ABSTRACT

RUPERT, CHRISTOPHER LEE. Control of Cross-Contamination During Retail Handling and Supplier Control of Cantaloupe. (Under the direction of Dr. Benjamin Chapman).

Cantaloupes have been implicated in several outbreaks of foodborne illness, including listeriosis and salmonellosis. The source of contamination for these outbreaks have historically been traced back to production or packing facilities. Little research has been conducted on the microflora found on cantaloupe contact surfaces in the food retail environment.

A study was performed to catalog cantaloupe contact surfaces and sanitation practices and to identify cross-contamination risks that may occur at retail. Surfaces, practices, and environmental samples were collected from two national grocery store chains. Results from this study revealed that *Listeria* species were found on eleven of the thirteen the cataloged surfaces, with 108 of 333 samples displaying prevalence. Many of the contact surfaces used to display whole melons on the retail floor were not designed to be easily cleaned or sanitized. Furthermore, store sanitation standard operating procedures only called for surfaces to be cleaned approximately every three months. Surfaces used to prepare fresh-cut cantaloupe were cleaned more regularly and had lower *Listeria* prevalence.

A second study was performed to determine the risk perception and buying preferences of retail food safety executives surrounding cantaloupe washing practices and provenance. This information was collected by administering an online survey to retail employees identified through food safety industry organizations. Eight responses were recorded. It was found that washed cantaloupe and cantaloupe from the Western United States were generally regarded as lower risk. These perceptions contrary to both standard agricultural practices and food safety recommendations, as cantaloupes from the Western
U.S. are normally sold unwashed, which is regarded as a lower risk practice. Employees acknowledged that washing could increase risk if conducted improperly but did not want to receive product with gross soil remaining.

Collectively, this research indicates that there are gaps in food safety knowledge and practices. On the retail floor, surfaces used to display cantaloupes are not designed for easy and effective sanitation and are rarely subjected to sanitation practices. At purchasing, cantaloupe buyers do not appear to understand the food safety hazards surrounding washing practices and request higher risk products from produce suppliers.
Control of Cross-Contamination During Retail Handling and Supplier Control of Cantaloupe

by

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To my mom and dad, without your unconditional love and support I would not be who I am today.

To Melissa, for encouraging me to always do my best.
BIOGRAPHY

Christopher Rupert was born in Phoenix, Arizona and raised in Chapel Hill, North Carolina. Growing up, Chris would often help his parents in the kitchen. This instilled a love of cooking within him. He attended Chapel Hill High School, where he developed an interest in science. While researching undergraduate majors he found food science; combining his love of food and fascination with science, Chris knew he had found his major.

Chris enrolled at North Carolina State University in 2012. He discovered the field of food safety late in his undergraduate career, joining the Chapman lab his senior year. After graduating in 2016, he remained at NC State to pursue a master’s degree.
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INTRODUCTION

The connection between *Listeria* monocytogenes and cantaloupe is relatively new compared to other foodborne pathogens, such as *Salmonella*. The first outbreak of listeriosis linked to whole cantaloupe occurred in 2011 and was linked to a Colorado farm. This outbreak ultimately sickened 147 people and caused 143 hospitalizations and 33 deaths, making it the deadliest outbreak of foodborne illness in the United States in over 25 years (1, 3). This outbreak was a wake-up call for the FDA and the cantaloupe industry. In response, the FDA issued a guidance document, the “National Commodity-Specific Guidelines for Cantaloupes and Netted Melons.” This document outlined safe processes for growing and processing cantaloupes, rehashing practices already suggested by the USDA’s “Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables”, the basis for Good Agricultural Practices (GAP) program. The California cantaloupe industry, which produces the majority of U.S. cantaloupes and had already lost an estimated $50 million dollars due to halted consumption, was prompted to issue a response. This response came from the California Cantaloupe Advisory Board, which issued mandatory guidelines for its growers and processors, similar to the FDA’s issued guidance. However, both of these documents solely focused on the contamination risks that could occur during growing, harvesting, or packaging. The guidance document issued by the California Cantaloupe Advisory board entirely neglected to address potential food safety risks that could arise in the retail environment. The FDA guidance briefly addressed the potential for contamination during user handling, but primarily focused on the risks associated with the production of fresh-cut melon. These issues were largely addressed in the FDA Food Code and were generally applicable to any food prepared at retail or in the home and included advice on
subjects such as refrigeration, handwashing, and using time as a public health control. The guidance did not mention the potential for contamination at retail due to cross-contamination, sanitation practices or surfaces acting as *Listeria* harborage sites.

Cantaloupes can be contaminated from a multitude of pathways; while on the farm, during or after harvest, and through handling during preparation. Washing practices in particular have been a source of contamination for cantaloupe and were found to be partly responsible for the 2011 *L. monocytogenes* outbreak. Chlorinated, recirculating wash tanks used to clean and chill cantaloupes were replaced with non-chlorinated, nonrecirculating wash tanks combined with felt rollers and brushes to manually clean and dry cantaloupes (3). The subsequent FDA investigation found that these surfaces were difficult to clean and sanitize and may have served to inoculate cantaloupe with *L. monocytogenes*.

Little research exists regarding *L. monocytogenes* contamination risks in the retail environment, which contrasts with research involving contamination in food manufacturing facilities. The bulk of existing research has focused on delis, where approximately 10% of environmental samples have displayed prevalence for *L. monocytogenes* (5). Ready-to-eat foods are often implicated in *L. monocytogenes* outbreaks and have been found in fresh cut salads, including low acid fruit (2). In 2011, an outbreak of *L. monocytogenes* was linked to fresh-cut melons prepared in a grocery store in Australia (4).

The first section of this thesis seeks to identify cross-contamination risks involving cantaloupe during the retail handling of cantaloupe (Chapter 2). This was accomplished by working with two national grocery chains to catalog contact surfaces, handling practices, and sanitation protocols, and to collect environmental samples from cataloged surfaces. A total of thirteen surfaces were identified, eleven of which showed presence of *Listeria* species.
Results from environmental samples found only prevalence for *L. monocytogenes* in only one sample. However, of the 333 samples taken, 108 (32.4%) showed presence for *Listeria* species. Surfaces associated with fresh-cut melons were found to be cleaned more frequently and had a lower presence for *Listeria* species. Surfaces used in whole melon display were found to be cleaned much less frequently and had a higher presence for *Listeria* species. The results of this study could be used to better educate retailers on good sanitation practices and the proper use of surfaces used to display produce.

The second part of this thesis seeks to determine the risk perceptions held by grocery retailers surround melon washing practices (Chapter 3). Currently, no research exists examining perceptions and buying practices of retailers. A survey was designed to examine the risk perception of washed and unwashed cantaloupe. Retailers were also asked about washing requirements and specifications and if they saw the practice of washing as increasing or decreasing risk. Results from the survey show that the majority of retailers require cantaloupes prior to receipt and see unwashed cantaloupes as having higher risk than washed cantaloupes. However, all participants in the survey acknowledged that washing could increase risk if not done properly. This data could provide the foundation to develop extension materials to better educate produce buyers and retailers the risks and benefits of washing cantaloupe.

The collective results of this thesis highlight the need to further examine handling and sanitation procedures in the produce area of grocery stores. Currently, many surfaces involved in the display of whole cantaloupe are cleaned infrequently and are not designed for easy sanitation. Furthermore, risk perceptions and buying practices requested by produce buyers may be prone to further contamination. This research may serve as a basis for future
studies on produce food safety at retail, with the goal of minimizing the risk of cross-contamination of produce and the education of produce buying standards.
REFERENCES


CHAPTER 1

Literature Review

The Centers for Disease Control and Prevention estimate that 48 million cases of foodborne illnesses occur each year (31). These 48 million cases will result in approximately 55,000 hospitalizations and 1,300 deaths (37). The economic burden of these illnesses, hospitalizations, and deaths are estimated to be 77.1 billion dollars (38). The number of cases of foodborne illness caused by the consumption of fresh produce has increased in recent decades. Fresh produce was linked to only 2 percent of foodborne illnesses in between 1973 and 1987 this link increased to 45.9 percent between 1998 and 2008. Outbreak sizes also increased, with the mean doubling between these two time periods (24, 33, 40). This rise in produce-borne illness is in part due to the increase in produce consumption, brought on by increased availability and increased awareness of the benefits of consuming higher amounts of fruits and vegetables due to public health initiatives. (15, 45). The cost of these produce-borne outbreaks has been estimated to be 39 billion dollars per year (31).

Melons are often found to be the cause of outbreaks associated with fresh produce consumption and were the cause of 3602 illnesses, 322 hospitalizations and 46 deaths (40, 45). Of these melon-borne outbreaks, cantaloupes were linked to 56% (n=19) of outbreaks between 1973 and 2011. Cantaloupes were more frequently implicated in larger, multistate outbreaks, causing 85% of outbreaks (45). A large portion of these illnesses, particularly hospitalizations and deaths are caused by two pathogens, Listeria monocytogenes and Salmonella enterica.

Characterization and Burden of Listeria monocytogenes and Salmonella enterica.
*L. monocytogenes* is a Gram-positive, rod-shaped, facultative anaerobe (11). *L. monocytogenes* is a motile bacteria, possessing flagella that assist in motility (32). It has been shown to grow in a variety of temperatures, ranging from -0.4°C to 50°C (11). The pH range within which *L. monocytogenes* is able to grow is dependent on the temperature, at 30°C *L. monocytogenes* can grow in environments with a pH as low as 4.39, this acid tolerance decreases with a decrease in temperature and a temperature of 4°C the minimum pH required is 5.23 (14).

*L. monocytogenes* is responsible for causing Listeriosis, a severe illness that was first described in a laboratory setting in 1926 (29). Listeriosis can be expressed in two ways, as non-invasive gastrointestinal listeriosis and as invasive listeriosis (2). In individuals with normal immune function, listeriosis normally manifests as non-invasive febrile gastroenteritis. However, immunocompromised and elderly individuals are disproportionately affected by *L. monocytogenes* which can cause serious symptoms, such as septicemia or meningoencephalitis (2). In 1986 the rate of listeriosis was found to be 150 times higher than the general population (13). The median age of non-pregnancy associated listeriosis between 1997 and 2007 in Austria was 66.2 years (21). Invasive listeriosis also poses a threat to pregnant women and can be transmitted from mother to fetus via the placenta (9). Once transmitted, *L. monocytogenes* can pose a significant danger to the fetus, with one-third of cases resulting in stillbirth or abortion (41). *L. monocytogenes* has a lower incidence rate than many other foodborne pathogens, with an approximately 1600 cases occurring in the United States each year. However due to the severity of the illness, *L. monocytogenes* has a higher hospitalization and fatality rate than most foodborne pathogens, causing an estimated 255 deaths per year (37).
*S. enterica* is a Gram-negative, rod-shaped, flagellated, facultative anaerobe (Salmonella, Medical Microbiology Textbook). The optimal growth temperature of *S. enterica* is 37°C, but it growth for certain serovars have demonstrated the ability to grow at temperatures as low as 5°C (27). The acid resistance of *S. enterica* is greater than that of *L. monocytogenes*, and possesses an acid tolerance response enabling it to grow at lower pH ranges (12).

