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Transfer of *Salmonella* from Skin to Flesh and Peelers during Peeling of Baby Cucumbers

ABSTRACT

Salmonella is of concern in the fresh produce sector, and a recent outbreak of *Salmonella* infections was associated with baby cucumbers in Australia. Some consumers advocate peeling cucumbers to improve food safety. We investigated the transfer of *Salmonella* Typhimurium (*n* = 2) and *Salmonella* Newport (*n* = 1) from unrinsed and rinsed cucumber skin to flesh and peelers (stainless steel or plastic) during peeling of baby cucumbers. Levels of *Salmonella* attached to cucumbers were ~7.64 to 7.87 log CFU/g (unrinsed) and ~6.75 to 7.40 log CFU/g (rinsed). Levels of *Salmonella* Typhimurium transferred onto the flesh were higher (~0.1 to 1.8 log %) than those of *Salmonella* Newport (~-1.7 to 1.4 log %) irrespective of rinsing prior to peeling. Levels of *Salmonella* transferred to the stainless steel peeler were generally lower (~-3.62 to 1.58 log %) than those transferred to the plastic peeler (~–3.74 to –0.52 log %). Rinsing reduced attachment of *Salmonella* to unpeeled cucumber (~0.50 to 1.00 log CFU/g) and reduced transfer to the flesh (~–1.71 to 1.11 log %) and peelers (~–3.71 to –1.42 log %). *Salmonella* strains and peeler material may contribute to the degree of transfer. Stainless steel peelers may be a better option for consumers, but use of these peelers does not eliminate the risk of *Salmonella* transfer during peeling.

INTRODUCTION

Cucumbers (*Cucumis sativus*) are grown widely throughout the year across Australia due to the conducive climate. Approximately 66 to 143 tons of Australian cucumbers are exported worldwide annually *(14)*. Cucumbers are grown in fields or generally in greenhouses to minimize crop damage due to hail, wind, and rain and allow effective control of pests *(1, 23)*. The production of cucumbers has risen from ~ 66,000 tons in 2010 to ~99,000 tons in 2018 *(13)*. Cucumbers are a rich source of phytonutrients, antioxidants, and anti-inflammatory agents *(21)*. They also are extremely juicy and can be used by consumers to enhance hydration. Of the various cultivars of cucumbers, mini cucumbers have been produced through innovations in fresh produce production in Australia and are marketed as baby cucumbers *(13)*. These baby cucumbers

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are ~8.5 to 12 cm wide and 1.5 to 2.5 cm thick *(13)*. The consumption of baby cucumbers has recently increased across Australia, where they are commonly consumed as snacks. These Australian baby cucumbers are also exported to Canada, Malaysia, and New Zealand *(24)*.

Salmonella is a common foodborne pathogen that has caused recent disease outbreaks associated with cucumbers *(9, 10)*. A recent outbreak of *Salmonella* Typhimurium infection associated with baby cucumbers occurred in Western Australia on 30 December 2022 *(10)*. *Salmonella* Newport was the causative agent for a 2014 outbreak associated with cucumbers that occurred across 29 U.S. states *(2)*. The reasons for most cucurbit outbreaks are contamination in the greenhouses, glasshouses, or farms or pathogen transfer to the flesh during food preparation *(5)*. *Salmonella* also can survive on the surface of cucumber skin and on sliced cucumbers *(3)*.

Some consumers peel cucumbers before slicing to remove any edible waxy preservative, which can contain lipids, proteins, and polysaccharides, is used to protect the fruit against environmental damages, but can have a bitter taste *(6)*. Other consumers peel the cucumber skin for aesthetics or merely to follow recipes provided by chefs to prepare such foods as cucumber salad *(19)*. Some consumers also advocate peeling cucumbers to improve food safety *(11)*. Peeling also can reduce pesticide residues on cucumbers (*25*). Although peeling may aid in removing bacterial pathogens on the surface of the cucumber skin, it may also facilitate transfer of pathogens to the cucumber flesh. The peeler blade material, such as plastic or stainless steel, may contribute to the attachment and transfer of *Salmonella* during cucumber preparation. Rinsing with water also is a common method of processing fruit before consumption for sanitization and removal of pesticides *(11)*.

