CENTER for PRODUCE SAFETY

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FINAL PROJECT REPORT

Project Title
Control of cross-contamination during field-pack and retail handling of cantaloupe

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Objectives
1. *Quantify the transfer of Salmonella and Listeria monocytogenes onto melons in field-packing operations from each potential cross-contamination surface.*
2. *Compare the effect of different sanitizers on Salmonella and Listeria monocytogenes survival on potential cross-contamination surfaces.*
3. *Assess melon handling practices at retail through case study methodologies including interviews and observation to identify potential risk factor points.*

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FINAL REPORT

Abstract

Approximately 60% of the foodborne-illness outbreaks related to the consumption of melons are linked to contaminated cantaloupe. Several of these outbreaks were attributed to cross-contamination. As a result, guidance documents have been developed to assist the industry in the safe production and handling of melons to reduce the risk of cross-contamination. A complicating factor in effective guidance is that the production and handling of melons is not uniform. Melons grown on the East Coast are commonly washed in packinghouses after harvest; melons grown on the West Coast are almost exclusively packed in the field without washing. While previous research has focused on cross-contamination of melons with foodborne pathogens from contact with other melons and surfaces under wet conditions, little research has examined cross-contamination of melons from these sources in dry conditions typical of western field-packing operations—specifically, metrics describing coefficients for pathogen transfer between melons and contact surfaces including gloves, knives, packing tables, rags, brushes, and bins.

The aim of this project was to provide scientific data on which to update/refine melon-specific best practice guidance to reduce to likelihood of cross-contamination events in field-packing operations by quantifying the transfer of *Salmonella* and *Listeria monocytogenes* onto melons from each potential cross-contamination surface (e.g., stainless steel, polyethylene, or corrugated cardboard–lined packing tables). A series of inoculation experiments were performed to calculate coefficients for pathogen transfer to melons upon single and subsequent touches to each potential contact surface. Furthermore, the survival of *Salmonella* and *L. monocytogenes* was accessed for each potential cross-contamination surface. Field-pack equipment is regularly cleaned and sanitized at the end of each day, so pathogen survival was evaluated at several time points to identify which contact surfaces have the greatest pathogen survival over time if contaminated. The effect of different sanitizers were tested to determine the most effective decontamination regime to reduce the potential transference of pathogens to melons. It is common that once packed melons leave the fields the carton lid is not removed until arrival at the distribution center or retail store. Thus, to fully understand cross-contamination risks throughout the distribution chain, melon handling in the retail environment was also evaluated. Information on melon handling practices at distribution centers and or retail stores was collected via case study methodology, including interviews with key personnel and observation of product movement to identify potential cross-contamination points, investigate surfaces and define risk control sites. Mitigation and intervention strategies specific to cantaloupe distribution, storage, handling and display were developed for retailers to limit these identified cross-contamination points to ensure the continued safety of melons from harvest to consumer. Through this project, we have identified “high risk” cross-contamination points that occur during the handling of melons at harvest (field-pack) and retail, and developed guidance aimed at reducing the occurrence of such cross-contamination events. This guidance was communicated by presentations to the industry as well as supported by peer-reviewed abstracts/publications that detailed the science-based data derived from the project.

Background

Recently, the melon industry has faced several high-profile outbreaks of foodborne illness. In 2011, a *Listeria monocytogenes* outbreak associated with cantaloupes (from Colorado) resulted in 147 illnesses and 33 deaths in 28 states (McCollum et al., 2013), and in 2012, a *Salmonella* outbreak, also associated with cantaloupe (from Indiana), resulted in 261 illnesses and 3 deaths in 24 states (FDA, 2013). While neither of these outbreaks was associated with cantaloupes