*S. enterica* is the causative agent of salmonellosis, which was first confirmed as a foodborne illness in 1888 (Foodborne Infections and Intoxications 3rd edition). Salmonellosis most commonly manifests itself as acute gastroenteritis. Diarrhea is the main symptom, with other cases reporting symptoms such as abdominal pain, joint pain, or headaches (Foodborne Infections and Intoxications 3rd edition). *S. enterica* causes the second highest number of domestically acquired foodborne illnesses in the United States, with an estimated 1 million cases each year (37). It is also a leading cause of world gastroenteritis, causing an estimated 93.8 million cases each year (25). The infection dose of *S. enterica* is highly variable with some outbreaks occurring after an estimated ingestion of $10^1$ CFU/g and others occurring after an ingestion of $10^{10}$ CFU/g (16). Ingestion of higher concentrations typically led to higher rates of illness and shorter incubation times (5). As with *L. monocytogenes*, immunocompromised individuals and the elderly are more susceptible to illness, however infections from *Salmonella* species effects children more disproportionately than *Listeria monocytogenes* (39). Nontyphoidal *Salmonella* spp. is estimated to cause approximately 1 million cases of foodborne illness in the United States, making it one of the leading cause of foodborne illness linked to a bacterium (37).

**Listeriosis and Salmonellosis Outbreaks Linked to Cantaloupe**
Listeriosis and Salmonellosis are two of the most common illness linked to cantaloupe and have caused a majority of the illnesses, hospitalizations and deaths in the United States. Two major outbreaks of *Listeria monocytogenes* have been linked to cantaloupe between 1973 and 2018 (Walsh, FDA database). The largest outbreak of listeriosis linked to cantaloupe was traced to a Colorado farm and was the first to be associated with cantaloupe and caused 147 illnesses, 143 hospitalizations, and 33 deaths across 28 states, making it the deadliest documented outbreak of foodborne illness in the United States (28). The median age of hospitalization for this outbreak was 77 years, and the median age of death was 81 years (28). The subsequent environmental investigation conducted by the US Food and Drug Administration (FDA) found that one third (13/39) of the environmental samples taken tested positive for *L. monocytogenes* that showed PFGE bands identical to two of the four strains linked to the outbreak. All environmental samples taken from the fields were negative for *L. monocytogenes*, suggesting that contamination did not occur in the growing fields. All positive samples for *L. monocytogenes* were found in both the packing facility and cold storage. The FDA evaluation found that the design of the facility and packing equipment may have promoted the spread of *L. monocytogenes*.

The second outbreak of *L. monocytogenes* linked to cantaloupe is currently occurring in Australia. On February 28, 2018 the New South Wales Food Authority (NSWFA) issued a departmental media release regarding a listeriosis outbreak linked to rockmelon. This release highlighted 10 cases of listeriosis in individuals who had previously consumed rockmelon. The outbreak was sourced to a single farm located in New South Wales, who voluntarily ceased production and issued a voluntary recall. In April, the NSWFA issued an investigation summary highlighting the cause of the outbreak. The NSWFA found that contamination
likely occurred through contact with the soil caused by inclement weather. Environmental sampling found *L. monocytogenes* in the packinghouse, including on packing equipment and flooring. *L. monocytogenes* samples from the New South Wales farms produced an exact match with reported cases (30).

Between 2011 and 2016 *Salmonella enterica* was responsible for 23 outbreaks of foodborne illness linked to cantaloupe in the United States (6). These outbreaks caused 911 illnesses, 220 hospitalizations, and 7 deaths. The largest of these outbreaks occurred in 2012 and was linked to a farm located in Indiana, resulting in 261 illnesses, 94 hospitalizations, and 3 deaths. The subsequent FDA investigation collected 70 environmental samples, 6 of which displayed indistinguishable PFGE strains from the outbreak strain. The FDA concluded that contamination in the growing environment, packinghouse, and holding areas likely contributed to the outbreak. Samples were taken from four field parcels throughout the farm, all of which tested positive for *Salmonella* species, one field parcel, in which cantaloupe was grown, tested positive for *Salmonella* with a PFGE pattern associated with the outbreak. In the packinghouse, the FDA identified oversights in equipment design that may have contributed to the spread of *Salmonella*. Packaging lines were made of surfaces that were difficult to clean, such as carpet used as a cushioning agent and wood as the sides of conveyor belts. Samples taken from the packinghouse tested positive for *Salmonella* newport but did not match the PFGE pattern associated with the outbreak. Additionally, cantaloupes were packed with field heat while still wet from washing. Lastly, wash water disinfectant levels were not adequately monitored. Although no *Salmonella* was isolated from samples in the immediate packing areas, the conditions would allow for *Salmonella* to persist in the environment. All three outbreaks, along with the majority of foodborne illness
outbreaks linked to cantaloupe, were caused by environmental contamination or poor facility design.

**Cantaloupe Contamination**

Cantaloupe, like most produce can become contaminated through a variety of pathways, including during cultivation, post-harvest handling, and preparation (42). Each of these different contamination routes requires different methods of mitigation. The netted structure of cantaloupes make it an ideal surface for the attachment of bacteria and make it difficult to completely remove once introduced (8). The exact method for which *L. monocytogenes* adheres to cantaloupe is poorly understood, but studies have examined the adherence of strains related to the 2011 cantaloupe outbreak where it was found that these strains largely had the same adherence as strains associated with other outbreaks (26). This same study found that rinsing with water provided a reduction in *L. monocytogenes* by approximately 1.5 to 2 logs. However, this reduction was temporary and increased to pre-rinse levels within 72 hours (26). Similar results have been found in separate studies, showing that water rinses and soaks can reduce pathogen levels (34). The United Stated Department of Agriculture (USDA) currently recommends washing produce, including cantaloupe, under tap water and scrubbing cantaloupe with a brush as a means to remove remaining soil (44). These recommendations explicitly advise against the use of detergents due to the fact that residues may remain on the surface of the produce and accidentally be ingested (44). However several studies have shown that there are more effective methods of washing cantaloupe than rinsing alone, including the addition of detergents or sanitizers (3, 43).
Part of the challenge of controlling *L. monocytogenes* and *Salmonella* lies in the natural presence of these two pathogens. Both *Salmonella* and *L. monocytogenes* can be naturally found in the soil and in decaying plant matter (10, 19). This was highlighted in the 2013 *Salmonella* outbreak, wherein identical stains were found in some of the growing fields, but not in the packinghouse itself. Water baths, which are common in packing sheds pose a risk of cross-contamination. Pathogens from a small quantity of contaminated produce may be able to contaminate wash water, which can contaminate subsequent lots of produce washed in the same water (4). This was partly to blame for the 2011 *L. monocytogenes* outbreak. In previous years the owners of the farm linked to the outbreak used a recirculating, chlorinated water bath to clean and cool cantaloupes prior to packing. However, in 2011 the farm replaced the chlorinated water bath with a non-recirculating, non-chlorinated wash bath combined with an array of rollers designed to clean, and felt brushes to dry, the cantaloupes, this equipment was purchased used had previously been used in potato production (28). Field packing can serve as a strong alternative to shed packing, as it serves as a reduces the chance of contamination from water, equipment or workers (4, 20).

A dichotomy exists surrounding the use of water in cantaloupe production. Cantaloupes grown in the western United States, namely California and Southwestern Arizona, are packed in the field. This is due to the arid climate found in these regions, which limits the amount of field soil that comes in contact with the melons (34). This contrasts with cantaloupe grown east of these areas, where they are washed with water prior to packaging (1). More frequent precipitation in these regions can cause excess soil to come in contact with melons (34). Many retailers require that gross soil be removed from produce prior to receipt, necessitating a wash step before packaging.
Once contaminated, cantaloupe is capable of harboring and promoting the growth of *L. monocytogenes*, which has been shown in a variety of studies (8). Fresh cut cantaloupe inoculated with a blend of four strains of *L. monocytogenes* and were stored at temperatures ranging from 4°C to 25°C over the course of a week. The results showed that *L. monocytogenes* can grow in fresh-cut cantaloupe, even at refrigerator temperatures, with faster growth occurring at higher temperatures. A mathematical model was produced with this data, predicting that a 1 log CFU/g increase in *L. monocytogenes* could be expected in 6 days at 4°C (8). Similar studies have been conducted modeling the growth of *Salmonella* and *Escherichia coli* O157:H7. These studies found that *Salmonella* can rapidly grow at room temperature and can reach high concentrations before visual spoilage occurs (22).

**Retail Food Safety**

Little research has been done to quantify the exact amount of foodborne illness that originates at grocery stores (36). However, prepared salads, including fresh-fruit salads have been estimated to be responsible for 4% of all cases of infectious intestinal disease (23). Grocery stores have been shown harbor foodborne pathogens, including *L. monocytogenes* (35). The pathways through which *L. monocytogenes* is introduced into grocery stores is difficult to pinpoint, as there are many potential contamination routes. Experts believe that direct contact and contamination may occur between floors, drains and food contact surfaces from the outside environment through cart wheels and shoes (17, 18). Once introduced *L. monocytogenes* has the ability to establish itself, resisting normal sanitation practices (7).
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CHAPTER TWO

Control of Cross-Contamination During Retail Handling of Cantaloupe

INTRODUCTION

The consumption of fresh produce has increased in the United States in recent decades in part due to the increased accessibility to seasonal produce from foreign markets as well as recommendations from public health programs raising awareness of the benefits of consuming a diet with higher levels of fresh fruits and vegetables (10, 45). While fresh produce was implicated in only 2 percent of foodborne illness outbreaks between 1973 and 1987 it is estimated to have caused 45.9 percent of outbreaks between 1998 and 2008, with the median size of the outbreaks doubling (23, 29, 40).

Cantaloupes have previously been implicated in outbreaks of foodborne illness and were responsible for 56% of melon-related outbreaks between 1973 and 2011. One notable outbreak of *Listeria monocytogenes* occurred in 2011 and spanned 28 states, resulted in 147 illnesses, and 33 fatalities. The subsequent US Food and Drug Administration investigation found that *L. monocytogenes* was harbored in packing equipment and allowed for the cross-contamination cantaloupes processed in that facility.

Research into the control of *L. monocytogenes* has predominately been focused on limiting contamination of products during post-harvest handling and processing (36). While this research into post-harvest processing has given processors better tools to control *L. monocytogenes* in their facilities, there has been comparatively less research examining the presence of *L. monocytogenes* in retail environments (36). What studies have been conducted have shown that *L. monocytogenes* can be found throughout the retail environment on a multitude of surfaces. The variety of surfaces where *L. monocytogenes* can be found suggests
that cross-contamination can occur at retail and can subsequently be dispersed throughout the environment and on to food contact surfaces (35, 36). Once spread throughout the environment, \textit{L. monocytogenes} has demonstrated the ability to grow on a variety of surfaces that can be found at retail and to transfer from surfaces to food (33). Additionally, \textit{L. monocytogenes} possesses the ability to form biofilms (21). These biofilms have been shown to be more difficult to remove with standard sanitation procedures, and once a biofilm has formed, it is able to shed cells into the environment (33). The same subtypes of \textit{L. monocytogenes} species have been able to be recovered at retail over long periods of time. However, it is difficult to discern whether or these subtypes are residential or if they are repeatedly removed and reintroduced due to iterative environmental contamination associated with grocery stores (36). Initial sources of contamination can be difficult to identify, for example \textit{L. monocytogenes} has been recovered from grocery cart wheels as well as consumers’ shoes and could potentially bring \textit{L. monocytogenes} into the grocery environment (13, 16, 37). Few studies examined contact surfaces and cross-contamination risks of cantaloupe at retail. Additionally, little is known about the sanitation procedures these surfaces undergo and whether or not they are effective. This study seeks to change that by identifying contact surfaces and sanitation protocols associated with the display of whole cantaloupes in a retail setting. Through environmental sampling it will be possible to determine which surfaces are more prone to harboring bacteria, particularly \textit{Listeria} species, and determine the efficacy of current sanitation procedures.