Information on *Salmonella* transfer from the surface of the cucumber skin to the flesh during peeling is limited. Some researchers have investigated the transfer of *Salmonella*, specifically *Salmonella* Newport, from full-size waxed cucumber skin to flesh and/or peelers to determine how cell surface components, such as curli and cellulose, impact attachment and transfer of *Salmonella* from the skin to flesh *(16)*. The transfer of *Salmonella* to baby cucumbers may be different because the surface-to-volume ratio of smaller fruit is typically larger than that of full-size fruit, possibly making this small fruit more vulnerable to *Salmonella* surface contamination. This study was undertaken to (i) determine the transfer of *Salmonella* Typhimurium and *Salmonella* Newport from the cucumber skin to plastic peelers, stainless-steel peelers, and cucumber flesh; (ii) determine whether rinsing with water minimized the transfer of *Salmonella*, and (iii) investigate whether the type of peeler contributed to *Salmonella* transfer during peeling. The results of this study provide an indication of whether rinsing and peeling cucumbers or vice versa are good practices to minimize *Salmonella* transfer during preparation of baby cucumbers.

MATERIALS AND METHODS

Preparation of baby cucumbers and peelers

Fresh baby cucumbers were purchased from a retail outlet. The baby cucumbers were stored at 4°C and used within 48 h. Baby cucumbers were chosen for this study because they are easy to work with them and because of a *Salmonella* outbreak associated with baby cucumbers in Western Australia that occurred in 2022 *(10)*. The absence of *Salmonella* naturally on these baby cucumbers was verified by enumeration as described under "Bacterial enumeration." Swivel peelers with either a stainless steel blade (Coles, Hawthorn East, Victoria, Australia; manufactured in China) or a plastic blade (Goodcook Essentials, Rancho Cucamonga, CA; manufactured in China) were used to peel the baby cucumbers. All peelers were cleaned as described previously with modifications *(27)*. Both stainless steel and plastic peelers were sterilized in 70% ethanol for 30 min, allowed to dry, and then treated with UV light in the biosafety cabinet for 30 min.

Bacterial cultures, inoculum preparation, and *Salmonella* attachment to baby cucumbers

Two strains each of *Salmonella* Typhimurium (ATCC 14028 and ATCC 13311) and one strain of *Salmonella* Newport (ATCC 6962) were used in this study. *Salmonella* strains were grown on xylose lysine deoxycholate medium (XLD; Oxoid, Basingstoke, UK) or in tryptone soy broth (Oxoid) at 37°C for 24 h. *Salmonella* cell suspensions were prepared as described previously *(26)*. Bacterial cultures of each strain were centrifuged at 6,000 × g for 20 min at 4°C. The resulting pellets were washed gently with saline and resuspended in 9 mL of saline to obtain a cell density of ~10^8 CFU/mL for inoculation onto baby cucumbers. The inoculum level was similar to that in previous work on *Salmonella* on cucumbers *(12, 16)*.

A 2-ml aliquot of each strain of *Salmonella* cell suspension at ~10^8 CFU/ml was inoculated onto a baby cucumber with a pipette to ensure the cell suspension was equally distributed over the entire cucumber surface. After inoculation, cucumbers were left undisturbed for 20 min for bacterial attachment. *Salmonella* cells attached to the cucumber were enumeration as described under "Bacterial enumeration and tranfer rate."

