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International Journal of Food Microbiology 99 (2005) 59–70

INTERNATIONAL JOURNAL OF Food Microbiology

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Reducing *Salmonella* on cantaloupes and honeydew melons using wash practices applicable to postharvest handling, foodservice, and consumer preparation

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Received 15 October 2003; received in revised form 1 June 2004; accepted 7 July 2004

Abstract

Washing conditions that included a soak or brush scrub were evaluated for removal of *Salmonella* from the surface of smooth (honeydew) or complex (cantaloupe) melon rinds. Melon rinds were spot-inoculated onto a 2.5 cm^2 area of rind (squares) with approximately 6.0 $\log_{10}$ CFU/square of an avirulent nalidixic acid-resistant strain of *Salmonella typhimurium*. Melons were washed by immersion in 1500 ml of water or 200 ppm total chlorine and allowed to soak or were scrubbed over the entire melon surface with a sterile vegetable brush for 60 s. Inoculated sites, uninoculated sites ("next to" sites) that were adjacent to inoculated sites, and sites on the side of the melon opposite (remote sites) the inoculated site were excised and pummeled in a stomacher for 2 min prior to plating onto tryptic soy or bismuth sulfite agar supplemented with 50 μg/ml nalidixic acid. *S. typhimurium* was reduced on the rind of cantaloupe by 1.8 log CFU/melon after soaking for 60 s in 200 ppm total chlorine, which was significantly better than the 0.7 log CFU/melon achieved with soaking in water. For both water and 200 ppm total chlorine, scrubbing with a vegetable brush was shown to be significantly (0.9 log CFU/cantaloupe) more effective than soaking alone. When honeydew melons were soaked or scrubbed in water, reductions of 2.8 log CFU/melon or >4.6 log CFU/melon (four of five samples), respectively, were observed. However, when water treatments were used, the presence of *Salmonella*-positive "next to" and remote sites indicated that bacteria were spread from inoculated site on the rind to uninoculated sites either through the rinse water (40–70 CFU/ml of *Salmonella*) or scrub brush (400–500 CFU/brush). Transfer to other sites occurred more often with cantaloupe than honeydew melons. This transfer was eliminated when 200 ppm total chlorine was used. When 200 ppm total chlorine was used, *Salmonella* could not be detected in the water or on the scrub brush. For optimal microbial removal in food service and home settings, melons should be scrubbed with a clean brush under running water. However, to ensure the benefits of brushing, instructions for cleaning and sanitizing brushes must also be emphasized. For food service settings where concentration and pH can be adequately measured, the use of chlorinated water may provide additional benefit.

Keywords: Cantaloupe; Wash; Chlorine; *Salmonella*

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doi:10.1016/j.ijfoodmicro.2004.07.014

1. Introduction

Cantaloupe has been associated with foodborne outbreaks involving *Escherichia coli* O157:H7 (Del Rosario and Beuchat, 1995), Norovirus (Iversen et al., 1987), and numerous serovars of *Salmonella*, including *Salmonella chester* (CDC, 1991), *Salmonella poona* (CDC, 1991; FDA, 1991; California Department of Health Services, 2000, 2001, 2002), *Salmonella oranienburg* (Health Canada, 1998), and *Salmonella saphra* (Mohle-Boetani et al., 1999). Common themes in these outbreaks were that the melons were cut and most had been subjected to temperature abuse. In some cases, melons were contaminated through inadvertent contact with raw meat (see Harris et al., 2003) or a human handler (Iversen et al., 1987), but in other cases, the contamination was thought to have been soil on the melon rind (Mohle-Boetani et al., 1999), packing house wash water, or shipping ice (Hedberg et al., 1994; Tauxe, 1997).

Contamination of produce can arise from a variety of sources including soil, water, equipment, humans, and animals (Beuchat, 1996). Cantaloupe can become contaminated during growth, postharvest handling and packing, transportation, distribution, or during final preparation at food service or in the home. During postharvest handling and packing, melons can become contaminated by equipment used to hold, transport, clean, grade, sort, or pack melons, or from unsanitary wash or cooling water or ice.

For the past several years, melons harvested in California have been predominantly field packed directly into cartons and are not washed prior to distribution in the markets (Suslow, 2001). Field packing reduces the potential for cross-contamination after harvest by limiting any potential localized field-acquired contamination to one carton or one bin. In addition, field packing would not typically introduce the potential for postharvest water to spread localized contaminants among melons. Field packing is not universally practiced or possible in all producing regions, and furthermore, due to heightened food safety concerns over the past 2 years, wash procedures are being reinstituted by some California shippers (Suslow, 2003). Field packing cantaloupe is not common or recommended in areas that receive a lot of rain and pest pressure during the growing season. Melons in these areas may be heavily soiled and have other surface deposits from foliar sprays or insect activity on leaves and must be washed prior to packing and shipping. In arid areas, where field pack operations are possible, crop, pest, and harvest management applications are far less likely to result in visible residues that require premarket removal.