\textbf{MATERIALS AND METHODS}

\textbf{Retailer Identification and Recruitment.} Retail partners for this study were identified based on sales volume, the direct sale of whole cantaloupe to consumers, and
existing partnerships with project team members. Once identified for potential involvement in the study, representatives from each retailer and project team members met to discuss the scope of the study as well as a swabbing and scheduling plan.

**Surface Identification/Determination.** Project team members systematically followed the flow of cantaloupes from initial unloading from supply trucks and ending at display on the retail floor at five locations per retail partner. This approach was employed to catalogue all potential cantaloupe contact surfaces. Each surface, whether used repeatedly such as display cases, or those considered disposable, such as gloves, were catalogued and information on material (pertinent to the cleaning and sanitizing of the surface) recorded.

**Sanitation Protocol Identification/Determination.** After all contact surfaces associated with whole cantaloupes were cataloged, sanitation protocols were collected from each retail partner specific to each surface, including frequency, and compounds used. The sanitation standard operating procedures (SSOPs) of Retail Partner 1 (RP1) were determined by referencing a manual of established SSOPs distributed to all the stores of RP1. Some cataloged surfaces did not have a sanitation protocol outlined in the SSOP manual. The sanitation procedures of these surfaces were determined through verbal confirmation with produce associates and managers who confirmed common sanitation protocols. Researchers were not given access to the sanitation manual at Retail Partner 2 (RP2), SOPs of RP2 were identified through verbal confirmation with a Produce Director.

**Time point Identification/Determination.** Time points were chosen after cataloging SSOPs and were designed to capture any *Listeria* species prevalence and microbial populations that may vary throughout the day and respond to any sanitation steps. The first and fourth time points were determined based off of the operation schedule at RP1, which
began operations at 5:00AM and ceased around 10:00PM. Time point 1 occurred before operations, while time point 4 took place shortly before the end of operations. Time points two and three were chosen based off of sanitation schedules used in the cut produce department. This schedule called for a complete sanitation after fresh cut fruit preparation was finished, usually between 11:00AM and 2:00PM. Time point 2 occurred approximately 30 minutes before this sanitation procedure and time point 3 occurred approximately 30 minutes after the sanitation procedure. These time points were chosen to examine the efficacy of the sanitation steps used in fresh cut preparation, as the sanitation process was much more thorough and involved RTE foods. RP2 was open 24 hours a day and did not have a sanitation protocol outlined for whole melon display. Five time points were chosen at RP2 at times and intervals similar to RP1. An additional time point was added to the schedule of RP2 due to a surplus of swabs and the overestimation of surface types by researchers. In addition to capturing any response to sanitation steps, the microbial population of surfaces may change over time due to consumer handling and possible restocking.

**Environmental Sampling.** In order to ensure that the area sampled remained at a constant size throughout the study, three 10 cm by 10cm square plastic templates were created. For flat, hard surfaces, a polylactic acid template was 3D printed using a LulzBot Mini (Lulzbot, Loveland, CO). For rounded or curved surfaces, two plastic templates were made by sealing empty plastic lamination sheets together and then removing the 10cm by 10cm square with a knife. Samples were collected using 3M Sponge Stick swabs moistened with Dey-Engley neutralizing broth (3M, Twin Harbors, Minnesota). Sampling procedures varied slightly for each surface due to the varying shapes and material but were kept in a
consistent order at each location. The majority of environmental samples were taken from the horizontal cross-section of surfaces. However, some samples were taken from the vertical cross-section if the horizontal cross-section could not be accessed. This vertical sampling practice was more common with the display barriers of RP1 as well as the wood and RPCs of RP2. The order in which samples were taken was kept the same at each location across the different time points.

After each surface was sampled, the template used in sampling was sanitized with either 91% isopropyl alcohol (Kmart, Hoffman Estates, IL) or 200 proof ethanol (DLI, King of Prussia, PA). The sanitizer was applied to the template using a spray bottle and then wiped with a paper towel saturated in the sanitizer before being allowed to air dry before using on the next surface. If visible soil was present it was removed with a paper towel prior to sanitization.

**Shipping.** Samples were individually placed in re-sealable plastic bags, given a code and placed in a cooler with gel ice packs. Samples collected at RP1 were double blinded so researchers could analyze sample surface and time points while specific store locations would remain anonymous. This double blinding was not used at RP2. Instead, samples were given a number that corresponded to a specific store location, surface, and time point. The cooler was then sealed and shipped to collaborators for processing.

**Plating.** Swabs were processed and plated to quantify total aerobic, coliform and *Escherichia coli* as well as test for the presence of *Listeria* species and *L. monocytogenes*. First, 50mL of peptone broth was added to the sponge stick swab and placed in a paddle blender for one minute to homogenize samples for plating. Blended peptone broth was plated at .25, 0, and 10⁻¹ concentrations on tryptic soy agar using the spread plate technique. For the
.25 concentrations, .25mL of peptone broth was plated on four TSA plates, giving a total volume of 1mL plated. To determine the presence of *Listeria* species as well as *L. monocytogenes*, 50mL of double strength buffered *Listeria* enrichment broth was added to the remaining peptone broth and incubated at 30°C for 4 hours. Following this incubation 360mL of *Listeria* selective enrichment supplement was added to the mixture and incubated at 30°C for 20 hours. For *Listeria* species determination 50μL of the broth was plated on to Modified Oxford Agar using a spread plate technique and incubated at 30°C for 48 hours the plates were then removed from the incubator and examined for colonies. The plates were then returned to the incubator and incubated at 30°C for another 48 hours before being examined for colonies a second time. *Listeria monocytogenes* plating medium was used to identify the presence of *L. monocytogenes*. 50μL of the enriched broth were streaked onto the LMPM plates which were allowed to incubate at 35°C for 48 hours. The plates were then removed and examined for prevalence, and were then returned to the incubator for 48 hours, this time at 35°C. The plates were then removed from the incubator and reexamined for prevalence. All quantitative microbial tests were plated in triplicate.

**Data Analysis.** Statistical analysis was performed using SAS Studio (SAS Institute Inc., Cary, NC) using Tukey’s honest significant difference (HSD) test. A p-value of less than or equal to 0.05 was used to determine statistical significance.

**RESULTS**

**Surfaces Identified.** Thirteen contact surfaces associated with whole melon display and fresh-cut preparation were identified across both retail chains for further study. Several contact surfaces, such as the cardboard shipping containers, gloves, and packaging were only used once prior to disposal or recycling and were not chosen for further study. Seven surfaces...
were chosen for environmental sampling from RP1: wash sinks used to wash melons prior to cutting, knives and cutting boards used to prepare fresh-cut produce, plastic lugs used to transport melons throughout the produce production area, drying racks used to dry produce after washing, foam padding used to cushion whole melons in angled display cases, and the front and side materials used to contain the melons in the display bin. Six surfaces were chosen from RP2: corrugated plastic board, plastic mesh, expanded polystyrene fruit cups, which were all used to cushion whole cantaloupes, as well as plastic carts, reusable plastic containers (RPCs), and various wood sides used in many displays. The angled display cases of RP1 as well as the corrugated plastic, mesh, expanded polystyrene fruit cups, RPCs, and wood found in RP2 were all located on the retail floor (Table 1). These surfaces were grouped together based on contact time with cantaloupe, sanitation schedule, and use. Surfaces were grouped into three groups, base surfaces, perimeter surfaces, and transport surfaces (Table 1).

Following the confirmation of contact surfaces individual stores were chosen for sampling. Collaborators from RP1 permitted five locations to be sampled. Three stores were chosen in the Raleigh metropolitan area due to proximity to NC State, one store located in the Charlotte metropolitan area, and one store in the Asheville area. The Food Safety Retail Specialist then contacted store managers to inform them of the scope of the study and to inform them of their involvement. After being informed by the Food Safety Retail Specialist stores were again contacted to identify the cleaning schedules and approximate times of each store. Collaborators from RP2 permitted five locations to be samples, all located in the New York area. A Produce Director informed all stores of the sampling procedures and time points and assisted researchers in locating necessary surfaces.
Sanitation Procedures Identified. Stainless steel wash sinks used at RP1 to wash produce prior to cutting were found to be cleaned once per day during a mid-day cleaning in which the produce preparation area, used for fresh-cut produce, was cleaned and sanitized. For the sinks this cleaning procedure involved washing with a mild detergent used in the deli area. This was followed by the use of a crème cleanser designed to remove any mineral deposits. The sinks would then be sanitized using a quaternary ammonium-based sanitizer. Finally, the sinks would be rubbed with mineral oil to prevent the formation of rust.

Cutting boards were cleaned daily during the mid-day cleaning. As a part of this mid-day cleaning the cutting boards were cleaned in a three-basin wash sink. During this cleaning step, loose soil was first removed through brushing, this was then followed by brush scrubbing with a mild deli detergent. Detergent was then removed from the cutting board using hot water. If the cutting boards were stained or discolored following cleaning they would be bleached using a block whitener. Following whitening, the cutting boards would then be sanitized using a quaternary ammonia-based spray sanitizer and then allowed to air dry on a rack located in the produce cut room.

Knives were cleaned and sanitized in a similar manner to the cutting boards. Knives were washed in a three-basin sink with a mild detergent before. The knives were then rinsed and finally sanitized in a wash basin filled with a pre-measured amount of quaternary ammonium-based sanitizer. Knives were then placed in a tray designed to secure the blades and were air dried until the following morning.

Drying racks were cleaned once per week. Racks were first removed of any products and wiped down to remove gross debris. Racks were then rolled into the produce preparation room and sprayed with a high-concentration quaternary-ammonium based, foaming ovicidal
treatment and sanitizer. The racks were then manually scrubbed and allowed to sit for 15 minutes, exceeding the manufacturer’s recommended contact time of 5 minutes. The racks were then thoroughly rinsed and sanitized using a quaternary-ammonium based sanitizer.

Transport lugs used by RP1 to move produce were found to be cleaned once per day, during the mid-day cleaning with a procedure similar to that used on the drying racks. These lugs were sprayed with a foaming ovacidal cleaning and sanitizing agent before being manually scrubbed and rinsed thoroughly. The lugs were then wiped with quaternary ammonium-based sanitizing wipes.

Similarly, the transport carts used at RP1 were found to be cleaned and sanitized once a day, usually in the evenings. Carts were first sprayed with water and scrubbed with a mild detergent before being sprayed and wiped with a quaternary ammonium-based sanitizer.

All other surfaces, those used to display and contain whole cantaloupes, were not found to have a specific sanitation protocol outlined in either the SSOPs or by partner employees. At both retail partners, these surfaces were described as being cleaned “as needed”, when visibly dirty or if melons had leaked onto any of the surfaces. This “as needed” cleaning was found to be rarely performed. Surface sanitation occurred quarterly during “resets” when produce locations would change throughout the department. During these “resets” removable surfaces, the foam, corrugated plastic, mesh, and expanded polystyrene fruit cups would be discarded and replaced if needed.