Salmonella transfer from unrinsed cucumber skin to flesh and peelers

Four laboratory scenarios (scenarios 1 through 4) were evaluated for this set of experiments *(Table 1)*. For each scenario, the unrinsed baby cucumbers were peeled aseptically in triplicate with either a stainless steel peeler or plastic peeler. Depending on the scenario, the entire surface of the peeled cucumber and peelers were rinsed with 20 ml of sterile water. The volume of water chosen was based on the nature and size of the fresh produce and utensils used in

TABLE 1. Description of procedures conducted on inoculated cucumbers

Description	Scenario no.	*Salmonella* transfer scenario
Peeling unrinsed cucumber	1	Unrinsed cucumber skin to unrinsed flesh
No rinsing of flesh and peelers after peeling	2	Unrinsed cucumber skin to unrinsed peelers
Peeling unrinsed cucumber	3	Unrinsed cucumber skin to rinsed flesh
Rinsing of flesh and peelers after peeling	4	Unrinsed cucumber skin to rinsed peelers
Peeling rinsed cucumber	5	Rinsed cucumber skin to unrinsed flesh
No rinsing of flesh and peelers after peeling	6	Rinsed cucumber skin to unrinsed peelers
Peeling rinsed cucumber	7	Rinsed cucumber skin to rinsed flesh
Rinsing of flesh and peelers after peeling	8	Rinsed cucumber skin to rinsed peelers

the study. The cucumbers and peelers were rinsed by pouring the running water from the top end of the cucumber or right end of the peelers to the base of the cucumber or the left end of the peelers. The rinse solution was collected in a discard container. Rinsing was conducted to mimic consumer practices in the kitchen setting. In previous studies, 81% of consumers rinsed their fresh produce under running water regardless of whether it was peeled, and this practice was considered a food safety measure *(18, 20)*. In real life scenarios, consumers may use a higher volume of water depending on the type and amount of fresh produce being rinsed, but our experiments were conducted under controlled laboratory conditions. The entire surfaces of the peeled cucumber and peelers were swabbed with a sterile swab (LP Italiana Spa, Milano, Italy) that had been moistened in saline. Swabs were then placed into 9 ml of saline, and *Salmonella* cells were detached from the swabs by vigorous mixing in a vortex mixer at 40 Hz for 3 min. *Salmonella* cells were then enumerated as described under "Bacterial enumeration and tranfer rate."

Salmonella transfer from rinsed cucumber skin to flesh and peelers

In another set of experiments (scenarios 5 through 8) *(Table 1)*, the baby cucumbers were rinsed with 20 ml of sterile water before being peeled. After rinsing, the entire experiment was repeated as per scenarios 1 through 4.

Bacterial enumeration and transfer rate

Baby cucumbers were analyzed for *Salmonella* levels by adding 225 ml of saline (Biochemicals, Australia) to 25 g of cucumber in a stomacher bag (Interscience, St. Nom la Bretêche, France). *Salmonella* cells were detached from the cucumber by vigorous mixing with a vortex mixer at 40 Hz for 3 min. The homogenate was serially diluted, and appropriate diluted samples were inoculated onto thin agar layer medium (TAL) and incubated at 37°C for 24 h to enumerate *Salmonella* cells *(17)*.

To determine the *Salmonella* transfer from the unrinsed and rinsed baby cucumbers to the flesh and respective peelers in the eight scenarios, serial decimal dilutions were made in saline from the *Salmonella* cells detached from the swabs, and appropriate diluted samples were inoculated on TAL and incubated at 37°C for 24 h to enumerate *Salmonella* cells *(17)*. XLD was used as the selective medium, and tryptone soy agar (Oxoid) was used as the nonselective medium. All *Salmonella* strains grown on TAL produced colonies with black centers. Colonies were counted after incubation, and results were transformed to log CFU per gram for the cucumbers and log CFU per square centimeter for the peelers. The transfer rate of *Salmonella* from the unrinsed and rinsed cucumbers to the flesh and respective peelers were determined using the formula described previously *(7, 25)*: (CFU recipient/CFU initial donor) × 100%. The overall experimental design is shown in *Figure 1*.

