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Reductions in Natural Microbial Flora, Nonpathogenic *Escherichia coli,* and Pathogenic *Salmonella* on Jalapeno Peppers Processed in a Commercial Antimicrobial Cabinet: A Pilot Plant Trial

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ABSTRACT

This experiment aimed to validate the use of antimicrobial solutions in a spray cabinet to inactivate natural microbial flora, nonpathogenic *Escherichia coli,* and *Salmonella* on jalapeno peppers. Jalapeno peppers, uninoculated or inoculated with a five-strain mixture of rifampin-resistant *E. coli* (3.9 log CFU/g) or novobiocin- and nalidixic acid–resistant *Salmonella* (4.2 log CFU/g), were passed through a commercial antimicrobial cabinet containing both a top and bottom bar spraying (1.38 bar and 2 liters/min) water, sodium hypochlorite (50 ppm), sodium hypochlorite with pH adjusted to 6.7, peroxyacetic acid (PAA; 80 ppm), PAA with pH adjusted to 6.7, lactic with citric acid (1%), lactic with citric acid with sodium lauryl sulfate (1,200 ppm), or chlorine dioxide (5 ppm). Bacteria were recovered in 0.1% buffered peptone water plus 0.1% sodium thiosulfate, which was followed by spread plating onto tryptic soy agar (TSA), TSA plus rifampin (100 μg/ml), and TSA plus novobiocin (25 μg/ml) and nalidixic acid (20 μg/ml). There were no significant differences ($P \geq 0.05$) in recovered natural microbial flora, *E. coli,* and *Salmonella* populations between untreated peppers (3.5 to 4.2 log CFU/g) and peppers treated with water (3.4 to 3.8 log CFU/g). Significantly fewer ($P < 0.05$) natural microbial flora, *E. coli,* and *Salmonella* populations were recovered on the peppers after they were treated with a majority of the antimicrobials applied in the commercial antimicrobial cabinet. The largest population reduction was observed on peppers sprayed with PAA. Interestingly, the pH adjustment did not make a difference ($P \geq 0.05$) in the recovered bacterial populations. These results validate the use of a commercial antimicrobial spray cabinet, and they are useful for developing application protocols for antimicrobials to control *Salmonella* during the postharvest processing of jalapeno peppers.

Key words: Antimicrobials; *Escherichia coli*; Jalapeno pepper; *Salmonella*; Spray cabinet

The U.S. Centers for Disease Control and Prevention reported that from 1998 to 2008, nearly half (46%) of all foodborne illnesses were attributable to the consumption of contaminated fresh produce *(4)*. Additionally, the U.S. Food and Drug Administration (FDA) reported that from 1996 to 2010, fresh produce was associated with 131 foodborne illness outbreaks, resulting in more than 14,000 sicknesses and 34 deaths *(28)*. Fresh and fresh-cut produce may come from multiple sources and is often consumed without further processing or cooking to reduce or eliminate microbiological food safety hazards. Therefore, during postharvest processing, a sanitizing process, such as washing, spraying, and rinsing, is typically the only step that can reduce potential pathogens on produce *(9)*.

Currently, in fresh produce processing, chlorine, primarily composed of hypochlorous acid (HOCl), is the most commonly applied sanitizer due to its strong ability to kill microorganisms in solutions, minimal impact on the produce quality, and economic feasibility *(24)*. However, free chlorine is easily consumed by organic matter, and repeatedly adding chlorine into wash solutions that are high in organic loads can generate elevated levels of toxic chlorine by-products, such as trihalomethanes and haloacetic acid *(8, 9, 25)*. Therefore, evaluating various chemical antimicrobials as alternatives to chlorine has become an increasing concern and priority for the produce industry *(9)*. The FDA recommends ClO_2 ($\leq$5 ppm), peroxyacetic acid (PAA; $\leq$80 ppm), and various organic acids (e.g., lactic and citric acids) as antimicrobial agents in water to decontaminate foodborne pathogens on whole fruits and vegetables *(27)*. Additionally, a study reported that adding surfactants, including sodium lauryl sulfate (SLS), into organic acid solutions increases the antimicrobial activities of sanitizers in produce wash water *(30)*.