**Listeria species and Listeria monocytogenes.** In total, 333 swabs were taken from each surface across all time points and locations. Eleven of the thirteen surfaces showed prevalence for *Listeria* species in at least one of these time points. Cutting boards and knives had the lowest prevalence, with no swabs showing prevalence. Two swabs (8%) from the
plastic carts showed *Listeria* species prevalence. RPCs showed presence for *Listeria* species five times (16.7%). Wash sinks showed prevalence in four (21.1%) of the samples. Wood siding of display cases tested showed prevalence for *Listeria* species six times (24%). Drying racks showed prevalence in six samples (31.6%). Transport lugs showed prevalence five times (26.3%). Mesh samples showed prevalence for *Listeria* species 12 times (30%). The expanded polystyrene fruit cups used on the retail floor displayed prevalence 21 times (46.7%). The sides of the angled display cases had nine (47.4%) samples that showed prevalence. Corrugated plastic sheeting displayed prevalence for *Listeria* species in 19 (54.3%) of samples. Lastly, all of the 19 foam samples (100%) showed prevalence for *Listeria* species. One sample, taken from mesh, showed the presence of *L. monocytogenes*.

Of the 333 total swabs taken, 75 were taken at time point 1, 68 were taken at time point 2, 75 were taken at time point 3, 75 were taken at time point 4, and 40 were taken at time point 5. Twenty-four of the swabs taken at time point 1, (32.0%) showed prevalence for *Listeria* species. The number of samples showing prevalence increased to 24 (46.4%) for swabs taken at time point 2. For samples taken at time point 3, 27 (36%) displayed prevalence. At time point 4, 20 (26.7%) of the swabs taken showed prevalence. Lastly, 24 (60%) of samples displayed prevalence for *Listeria* species.

**Total Aerobic and Coliform Counts.** Corrugated plastic had the highest aerobic and coliform counts, with means of 1.9x10^6 and 6.3x10^3, respectively. Expanded polystyrene fruit cups had the second highest aerobic and coliform counts, with means of 8.5x10^5 and 4.4x10^4, respectively. Cushioning foam had the third highest aerobic and coliform counts with means of 1.7x10^5 and 2.0x10^3, respectively. Plastic transport carts had the fourth highest aerobic count, with a mean of 1.7x10^5 and the fifth highest coliform counts, with a mean of
1.3x10^3. RPCs had the fifth highest aerobic count with a mean of 7.8x10^4 and the sixth highest coliform counts, with a mean of 7.9x10^2. Wood barriers had the sixth highest aerobic counts, with a mean of 7.7x10^4 and fourth highest coliform counts with a mean of 1.8x10^3. Mesh had the seventh highest aerobic and coliform counts, with means of 6.3x10^4 and 1.5x10^2, respectively. Display barriers had the eighth highest aerobic and coliform counts with means of 2.5x10^3 and 3.0x10^1, respectively. Transport lugs had the ninth highest aerobic counts with a mean of 7.9x10^2 and the seventh highest coliform count with a mean of 1.5x10^2. Drying racks had the tenth highest aerobic count with a mean of 5.0x10^2 and the ninth highest coliform counts with a mean of 1.7x10^1. Wash sinks had the eleventh highest aerobic count, with a mean of 1.7x10^2 and the lowest coliform count, with a mean of 1.9x10^0. Cutting boards had the twelfth highest aerobic count, with a mean of 3.3x10^1 and the eleventh highest coliform counts with a mean of 2.7x10^0. Lastly knives had the lowest aerobic count with a mean of 1.9x10^1 and the twelfth highest coliform counts with a count of 2.1x10^0.

**DISCUSSION**

The results show that *Listeria* species are capable of being found in a variety of contact surfaces associated with cantaloupe in retail environments. Eleven of the 13 surfaces showed the presence of *Listeria* species on MOX agar at least once in at least one retail location. As expected, surfaces that were cleaned daily had lower of *Listeria* prevalence, lower coliform counts, and lower total aerobic counts when compared to surfaces that were cleaned less frequently or not cleaned at all. Across the thirteen surfaces cataloged at RP1 and RP2, four usage patterns were identified, fresh-cut surfaces, base surfaces, perimeter surfaces, and transport surfaces. Fresh-cut surfaces were used in the preparation of fresh-cut
fruit. These surfaces were found to be subjected to sanitation on a regular basis, with the majority being cleaned and sanitized daily. Base surfaces were used to support or cushion the cantaloupe. These surfaces were generally kept in constant contact with cantaloupe and were oriented on a horizontal, or nearly horizontal axis. Perimeter surfaces, surfaces that acted as a barrier were used to contain melons or contain the cushioning material were also found. These barriers had less contact with the melons than the cushioning surfaces and were normally oriented at a vertical, or nearly vertical axis. Lastly, transport surfaces associated with transport of cantaloupe were identified. These surfaces were found to have the least amount of contact time with cantaloupe and were most likely to be used with a variety of produce besides cantaloupe.

**Fresh-cut Surfaces.** Four different surfaces were found to be associated with the production of fresh-cut melons, wash sinks, cutting boards, knives, and drying racks. All surfaces were used exclusively at RP1, as the fresh-cut production facilities at RP2 were not accessible to researchers. However, some surfaces, such as the wash sinks, cutting boards, and knives, were present at RP2.

Wash sinks were used at all of the retail facilities to clean the surface of fresh fruit destined for fresh-cut sales. A variety of fruits were used in the sinks, including cantaloupe, pineapple, watermelon, honeydew, and grapes. At the beginning of operations, approximately two hours before the opening of the store, produce associates would begin preparing fresh-cut fruit by washing the fruit that would be used the following day. Wash sinks have been shown to harbor *L. monocytogenes* in retail delis and have higher levels of aerobic bacteria when compared to other surfaces like cutting boards and scales in produce plants (20, 36). Cutting boards used by this retail chain were composed of high-density
polyethylene and were used as a preparation surface on which to cut the washed produce bound for use in fresh-cut sales. Like the wash sinks they were used in conjunction with several different types of fruit including cantaloupe, pineapple, honeydew, watermelon, and grapes. L. monocytogenes has been shown to be harbored in cutting boards and has the ability to attach to polyethylene (4, 14). Knives used in these retail stores were made with a stainless-steel blade fitting into a polypropylene handle. A variety of knife shapes would be used, according to the type of fruit and cut style desired. Fresh cut cantaloupe was offered in a variety of forms, including quarters and halves, which had the rind still attached, and cubes, in which the rind was removed prior to packaging. Knives and cutting boards would contact the same types of fruits, including cantaloupe, pineapple, honeydew, watermelon, and grapes. Listeria has been able to be recovered from knives in food processing facilities and both the knife handle and knife blade have been shown to sustain aerobic bacterial growth. Additionally, knives have been shown to be a potential pathway for cross-contamination, carrying pathogens from the rind of the cantaloupe into the fruit (22, 44). Drying racks were used to dry and store washed produce after washing in the produce wash sinks. These racks were made of stainless steel tubes welded together to securely hold produce while allowing water to drain and air to circulate. Racks were kept in the produce walk-in refrigerator and kept below 41°F. These racks were used for larger fruit that required longer drying times before being cut, including cantaloupe, honeydew, watermelon, and pineapple. Although the drying racks appeared to be made with sanitary welds, the racks did possess sharp corners throughout the structure. Sharp corners, and increased the roughness that can accompany welded areas can be more prone to harboring bacterial colonies (42). Furthermore, some
strains of *Listeria monocytogenes* have shown the ability to form biofilms and resist sanitization procedures on stainless steel surfaces (34).

A thorough sanitation schedule was made available at RP1 for fresh-cut surfaces. Wash sinks were found to be washed, rinsed and sanitized before being wiped with mineral oil. However, after this cleaning procedure, which occurred during the middle of the day, the sinks could be used to wash other produce including leafy greens. The sink would then sit unused after this washing procedure until the following morning when fruit would be washed before being cut. The bottoms of the sinks were sloped downward to promote the drainage of water. However, some water could collect, particularly around the sink-drain junction.

Cutting boards and knives were both cleaned in a three-basin wash sink. This cleaning step involved washing with a detergent and scrubbing with a plastic brush. Boards and knives were then rinsed in warm water and immersed in a quaternary ammonium-based sanitizer that was automatically diluted into a separate compartment of the sink. Knives and boards were then allowed to air dry and were unused until the following day. Drying racks were cleaned weekly, the least frequently of any fresh-cut surfaces. This process involved spraying the entire rack with a cleaning and sanitizing foam and scrubbing before rinsing and allowing to dry.

Fresh-cut surfaces displayed the lowest prevalence of all surfaces, with ten of 76 samples (11.8%) showing the presence of *Listeria* species. Four of the 19 samples taken from the wash sink showed prevalence of *Listeria* species. Samples were collected from an area including the sink-drain junction, which several niches that could potentially be difficult to clean and sanitize. *L. monocytogenes* has previously been found in produce wash sinks (3). *Listeria* prevalence varied throughout the day, suggesting that species found could be
transient and repeatedly reintroduced instead of harbored. The addition of mineral oil at the end of the sanitation step could potentially serve as a pathway to introduce *L. monocytogenes*, as it has been linked to outbreaks of listeriosis (38). Furthermore, the use of mineral oil as a means of could potentially reduce the efficacy of sanitizing agents (12).

Knives and cutting boards were the only surfaces with no *Listeria* species prevalence. This was surprising as a portion of the samples were taken shortly after the cutting boards and knives were used and were visibly dirty. This low prevalence could potentially be explained by the short contact time and change in sanitation procedures compared to other fresh-cut surfaces. Wash sinks and drying racks could be kept in direct contact with cantaloupe for upwards of an hour. This contrasts with knives and cutting boards, where individual produce would only remain in contact until cutting was finished, which would take a few minutes or less, depending on the produce associate cutting, below the demonstrated adherence time (24). The cutting boards and knives had the most thorough sanitation protocols of all surfaces and were the only surfaces that were able to be cleaned using discrete wash, rinse, and sanitize steps in a three-basin sink. This sanitation procedure included manual scrubbing, which has shown to be an effective way of cleaning and removing biofilms (9, 15).

Additionally, cutting boards were occasionally bleached using a block whitener to maintain white appearance. This block whitener contained sodium hydroxide, which has been demonstrated to have listeriostatic effects. Drying racks displayed the highest prevalence of fresh-cut surfaces, with six (31.6%) of samples showing prevalence. This higher prevalence could potentially be due to the less frequent sanitation, as drying racks were only cleaned once per week. Drying racks also had the longest contact time of all fresh-cut surfaces. After being placed on the drying rack, cantaloupes would be dried for approximately 24 hours.
This is well within the amount of time required for *L. monocytogenes* to attach to steel (25). Along with having more stringent sanitation procedures, fresh-cut surfaces may have been in contact with melons with a lower initial microbial load when compared to when compared to base and perimeter surfaces. Produce associates were advised to discard bruised or damaged melons and not use them for fresh-cut consumption. Bruised and damaged melons have been shown to have higher microbial loads than intact melons and can be more likely to harbor pathogens (7).

**Base Surfaces.** Four different types of base surfaces were identified between RP1 and RP2, foam, corrugated plastic, mesh, and expanded polystyrene fruit cups. Foam was used exclusively as the base surface at RP1, while corrugated plastic, mesh, and expanded polystyrene fruit cups were used at RP2, with multiple types being used in each store.