Statistical analysis

All the *Salmonella* assays for the baby cucumbers were carried out in triplicate with independently grown *Salmonella* cultures, and the values were expressed as the mean ± standard deviation. A two-way analysis of variance with Tukey's post-hoc test was conducted to compare the differences between the types of peelers for each scenario and to compare these results between the two treatments (unrinsed and rinsed cucumber) using the respective peelers. The statistical analysis was performed with SPSS software (SPSS 29, IBM, Armonk, NY) and a 95% confidence level.

RESULTS AND DISCUSSION

Salmonella transfer from unrinsed cucumber skin to flesh and peelers

Numbers of attached cells for all *Salmonella* strains on baby cucumbers was ~7.64 to 7.87 log CFU/g. No significant differences ($P > 0.05$) were found between *Salmonella* strains for attachment on the cucumbers. The

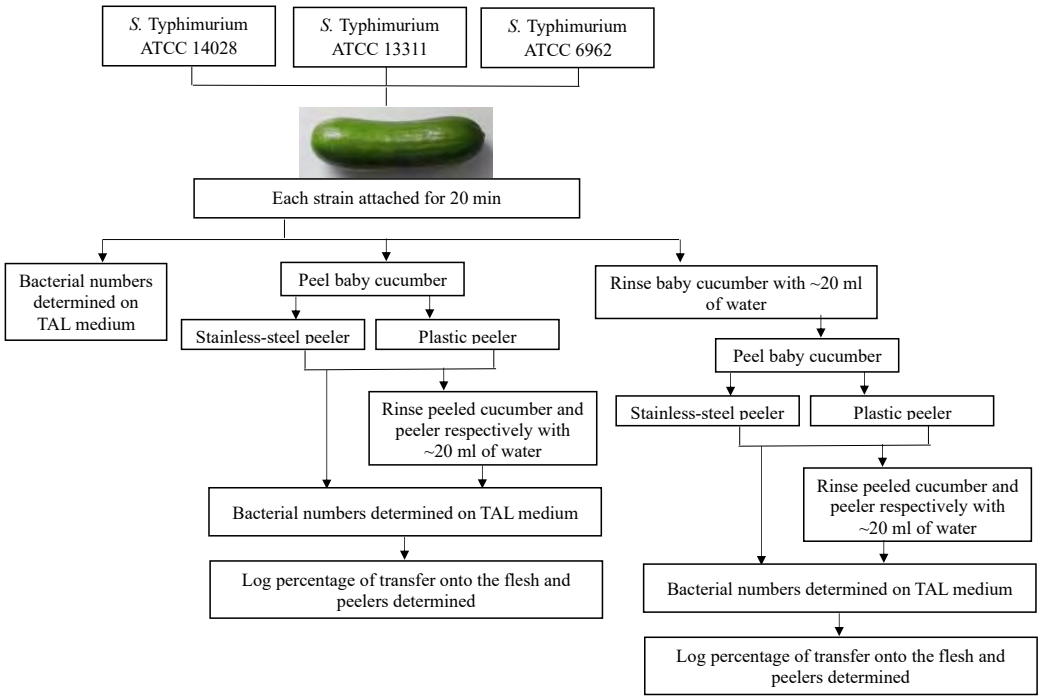

Figure 1. Experimental design for evaluating transfer of *Salmonella* from skin to flesh and peelers during peeling of baby cucumbers.

log transformed percentage transfer of *Salmonella* cells from unrinsed cucumber skin to flesh by using either a plastic or stainless steel peeler are shown in *Figure 2A*. A lower number of *Salmonella* cells across all strains were transferred to a rinsed peeled cucumber after peeling than to the unrinsed peeled cucumber. The transfer of cells of both *Salmonella* Typhimurium strains on the peeled cucumber was higher after using the plastic peeler than after using the stainless steel peeler. Plastic is more hydrophobic than stainless steel, and *Salmonella* is more adhesive on hydrophobic surfaces *(30)*. Overall, the transfer rate of *Salmonella* Typhimurium was higher than that of *Salmonella* Newport when peeling an unrinsed cucumber with a plastic peeler as compared with a stainless steel peeler. The transfer rate of *Salmonella* Typhimurium ATCC 14028 was significantly higher ($P \leq 0.05$) than that of the other strains in this study. The type of peeler surface, serovar, and strains may affect the transfer rate of *Salmonella* on cucumbers. In previous studies, more of the *Salmonella* Newport cells were left on the peeled cucumber skin during peeling than were transferred to the cucumber flesh or the peelers *(16)*.