Chili peppers are a major commercial crop with an annual production of approximately 2 million tons (1.8 billion kg), 35% of which are jalapeno peppers. The majority of jalapeno peppers that are available at domestic markets come from the Papaloapan River basin in Mexico and New Mexico and Texas in the United States *(14)*. As for other fresh produce, jalapeno peppers are most commonly prepared in green salads or sauces from raw status, without processing, to

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reduce or eliminate natural microorganism flora and possible pathogenic organisms. In April 2008, a jalapeno and serrano pepper *Salmonella* Saintpaul outbreak infected 1,442 people in 43 states, resulting in 286 hospitalizations and two deaths *(5)*. In November 2009, a multistate *Salmonella* Montevideo outbreak of black and red pepper resulted in 272 sicknesses in 40 states and the District of Columbia *(6)*. Although the growth behavior of foodborne pathogens, including *Listeria monocytogenes, Escherichia coli* O157:H7, and *Salmonella* spp., has been well documented in previous studies *(7, 10, 11),* little is known about the antimicrobial efficacy of commercial antimicrobials to reduce bacterial pathogens on jalapeno peppers. To the best of our knowledge, only one study has been published on this topic *(14),* and it found that immersing jalapeno peppers in 200 ppm of sodium hypochlorite (SH), acidified sodium chlorite, or PAA for 10 min reduced *Salmonella* Saintpaul by 1.5 to 2.4 log CFU/g.

In the past 10 years, the FDA, together with the fresh produce industry and other stakeholders, developed and published commodity-specific guidance that addresses food safety considerations for the growing, harvesting, and postharvest handling of fresh and fresh-cut produce, including tomatoes, melons, leafy greens, and sprouts *(28)*. However, science-based best practices and standards for the postharvest processing of peppers are missing. Therefore, the objective of this study was to validate the use of seven commercial antimicrobial solutions in a pilot-scale commercialized spray cabinet to inactivate natural microbial flora, *E. coli,* and *Salmonella*.

MATERIALS AND METHODS

Bacterial strains and inoculum preparation. For the experiment examining the reduction of *E. coli* on jalapenos, the following five rifampin-resistant nonpathogenic *E. coli* strains were used: ATCC BAA-1427, ATCC BAA-1428, ATCC BAA-1429, ATCC BAA-1430, and ATCC BAA-1431 (American Type Culture Collection, Manassas, VA). These strains were chosen based on published research that validated them for use as pathogen surrogate organisms on beef (*3, 13, 16, 20)*. Additionally, minimal data suggest that these organisms can also be used as *E. coli* O157:H7 and *Salmonella* surrogates in produce experiments *(18)*. For each strain, rifampin-resistant isolates were selected by using the previously described method *(12)* for their selective detection and enumeration from natural flora. Individual strains were activated (35°C, 24 ± 2 h) from frozen stock cultures and subcultured once (35°C, 24 ± 2 h) in 10 ml of tryptic soy broth (TSB; Alpha Biosciences, Baltimore, MD) that was supplemented with 100 μg/ml rifampin (Sigma-Aldrich, St. Louis, MO). Cultures were combined and harvested by centrifugation (4,629 × *g* for 15 min; VWR Symphony 4417, VWR International, Radnor, PA), washed once with 50 ml of phosphate-buffered saline (PBS; pH 7.4; 0.2 g of KH_2PO_4, 1.5 g of $NaHPO_4 \cdot H_2O$, 8.0 g of NaCl, and 0.2 g of KCl in 1 liter of distilled water) to remove residual media and rifampin, centrifuged, and suspended in and diluted with PBS to obtain a target concentration of 6.9 log CFU/ml.