Foam padding used at RP1 served to protect cantaloupe from damage and bruising during display and stacking. The foam was approximately ½ inch thick and was composed of a porous acrylonitrile butadiene styrene finished with a smooth layer on both the top and bottom the foam. Foam was only used with whole cantaloupe display and was placed between cantaloupe and the surface of wood display boards. Little research has been conducted on the use of acrylonitrile butadiene styrene in food processing environments but previous studies in the medical field have shown that it can to promote the growth of bacteria (6). Corrugated plastic sheets used by RP2 and were composed of two extruded polypropylene sheets with fluting between sheets. This fluting was designed to provide a limited amount of cushioning to any produce displayed above. These sheets were approximately 1/8 inch thick. Corrugated plastic sheets were said to be favored as the smooth, solid surface made it easier to clean and sanitize. *L. monocytogenes* has been
demonstrated the ability to adhere to polypropylene surfaces after two hours of contact time, far shorter than the expected contact time between cantaloupe and plastic sheets (39). The use of mesh consisted of plastic mesh netting layered on top of the plywood surface of retail displays. This mesh acted as a method to reduce direct contact between plywood and the cantaloupe but did little to provide any cushioning to produce placed on top of it. These sheets were likely composed of polypropylene and were approximately 1/32\textsuperscript{nd} of an inch thick, with several layers stacked on top of each other. Mesh would be attached to the underlying plywood with a metal screw. Expanded polystyrene fruit cups were used in whole melon display and served as a method to cushion displayed fruit. These cups were made of polystyrene sheets approximately 1/8\textsuperscript{th} of an inch thick and molded into an egg crate pattern approximately 3 inches in height. Fruit cups were initially used in the handling of small fruits, such as apples or pears, to prevent damage during shipping. These cups would then be reused throughout the produce department to display whole.

An explicit sanitation schedule was not outlined for any of the base surfaces at both RP1 and RP2 and instead were said to be cleaned on an “as-needed” basis. This “as-needed” cleaning was regarded as when displays became visibly soiled, however the point at which cleaning was necessary was not stated. The only regular sanitation procedures found occurred during quarterly resets. During these quarterly resets, worn or soiled surfaces were replaced and produce displays were moved throughout the department. At RP1, one employee stated that foam pads were cleaned nightly to remove loose debris from the display case however this was not corroborated by produce associates, who again claimed that loose debris was removed on an as-needed basis. Foam pads would be replaced when worn and cushioning ability was lost, parameters for wear, cushioning ability, or a replacement
schedule were not found in SSOPs. The mesh used at RP2 was affixed to the plywood of the display stand, making it difficult to clean and sanitize individual layers of mesh and virtually impossible to clean and sanitize plywood without removing screws and disassembling the display. Fruit cups were more fragile than many other surfaces and were prone to cracking and chipping during regular use and were therefore more frequently discarded than other surfaces. Produce associates stated that the length of use for these cups could vary but could be replaced several times a week if necessary. This more frequent replacement would reduce the number of cantaloupes coming in contact with a specific fruit cup but would still allow sufficient time for biofilm development (32). Researchers found that many underlying fruit cups had dried plant debris or other gross soil, suggesting that fruit cups contamination can penetrate several layers of fruit cups, or that fruit cups are not sanitary when first placed on display.

Base surfaces showed a presence of *Listeria* species on 73 of the 165 samples taken (44.2%). One sample taken from mesh, showed the presence of *L. monocytogenes*. This prevalence was higher than the fresh-cut, perimeter, and transport surfaces. As none of the base surfaces were subjected to any cleaning and sanitizing procedures during any of the time points, it cannot be determined whether these surfaces can serve as a harborage site for *Listeria* species or if the results indicate a buildup of transient *Listeria* species resulting from infrequent cleaning. All of the 19 samples taken from the foam padding displayed presence of *Listeria* species, the highest prevalence rates of any surface. The foam padding was made of porous material, which has been shown to resist the removal of *Listeria* species (26). Additionally, the quarterly sanitization procedure of wiping the foam padding with a quaternary ammonium-based wipe may have reduced efficacy due to the absence of a
cleaning procedure preceding the use of sanitizing wipes (17). Despite the smoother surface and being considered easiest to clean compared of all whole melon surfaces used at RP2, 19 of the 35 samples taken from the corrugate plastic showed prevalence for *Listeria* species, the second highest prevalence of *Listeria* species of all other surfaces. Additionally, the corrugated plastic sheets had the highest aerobic count and was significantly higher than all surfaces except expanded polystyrene fruit cups. The higher aerobic and coliform counts could potentially be caused by the fact that plastic sheets were more likely to be reused than other surfaces at RP2. While mesh and expanded polystyrene fruit cups would be disposed of during resets, corrugated foam was able to be cleaned and reused. Additionally, the infrequency of cleaning and sanitizing could lead to reduced efficacy of *Listeria* species to be removed using quaternary ammonium (46). The corrugated plastic sheeting also appeared to be the least permeable of the surfaces used for whole melon display. This impermeability increases the efficacy of any sanitizers used on the surface when compared to more permeable surfaces but would cause any pulp or juices that were leaked onto the sheet to pool and dry. Even after drying, foodborne pathogens have been shown to be transferable and pose a contamination hazard on less permeable contact surfaces (19). Twelve of the 40 samples taken from mesh showed prevalence for *Listeria* species. The exact type of plastic used in the mesh could not be determined however *Listeria* species have been shown to be able to grow and form biofilms on wood surfaces, which were found underneath mesh layers (1). *Listeria* species prevalence associated with mesh was lower than both the expanded polystyrene fruit cups and the corrugated plastic sheeting. This was surprising due to the similar sanitation procedures applied to all three surfaces at RP2. It is possible that the open cells in the mesh would allow any juice or leakage from cantaloupes to leak down into the
plywood away from the cantaloupes themselves. This could potentially reduce the contact between melons and loose juice or pulp, which has been shown to promote the growth of *L. monocytogenes* (31). Fruit cups had the fourth highest prevalence of *Listeria* species, with 21 of 45 samples testing exhibiting prevalence, the third highest of all surfaces. This high prevalence was not surprising due to the infrequent cleaning as well as the shape and porousness of the polystyrene. The egg carton shape of the fruit cups provided harder to access areas and was more challenging to clean than other surfaces. Additionally *L. monocytogenes* has demonstrated the ability to grow on polystyrene and is more resistant to quaternary ammonium based sanitizers than less porous surfaces such as stainless steel (32).

**Perimeter Surfaces.** Three different types of perimeter surfaces were found at RP1 and RP2: display barriers, which were made of either acrylic or laminated wood and used at RP1, reusable plastic containers (RPCs), and wood panels, both used at RP2. These surfaces were designed to contain cantaloupe and provide support for the base surfaces.

Whole cantaloupe display boards used at RP1 were made of a variety of surfaces depending on the store and location within the produce area including acrylic, laminated plastic, or wood. These barriers served to keep the cantaloupes contained within the display board, preventing them from mixing with other produce displayed nearby. Depending on the type of display board used, these barriers could form sharp angles at intersection points, which could decrease the effectiveness of cleaning and acrylic surfaces are less prone to promote the formation of biofilms when compared to surfaces such as stainless steel or wood, but are still capable of harboring bacteria (27). Reusable Plastic Containers (RPCs) are used across the produce industry to transport produce throughout the supply chain. These containers can be used in place of cardboard boxes, which are not designed for reuse. RPCs
were used by RP2 to display whole cantaloupes by providing support and containing the expanded polystyrene fruit cups. RPCs functioned in a similar method as the display barriers at RP1, containing produce in the display and separating different produce types. As such, there was limited contact between RPCs and cantaloupe when compared to expanded polystyrene fruit cups. Wood found at RP2 was predominantly used to contain produce in specified bins and support any cushioning surface that produce would be placed on, similar to how RPCs were used. Wood was found to be used in conjunction with both mesh surfaces and corrugated plastic.

Perimeter surfaces were found to have the same sanitation schedules as the base surfaces, as needed or during the quarterly resets. One key difference between base and some transport surfaces existed, the display barrier at RP1 and the wood used at RP2 were permanently attached to the display and could not be replaced. These surfaces fully relied on sanitation practices to reduce bacterial populations. The RPCs of RP2 were not permanently fixed to any surfaces and could be disassembled for easier sanitation or replaced as needed. Display barriers at RP1 were cleaned along with the foam padding on a quarterly schedule, when displays would be reorganized or moved to other areas of the produce department. Loose debris would be removed on an as-needed basis, however since the display barriers were often at a vertical or near-vertical orientation they were less likely to accumulate loose debris. Sampling of RPCs concentrated on the bottom or interior sides. These sections were unlikely to be frequently cleaned or sanitized due to the large quantity of items placed inside. However, these portions of the RPCs were unlikely to have frequent contact with cantaloupe due to the large amount of expanded polystyrene fruit cups placed inside. Despite this, the RPCs were found to have visual soil, such as plant debris, on the sides and bottoms. If this
debris contained pieces of cantaloupe rind, it could potentially be a source of *Listeria* species, as cantaloupe rind has been shown to be able to harbor *L. monocytogenes* for up to 15 days (43).

Nine of the 19 samples taken from display barriers at RP1 showed prevalence of *Listeria* species, the second highest of all surfaces, with no samples showing prevalence for *L. monocytogenes*. While this higher level was expected, the disparity between the prevalence of the foam padding and the display barrier was surprising, given that both surfaces have approximately the same cleaning schedule. This could potentially be due to the reduced contact between cantaloupes and the display barriers then the foam padding as the number of cantaloupe contacting the barriers would vary depending on the capacity and number of melons placed in the display case. It could also reflect the differences in material used between the two surfaces. Acrylic plastic is much easier to clean and sanitize and less likely to act as a harborage site for bacteria. As with the foam padding, it is difficult to tell whether the barriers act as a harborage site for *Listeria* species or are simply a buildup of transient bacteria as the barriers were not cleaned during any time points. Of the 30 samples taken from RPCs, five showed prevalence for *Listeria* species. The prevalence of the *Listeria* species was comparatively lower than the display barriers at RP1, despite the fact that both functioned in a similar manner. This discrepancy in prevalence could potentially be caused by the prevalence of *Listeria* species on the adjacent surfaces. At RP1, the display barriers were used in conjunction with foam, where 100% of all samples showed prevalence. Conversely, RPCs at RP2 were adjacent to expanded polystyrene fruit cups, which had a *Listeria* species prevalence of only 46.7%. The material of the RPCs was not determined but was likely composed of polyethylene or polypropylene, both of which have been shown to be
able to harbor bacteria \((24, 28)\). Despite having a lower \textit{Listeria} prevalence than the display barriers of RP1, the RPCs had a significantly higher aerobic count. Six of the 25 samples taken from the wood of RP2 showed the presence of \textit{Listeria} species. This prevalence was comparatively lower than the display barriers used at RP1, despite some of the barriers used at RP1 being made of similar materials. This could potentially be caused by the differences in prevalence of adjacent surfaces. \textit{Listeria} prevalence of wood was comparatively higher than the RPCs. This was surprising as bacteria has been shown to be less likely recovered from wood surfaces than plastic surfaces \((2)\).

**Transport Surfaces.** Two different transport surfaces were found at RP1 and RP2. RP1 was found to use small plastic lugs, similar to those that would be used in meat production facilities. These lugs would be placed on top of metal carts to be moved throughout the store. RP2 used solid plastic carts and could place produce boxes directly on carts.