Transfer of bacteria from the rind to edible melon flesh can occur during cutting (Suslow et al., 2000; Ukuku and Sapers, 2001). This transfer of bacteria has also been observed during the slicing of other melons (Gayler et al., 1955) and tomatoes (Lin and Wei, 1997). *Salmonella* or *E. coli* O157:H7 can grow to high levels (6.8 to greater than 7 $\log_{10}$ CFU/g) on cut melons stored at ambient temperature (Golden et al., 1993; Del Rosario and Beuchat, 1995; Suslow, 2001). High levels of pathogens can be reached before signs of spoilage are evident.

Currently, consumers are advised to wash fruits and vegetables under running water, and when possible, to scrub produce, including melons, with a clean brush (USDA FSIS, 1999; FDA, 2000; Parnell et al., 2003). The FDA (1991, 2001a,b) offers guidance to the food service and retail industries for washing intact melons under potable cool running water prior to cutting. Although these recommendations are widely accepted, published data providing information on the efficacy of these recommendations in removing *Salmonella* from the cantaloupe surface are limited.

Most studies to date have focused on removal of *Salmonella* from cantaloupe using chemicals and handling methods applicable to packinghouse practices. However, concentrations higher than that practiced, advised, or legally permitted are often included in these studies (Park and Beuchat, 1999; Ukuku and Sapers, 2001). Many studies define efficacious concentrations that would not be safe or permissible in a commercial environment. Few studies have focused on practices that would be more common to consumers or food service workers. Consumer washes making antimicrobial claims must be approved and registered by the U.S. EPA (Harris et al., 2001). Currently, no such consumer products have such EPA approval.

The objective of this study was to further evaluate the efficacy of washing methods on cantaloupe under

conditions that would be typically used in the home by consumers or by foodservice operators. A further objective was to evaluate the implications of inadequate water disinfection on commercial packing and minimal fresh-processing operations that utilize brush washing as part of the postharvest handling operation.

2. Materials and methods

2.1. Bacteria cultures

Avirulent *Salmonella typhimurium* LT2 (Maloy et al., 1996) was provided by Dr. Erika Barrett, University of California, Davis. *S. typhimurium* LT2 resistant to 50 μg/ml of nalidixic acid were selected from plate count agar (PCA; Difco Laboratories, Detroit, MI) made with increasing amounts of nalidixic acid (Sigma, St. Louis, MO) (Olsen, 1999). Briefly, 100 μl of an overnight culture was spread onto plate count agar containing 0–50 μg/ml nalidixic acid. After incubation for 24 h at 37 °C, isolated colonies were selected from the plate containing the highest level of nalidixic acid and cultured overnight in nutrient broth. This procedure was repeated until a variant resistant to 30 μg/ml nalidixic acid was obtained. Growth curves of the parent and variant strains were similar in tryptic soy broth (Difco) (data not shown).

2.2. Inoculum preparation

Frozen 15% glycerol (wt/vol) stock cultures were streaked onto tryptic soy agar (TSA; Difco) with 0.1% of pyruvic acid (Fisher, Fair Lawn, NJ) and 50 μg/ml of nalidixic acid (TSAPN), and were incubated for 24 h at 37 °C. Cultures were transferred for two additional consecutive 24-h periods onto TSAPN, spreading to produce a bacterial lawn. To prepare the inoculum, growth from the TSAPN plate was transferred with a sterile cotton swab to 0.1% peptone (Difco) to an absorbance of 0.2% (Biolog 21907 turbidity meter, OD 590 nm, Biolog, Hayward, CA). The resulting inoculum concentration of 10^8 CFU/ml was determined by plating appropriate serial dilutions of the inoculum onto TSAPN and incubating the plates for 24 h at 37 °C.

2.3. Fruit

Cantaloupe and honeydew melons were purchased at local grocery stores or produce markets. Melons used in experiments were ripe with no visible microbial growth and were free from visible physical defects. Occasionally, some melons had small amounts of soil on the rind; however, melons were not washed prior to use in experiments. Melons were stored at 4 °C and brought to ambient temperature (24±2 °C) prior to use.

2.4. Inoculation procedure

The rind of intact whole melons or melon quarters was marked with two to three squares (2.5 cm^2) using a permanent marker. Squares were inoculated with 20 μl of *S. typhimurium* LT2 resulting in a total of 10^6 CFU/square. Sites not inoculated but adjacent to ("next to") inoculated sites or on the side opposite (remote sites) the inoculated site were examined for the spread of bacteria through the washing process. In all cases, inoculated melons were dried for 1 h±15 min at an ambient temperature (24±2 °C) within a biohood with the fan running.

