The identity of colonies of each rifampin-resistant organism was confirmed by isolating a representative number of colonies and conducting standard biochemical tests, including lactose fermentation, production of gas and H₂S in triple sugar iron agar, production of lysine decarboxylase and H₂S in lysine iron agar, and production of urease in urea broth.

Sensory evaluation. For product subjected to WW and lactic acid spray, surface firmness, odor, and color were evaluated by a trained panel using hedonic scales. For firmness, the scale was from 1 (unacceptable softness) to 4 (no surface depression after gentle pressure). For color, the panelists were asked to decide whether the products presented typical or atypical color based on previous trained observation of fresh high-quality products. Odor was graded from 1 (off) to 3 (typical).

Statistical analysis. Count data for each organism were transformed into log values prior to analysis. To facilitate the statistical analysis, samples with bacterial counts below the minimum detection level were given a value of 1.5 CFU/cm² (between 0 and the minimum detection level of 3.3 CFU/cm²), and this theoretical value was converted into a log value before analysis. Mean log values and sensory evaluation data for each treatment were compared using the general linear model procedure of SAS. When this procedure indicated significant differences among means (P < 0.05), means were separated using Duncan’s multiple range test.

RESULTS AND DISCUSSION

Effect of chlorine treatment on bacteria on cantaloupe. Experiments to test the value of hypochlorite as a produce sanitizer indicated that chlorine treatment does have an antimicrobial effect when applied to the surface of the product. Populations of Salmonella Typhimurium and E. coli O157:H7 were significantly reduced on cantaloupes subjected to chlorine treatments (Table 1). The bacterial counts were reduced by 2.1 to ≥3.4 log CFU/cm² for Salmonella Typhimurium and 1.5 to 2.7 log CFU/cm² for E. coli O157:H7, with significant differences at increased chlorine concentrations only for Salmonella when the pH of the solution was pH 9.2. For all other instances, the counts did not differ between melons sprayed with solution with or without the pH adjustment. The amount of active chlorine was lower in the solution that was not subjected to pH adjustment and had an average pH of 9.2. Produce packers are advised to adjust the pH when adding chlorine to water in wash tanks to ensure that they maintain high levels of active chlorine in the water. The antimicrobial ef-
TABLE 2. Effect of postharvest treatment on counts of 
Salmonella Typhimurium and E. coli O157:H7 on whole cantaloupes

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Salmonella Typhimurium (log CFU/cm²)</th>
<th>E. coli O157:H7 (log CFU/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTRL</td>
<td>4.4 ± 0.3 A</td>
<td>4.7 ± 0.3 A</td>
</tr>
<tr>
<td>WW</td>
<td>3.9 ± 0.7 b</td>
<td>4.7 ± 0.3 A</td>
</tr>
<tr>
<td>WAX</td>
<td>3.4 ± 0.6 b</td>
<td>3.8 ± 0.3 b</td>
</tr>
<tr>
<td>CLD</td>
<td>2.5 ± 1.5 c</td>
<td>4.5 ± 1.4 AB</td>
</tr>
<tr>
<td>CLS</td>
<td>2.5 ± 1.2 c</td>
<td>4.2 ± 1.3 AB</td>
</tr>
<tr>
<td>CHD</td>
<td>3.5 ± 0.8 b</td>
<td>4.4 ± 0.5 AB</td>
</tr>
<tr>
<td>CHS</td>
<td>3.5 ± 0.8 b</td>
<td>4.7 ± 0.5 a</td>
</tr>
<tr>
<td>LAD</td>
<td>1.5 ± 1.0 b</td>
<td>3.1 ± 1.2 CD</td>
</tr>
<tr>
<td>LAS</td>
<td>1.4 ± 0.9 b</td>
<td>2.7 ± 0.9 d</td>
</tr>
</tbody>
</table>

*CTRL, control; WW, water wash; WAX, covering with wax; CLD, dipping in 200 mg/liter hypochlorite solution for 15 s; CLS, spraying with 200 mg/liter hypochlorite solution for 15 s; CHD, dipping in 10% Ca(OH)₂ for 15 s; CHS, spraying with 10% Ca(OH)₂ for 15 s; LAD, dipping in 2% l-lactic acid at 55 to 60°C for 15 s; LAS, spraying with 2% l-lactic acid at 55 to 60°C for 15 s.