from California (CA), the CA cantaloupe industry suffered significant economic losses (Russell, 2014). In an effort to rebuild consumer confidence in the safety of cantaloupes, the industry adopted a mandatory food safety plan for all CA cantaloupe producers, involving a series of food safety checkpoints and completion of a CA Department of Food and Agriculture audit. Additionally, the California Cantaloupe Advisory Board and the California Melon Research Board partnered with the Center for Produce Safety (CPS) to fund research projects related to melon food safety. Some previously funded CPS projects have examined the safety of melons in production, specifically in relation to irrigation water quality on the risk of preharvest contamination (Suslow, Award No. 2011-146); and in storage, specifically the use of antimicrobial coatings during postharvest handling of melons to inhibit pathogenic and spoilage microorganisms (Zhong, Award No. 2013-272). While these funded projects have focused on microbial hazards/risks during growing or holding of melons, little research has focused on understanding those risks during field-pack and retail handling of melons. Data was lacking on the identification of "high risk" cross-contamination points and mitigation strategies for melons packed in the field. The 2011 and 2012 cantaloupe outbreaks linked to packinghouse sanitation are contrasted by the recent speculation by certain produce commodity groups on the increased risk(s) associated with field-packed produce. Moreover, little was known about the handling practices of melons upon arrival in the retail environment.

According to western melon growers (Russell et al., 2014), melons in field-pack operations are hand-harvested with bare hands or hands protected with disposable (nitrile) or reusable (cotton) gloves. Melons are removed from the plant by knives (stainless steel) and transferred to mobile field packing tables to be sorted and graded. Western melons are often so clean they can be packed without the use of water or sanitizer to clean the melon. However, approximately 2% of western melons may require cleaning before being packed. Cleaning of melons in the field is typically done with a rag or plastic bristle brush dipped in sanitizer. Once melons have been sorted and graded, they are packed into corrugated cardboard boxes or vinyl-coated bins. At the end of the day, reusable worker gloves are laundered, disposable gloves are discarded, and melon-cleaning rags and brushes and cutting knives are washed (with detergent) and sanitized. Packing tables are washed and sanitized at the end of each day and sanitized before the start of each harvest day. Therefore, six potential cross-contamination points were identified for study: gloves, knives, packing tables, rags, brushes, and bins.

This project is important and timely because netted melons are widely seen as a high-risk produce commodity. Foodborne pathogen contamination of melons can occur at various points along the distribution chain (e.g., production, packing, storage) (Parnell et al., 2005; Suslow, 2010), and data on control of cross-contamination of foodborne pathogens during field-pack and retail handling of melons is relatively scarce. **Figure 1.0** illustrates the various cantaloupe contact surfaces throughout the supply chain. Previous research has shown cross-contamination to be a factor in microbial contamination of produce. Moreover, cross-contamination can occur during harvesting and packing of produce due to the use of contaminated equipment and or improper handling by workers (Brar et al., 2013; Sreedharan et al., 2014). Similar studies on other commodities and environments have found movement of pathogens from one surface to another is dependent on the type of bacteria (MacKintosh and Hoffman, 1984), type of surface (Chen et al., 2001), moisture level (Gill and Jones, 2002), and inoculation dose (Montville and Schaffner, 2003). Thus this project focused on identifying cross-contamination points during field-pack and retail handling of melons, and bridging the gaps on which to base melon-specific best practice guidance to reduce the likelihood of cross-contamination events from harvest through to consumers.

Research Methods and Results

Objective 1. Quantify the transfer of *Salmonella* and *L. monocytogenes* onto melons in field-packing operations from each potential cross-contamination surface.

This objective focused on identifying the transfer coefficients using a dry inoculum, except when water/sanitizers might be present, to determine the contamination risk of certain practices in field-pack melon operations.