2.5. Washing procedures

After drying, melons were placed into 24-l sterile plastic buckets, and 1500 ml of sterile distilled water or 200±10 ppm total chlorine (sodium hypochlorite, Aldrich Chemical, Milwaukee, WI) was poured over the melon. The 200 ppm total chlorine treatment (pH 7.2) was prepared in sterile 0.1 M phosphate buffer (BBL, Becton Dickinson and Company, Cockeysville, MD). The total chlorine concentration was measured using a chlorine test kit (Hach Chemical, Loveland, CO). Whole melons placed into a treatment were either allowed to soak for 60 s or were scrubbed for 60 s over the entire melon with a sterile vegetable brush (purchased at a local grocery store). Each melon was removed from treatment and placed on dry sterile paper towels. Marked rind squares were immediately excised for recovery of bacteria. Scrub brushes and paper towels were autoclaved for 15 min at 121 °C to sterilize prior to use in experiments. Although an avirulent strain was used, immersion rather than rinsing was selected as a

practical solution to satisfy needs of microbial containment.

Comparison of scrub times needed to reduce inoculated populations were examined. Melons were wet with 1500 ml of sterile water, scrubbed on the inoculated rind square for 5 or 10 s followed by an immersion in water for 25 s or 20 s, respectively, or immersed for a total of 30 s (control). Rind squares were excised immediately for recovery of bacteria.

Inoculated melons receiving no treatment (untreated) were examined after drying to determine the number of cells on the melon rind. The $\log_{10}$ reduction of bacteria reported was calculated as the untreated ($\log_{10}$ recovered CFU/sample) minus treated melon samples ($\log_{10}$ recovered CFU/sample).

To increase detection of cells in the chlorine wash solution, 10–100 ml of treatment solution was filtered through a 0.45-μm analytical test filter with a cellulose nitrate membrane (Nalgene, Nalge Nunc International, Rochester, NY). Each filter was rinsed twice by pipetting 20 ml of 0.1 M phosphate buffer (BBL) over the filter, plated onto bismuth sulfite agar (BSA; Difco) with 50 μg/ml nalidixic acid (BSAN), and incubated for 24–48 h at 37 °C.

Scrub brushes were placed in a sterile plastic bag with 100 ml, or 50 ml when lower counts were anticipated, of 0.1% peptone and agitated for 60 s. The 0.1% peptone was plated on TSAPN and BSAN to determine the number of bacteria on the brushes after scrubbing inoculated melons.

Rind squares were enriched in Rappaport–Vassiliadis broth R10 (RVB; Difco). RVB (12 ml) was added to each sample and incubated for 16–24 h at 43 °C. Each sample was streaked onto BSAN, incubated at 37 °C for 48 h and observed for the presence or absence of growth of nalidixic acid-resistant *Salmonella*. Inoculum (20 μl) used in experiments was processed through the enrichment procedure as a positive control.

2.6. Recovery of inoculated cells

All marked squares were excised with a flame-sterilized scalpel and tweezers taking care to remove only the rind. Two methods of recovery were examined for removal of *Salmonella* from the rind. The first method consisted of placing each square into a 180-ml (6 oz) stomacher bag (Whirl-pak #B679 Nasco, Modesto, CA) with 9 ml of 0.1% peptone and processing (Stomacher 400, Seward, England) for 2 min on the normal setting. For comparison, squares were aseptically cut into strips, placed into a test tube with 9 ml of 0.1% peptone, and vortexed for 2 min.

Samples were serially diluted in 0.1% peptone and plated on TSAPN or BSAN media by spread plating (0.1 ml) using the Autoplater 4000 Spiral Plater (Spiral Biotech, Bethesda, MD). Plates were counted by hand at 24–48 h after incubation at 37 °C, following the guidelines outlined in the *Compendium of Methods for the Microbiological Examination of Foods* (Downes et al., 2001).

Colonies were identified as presumptive *Salmonella* by their appearance on BSAN. Several (2–3 colonies from TSAN plates/replicate experiment) were confirmed using BBL Entertotube II (Becton Dickinson and Company). A multiplex-based PCR method was also sometimes used as an alternative method to confirm *Salmonella* (Soumet et al., 1999).

2.7. Scanning electron microscopy

Cantaloupe and honeydew fruit were collected directly from production fields in the Central Valley of California during peak production periods between August and September. Samples were prepared for scanning electron microscopy (SEM) following instructions provided by University of California, Davis Microscopy Services (UCDMS). Briefly, triplicate 1 cm^2 disks were excised from the outer adaxial rind of immature and mature (full-slip) cantaloupe and honeydew. Care was taken not to disrupt the netted rind central to the disk area. Samples were immersed in glutaraldehyde (2.5% (vol/vol)) in 0.1 M sterile cacodylate buffer (pH 7.2) for 2 h, then rinsed three times (15 min each) in 0.1 M sterile cacodylate. Disks were transferred through an ethanol dehydration series of 30%, 50%, 70%, and 80% (vol/vol) for 15 min, at each dehydration step. A final rinse in 100% ethanol was performed three times prior to critical point drying. Additional preparative steps, including CO_2 critical point drying and gold sputter coating, were conducted according to standard protocols as performed by technical staff at UCDMS. Operation of the SEM was performed by UCDMS staff in the presence of author Suslow.