Transport lugs used in this retail establishment were composed of solid polypropylene plastic and were used to transport washed and unwashed melons between the walk-in refrigerator, the drying rack, and the produce wash sink. Lugs were used to transport a variety of fruit, including pineapple and other melons. Previous studies have been able to recover \textit{E. coli} from transport lugs in produce production facilities and have shown that \textit{L. monocytogenes} is able to attach to polypropylene plastics after contact times as short as 20 minutes, which is well within the expected contact time between cantaloupes and the transport lugs. Transport carts were used to transport a variety of carts from unrefrigerated produce holding areas onto the retail floor. These carts were made of polyethylene and were equipped two shelves and wheels coated in a rubbery substance. Carts were stored off of the
retail floor, near the unloading area when not in use. The amount of contact between transport carts and produce was variable depending on what produce was being restocked and the style of box used to contain the produce. Produce boxes would have varying sizes of holes in the side or bottoms of the box, this would allow for more produce to come in contact with carts.

Transport surfaces, like fresh-cut surfaces, had a regular cleaning schedule. At both RP1 and RP2, transport surfaces were cleaned daily. Transport lugs at RP1 were cleaned daily as a part of the mid-day cleaning but were subjected to a different cleaning procedure than the sinks or knives and cutting boards. As part of the cleaning procedure, transport lugs were first wiped to remove gross debris that could limit additional cleaning and sanitizing steps. The lugs were then cleaned with a foaming cleaning agent used throughout the rest of the produce preparation room. The lugs were then manually cleaned with scrub brushes before rinsing with water and being allowed to dry. Lugs were then sanitized with quaternary ammonium-based wipes. Transport lugs were occasionally used later in the day to move a variety of produce from the walk-in produce cooler out to the store floor. Use of the transport lugs would depend on the stock levels of produce at the store floor. Carts at RP2 were cleaned once per day, usually in the evening. This cleaning procedure consisted of a wash, rinse, sanitize procedure. The carts would be washed with a detergent and manually scrubbed with a brush. The carts would then be rinsed with potable water before being sprayed with a quaternary ammonium-based sanitizer.

Five of the 19 samples taken from the transport lugs tested showed presence for *Listeria* species, with no samples showing presence of *L. monocytogenes*. One sample showed the presence of *Listeria* species and was found before the start of operations. Leafy
greens were observed to be moved in the transport lugs on several instances after the mid-day cleaning, which have been shown to carry *Listeria* (11). Two samples from plastic transport carts showed the presence of *Listeria* species across 25 samples. This was the lowest prevalence of any surface, except knives and cutting boards. This low prevalence could potentially be caused by the more thorough sanitation protocols. The wash step included manual scrubbing, which has been shown to lower aerobic bacterial load and reduce *L. monocytogenes* (15, 41). The increase in sanitation frequency could also reduce the time for *Listeria* biofilms to develop (5, 46). However, *L. monocytogenes* has demonstrated the ability to adapt to repeated use of sanitizers, including quaternary ammonium compounds (30). In one of the facilities, a cleaned plastic cart was observed stacked on top of another recently cleaned plastic cart, with the wheels resting on the upper shelf of the underlying cart, where produce would be placed. This could potentially be a source for the introduction of *Listeria* species, which have been found on grocery cart wheels in retail settings as well as equipment wheels in processing plants (18, 36). This cross contact has been a focus in recent guidance from the Food and Drug for food manufacturing facilities, who have issued guidance promoting the use of hygienic zoning (8). Cross contact between surfaces that contact floors, such as cart wheels and a surface that may come in contact with produce would go against common hygienic zoning practices.

Stark differences existed between the sanitation protocols of the fresh-cut surfaces, base and perimeter surfaces and the transport surfaces. Fresh-cut surfaces had the lowest *Listeria* species prevalence, with nine of the 76 samples showing prevalence. This lower prevalence was likely due to the more frequent and more thorough sanitation practices. The majority of fresh cut surfaces were cleaned everyday with distinct wash, rinse, and sanitize
steps. This increased frequency would limit the amount of time available for *Listeria* species to buildup biofilms. The more thorough cleaning, which involved manual scrubbing, would help reduce the niches that could harbor *Listeria*. Base surfaces had the highest *Listeria* species prevalence of all surface groupings, with 73 of 164 samples showing prevalence for *Listeria* species. There are several factors that could lead to this prevalence, including contact time, orientation, surface materials, and sanitation protocol. Base surfaces had the highest contact time of all surface groupings, with surfaces contacting melons virtually at all times. Base surfaces were aligned at a horizontal or near horizontal orientation, parallel to the floor. This would allow soil and potential leakage from melons to pool. Base materials were often porous, or difficult to clean, prone to permitting the growth of *Listeria* species. Lastly sanitation protocols were found to be lacking. Base surfaces were only cleaned and sanitized once per quarter, during resets. Additionally, sanitation procedures consisted of wiping with a quaternary ammonium-based wipe or using quaternary ammonium containing spray. This procedure did not include a cleaning step to remove gross soil, which would decrease its efficacy. Perimeter surfaces had a lower prevalence for *Listeria* species, with 20 of 74 samples showing prevalence. This lower prevalence could potentially be caused by reduced contact time or orientation. Perimeter surfaces were only in contact with cantaloupes when displays were full and required a barrier to contain. Perimeter surfaces were also oriented at a vertical orientation, perpendicular to the floor. This would allow soil and moisture to drain away from the surface. Sanitation procedures were the same for both perimeter and base surfaces. Lastly transport surfaces had the lowest prevalence of all three groups, with 10 of 49 showing prevalence. These surfaces differed from base and perimeter surfaces, due to the reduction in contact time and more frequent sanitation procedures. Transport surfaces only
came in contact with cantaloupes during restocking, with contact being further limited by any boxes the cantaloupes were stored in. Transport surfaces were cleaned daily and included a cleaning and rinsing step prior to sanitization. This addition of a cleaning step would make for a more effective procedure.
Table 2.1 Microbiological contamination of cantaloupe contact surfaces in retail settings

<table>
<thead>
<tr>
<th>Surface</th>
<th>Grouping</th>
<th>n</th>
<th>Listeria spp. Presence/Absence (%)</th>
<th>Mean Log TAC</th>
<th>Tukey’s Grouping</th>
<th>Sanitation Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wash sinks</td>
<td>Fresh-cut surfaces</td>
<td>19</td>
<td>4 (21.1%)</td>
<td>2.23</td>
<td>DEF</td>
<td>Daily, at mid-day</td>
</tr>
<tr>
<td>Cutting boards</td>
<td>Fresh-cut surfaces</td>
<td>19</td>
<td>0 (0%)</td>
<td>1.52</td>
<td>EF</td>
<td>Daily, at mid-day</td>
</tr>
<tr>
<td>Knives</td>
<td>Fresh-cut surfaces</td>
<td>19</td>
<td>0 (0%)</td>
<td>1.31</td>
<td>F</td>
<td>Daily, at mid-day</td>
</tr>
<tr>
<td>Drying racks</td>
<td>Fresh-cut surfaces</td>
<td>19</td>
<td>6 (31.6%)</td>
<td>2.70</td>
<td>DE</td>
<td>Weekly</td>
</tr>
<tr>
<td>Corrugated plastic sheeting</td>
<td>Base surfaces</td>
<td>35</td>
<td>19 (54.3%)</td>
<td>6.29</td>
<td>A</td>
<td>Quarterly, or as needed</td>
</tr>
<tr>
<td>Mesh</td>
<td>Base surfaces</td>
<td>40</td>
<td>12 (30%)</td>
<td>4.61</td>
<td>C</td>
<td>Quarterly, or as needed</td>
</tr>
<tr>
<td>Polystyrene fruit cups</td>
<td>Base surfaces</td>
<td>45</td>
<td>21 (46.7%)</td>
<td>5.93</td>
<td>AB</td>
<td>Quarterly, or as needed</td>
</tr>
<tr>
<td>Cushioning foam</td>
<td>Base surfaces</td>
<td>19</td>
<td>19 (100%)</td>
<td>5.24</td>
<td>BC</td>
<td>Quarterly, or as needed</td>
</tr>
<tr>
<td>Reusable plastic containers</td>
<td>Perimeter surfaces</td>
<td>30</td>
<td>5 (16.7%)</td>
<td>4.89</td>
<td>C</td>
<td>Quarterly, or as needed</td>
</tr>
<tr>
<td>Wood</td>
<td>Perimeter surfaces</td>
<td>25</td>
<td>6 (24%)</td>
<td>4.8</td>
<td>C</td>
<td>Quarterly, or as needed</td>
</tr>
<tr>
<td>Display barrier</td>
<td>Perimeter surfaces</td>
<td>19</td>
<td>9 (47.4%)</td>
<td>3.39</td>
<td>D</td>
<td>Quarterly, or as needed</td>
</tr>
<tr>
<td>Transport lug</td>
<td>Transport surfaces</td>
<td>19</td>
<td>5 (26.3%)</td>
<td>2.90</td>
<td>D</td>
<td>Daily, at mid-day</td>
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<tr>
<td>Transport cart</td>
<td>Transport surfaces</td>
<td>25</td>
<td>2 (8%)</td>
<td>5.23</td>
<td>BC</td>
<td>Nightly</td>
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Table 2.1 Microbial contamination of cantaloupe contact surfaces in retail settings

(continued)

<table>
<thead>
<tr>
<th>Surface</th>
<th>Grouping</th>
<th>n</th>
<th>Mean Log Coliforms</th>
<th>Tukey’s Grouping</th>
<th>Mean Log E. coli</th>
<th>Tukey’s Grouping</th>
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<td>19</td>
<td>0.29</td>
<td>F</td>
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<td>A</td>
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<td>0.33</td>
<td>F</td>
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<td>A</td>
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<tr>
<td>Drying racks</td>
<td>Fresh-cut surfaces</td>
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<td>1.24</td>
<td>EF</td>
<td>0</td>
<td>A</td>
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<td>4.81</td>
<td>A</td>
<td>0</td>
<td>A</td>
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<tr>
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<td>AB</td>
<td>0</td>
<td>A</td>
</tr>
<tr>
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<td>3.32</td>
<td>BC</td>
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<td>A</td>
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<tr>
<td>Reusable plastic</td>
<td>Perimeter surfaces</td>
<td>30</td>
<td>2.91</td>
<td>CD</td>
<td>0</td>
<td>A</td>
</tr>
<tr>
<td>containers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood</td>
<td>Perimeter surfaces</td>
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<td>3.25</td>
<td>C</td>
<td>0</td>
<td>A</td>
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<tr>
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<td>DEF</td>
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<td>EF</td>
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<tr>
<td>Transport cart</td>
<td>Transport surfaces</td>
<td>25</td>
<td>3.12</td>
<td>C</td>
<td>0</td>
<td>A</td>
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Figure 2.1 Contact surface flow diagram
Figure 2.2 Dried pulp on corrugated plastic sheeting

Figure 2.3 Mesh overlaid on plywood, with surrounding wood perimeter surface
Figure 2.4 Expanded styrene fruit cups displayed in a reusable plastic container

Figure 2.5 Produce carts stacked after cleaning
Figure 2.6 RPC used with expanded polystyrene fruit cups

Figure 2.7 Cushioning foam used at RP1
Figure 2.8 Display barrier made of wood used at RP1
REFERENCES


CHAPTER THREE
Retailer Acceptability and Risk Perceptions of Washed and Unwashed Cantaloupe

INTRODUCTION

Cantaloupe (*Cucumis melo*) is a member of the Cucurbitaceae family characterized by its fragrant fruit with pale orange flesh surrounded by a corky, netted rind. The United States is the fifth largest producer of cantaloupe in the world (7). Most of this production is mainly split between two types of cantaloupe, eastern-type and western-type (7). Eastern-type cantaloupes, like the Athena cultivar, are ribbed and have a densely netted rind when compared to western-type cantaloupes. The majority of eastern-type cantaloupes are grown in Indiana, Georgia, and Colorado and are most often consumed in local markets (12, 17). Western-type cantaloupes in contrast lack ribbing and are less densely netted than eastern-type cantaloupes. These are mainly grown in California and Arizona and make up the majority of all cantaloupes grown in the US (7).