Counts are expressed as the mean (±standard deviation) log counts from six melons for each treatment group. Within columns and treatment groups, means followed by the same letter are not significantly different (P > 0.05).

Effect of chlorine differs among different studies (1, 2, 33, 34), usually with reductions of no more than 1 log unit. In this study, a dip treatment was used; however, surface components of the fruit may neutralize chlorine (6). The inability of hypochlorous acid to contact microorganisms in natural pores and crevices within a hydrophobic structure contributes to the lack of effectiveness of chlorine treatments (22). Because the chlorine treatments in this experiment were applied by spray, the bacterial reductions obtained might have been due to a combination of a washing effect and the antimicrobial effect of the chlorine.

Comparison of treatments for cantaloupe. The data in Table 2 show the effect of the sanitizer and the method of application on the populations of *Salmonella Typhimurium* and *E. coli* O157:H7 on cantaloupe. According to these results, WW alone did not reduce the populations of either pathogen in comparison to untreated melons, which may indicate that the pathogens were adhered to the cantaloupe surface and that the roughness of the surface enhances bacterial attachment. This hypothesis is supported by the findings of Annous et al. (4), who reported that *Salmonella* can attach to the rind of cantaloupes, and visible fibrillar material can develop within 2 h of contact at 20°C. These authors suggested that the unique characteristics of the cantaloupe surface provide a large number of attachment sites for bacteria and impede contact between bacteria and aqueous sanitizers. No further reductions in bacterial counts were found after the melons were covered with vegetable wax or treated with Ca(OH)₂. The lower counts on waxed melons might be an artifact of the interference of the wax with release of the microorganisms into the aqueous dilution used for plating. In contrast, the use of sanitizers such as chlorhexidine or lactic acid resulted in significantly lower counts compared with those of all other treatments. No significant differences were observed between dip or spray application of the sanitizers; but lactic acid resulted in significantly lower counts than did chlorine treatments (P < 0.05). Lactic acid sprays are widely used for carcass decontamination, and in various studies this compound has been effective when used as part of a pathogen intervention program for carcasses (9, 15). Materon (16) reported that dipping inoculated cantaloupes in a bath with 1.5% lactic acid solution at 25°C resulted in a 6.6-log reduction of *E. coli* O157:H7, even greater than the reduction produced by a mixture of lactic acid and hydrogen peroxide (6.1 log CFU). Dipping in 200 mg/liter chlorine resulted in a 4.3-log reduction. Reductions obtained in our study were not as large as those obtained by Materon (16), but the superiority of lactic acid to chlorine as a sanitizer also was observed.

Comparison of treatments for bell peppers. For inoculated bell peppers, WW alone resulted in a significant reduction in populations of both pathogens (Table 3). Ca(OH)₂ treatment resulted in an additional reduction in comparison to WW alone and WW followed by waxing. Lactic acid treatment groups had the lowest counts. For *Salmonella Typhimurium*, the counts were close to or below the detection limit of the method. For both pathogens, application of lactic acid by spray resulted in significantly lower counts of both pathogens than did all other treatments (P < 0.05). Although bell peppers never have been associated with foodborne illness, this fruit was chosen for comparison with cantaloupes because of its smooth surface. From the results obtained, it appears that surface roughness affects the effectiveness of produce disinfection, a finding consistent with those of other researchers (3, 25).

Pathogen survival after lactic acid treatment and during refrigerated storage. Counts of both pathogens on cantaloupes treated with WW alone or WW followed by

TABLE 3. Effect of postharvest treatment on counts of *Salmonella Typhimurium* and *E. coli* O157:H7 on bell peppers

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Salmonella Typhimurium (log CFU/cm²)</th>
<th>E. coli O157:H7 (log CFU/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTRL</td>
<td>3.4 ± 0.8 A</td>
<td>5.1 ± 0.7 A</td>
</tr>
<tr>
<td>WW</td>
<td>1.8 ± 1.0 B</td>
<td>4.2 ± 0.7 BC</td>
</tr>
<tr>
<td>WAX</td>
<td>2.4 ± 0.8 B</td>
<td>4.6 ± 0.6 AB</td>
</tr>
<tr>
<td>CHD</td>
<td>1.1 ± 0.6 C</td>
<td>3.4 ± 1.5 D</td>
</tr>
<tr>
<td>CHS</td>
<td>2.0 ± 0.9 B</td>
<td>3.2 ± 0.7 CD</td>
</tr>
<tr>
<td>LAD</td>
<td>0.5 ± 0.3 CD</td>
<td>2.7 ± 1.4 D</td>
</tr>
<tr>
<td>LAS</td>
<td>&lt;0.5 ± 0.6 D</td>
<td>1.5 ± 1.3 E</td>
</tr>
</tbody>
</table>