The log transformed percentage transfer of *Salmonella* cells from unrinsed cucumber skin to plastic or stainless steel peelers is shown in *Figure 2B*. Use of a plastic peeler generally resulted in a significantly higher transfer ($P \leq 0.05$) than use of a stainless steel peeler for both *Salmonella* Typhimurium strains on an unrinsed cucumber. However, transfer of cells was lower for *Salmonella* Typhimurium ATCC 13311 on rinsed peelers after peeling. *Salmonella* Newport exhibited a different trend, with use of a stainless steel peeler having a slightly higher transfer rate than use of a plastic peeler, whereas the reverse was observed with the rinsed peelers after peeling. Some researchers have reported that *Salmonella* attaches better to hydrophobic surfaces such as plastic than to hydrophilic surfaces such as stainless steel *(4, 15, 32)*. However, in previous studies the greater attachment of *Salmonella* on hydrophilic surfaces such as stainless steel than on hydrophobic surfaces was associated with higher free surface energy *(8, 22)*. Bacterial surface hydrophobicity may also be associated with the attachment of *Salmonella* onto a surface *(31)*. The log percentage transfer of *Salmonella* from the unpeeled cucumber to both plastic and stainless steel peelers across all strains was negative, indicating that most of the *Salmonella* cells were either removed during the rinsing process or were transferred to the peeled cucumber.

Salmonella transfer from rinsed cucumber skin to flesh and peelers

Attachment of all *Salmonella* strains was ~6.75 to 7.40 log CFU/g on baby cucumbers after they were rinsed with water. Rinsing with water significantly reduced *Salmonella* attachment on unpeeled cucumbers. Similar to the unrinsed cucumbers, no significant differences ($P > 0.05$) between *Salmonella* strains were found for attachment on cucumbers after they were rinsed with water. The log transformed percentage transfer of *Salmonella* from rinsed cucumber