2.8. Statistical analysis

Tukey's post hoc grouping and repeated-measures analyses were performed using PROC GLM in the SAS software package (Statistical Analysis Systems Institute Cary, NC, Version 8). Differences were considered significant at $P<0.05$.

3. Results and discussion

3.1. Electron microscopy

Scanning electron micrographic (SEM) images of cantaloupe rind revealed many crevices and cracks thought to provide protection for organisms (Fig. 1). Protection provided by the netted rind of cantaloupe is thought to make removal of pathogens more difficult as the cells can evade cleaning procedures and the effect of sanitizers. In contrast, the smooth, waxy surface of the related honeydew melon (Fig. 2) is considered more amenable to microbial removal. Lower populations of *Salmonella* and *E. coli* O157:H7 were reported on honeydew melons than on cantaloupes after scrubbing by hand for 3 min with water, chlorine, acidified chlorine, or hydrogen peroxide (Park and Beuchat, 1999). Like the rind of honeydew, less mature cantaloupes have a waxy surface layer (Fig. 3), but this becomes heavily disrupted with the emergence of the net (data not shown) (Webster and Craig, 1976). Both honeydew melons and cantaloupe were included in the current study to compare the efficacy of soaking and scrubbing for removing pathogens on smooth and complex surfaces.

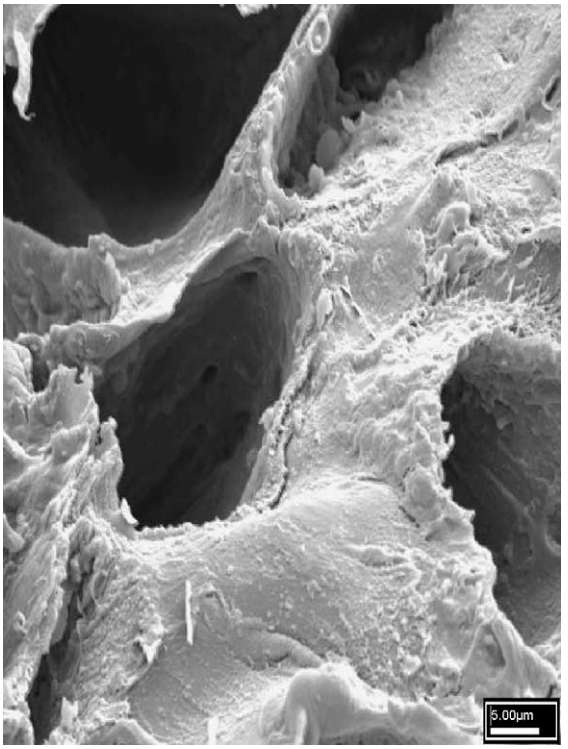

Fig. 1. Scanning electron micrograph of mature netted cantaloupe rind.

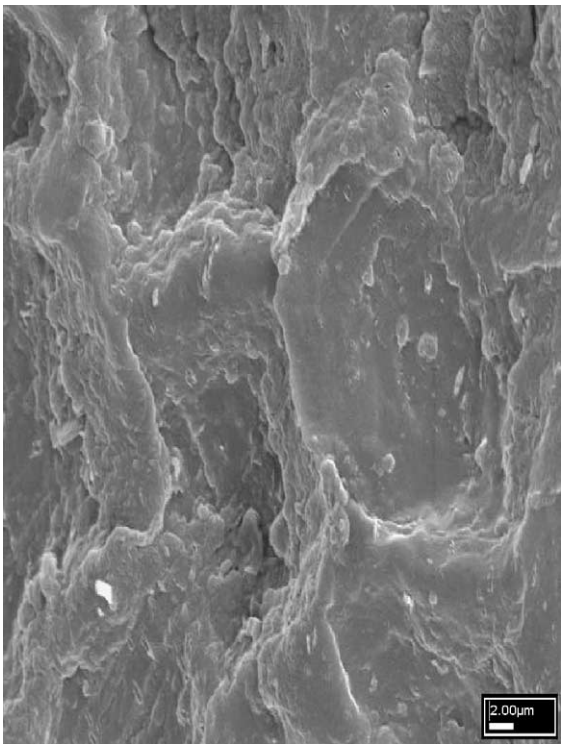

Fig. 2. Scanning electron micrograph of mature honeydew melon rind.