*CTRL, control; WW, water wash; WAX, covering with wax; CHD, dipping in 10% Ca(OH)₂ for 15 s; CHS, spraying with 10% Ca(OH)₂ for 15 s; LAD, dipping in 2% l-lactic acid at 55 to 60°C for 15 s; LAS, spraying with 2% l-lactic acid at 55 to 60°C for 15 s.

Counts are expressed as the mean (±standard deviation) log counts from 12 peppers for each treatment group. Within columns and treatment groups, means followed by the same letter are not significantly different (P > 0.05).
lactic acid spray did not increase during refrigerated storage. *E. coli* O157:H7 counts steadily declined during the storage period, whereas *Salmonella* survived during the first 14 days and declined by 21 days on lactic acid–sprayed melons. For melons subjected to WW only, small numbers of *Salmonella* were detected on days 21 and 28 of storage (Fig. 1). On day 7, counts of *Salmonella* were markedly decreased. It is unlikely that this decrease was due to the effect of the WW. Instead, this decrease may be due to a great variability in bacterial populations associated with the unique surface characteristics of cantaloupe. Sensory evaluation data indicated no differences in subjective firmness, color, and odor in melons treated with lactic acid in comparison to those subjected to WW only during the 28 days of refrigerated storage (data not shown). No pathogens were detected on bell peppers during storage for any treatment, except for one instance when small numbers of both pathogens were detected on individual samples of peppers on day 28 (data not shown). The random detection of pathogens in samples at advanced stages of storage for both bell peppers and cantaloupes indicates that although the lactic acid sprays reduced pathogens on the cantaloupe surface few cells may still survive during storage. These cells can be transferred to the fruit flesh during cutting and then grow if the fresh-cut produce is not stored appropriately. The risk of cell transfer to the fresh-cut flesh can be decreased by use of an appropriate surface sanitizer. Ukuku et al. (24) did not detect *E. coli* O157:H7 or *Listeria monocytogenes* on fresh-cut cantaloupe or honeydew melons that had been contaminated on the rind and then treated with a mixture of hydrogen peroxide, nisin, sodium lactate, and citric acid.

Our results indicate that lactic acid sprays can reduce bacterial pathogens by almost 3 log CFU on cantaloupes and 3.6 log CFU on produce with smooth surfaces, such as bell peppers. Other researchers have found that bacteria in or on fruits and vegetables are recalcitrant to aqueous sanitizers mainly because of superficial and physicochemical characteristics of these food products of plant origin (4, 24, 26). In contrast, Rodgers et al. (20) reduced *E. coli* O157:H7 and *L. monocytogenes* on produce by ca. 6 log CFU with a 5-min treatment with peracetic acid, chlorinated trisodium phosphate, chlorine dioxide, or ozone solutions. Their study is one of the few in which a large bacterial reduction was obtained by treating produce with aqueous sanitizers. The addition of sanitizers to wash tanks in produce packing operations usually is done not to sanitize the product but to prevent cross-contamination between product units. From the results of this study and other reports, it is clear that produce disinfection can produce poor results. Nevertheless, the relatively poor results obtained when treating produce with aqueous sanitizers should not discourage the produce industry from including a decontamination step. The guidelines contained in the document outlining good agricultural practices (29) include among their principles the fact that it is more effective to prevent contamination than to disinfect the produce once it has become contaminated. Pathogen interventions such as product sanitation should not be used in operations where good hygiene practices are not in place. Produce operations should have good agricultural practices in place and good hygiene practices at the packing facility. However, after hygiene is ensured, produce disinfection can be considered an additional hurdle in a holistic approach to produce safety. Despite the anatomical and physiological characteristics of fruits and vegetables that may make it difficult to sanitize these products, the bacterial reductions obtained in this study indicate that these interventions may be worth considering, at least for specific commodities.

**ACKNOWLEDGMENTS**

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**REFERENCES**