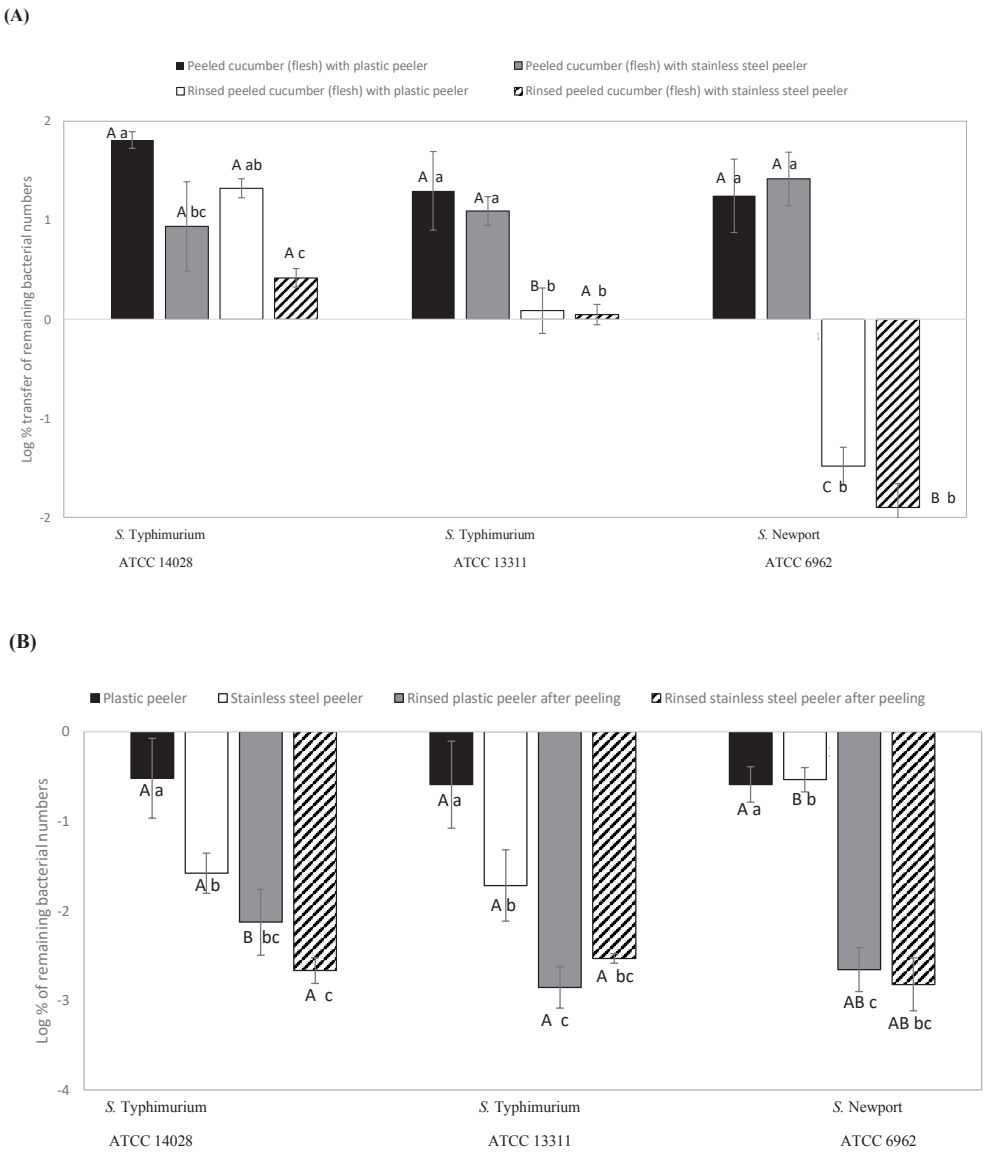

Figure 2. Log transformed percentage transfer of *Salmonella* from cucumber skin to flesh after using either a plastic or stainless steel peeler. Transfer from unrinsed cucumber skin to flesh (A) and from unrinsed cucumber skin to peelers (B). Different uppercase letters indicate significant differences between strains within a scenario. Different lowercase letters indicate significant differences between scenarios within a strain. Values are means ± SD, n = 3.

skin to flesh after using either a plastic or stainless steel peeler is shown in *Figure 3A*. The transfer of both *Salmonella* Typhimurium strains was higher on the peeled cucumber when peeled with the stainless steel peeler than when peeled with the plastic peeler. However, the result was different for the *Salmonella* Newport strain. After rinsing the peeled cucumber after peeling, both *Salmonella* Typhimurium strains again had a higher transfer rate after both types of peelers were used, and the transfer rate of *Salmonella* Newport was significantly lower. The log transformed percentage transfer of *Salmonella* from unrinsed cucumber skin to plastic or stainless steel peelers is shown in *Figure 3B*. For transfer of *Salmonella* Typhimurium from the rinsed cucumber to both types of peelers, there were no significant differences between the rinsed peelers after peeling and the unrinsed peelers for all strains.