3.2. Recovery of S. typhimurium LT2 from cantaloupe and honeydew rind

A spot inoculation method was chosen for use in this study to represent a single point of contamination such as feces, contact with soil, water, humans, or

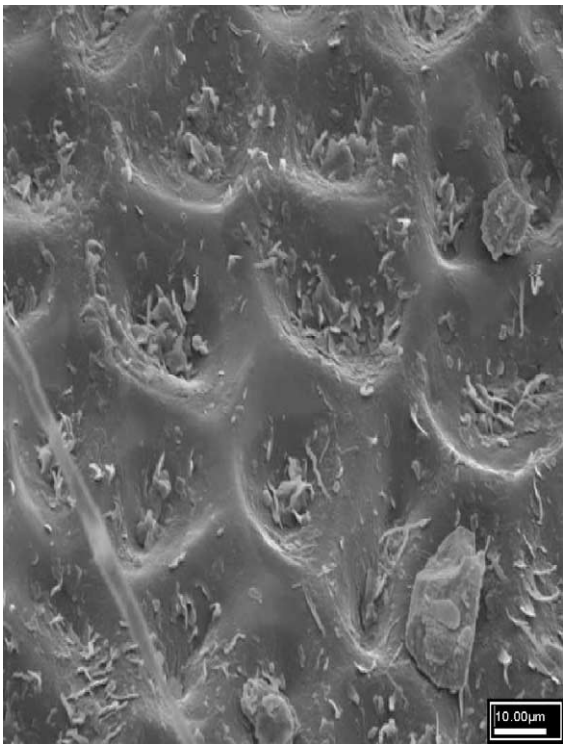

Fig. 3. Scanning electron micrograph of immature cantaloupe rind.

other sources that could contaminate the surface of melon rind (Beuchat et al., 2001b). After inoculating the rind with *S. typhimurium* LT2, samples were excised at time 0 or after 1 h of drying and either placed into a test tube or stomacher bag with 9 ml of 0.1% peptone and vortexed or stomached for 2 min. No significant differences were observed in recovered populations using either the stomach or vortex method for either melon type (Table 1). Populations recovered from cantaloupe rind immediately after inoculation (0 h) were 0.4–0.7 $\log_{10}$ CFU/sample (vortexing) or 0.4–0.5 $\log_{10}$ CFU/sample (stomaching) lower than the calculated inoculum level ($\log_{10}$ 6.2 CFU/sample). Compared to the initial recovery, a decrease of 0.3–0.7 $\log_{10}$ CFU/sample was observed on cantaloupe rind while 1.2 $\log_{10}$ CFU/sample was observed on honeydew rind after 1 h of drying. This decrease during drying is attributed to cell death due to desiccation. This has also been observed for apples (Parnell and Harris, 2003) and tomatoes (Beuchat et al., 2001a). There were no significant differences between TSAPN and BSAN at either time.

Stomaching has been found to be acceptable for recovery of bacteria from cantaloupe rind (Olsen, 1999), broccoli (Parnell, 2002), and strawberries (Knudsen et al., 2001). Burnett and Beuchat (2001) examined homogenizing, stomaching, or washing in 0.1% peptone for recovery of *Salmonella* from 26 types of produce (Burnett and Beuchat, 2001). Melons were not analyzed in this study; however, complex produce such as strawberries, lettuce, and parsley were examined. In general, results indicated no significant difference among methods; however, differences were observed within some commodities. Because there was no significant difference between stomach and vortex methods in the current study, a stomaching method was used in further experiments.

3.3. Evaluation of a water soak treatment on intact cantaloupe or honeydew rind

Washing cantaloupe with running water and a scrub brush is currently recommended to consumers (USDA FSIS, 1999; FDA, 2000); however, there is little published data regarding the efficacy of this method. Consumers surveyed most commonly use water to rinse fruits and vegetables prior to

Table 1
Examination of recovery methods for removal of *S. typhimurium* LT2 from cantaloupe and honeydew rind

Method	*Salmonella* recovered[a]		
	Cantaloupe		Honeydew
	TSAPN[b]	BSAN[c]	BSAN
Estimated inoculum	6.2	6.2	6.2
Vortex (2 min)			
0 h (before drying)	5.8±0.2 A[d]	5.8±0.2 A	5.5±0.5 A
1 h (after drying)	5.4±0.1 B	5.2±0.1 B	4.3±0.1 C
Stomach (2 min)			
0 h (before drying)	5.8±0.2 A	5.7±0.2 A	5.6±0.1 A
1 h (after drying)	5.3±0.1 A	5.0±0.1 B	4.4±0.4 C

[a] $\log_{10}$ CFU/sample, values are the average of three samples from one experiment (n=3).

[b] TSAPN, tryptic soy agar supplemented with 50 µg/ml nalidixic acid and 0.1% pyruvic acid.

[c] BSAN, bismuth sulfite agar supplemented with 50 µg/ml nalidixic acid.