A series of inoculation experiments were performed in the laboratory to quantify the coefficients of contamination onto melons during field packing from each potential cross-contamination surface. First, experiments were performed to identify a dry inoculation procedure that could uniformly and consistently be used to stimulate *Salmonella* or *L. monocytogenes* contamination in a dry environment. Three methods of drying were evaluated (oven, desiccator with vacuum, and incubator) and three carrier mediums were tested (sand, marking powder, and chalk). The final dry inoculation procedure that was selected consisted of the following: liquid *Salmonella* or *L. monocytogenes* inoculum (17.5 mL; ~8–9 log CFU/mL) was mixed with 100 g of sterilized sand and dried in a sterile weigh boat (no filter paper) for a minimum of 24 h in a desiccator with vacuum. The average amount of *Salmonella* and *L. monocytogenes* recovered after the dry inoculation procedure was ~7 and 6 log CFU/g, respectively. Upon testing small batches (4 x 25 g) of the 100 g dried *Salmonella*– or *L. monocytogenes*–sand mixture (>24 h in vacuum-sealed desiccator), there was no significant difference in respective pathogen log CFU/g between the small batches ($P \leq 0.05$), indicating a homogenized inoculation. To simulate contamination events, surface coupons or melon pieces were shaken and rubbed in the 100 g of dry pathogen-sand mixture in sterile bags (up to 1 min); subsequent experiments to simulate likelihood of cross contamination were performed by applying different amounts of pressure and contact from the contaminated surface coupon (5–6 log CFU/coupon) to melon or contaminated melon (5–6 log CFU/piece) to surface coupon. The next phase was to evaluate the pathogen transfer from contaminated melons to contact surfaces and vice versa (from contaminated surfaces to melon) upon single and subsequent touches. The contact surfaces tested included cotton (gloves, rags), rubber (gloves), nitrile (gloves), stainless steel (pack tables, knives), polyethylene (pack tables), and plastic bristles (brushes).

The transfer of *Salmonella* and *L. monocytogenes* from contaminated cantaloupe to surfaces or from contaminated surfaces to cantaloupe was low when using a dry inoculum. Since transfer was low, it is imperative to have a good sanitation program to prevent pathogen harborage sites or pathogen biofilm formation, which may aid in transfer. Best practices should include cleaning and sanitizing the contact surfaces on schedule (e.g., daily). The transfer of both pathogens from contaminated cantaloupe to surfaces or from contaminated surfaces to cantaloupe was not significantly different for all tested surfaces when using a wet inoculum, except for the cotton contact surface. We hypothesized that the wet inoculum soaked into the cotton material and this impacted the contamination potential or transfer to cantaloupe and/or surfaces.

In general, less transfer can be expected with shorter contact times and with more pressure/friction. There was less transfer of *Salmonella* and *L. monocytogenes* from contaminated cantaloupe to surfaces or from contaminated surfaces to cantaloupe when contact times were shorter (i.e., highest transfer of pathogens was observed with 20-second contact compared with 5- and 10-second contact) (e.g., see **Figure 1.1** for results with *Salmonella* transfer between cantaloupe and gloves). Very low transfer coefficients were obtained from tests with polyethylene and plastic bristles. For example, using mild pressure and a medium contact time (10 seconds), which are conditions often observed for a typical field-pack melon harvest operation, the transfer coefficients from inoculated melon to polyethylene were 0.07±0.02 (or ~7%), and those from inoculated polyethylene to melon were 0.05±0.03 (or ~5%). Lower transfer coefficients (<5%) were observed in tests with plastic bristles and

cantaloupe. The plastic bristle brushes were very difficult to inoculate compared with cotton, rubber, or smooth surfaces (e.g., stainless steel and polyethylene).

In general, there was less transfer of *Salmonella* and *L. monocytogenes* from contaminated cantaloupe to some surfaces or from contaminated surfaces to cantaloupe when pressure was greater (i.e., lowest transfer of pathogens was observed with vigorous pressure compared with mild and no pressure). To investigate further, the three different pressures were studied to elucidate the *Salmonella* and *L. monocytogenes* transfer with the three types of gloves after a 20-second contact time. We observed that more pressure resulted in greater *Salmonella* and *L. monocytogenes* transfer for rubber gloves compared with cotton and nitrile gloves (e.g., see **Figure 1.2** for *Salmonella* transfer results). Rubber gloves had the most transfer of *Salmonella* and *L. monocytogenes*, regardless of contact time or pressure, while nitrile gloves had the least transfer; the rubber gloves commonly used on harvesters and in experiments had ridged grooves. Interestingly, when pressure was standardized, cotton gloves behaved similarly to nitrile gloves.