Similar to our previous study with other surfaces, rinsing with water significantly reduced *Salmonella* attachment on unpeeled cucumber, peeled cucumber, and both types of peelers *(28)*. The transfer rates from the rinsed cucumber

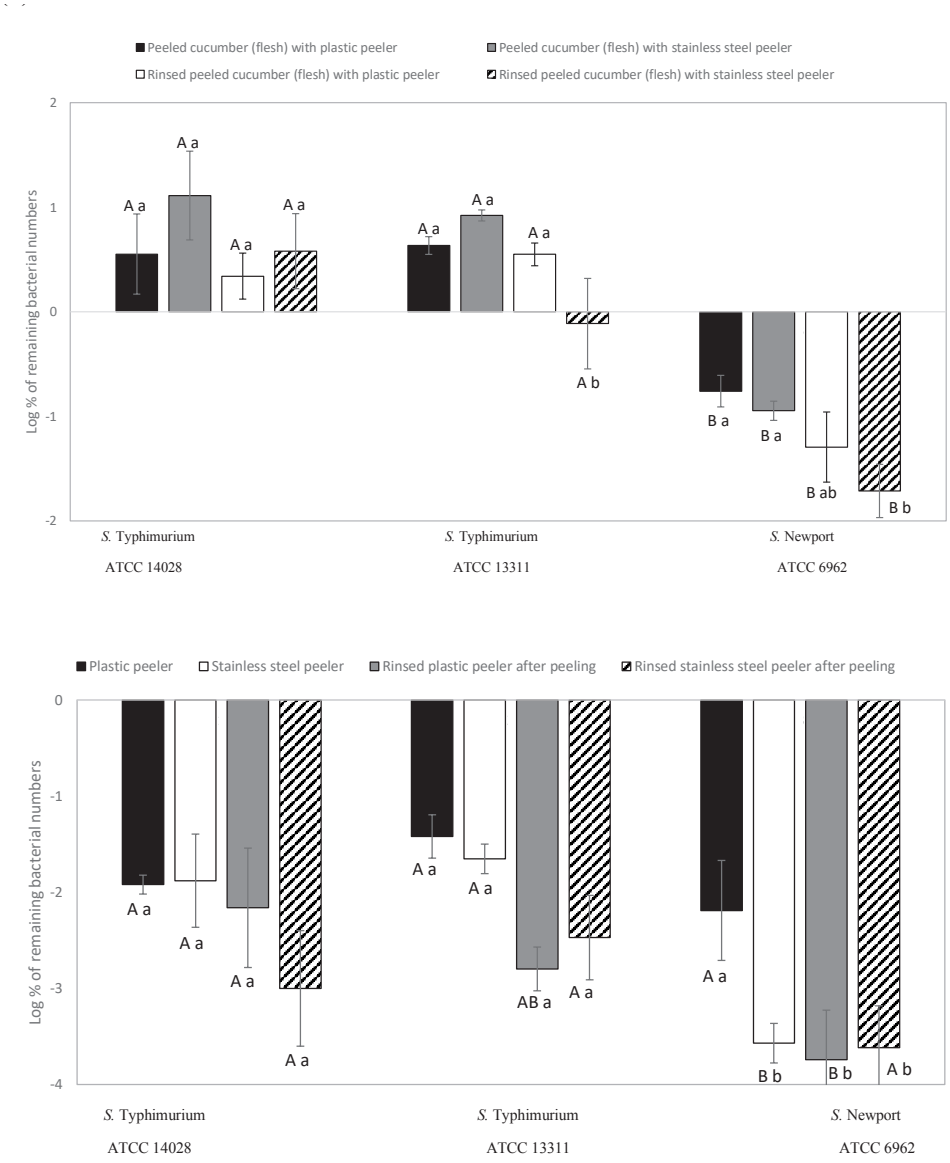

Figure 3. Log transformed percentage transfer of *Salmonella* from cucumber skin to flesh after using either a plastic or stainless steel peeler. Transfer from rinsed cucumber skin to flesh (A) and from rinsed cucumber skin to peelers (B). Different uppercase letters indicate significant differences between strains within a scenario. Different lowercase letters indicate significant differences between scenarios within a strain. Values are means ± SD, n = 3.