[d] Different letters indicate significance (P<0.05).

consumption (Li-Cohen and Bruhn, 2002). Water treatments are thought to rinse cells off the surface along with soil and debris and 1-log reductions are typically expected (Beuchat, 1998). A 0.7 $\log_{10}$ CFU/sample reduction of *Salmonella* was achieved by soaking cantaloupe in water for 60 s (Table 2). In contrast, a reduction of 2.8 $\log_{10}$ CFU/sample was achieved by soaking honeydew melon in water for 60 s (Table 3). *S. typhimurium* LT2 was not recovered by direct plating of uninoculated cantaloupe or honeydew squares, and none of the tested untreated controls were positive for *Salmonella* after enrichment. However, after enrichment of soaked melon, 100% or 20% of the "next to" inoculated cantaloupe or honeydew squares, respectively, and 86% of the remote site cantaloupe squares were positive for *Salmonella* on BSAN (Tables 2 and 3). None of the honeydew remote sites were positive for *Salmonella* after enrichment (Table 3).

3.4. Evaluation of a water scrub treatment on intact cantaloupe and honeydew rind

Scrubbing the rind was shown to be more effective than soaking alone. Different scrubbing times, focusing only on the inoculated square, were examined to determine the number of seconds needed to reduce *Salmonella* on one site. After scrubbing cantaloupe for 5 or 10 s on the inoculated square, *S. typhimurium* LT2 populations were significantly reduced by 1.7 and 1.6 $\log_{10}$ CFU/sample, respectively (Table 4). Melons immersed for 30 s (control) were not significantly different from untreated samples.

After corresponding melons were immersed for 30 s and appropriate sections enriched, 100% of the "next to" inoculated squares and 75% of the remote site samples tested positive for *S. typhimurium* LT2. Melons scrubbed for 5 or 10 s also showed similar results, with the "next to" inoculated squares (100%)

Table 2
Comparison of soaking or scrubbing in water or 200 ppm total chlorine for 60 s to remove *S. typhimurium* LT2 from the rind of intact cantaloupe

Treatment	Water			Total chlorine (200 ppm)		
	Salmonella recovered/melon[a]		# Positive on BSAN after enrichment/# tested	*Salmonella* recovered/melon		# Positive on BSAN after enrichment/# tested
	TSANP[b]	BSAN[c]		TSANP	BSAN	
Estimated inoculum	6.2±0.3	5.9±0.8		6.2±0.2	6.2±0.2	
Untreated						
Inoculated site	5.2±0.3 A[d]	5.2±0.4 A	7/7	5.3±0.3 A[e]	5.3±0.3 A	8/8
Next to site	<1.7±0.0 B[e]	<1.7±0.0 B	0/8	<1.7±0.3 B[f]	<1.7±0.3 B	2/12
Soak 60 s						
Inoculated site	4.5±0.3 C	4.4±0.3 C	7/7	3.5±0.5 C	3.2±0.6 C	8/8
Next to site	<1.7±0.0 B	1.8±0.3 B	7/7	<1.7±0.0 B	<1.7±0.0 B	2/12
Remote site	<1.7±0.0 B	<1.7±0.0 B	6/7	<1.7±0.0 B	<1.7±0.0 B	0/8
Rinse solution (1500 ml)	5.2±0.0	4.8±0.5	ND	<3.6±0.3	<3.6±0.3	ND[f]
Scrub 60 s						
Inoculated site	3.6±0.3 D	3.2±0.6 D	8/8	2.6±0.6 D	2.2±0.5 D	8/8
Next to site	<1.7±0.0 B	<1.7±0.0 B	8/8	<1.7±0.0 B	<1.7±0.0 B	2/12
Remote site	<1.7±0.0 B	<1.7±0.0 B	8/8	<1.7±0.0 B	<1.7±0.0 B	0/8
Rinse solution (1500 ml)	4.8±0.8	4.8±0.3	ND	<3.6±0.3	<3.6±0.3	ND
Scrub brush	ND	2.7±0.3	ND	<2.4±0.0	<2.4±0.0	ND

[a] $\log_{10}$ CFU/sample, values are the average of four samples from each of three experiments (n=12).
[b] TSAPN, tryptic soy agar supplemented with 0.1% pyruvic acid and 50 μg/ml nalidixic acid.
[c] BSAN, bismuth sulfite agar supplemented with 50 μg/ml nalidixic acid.
[d] Different letters indicate significance across the entire table (P<0.05).
[e] <, one or more samples below level of detection (<5 CFU/sample).
[f] ND, not done.