For the experiment that examined the decrease in *Salmonella*-inoculated jalapenos, the following five nalidixic acid– and novobiocin-resistant *Salmonella* strains were used: *Salmonella* Enteritidis, *Salmonella* Heidelberg, *Salmonella* Montevideo, *Salmonella* Newport, and *Salmonella* Typhimurium (kindly provided by Dr. Thomas Edrington, U.S. Department of Agriculture, Agricultural Research Service, College Station, TX). Resistance to novobiocin (25 μg/ml) and nalidixic acid (20 μg/ml) allowed for the selective enumeration of *Salmonella* from the natural flora. As for the *Salmonella* strains, individual *Salmonella* strains were activated from frozen stock cultures and subcultured in TSB supplemented with novobiocin (25 μg/ml; Sigma-Aldrich) and nalidixic acid (20 μg/ml; Sigma-Aldrich); they were then combined, washed, and suspended in PBS to a target concentration of 6.9 log CFU/ml. Additionally, strains were verified to grow and produce hydrogen sulfide on xylose lysine desoxycholate agar (Difco, Sparks, MD) that was supplemented with nalidixic acid and novobiocin to confirm that strains exhibited the desired *Salmonella* characteristics.

Jalapeno pepper selection, inoculation, and antimicrobial treatment. Jalapeno peppers were purchased at a local grocery store (Commerce City, CO) and transported to the Birko Research and Development Microbiology Laboratory (Henderson, CO) for experimentation. Peppers used for testing of natural microbial flora were not inoculated with any microorganism, but they were weighed and treated with antimicrobials. Peppers used to evaluate *E. coli* and *Salmonella* were weighed and inoculated by placement in a sterile sample bag (4 mil, 14 by 23 cm; VWR International) containing 250 ml of the inoculum for 5 min. The peppers were removed from the inoculum and placed in a class II biosafety cabinet (Esco Airstream, Esco Technologies, Horsham, PA) for 30 min to allow for bacterial attachment. Antimicrobial treatments were applied to peppers as they passed through a commercial antimicrobial cabinet (Chad Equipment, Olathe, KS; Fig. 1) containing a single top and bottom spray bar operating at a system pressure between 1.24 and 1.51 bar (1.38 bar target; 2 liters/min) and belt speed between 0.8 and 1.0 cm/s (0.9 cm/s target). Treatments were selected based on their current or proposed use in industry and included the following: no treatment, water, SH (50 ppm; 10-Chlor, Birko, Henderson, CO), SH with pH adjusted to 6.7 (ASH) with citric acid, PAA (80 ppm; Birkocide MP-2, Birko), PAA with pH adjusted to 6.7 (APAA) with sodium hydroxide, lactic with citric acid (LCA; 1%; Veggiexide, Birko), LCA with SLS (1,200 ppm; Stepanol WA-100, Stepan Co., Northfield, IL), and chlorine dioxide (CD; 5 ppm; GO_2, GO_2 International, Westlake Village, CA) *(21)*.

Microbiological analysis. After treatment, individual peppers were placed, as soon as possible, in a sterile sample bag (VWR International) containing 100 ml of 0.1% buffered peptone water (BPW; Alpha Biosciences) that was supplemented with 0.1% sodium thiosulfate (Fisher Scientific, Springfield, NJ). Bags were vertically shaken 30 times for approximately 30 s to allow for cell detachment *(1)*. Serial 10-fold dilutions of each sample were performed in 0.1% buffered peptone water, and dilutions were plated in duplicate on tryptic soy agar (TSA; Alpha Biosciences), TSA supplemented with 100 μg/ml rifampin, or TSA supplemented with 25 μg/ml novobiocin and 20 μg/ml nalidixic acid for the enumeration of the natural bacterial flora, rifampin-resistant *E. coli,* and *Salmonella* populations, respectively. TSA plates were incubated at 27°C for 48 ± 2 h, and TSA supplemented with 100 μg/ml rifampin and TSA supplemented with 25 μg/ml novobiocin and 20 μg/ml nalidixic acid plates were incubated at 35°C for 24 ± 2 h to allow for bacterial growth before visual enumeration and manual counting.