skin to the peeled cucumber, rinsed peeled cucumbers, peelers, and rinsed peelers were relatively lower than the transfer rates from the unrinsed cucumber skin to the peeled cucumber, rinsed peeled cucumbers, peelers, and rinsed peelers. Overall, both *Salmonella* Typhimurium strains had a higher transfer from cucumber skin to cucumber flesh than did *Salmonella* Newport regardless of whether the cucumbers were rinsed before peeling. This result indicates that *Salmonella* Typhimurium may be more adhesive to cucumber flesh. In previous studies, specific *Salmonella* serovars utilize the nutrients from cucumber to enhance survival *(29)*. Genomic differences among these serovars and strains may also contribute to differences in adhesion. Whole genome sequences of both *Salmonella* Typhimurium strains are available on the National Center for Biotechnology Information website. However, the whole genome of *Salmonella* Newport ATCC 6962 has yet to be sequenced. Future studies should be conducted to examine the genetic differences among these strains. Food handlers also play a vital role in preventing cross-contamination of

Salmonella while preparing meals or snacks. The risk of cross-contamination increases with lack of proper hygiene and lack of understanding of how to concurrently handle fresh produce and meat or raw seafood. Any contaminated surfaces that come into contact with these food products increase the risk of *Salmonella* transfer. Consumers should be educated on appropriate food safety practices to minimize the risk of cross-contamination during food handling. Our study provides insights into appropriate food safety practices in households and foodservice settings but has some shortcomings. The experiments in our study were conducted under controlled laboratory conditions and did not include other cucumber cultivars or various environmental factors, handling practices, and ergonomics that could influence *Salmonella* transfer.

CONCLUSIONS

Rinsing of unpeeled cucumbers is essential for dislodging attached *Salmonella* cells and minimizing the transfer of these cells onto the peeled cucumber and peelers, regardless of the peeler material. Rinsing of cucumber flesh after peeling may also reduce *Salmonella* transfer, depending on the serovar. However, the risk of transfer to the cucumber flesh might be higher depending on the type of peeler being used. Peeling of cucumber skin does not effectively reduce the transfer of *Salmonella* cells and may promote cross-contamination to other vegetables, such as during the preparation of a salad. Therefore, it is better to not peel cucumbers. *Salmonella* strain and peeler material may affect the degree of transfer during peeling of baby cucumbers. Although rinsing and peeling of baby cucumbers leaves a significant percentage of *Salmonella* cells on the cucumber peel, the transfer of these cells to the cucumber flesh still poses a risk to food safety. Overall, the transfer rate of *Salmonella* was significantly lower ($P \leq 0.05$) to stainless steel peelers than to plastic peelers. Stainless steel peelers are preferred by consumers over plastic peelers, and the transfer of *Salmonella* is generally lower onto stainless steel than onto plastic, which is important when the peeler is going to be used subsequently on another fruit or vegetable. This difference in transfer could be associated with the smoothness and lack of porosity of stainless steel. Stainless steel peelers are a significantly better choice for consumers, but these peelers do not eliminate the risk of *Salmonella* transfer during peeling of baby cucumbers. This study may have implications for other fresh produce that may require peeling. If *Salmonella* were present on a piece of fresh produce, peeling may promote cross-contamination, which could lead to future *Salmonella* outbreaks. Further studies are needed to determine the transfer of *Salmonella* when slicing baby cucumber using stainless steel versus plastic knives to provide a better understanding of *Salmonella* transfer during slicing versus peeling of these cucumbers. The reduction of *Salmonella* levels by peeling and rinsing does not eliminate the risk of contamination from the farm to packaging. Studies on the use of novel effective antimicrobial agents from farm to packaging are needed to eventually reduce and perhaps eliminate *Salmonella* from baby cucumbers.

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In Memory

IAFP was notified of the passing of member **James "Jim" Bloom.** The Association extends our deepest sympathy to his family and colleagues. IAFP has sincere gratitude for his contribution to food safety.