Due to the netted rind found on cantaloupes they are prone to harboring pathogens if contaminated. Once contaminated, it is extremely difficult to kill or remove these pathogens. This has been recognized by the melon industry, which has acknowledged that it is more effective to enact preventive measures to prevent surface contamination than it is to reduce or eliminate contaminants after contamination has occurred (12). In addition to the rind’s propensity to harbor pathogens, the flesh of cantaloupe has high concentrations of sugar but lacks the acidity of many other fruits, making it highly favorable to the growth of bacteria (8).

Cantaloupes, like many types of fresh produce are often washed by packers to reduce microbial risks. These wash practices utilize large amounts of water, in order to reduce water
use, packers recirculate and reuse water (16). This practice has been approved by the USDA, provided the water meets certain microbial guidelines (USDA 416.2(g)). In order to reduce the spread of pathogens to produce, this recirculated water must be treated to decrease microbial loads (16) (also FDA guide to fresh-cut fruits). Maintaining reduced microbial loads is critical, as pathogens are capable of attachment onto plant surfaces in contaminated wash water (19). Cantaloupes are no exception to this, as Salmonella poona has been shown to infiltrate the rind of cantaloupes during hydrocooling (14). Field packing can serve as an alternative to hydrocooling and can limit cross-contamination risks acquired in the field to a single carton or bin (11). Field packing is often used in dryer production areas, such as California and Arizona because melons are often cleaner, due to reduced rainfall. Melons from areas that receive frequent rain are more likely to have visible soil that must be removed prior to sale (11). This soil is frequently removed through washing.

Little is known about the risk perceptions of retailers surrounding cantaloupe washing practices and differences between eastern and western cantaloupes. This study seeks to fill this gap in knowledge by surveying produce and food safety experts employed by large grocery chains. By conducting this survey it will be possible to uncover risk perceptions held by grocery experts relating to cantaloupe and cantaloupe washing practices. This increased understanding could be potentially used to design materials to better educate retail employees on the risks associated with cantaloupes and washing.

**MATERIALS AND METHODS**

**Survey Development.** A draft survey (Figure 1) was designed to gauge risk perceptions of washed and unwashed cantaloupe and determine what data would be necessary to promote the acceptance of unwashed cantaloupes to produce buyers. This
The survey was modified, removing questions focusing on data determination and adding questions regarding the washing practices of fresh cut melon, the final survey consisted of ten questions (Figure 2.) Questions were designed to gauge the risk perceptions of produce buyers towards washed and unwashed cantaloupe as well as corporate policies regarding the purchase of washed and unwashed cantaloupe.

An online survey was used for ease of distribution and use by participants. Surveys were administered using the online survey platform SurveyMonkey. An introduction to the purpose of the survey as well as guidance on how to participate was given in an email containing the survey link. Questions were a mixture of ranking, multiple choice and short answer questions. Some of the questions were linked, asking participants to expand upon the reasoning for answering previous questions. Participants were informed that both qualitative and quantitative analysis would be used for answers.

**Participant Selection and Survey Distribution.** Participants for the survey were chosen based on their employer and involvement with the International Association for Food Protection (IAFP). Membership in IAFP was chosen as a criterion of selection as members would likely have a working knowledge of food safety. Recruitment began by first identifying the largest food retail and wholesale chains in the United States and Canada by total sales based on the Supermarket News 2016 Annual Report (Figure 3). Retail and wholesale chains were chosen based on three criteria: they sold products directly to the public at retail or wholesale, had a significant number of stores in the United States, and were likely to sell fresh produce. The names of these companies, or their parent companies, were searched in the IAFP membership directory. All employees of the companies were noted and the most appropriate employees were noted for potential contact. Employees were chosen
based of their title or job. If multiple employees were members of IAFP preference was given if their title or job description included produce or food safety. Identified individuals were sent an email requesting their participation in the survey and were given the option to take the survey online or over the phone. Individuals requesting to take the survey online were then sent a subsequent email containing a link to the survey. Individuals who did not respond to the initial email were sent a reminder email requesting participation. If no response was given to the reminder email, a final, third email was sent. If the individual did not respond to the third email, contact was ceased and further participation was not pursued. No incentive was given for participation. Survey responses were anonymized, with no identifiable information collected in the survey.

**Data Analysis.** Quantitative data was analyzed using JMP (SAS Institute, Cary, NC). Thematic analysis was used for qualitative responses.

**RESULTS**

**Survey Response.** Of the 20 people contacted to complete the survey, eight individuals ultimately responded, after varying rounds of follow-up emails.

**Safety Ranking.** Participants were first asked to rank the safety of eastern cantaloupe, tomatoes, cabbage, and sweet potatoes from one to five, with one being low risk, and five being high risk. Eastern cantaloupe was rated as the highest risk, with a perceived risk of 3.875, tomatoes were rated as the second highest risk, at 3.375, cabbage was rated at 2.875, sweet potatoes were rated as the lowest risk, with a risk of 2. Participants were then asked to rate the perceived safety of eastern cantaloupe, western cantaloupe, unwashed cantaloupe, and washed cantaloupe. As with the previous question participants rated the perceived safety from one to five, with one meaning low risk and five meaning high risk.
Unwashed cantaloupes were rated as the highest risk, with a perceived risk of 4.25, eastern cantaloupes were rated as the second highest risk, with a ranking of 3.875, western cantaloupe were rated as a 3.5, washed cantaloupes were rated as the lowest risk with a rating of 3.125.

**Washing Practices.** Participants were asked if retailers currently required cantaloupe suppliers to provide washed products. Six of the eight respondents did require washed product and two did not. When asked if any changes were to cantaloupe washing specifications following recent foodborne illness outbreaks five respondents replied that changes were made to washing procedures, with three replying that changes were not made. Participants were then asked to elaborate on the changes made to washing procedures. One respondent specifically mentioned the Jensen Farms outbreak as well as the subsequent FDA guidance for cut melons stating that specifications for wash water sanitation were given [6]. One response explicitly mentioned the implementation of two food safety management systems, Good Food Safety Initiative (GFSI) and Global Good Agricultural Practices (GlobalG.A.P.), and the use of third party auditors, such as Primus. Three of the participants skipped the question and one was unsure of the purpose of the question. Survey participants were then asked if suppliers were required to use sanitizers in their wash water and provide a reason as to why or why not it was required. Seven of the eight participants stated that they required some sort of water treatment, with three explicitly mentioning sanitizer use. One participant stated that washing was not required and that field packing was preferred, citing that field packing could reduce the spread of foodborne pathogens when compared to cantaloupe washed in large baths. Two respondents specified that the specific use of sanitizer was not required, but that microbial loads must be kept low. One participant claimed that
Sanitizer concentration was required to be monitored by suppliers if sold as an RTE food. Wash policies differed between fresh-cut and whole cantaloupe. Of the seven stores that cut melon in-store, all required that cantaloupe be washed prior to use. Four of the seven participants stated that sanitizer was used in the wash water used to wash cantaloupe, with three stating the sanitizer used. Two participants responded saying that peracetic acid was used, with one stating that citric acid was used. At all of the retailers, cantaloupe sold whole was not washed in-store prior to sale.

**Wash risk perceptions.** Survey participants were asked if the act of washing cantaloupes was seen as having an effect on the risk of foodborne pathogen contamination and asked participants to elaborate on their reasoning behind their answers. All eight participants stated that washing could potentially increase risk however risk perceptions varied depending on where washing was conducted in the supply chain. Six of the eight participants specifically mentioned that risk could be increased during washing conducted by the suppliers. Two participants mentioned the importance of treating water or using sanitizers in wash water and an additional two mentioned that the increase in moisture may promote pathogen growth. Participants were asked how buyers would respond to a request to provide unwashed Eastern cantaloupes and what would factor into their decisions. Responses were varied, with few participants directly responding to the question. Four of the eight participants were open to the possibility of purchasing unwashed Eastern cantaloupe after evaluation if they met certain criteria such as not having gross soils on the product or following food safety programs such as GAPS and GFSI certification. One participant stated Eastern cantaloupes were not purchased due to quality concerns. When asked where in the supply chain cantaloupes should be washed, the majority of participants responded that
washing was preferred to be conducted by the packer, prior to receipt by retailers. Two respondents expanded upon this, stating that washing by packers was preferred as washing protocols were more stringent and could be verified. Two participants stated that the preferred washing location was by the consumer, prior to consumption.

**DISCUSSION**

**Risk ranking and perceptions.** Eastern cantaloupes were ranked as the highest risk product among tomatoes, cabbage, and sweet potatoes. The ranking of cantaloupe as having higher risk than tomatoes was surprising. Between 1998 and 2016 tomatoes were linked to 163 outbreaks resulting in 8337 illness, 848 hospitalizations and 9 deaths. This is considerably lower than cantaloupe, which has been linked to 43 outbreaks, resulting in 1723 illnesses, 367 hospitalizations, and 40 deaths in the same period of time (CDC-NORS).

Tomatoes have higher risk in pathogen-produce pair attribution risk modeling, where tomatoes and *Salmonella enterica* was found to be the second highest risk combination of ten commodity groups tested. Cantaloupes were not exclusively modeled, but melons and *S. enterica* were found to have the fourth highest risk (3). The lower ranking of cabbage and sweet potatoes was expected, as both are rarely implicated in foodborne illness outbreaks. Cabbage has been the cause of 14 outbreaks resulting in 557 illnesses and 10 hospitalizations. Similarly, sweet potatoes have been linked to 6 outbreaks causing 191 illnesses and 2 hospitalizations. Furthermore, sweet potatoes are generally considered a raw agricultural commodity and are cooked before eating.

One potential factor for the higher perceived risk of cantaloupe is the nature of the outbreaks. Tomatoes have been linked to a larger number of outbreaks with greater numbers of illnesses when compared to cantaloupes. However, few of these outbreaks caused fatalities
and those with fatalities were relatively low. This contrasts with cantaloupe, which in 2011 was implicated in one of the deadliest outbreak of foodborne illness in US history, in which 33 fatalities occurred (4). This outbreak garnered significant media attention and prompted changes in the cantaloupe industry. The FDA issued two guides, the Guidance for Cantaloupe and Netted Melons and Letter to Firms that Grow, Harvest, Sort, Pack, Process, or Ship Fresh Cantaloupe (6). Increased media attention has been linked to an increased awareness of food safety hazards, which could potentially account for the difference in risk perception between cantaloupe and other produce (5).

When ranking the safety of eastern vs. western and washed and unwashed cantaloupes, participants rated unwashed cantaloupes as the highest risk, followed by eastern cantaloupes, western cantaloupes, and washed cantaloupes. The perception that unwashed cantaloupes pose a higher risk than washed cantaloupes was not surprising and could have been influence by the USDA and FDA recommendations for washing produce before consumption. Ranking western cantaloupes as a lower risk product than eastern cantaloupes was also expected. The two largest outbreaks of foodborne illness linked to cantaloupe were located in Colorado and Indiana, where eastern cantaloupe washing practices are more likely to be used. Additionally, the California Melon Board issued statements proclaiming the safety of melons grown in California, stating they had never been linked to an outbreak of Salmonella.