Statistical analysis. The experiment was repeated twice, and three samples were analyzed in each repeat evaluation (six total samples per treatment). Bacterial counts were converted to log

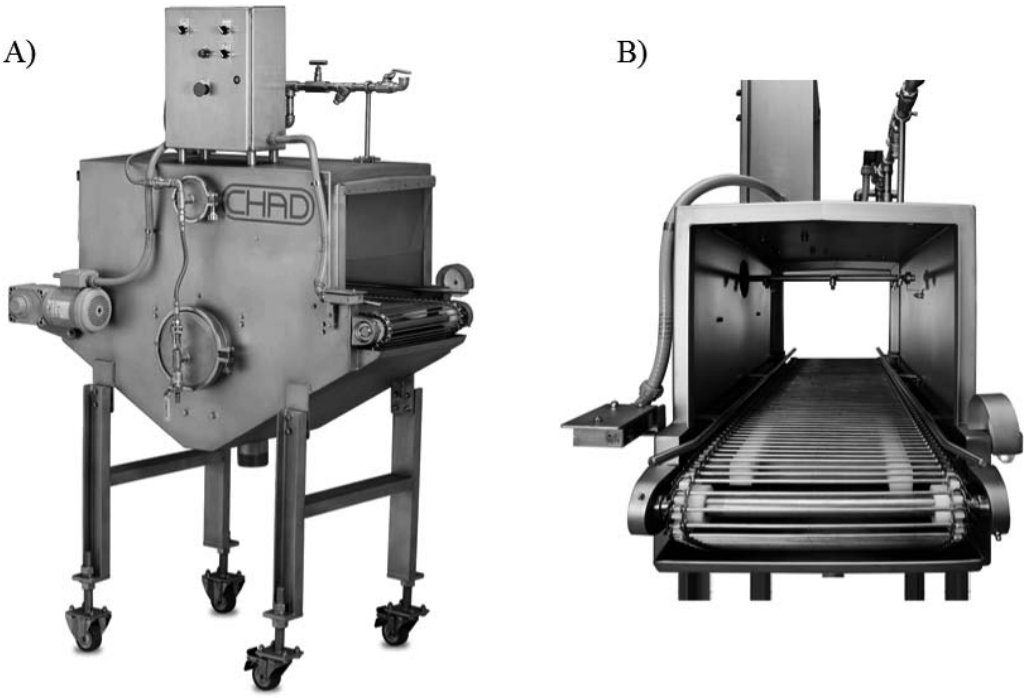

FIGURE 1. *Full side view (A) of a commercial antimicrobial cabinet and an end view (B) of the conveyor belt and top spray bar (the bottom spray bar is unseen, located below the belt, and positioned to spray up through the belt). The cabinet was set to apply antimicrobials at 1.4 bar and 2 liters/min onto jalapeno peppers as they were carried 0.9 cm/s via the conveyor belt through the cabinet.*

CFU per gram before statistical analysis. Bacterial survival data for natural flora, *E. coli,* and *Salmonella* were analyzed using the one-way analysis of variance procedure of SAS (version 9.2, SAS Institute Inc., Cary, NC). The average control (untreated) plate counts (N_0) were divided by the plate count of each individual water or antimicrobial treated sample (N) to give a reduction ratio (N_0/N). The $\log(N_0/N)$ of the ratios was then used to determine the reduction data, and variances within each treatment were used to calculate the standard deviation. A mixed model procedure of SAS was used to compare the reduction between *E. coli* and pathogenic *Salmonella,* which includes individual factors of bacteria, treatments, and their interaction. Based on the significance in the model, means were compared using a least significant difference test at a significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

The natural microbial flora of fresh jalapeno peppers were at a level of 3.5 log CFU/g (Table 1), and *E. coli* and *Salmonella* populations that were recovered on the artificially inoculated and untreated jalapeno peppers were 3.9 log CFU/g (Table 2) and 4.2 log CFU/g (Table 3), respectively. There was no difference ($P \geq 0.05$) in the natural flora, *E. coli,* and *Salmonella* populations recovered from untreated peppers and those sprayed with regular tap water (Tables 1 through 3). However, there were fewer recovered populations, suggesting there was some bacterial removal from the jalapeno pepper surfaces. Authors of a previous study *(14)* immersed jalapenos in antimicrobials for 10 min and reported that a water wash removed *Salmonella* Saintpaul from the inoculated jalapeno peppers (0.5 log). This, in comparison with the data presented in this article, indicates that water alone is not sufficient to reduce the bacteria on the jalapeno pepper surfaces.