Table 3
Comparison of soaking or scrubbing in water for 60 s to remove *S. typhimurium* LT2 from the rind of intact honeydew

Treatment	*Salmonella* recovered/melon[a]	
	BSAN[b]	# Positive on BSAN[b] after enrichment/# tested
Estimated inoculum	6.4	ND[c]
Untreated		
Inoculated site	5.8±0.1 A[d]	ND
Next to site	ND	ND
Water soak 60 s		
Inoculated site	3.0±0.3 B	5/5
Next to site	<1.7±0.0 C[e]	1/5
Remote site	<1.7±0.0 C	0/5
Rinse solution (1500 ml)	4.4±0.2	ND
Water scrub 60 s		
Inoculated site	<1.7 (4 samples) C 3.1 (1 sample) B[f]	5/5
Next to site	<1.7 (4 samples) C 1.7 (1 sample) C[f]	5/5
Remote site	<1.7±0.0 C	1/5
Rinse solution (1500 ml)	5.0±0.3	ND
Scrub brush	2.6±0.2	ND

[a] $\log_{10}$ CFU/sample, values are the average of five samples from a single experiment (n=5).
[b] BSAN, bismuth sulfite agar supplemented with 50 μg/ml nalidixic acid.
[c] ND, not done.
[d] Different letters indicate significance across the entire table ($P < 0.05$).
[e] <, one or more samples below level of detection (<5 CFU/ml).
[f] Not all samples were enriched.

and remote sites (75% and 50%, respectively) testing positive for *S. typhimurium* LT2.

It was estimated that scrubbing the entire melon surface for 60 s would result in approximately 5–10 s of direct scrubbing of the inoculated 2.5 cm^2 square. Scrubbing the entire cantaloupe with a brush for 60 s significantly improved the reduction over soaking in water to 1.6 $\log_{10}$ CFU/sample (Table 2), while scrubbing honeydew increased the reduction to >4.6 $\log_{10}$ CFU/sample in four of five samples (Table 3). After the scrubbing treatment, 100% of the "next to" (cantaloupe and honeydew) and 100% (cantaloupe) or 20% (honeydew) remote squares were positive for *Salmonella* after enrichment.

The presence of *Salmonella*-positive "next to" and remote sites indicates that bacteria were spread from the inoculum site on the rind to uninoculated sites either through the rinse water, containing approximately 40–70 CFU/ml of *Salmonella*, or the scrub brush, containing approximately 400–500 CFU/brush of *Salmonella*. While most of the contamination probably occurred through the rinse water, the counts

Table 4
Comparison of scrubbing times in water on an inoculated spot of cantaloupe rind to remove *S. typhimurium* LT2

Treatment	*Salmonella* recovered[a]		# Positive on BSAN after enrichment/# tested[d]
	TSAPN[b]	BSAN[c]	
Estimated inoculum	6.4±0.0	6.3±0.1	
Untreated	5.5±0.4 A[e]	5.3±0.4 A	ND[f]
Untreated next to site	<1.7±0.3 B[g]	<1.7±0.3 B	0/4
Scrub 5 s			
Inoculated site	3.8±0.6 C	3.3±0.6 C	ND
Next to site	2.2±0.4 D	1.8±0.3 D	4/4
Remote site	<1.7±0.0 B	<1.7±0.0 B	3/4
Rinse solution (1500 ml)	4.6±0.6	4.7±0.6	ND
Scrub brush	3.4±0.2	3.5±0.3	ND
Scrub 10 s			
Inoculated site	3.9±0.0 C	3.6±0.3 C	ND
Next to site	<1.7±0.0 B	1.2±0.8 B	4/4
Remote site	<1.7±0.0 B	<1.7±0.0 B	2/4
Rinse solution (1500 ml)	5.4±0.1	4.9±0.6	ND
Scrub brush	3.7±0.2	3.5±0.2	ND
Immerse 30 s (control)			
Inoculated site	5.1±0.2 A	4.8±0.4 A	ND
Next to site	<1.7±0.0 B	2.1±0.6 D	4/4
Remote site	<1.7±0.0 B	<1.7±0.0 B	3/4
Rinse solution (1500 ml)	5.8±0.1	5.5±0.4	ND

[a] log CFU/sample, values are the average of two samples from two experiments (n=4).
[b] TSAPN, tryptic soy agar supplemented with 0.1% pyruvic acid and 50 μg/ml nalidixic acid.
[c] BSAN, bismuth sulfite agar supplemented with 50 μg/ml nalidixic acid.
[d] Not all samples were enriched.
[e] Different letters indicate significance (P<0.05).
[f] ND, not done.
[g] One or more samples below level of detection (<5 CFU/ml).

on the brush indicate that bacterial spread could also be due in part to scrubbing with a contaminated brush.