There appears to be a disconnect between the acknowledged risk posed by washing cantaloupe and the perceived risk of washed and unwashed cantaloupe. All eight participants acknowledged that the act of washing cantaloupes may increase the risk of foodborne pathogen contamination, however washed cantaloupes were rated as having less risk than
unwashed cantaloupes. This disconnect is also highlighted in the difference in risk perception based on washed status and cantaloupe origin. Washed cantaloupes were ranked as a lower risk product than unwashed cantaloupes and western cantaloupes were ranked as lower risk than eastern cantaloupes. This runs contrary to traditional growing practices, as western cantaloupes are traditionally packed in the field with no wash step while eastern cantaloupes are washed and packed in a packinghouse (2, 11).

**Washing behaviors.** Buyers overwhelmingly preferred cantaloupe to be preferred at least once in the supply chain. Six of the eight participants required that cantaloupes were washed by suppliers prior to receipt. Of these six, five stated that wash procedures had changed after recent outbreaks of foodborne illness due to cantaloupe. Washing cantaloupe serves two practical purposes, removing field heat and removing soil and debris. Two participants mentioned that washing served to remove gross soils from cantaloupes, adding that cantaloupe would not be accepted with gross soil and the removal of gross soil would increase safety. Studies have shown that the safest time and method to wash cantaloupe is immediately prior to consumption after scrubbing with a produce brush (11).

This tendency to favor washed cantaloupe extended to fresh-cut cantaloupe. Seven of the eight participants stated that cantaloupe was cut in-store, all of which additionally stated that cantaloupes were washed prior to cutting. Two participants mentioned FDA melon guidelines, with one citing the increase in use after the outbreak at Jensen Farms and other cantaloupe-linked foodborne illness outbreaks. One such guideline addresses proper handling procedures in retail, foodservice, and consumer environments and make a series of recommendations designed to prevent inadvertent contamination of *Salmonella, E. coli* O157:H7, and rotovirus (12). As this guidance was released in 2005 before the Jensen Farms
outbreak, it does not address *L. monocytogenes* contamination as directly as newer guidelines. The guide makes a variety of suggestions namely discarding damaged or decaying melons, using proper handwashing, maintaining temperature controls, and washing melons before cutting (12). Discarding damaged or decaying melons is important, as they have been shown to be more prone to be harboring *Salmonella poona*, when compared to undamaged cantaloupes (13). While good hand hygiene is an important part of food safety practices, handwashing with soap and water has been shown to not entirely remove *L. monocytogenes* from hands (18). These guidelines stress the importance of temperature control, suggesting that melons be kept below 41°F for no more than seven days and are discarded after four hours if displayed without temperature control. These recommendations are designed to minimize the growth of pathogens as well as spoilage organisms. Ideally, fresh-cut cantaloupe would be refrigerated immediately, as *L. monocytogenes* has been shown to grow more quickly at 20°C than 5°C (21). Lastly, the guidelines stress that melons should be thoroughly washed and scrubbed with a produce brush in compliance with section 3.302.15 of the 2005 FDA Food Code. Scrubbing has also been shown to be more effective at removing *Salmonella* than soaking in wash water alone (11). However, scrubbing can also introduce pathogens into the wash water, potentially contaminating adjacent melons in the wash sink (11). Washing fresh produce prior to cutting can help reduce the transfer of *L. monocytogenes* from the rind to the flesh during cutting, particularly if the wash water is treated with sanitizers like chlorine or hydrogen peroxide (20).

Participants explicitly stated the use of peracetic acid and citric acid as a sanitizer solution. While the concentration of the peracetic acid was not given by either participant, the use of peracetic acid as a sanitizer has shown limited success when used with cantaloupe to
reduce *L. monocytogenes* levels when compared to other sanitizers, such as chlorine (15). However, peracetic acid has been shown to be an effective wash water when used with lettuce, where it is able to reduce the levels of both *E. coli* O157:H7 and *L. monocytogenes*. Similarly, no usage levels were given for the citric acid wash. Citric acid has been shown to be an effective sanitizer, reducing levels of *L. monocytogenes* and *E. coli* O157:H7 in lettuce wash water(1, 9). These recommendations would help decrease the spread of pathogens during fresh-cut preparation but would do little to prevent the contamination of whole cantaloupes, which are washed prior to receipt by retailers.

This study was hampered by a low response rate coupled with a limited population of interest. The population of interest, produce and food safety executives, working at large companies were difficult to identify. Using the Supermarket News 2016 Annual Report helped identify large retail chains who collectively would serve a large portion of the US population. However, this method of chain identification would overlook small and independent retailers. While small and independent retailers likely make up a smaller portion of total cantaloupe sales, it would be interesting to see if differences in risk perceptions and washing practices differ between large and small operations. Membership in IAFP was used to identify participants as members were likely to have some knowledge or a connection to food safety. Additionally, the option to search for membership by employer was convenient and provided results quickly, with contact information. Companies were found to have a varying number of employees who were members of IAFP, which complicated contact. Furthermore, some identified companies did not have any IAFP members as employees, which excluded them from contact. A more thorough method to identify produce and food safety executives could potentially be conducted using professional networking websites,
such as LinkedIn, which has a larger member base. Some contacts were found to be unable to answer due to mergers and acquisitions, or no longer employed by the company. After identifying and contacting 20 individuals, only eight surveys (40%) were completed, with an initial contact email introducing the survey and several follow-up emails if no response was given. A higher response rate could potentially have been elicited had the survey been given over the phone, which have been shown to have a higher response rate (10).
Figure 3.1 Draft Survey

The below questions will be delivered via telephone to food safety program leadership as well as retailer category buyers for cantaloupe.

Demographic questions will be collected such as name, gender, years in position, years in industry, and geographic location. The following questions are delivered via Likert scale (5: high risk, 1: low risk)

1. Please rate the safety of the following products
   a: Eastern cantaloupes
   b: Tomatoes
   c: Cabbage
   d: Sweetpotatoes

2. Please rate the safety of the following products
   a: Eastern cantaloupes
   b: Western cantalopes
   c: Unwashed cantaloupes
   d: Washed cantaloupes

The following questions open-ended and will be analyzed using both qualitative (through content analysis) and quantitative means (descriptive statistics from coding).

3. Do you currently require your cantaloupe suppliers to provide washed product? Please explain why you require this.

4. Have you made any changes to your cantaloupe washing specifications following recent foodborne illness outbreaks?

5. Please describe the impacts of requiring washing of Eastern cantaloupes?
6. Do you see the act of washing cantaloupes as increasing risk, decreasing risk or not affecting the risk of foodborne pathogen contamination. Prompt: please explain why.

7. If a producer was to request providing you with unwashed Eastern cantaloupes, how would you address their question? What factors would weigh into your decision?

8. What data would you need to see to reevaluate your Eastern cantaloupe washing requirements?

9. What form would you like to see this data in? Interviewer to provide a summary of preliminary data from year 1 of project to participants including microbial data as well as remaining soil data.

10. Based on what I just shared, can you tell me your reaction? Is this information important to your business?

Figure 3.2 Final Survey

1. Please rate the safety of the following products. (1=low risk, 5=high risk)

   Eastern Cantaloupe
   Tomatoes
   Cabbage
   Sweet Potatoes

2. Please rate the safety of the following products. (1=low risk, 5=high risk)

   Eastern Cantaloupes
   Western Cantaloupes
   Unwashed Cantaloupes
   Washed Cantaloupes
3. Do you currently require your cantaloupe suppliers to provide washed product?
   Yes
   No

4. Have you made any changes to your cantaloupe washing specifications following recent foodborne illness outbreaks?
   Yes
   No

5. If yes, what changes have you made to your cantaloupe washing specifications?

6. Do you see the act of washing cantaloupe as increasing risk, decreasing risk or not affecting the risk of foodborne pathogen contamination? Please explain why?

7. If a producer was to request providing you with unwashed Eastern cantaloupes how would you address their question? What factors would weigh into your decision?

8. Do you require cantaloupe suppliers to use sanitizers in their wash water? Why or why not?

9. Do you have different washing specifications for cantaloupes that are to be sold whole versus cut in store? Why or why not?

10. Where in the distribution chain do you believe cantaloupes should be washed? Why?
REFERENCES


CONCLUSION

Gaps were found in food safety practices surrounding whole cantaloupe display. The first study cataloged cantaloupe contact surfaces, sanitation practices, and collected environmental sample from these surfaces. Between two retailers, thirteen surfaces were cataloged, four associated with the production of fresh-cut fruits and nine associated with the display of whole cantaloupes. Across these surfaces, 333 environmental samples were collected, 108 (32.4%) of which showed the prevalence of _Listeria_ species, one sample showed presence for _L. monocytogenes_. It was found that cantaloupe contact surfaces were not always standardized and could vary not only from retailer to retailer but from store to store. These surfaces used to display whole melons were found to be highly porous, permanently affixed to display cases, or reused in ways that could not effectively be effectively cleaned and sanitized. The challenges associated with cleaning and sanitizing these surfaces were compounded by the frequency with which sanitation were undertaken. Sanitation procedures for display surfaces were not explicitly outlined in corporate standard sanitation operating procedures and were said to be cleaned during quarterly resets, when produce departments were seasonally rearranged. These long periods between sanitation could allow for otherwise transient _Listeria_ species to be harbored on surfaces.

The second study illustrates the need to further educate produce buyers on safe melon production. All produce buyers who participated in the study were aware that washing cantaloupes could increase the risk of pathogen contamination if done incorrectly, with several citing practices leading Jensen Farms outbreak. However, despite the universal acceptance of this risk, the majority of buyer stated that cantaloupes were required to be washed prior to receipt, in order to remove excess field dirt. Reasons for these perceptions
could potentially be regulatory bodies’ recommendations to wash produce prior to consumption. These beliefs could potentially lead to higher risk cantaloupes being stocked in grocery stores.

The results of these studies highlight three opportunities to educate retailers on good food safety practices. First, produce associates and managers should be educated on the importance of proper sanitation, involving discrete cleaning and sanitizing steps. Current sanitation practices do not call for a cleaning step prior to the use of a sanitizer. This procedure can reduce the efficacy of sanitizers used. Second, store managers and executives should be educated how to choose appropriate surfaces on which to display melons. The importance of using proper, nonporous surfaces has been stressed in food manufacturing facilities and should extend to produce display areas at retail. Finally, produce buyers should be informed on the risks associated with cantaloupe washed by producers and packers. Washed melons are currently preferred by retailers but may pose a higher risk than unwashed melons.

Further studies should be conducted focusing on the surfaces used for whole melon display. Transfer studies should be undertaken to examine the quantity and time required for *Listeria* to transfer from cantaloupe to surfaces and from surfaces to cantaloupe. This would better quantify the risk of using surfaces that may act as harborage points. Additional research could be done to assess what factors influence the harborage of *Listeria* species and could potentially lead to the development of a model with which to predict the growth or harborage of *Listeria*. Further environmental sampling should include typing of isolates. Not only would this ensure the accuracy of cultural methods but could be used to show persistence and determine whether *Listeria* species are harbored or transient.