The addition of antimicrobials to the spray water to facilitate the removal and inactivation of bacteria on the surfaces of jalapeno peppers was examined. CD was not an effective antimicrobial because recovered natural flora, *E. coli,* and *Salmonella* on jalapeno peppers treated with water and CD were similar ($P \geq 0.05$; Tables 1 through 3). However, CD is readily used in wash waters in the produce

TABLE 1. *Natural microbial flora recovered from jalapeno peppers after treatment with various antimicrobials*

Antimicrobial treatment[a]	Recovered total aerobic bacteria, mean ± SD (log CFU/g)
Inoculated, no treatment	3.5 ± 0.6 A[b]
Water	3.4 ± 1.1 A
CD (5 ppm)	3.3 ± 1.0 A
LCA (1%)	2.1 ± 0.4 B
LCA (1%) with SLS (1,200 ppm)	2.1 ± 0.5 B
PAA (80 ppm)	1.9 ± 0.2 B
APAA (80 ppm)	2.1 ± 0.4 B
SH (50 ppm)	2.0 ± 0.6 B
ASH (50 ppm)	2.3 ± 0.6 B

[a] CD, chlorine dioxide; LCA, lactic and citric acid blend; SLS, sodium lauryl sulfate; PAA, peroxyacetic acid; APAA, PA with pH adjusted to 6.7; SH, sodium hypochlorite; ASH, sodium hypochlorite with pH adjusted to 6.7.

[b] Mean values followed by different letters are significantly different ($P < 0.05$).

TABLE 2. E. coli *populations recovered from jalapeno peppers after treatment with various antimicrobials*

Antimicrobial treatment[a]	Recovered *E. coli,* mean ± SD (log CFU/g)
Inoculated, no treatment	3.9 ± 0.3 A[b]
Water	3.7 ± 0.3 A
CD (5 ppm)	3.6 ± 0.4 AB
LCA (1%)	3.3 ± 0.4 BC
LCA (1%) with SLS (1,200 ppm)	3.0 ± 0.8 C
PAA (80 ppm)	2.9 ± 0.4 C
APAA (80 ppm)	2.9 ± 0.4 C
SH (50 ppm)	3.1 ± 0.3 C
ASH (50 ppm)	3.1 ± 0.6 C

[a] CD, chlorine dioxide; LCA, lactic and citric acid blend; SLS, sodium lauryl sulfate; PAA, peroxyacetic acid; APAA, PA with pH adjusted to 6.7; SH, sodium hypochlorite; ASH, sodium hypochlorite with pH adjusted to 6.7.
[b] Mean values followed by different letters are significantly different ($P < 0.05$).

TABLE 3. Salmonella *populations recovered from jalapeno peppers after treatment with various antimicrobials*

Antimicrobial treatment[a]	Recovered *Salmonella,* mean ± SD (log CFU/g)
Inoculated, no treatment	4.2 ± 0.2 A[b]
Water	3.8 ± 0.4 AB
CD (5 ppm)	3.2 ± 0.2 BCDE
LCA (1%)	3.1 ± 0.6 CDE
LCA (1%) with SLS (1,200 ppm)	2.8 ± 1.2 DE
PAA (80 ppm)	2.6 ± 0.4 E
APAA (80 ppm)	3.2 ± 0.9 BCDE
SH (50 ppm)	3.7 ± 0.2 ABC
ASH (50 ppm)	3.4 ± 0.5 BCD

[a] CD, chlorine dioxide; LCA, lactic and citric acid blend; SLS, sodium lauryl sulfate; PAA, peroxyacetic acid; APAA, PA with pH adjusted to 6.7; SH, sodium hypochlorite; ASH, sodium hypochlorite with pH adjusted to 6.7.
[b] Mean values followed by different letters are significantly different ($P < 0.05$).