3.5. Evaluation of a chlorine treatment on intact cantaloupe rind

Household chlorine bleach is not labeled for use as a produce rinse and as such is not recommended and only rarely used by consumers (Li-Cohen and Bruhn, 2002). However, chlorine at typical label rates of 50–200 ppm is commonly used at a contact time of 1–2 min for disinfection of fruits and vegetables in the food processing industry (Beuchat, 1998). *S. typhimurium* LT2 was reduced on the rind of cantaloupe by 1.8 $\log_{10}$ CFU/sample after soaking for 60 s in 200 ppm total chlorine. This was a significant improvement over that achieved with a water soak, but was not significantly better than scrubbing with water. Scrubbing with a brush for 60 s in 200 ppm total chlorine improved removal by approximately 1 $\log_{10}$ CFU/sample over soaking. More importantly, the presence of chlorine limited the cross contamination from the inoculated square in both the soak and scrub treatments to 16% of the "next to" inoculated squares and 0% of the remote squares positive for *Salmonella* after enrichment (Table 2). Cells were not recovered (<5 CFU/ml) in the rinse solution or on the scrub brushes.

Cantaloupe flesh contains organic matter thought to decrease the free chlorine needed to inactivate bacteria cells (Beuchat and Ryu, 1997; Kotula et al., 1997). Protection provided by the netted melon rind (Fig. 1) and the decreased concentration of free chlorine due to organic matter on the rind contributes to decreased effectiveness of chlorine on cantaloupe. It is possible that a surfactant would improve contact of chlorine with the bacteria; however, limited published studies do not support this hypothesis (Adams et al., 1989; Zhang and Farber, 1996). In addition, surfactants often caused sensory problems and in some cases may increase decay or spoilage by increasing water soaking of intercellular spaces. For these reasons, the use of household detergents to wash produce is not currently recommended to consumers because they are not approved for use on food and there is potential for soap residues (USDA FSIS, 1999; FDA, 2000).

4. Conclusions

In a national mail survey, 81% of consumers report washing produce just prior to consumption. However, only 64% of consumers report washing whole melons during preparation (Li-Cohen and Bruhn, 2002). Consumers report not washing produce prior to consumption because they do not eat the produce with the skin on (16%), or they thought the produce was already clean (9%). Survey results indicate consumers need to be informed about the importance of washing fruits and vegetables prior to consumption. The importance of washing produce, even if the rind is not eaten, must be stressed due to the transfer of contamination from the rind to the inside edible flesh during slicing. In addition, opportunity for contact of the edible flesh with the rind commonly occurs when rind-on cantaloupe slices are stacked for display or in use as a garnish.

In the current study, scrubbing with water resulted in reductions comparable to soaking in 200 ppm of total chlorine, while scrubbing in chlorine provided the greatest reduction. However, in the absence of chlorine, *Salmonella* spread from inoculated to uninoculated surfaces. Washing cantaloupes in a common batch-water system is strongly discouraged for packinghouses, processors, foodservice, and home consumers.

If comingling of melons in water cannot be avoided in shed-pack operations, adequate water disinfection is essential. Soaking contaminated melons in inadequately treated water will cause localized contamination to spread and make the situation worse. In shed-pack operations using brush-washing methods, adequate water disinfection may be essential to maintain sanitation of the brushing equipment. Further research is needed to assess the potential for commercial brushing equipment to transfer pathogens among produce. In the US, packinghouses handling unprocessed produce (raw agricultural commodities) are restricted to EPA-registered sodium hypochlorite or other antimicrobial products as per label instructions (Gorny, 2001).

Sodium hypochlorite is approved for use in the US as a wash aid for processed fruits and vegetables in processing and food service establishments if followed by a potable water rinse (FDA, 2001a,b, 2003). Sodium hypochlorite, if consistently applied at appropriate concentrations (50–200 ppm) and pH (6.5–7.5), could be of use to increase reduction of pathogens on melon rind. Similar reductions would be expected by maintaining a redox potential of 750–850 mV (White, 1999; Suslow, 2000). Although means to control and test chlorine concentrations may be common in food processing establishments, they are less likely in the food service sector possibly limiting its use in this setting.

Currently, there are no consumer produce washes in the US that are registered with the EPA and that can legally support antimicrobial claims (Harris et al., 2001). In addition, issues of concentration and pH measurements make it more difficult to recommend the use of chlorine to consumers. However, benefits in reduced contamination and prevention of cross contamination might be realized by using an alternative antimicrobial specifically approved for produce when washing cantaloupes in the home. The evaluation of effective and safe alternative wash aides and antimicrobial formulations is being actively pursued.

In agreement with current recommendations, consumers and food service industries should scrub melons with a clean brush under running water. It is important that these instructions also include advice on cleaning and sanitizing brushes prior to and after preparation as using a contaminated scrub brush may negate the benefits achieved with washing. Brushes can be cleaned either by washing in the dishwasher with a hot cycle or by soaking in a 200 ppm total chlorine solution made with 45 ml household bleach (5% sodium hypochlorite)/l water.

Acknowledgements

This research was supported by the California Melon Research Board, the California Cantaloupe Advisory Board and FDA CFSAN grant (grant number FD-U-001629-01-1) in collaboration with Dr. Christine Bruhn and Amy Li-Cohen (University of California, Davis).

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