industry and may be more effective at concentrations, volumes, and exposure times that are greater than those evaluated in this experiment. Like most oxidizing agents, the antimicrobial action of chlorine and PAA includes protein denaturing and cell wall disruption *(2, 17)*. PAA and SH significantly ($P < 0.05$) reduced the total microbial counts on peppers, reaching 1.5 log CFU/g (PAA) to 1.1 log CFU/g (SH) compared with those treated with water (Table 1). For *E. coli,* PAA and SH showed similar ($P \geq 0.05$) antimicrobial effects under the same spraying conditions and reduced populations by 0.6 and 0.8 log CFU/g, respectively (Table 4), with an additional ($P < 0.05$) 0.4- to 0.6-log CFU/g reduction compared with water treatment (Table 4). A similar observation was made in a 2012 pilot plant study *(15),* which reported a 0.8- to 0.9-log CFU/g reduction in nonpathogenic *E. coli* O157:H7 on baby spinach in a semicommercial-scale washing tank. For *Salmonella,* PAA and SH achieved reductions of 1.6 and 0.5 log CFU/g, respectively, which were significantly greater than that of the water treatment (Table 4).

During the produce washing process, maintaining a chlorinated water solution at a constant, slightly acidic pH of 6.5 to 6.8 with citric acid is generally recognized to keep free chlorine in its most effective form, hypochlorous acid, instead of the less efficacious form of hypochlorite ions *(15)*. Although not typical in produce processing, adjusting the pH of PAA is a common practice in other industries to increase the product yield and decrease the negative organoleptic effects of PAA. In general, simply adjusting the pH of chorine and PAA sanitizing solutions to near neutral levels did not improve the antimicrobial efficacy on pepper surfaces (Tables 1 through 5). However, the impact on the organoleptic quality was not assessed in the present study.

For natural flora and *E. coli,* LCA reduced ($P < 0.05$) the populations by 1.3 and 0.8 log CFU/g, respectively, which was similar ($P \geq 0.05$) to the observed effects for PAA and SH (Table 4). For *Salmonella,* LCA and LCA with SLS achieved a reduction of 1.1 and 1.4 log CFU/g, respectively, significantly greater than that of the water treatment (Table 4). LCA reduces the bacterial intracellular pH and disrupts the transmembrane proton motive force *(22, 23)*. Additionally, LCA can reduce, but not eliminate, the natural flora and inoculated bacteria from jalapeno surfaces. A surfactant was added to LCA to increase both the antimicrobial exposure to surface-bound bacteria and its efficacy, as observed on poultry *(30)*. This study and a previous pilot plant study *(15)* found that adding a chemical surfactant, such as SLS, into the sanitizing solution did not enhance the microbial inactivation of LCA.

The response of *E. coli* (compared with *Salmonella*) to antimicrobials on jalapeno peppers is shown in Table 4. Reductions observed after the application of tap water, LCA, LCA with SLS, APAA, SH, and ASH ranged from 0.2 to 1.4 log CFU/g and were not different ($P > 0.05$) for *E. coli* versus *Salmonella* (Table 4). The application of CD and PAA generated a reduction of 0.3 and 1.0 log CFU/g for *E. coli,* respectively; which was less ($P < 0.05$) than for *Salmonella* (1.0 and 1.6 log CFU/g, respectively; Table 4). These results suggested that the five-strain cocktail of nonpathogenic *E. coli* used in this study can survive during the antimicrobial process as well as, or better than, the target pathogenic *Salmonella*. Therefore, the five strains of *E. coli* could potentially be used as the surrogates of *Salmonella* for validating antimicrobial interventions on fresh produce in settings in which pathogens might not be used due to biological safety concerns.

Using a cabinet spraying system to apply commercially available antimicrobials is a new strategy in the fresh and fresh-cut produce industry for controlling foodborne pathogens. Compared with the traditional produce washing system, which includes a prewash, primary and secondary washing tanks, and final rinsing steps, the application of antimicrobials in a cabinet spraying system has several

TABLE 4. *A comparison of the reduction of* E. coli *and* Salmonella *populations on jalapeno peppers after treatment with various antimicrobials*

Antimicrobial treatment[a]	*E. coli,* mean ± SD (log CFU/g)	*Salmonella,* mean ± SD (log CFU/g)
Water	0.2 ± 0.3 A[b]	0.4 ± 0.4 A
CD (5 ppm)	0.3 ± 0.4 A	1.0 ± 0.2 B
LCA (1%)	0.6 ± 0.4 A	1.1 ± 0.6 A
LCA (1%) with SLS (1,200 ppm)	0.9 ± 0.8 A	1.4 ± 1.2 A
PAA (80 ppm)	1.0 ± 0.4 A	1.6 ± 0.4 B
APAA (80 ppm)	1.0 ± 0.4 A	1.0 ± 0.9 A
SH (50 ppm)	0.8 ± 0.3 A	0.5 ± 0.2 A
ASH (50 ppm)	0.8 ± 0.6 A	0.8 ± 0.5 A

[a] CD, chlorine dioxide; LCA, lactic and citric acid blend; SLS, sodium lauryl sulfate; PAA, peroxyacetic acid; APAA, PA with pH adjusted to 6.7; SH, sodium hypochlorite; ASH, sodium hypochlorite with pH adjusted to 6.7.
[b] Mean values followed by different letters within a row are significantly different ($P < 0.05$).

advantages. First, fresh single-use solutions do not have the organic matter buildup found in a commercial washing tank; therefore, high residual effective and constant antimicrobial concentrations (especially for SH) can be applied during the spraying process. Second, because the contact time is typically much shorter than that in the traditional washing tank (approximately 20 s versus >1 h), higher concentrations of antimicrobials can be used without having a negative impact on the produce quality (especially for acid-based antimicrobials). Finally, the water level used in a cabinet system (2 liters/min) is much lower than that in conventional washing tanks (>3,000 liters), which makes cabinet spraying a cost-effective step for decontaminating microorganisms on produce with sanitizers.

From a regulatory perspective, to satisfy the first element of validation, an establishment must gather the necessary scientific technical documents to support the in-process application of antimicrobials in their food safety systems *(19, 26, 29)*. The data presented in this article may be used to satisfy such a requirement. A further component of validation is the determination of the critical operating parameters of the antimicrobial application system to monitor and establish upper and lower limits. This article identifies the application pressure and belt speed as critical operating parameters for the top and bottom spray cabinets. Furthermore, the critical limits implemented, and thus established, are 1.24 to 1.51 bar for the system pressure, with a target of 1.38 bar, and 0.8 to 1.0 cm/s for the belt speed, with a target of 0.9 cm/s. The previously mentioned may be used for the first element of validation and as guidance for the second element of validation, which is the in-plant demonstration that the antimicrobial system is effective as applied.

TABLE 5. *The pH values of the antimicrobial solutions applied onto jalapeno peppers*

Antimicrobial treatment[a]	pH, mean ± SD
Water	6.57 ± 0.85
CD (5 ppm)	5.36 ± 0.25
LCA (1%)	2.48 ± 0.08
LCA (1%) with SLS (1,200 ppm)	2.43 ± 0.08
PAA (80 ppm)	3.78 ± 0.48
APAA (80 ppm)	6.68 ± 0.06
SH (50 ppm)	9.41 ± 0.90
ASH (50 ppm)	6.65 ± 0.09

[a] CD, chlorine dioxide; LCA, lactic and citric acid blend; SLS, sodium lauryl sulfate; PAA, peroxyacetic acid; APAA, PA with pH adjusted to 6.7; SH, sodium hypochlorite; ASH, sodium hypochlorite with pH adjusted to 6.7.

In conclusion, in this study, the application of SH (with or without pH adjustment), PAA (with or without pH adjustment), and LCA (with or without SLS) as antimicrobial treatments in a commercial top and bottom spray antimicrobial cabinet effectively inactivated natural microbial flora, *E. coli,* and *Salmonella* on jalapeno peppers that ranged from 0.6 to 1.6 log CFU/g. The results also indicate that PAA and LCA are potential alternatives to chlorine for controlling *Salmonella* during fresh produce processing. Future studies are needed to determine whether such treatments will negatively affect the sensory attributes of fresh produce and whether their application is economically feasible.

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