Additionally, the PI and research technician visited field-packing operations in CA and Arizona to observe melon harvest and perform environmental swabbing of contact surfaces to assess the microbial quality of each surface throughout the operational run (i.e., how dirty each surface becomes over time). The goal of the trip to the melon operations was to (i) confirm the contact surfaces used during field packing of melons (learn from the industry) and (ii) simulate the amount of “dirt” found on each contact surface for the laboratory inoculation experiments (an accumulation of dirt/grime throughout the day may affect the transfer coefficients). The focus was to swab contact surfaces at different operations and of different crews. **Figure 1.3** shows the different glove types and the swabbing of surfaces. (Each crew works a harvester; typical operations have 7–10 harvesters working a location). Three different melon operations were visited in June 2016: AZ1 (Yuma, Arizona; specialty melons); CA1 (Blythe, California; cantaloupe); and CA2 (Holtville, California; cantaloupe). At each location, the team visited with the management leadership/staff and discussed surfaces that melons may come in contact with (also which contact surfaces were single-use and which were sanitized, and the sanitation process). For AZ1, a total of 5 harvesters were sampled at two timeframes: morning (7 am to 10 am) and afternoon (11 am to 2 pm). For CA1 and CA2, 6 harvesters were sampled at each site at the same two timeframes. A total of 284 swabs were collected (80, 102, and 102 from AZ1, CA1, and CA2, respectively). Specifically, AZ1 contact surfaces consisted of cotton gloves for both pickers and packers, cotton rags, plastic bristle brushes, stainless steel pack tables and knives; CA1 contact surfaces consisted of nitrile gloves for both pickers and packers, plastic bristle brushes, stainless steel and cardboard-covered pack tables, and stainless steel knives; and CA2 contact surfaces consisted of rubber gloves for both pickers and packers, plastic bristle brushes, stainless steel and vinyl-covered pack tables, and stainless steel knives.

The aerobic plate counts ranged from 5.2 to 7.4 log CFU/swab, with a mean of 6.5 log CFU/swab. The coliform counts ranged from 3.4 to 6.4 log CFU/swab, with a mean of 5.0 log CFU/swab. The *E. coli* counts ranged from 2.3 to 3.1 log CFU/swab, with a mean of 2.4 log CFU/swab. The majority of the swabs tested for *E. coli* had counts below 250 CFU/swab. There was no significant difference in microbial load for aerobic plate count, coliforms, or generic *E. coli* between the two timeframes (morning and afternoon; $P \leq 0.05$). This result was surprising to the research team but not to the melon industry. The conditions during field-pack are quite dry (average temperature was >100°F on each day that samples were collected) and equipment and melons stay relatively “clean” throughout the day. Dirt or grime accumulation was observed only when fields were a bit wet from the dew; this occurrence was rare and thus did not significantly affect the overall data.

Figure 1.4 shows a comparison of microbial loads (aerobic plate count, coliforms, and generic *E. coli*) on field-pack contact surfaces collected between 7 and 10 am (morning

timeframe). No significant differences in microbial loads were observed among the types of gloves worn by pickers or packers (nitrile, rubber, or cotton); however, there was a general trend that lower microbial loads were found on packers' gloves than on pickers' gloves. This result may be due to pickers' hands being closer to the soil as they are cutting melons from the vine, whereas packers transfer melons into single-use boxes. Also, no significant difference in microbial loads was observed among pack table surfaces (stainless steel, vinyl, and cardboard); however, there was a clear trend that lower microbial loads were found on the stainless steel pack tables and the highest loads on the vinyl-covered pack tables. Interestingly, when this finding was discussed with field harvest staff, the research team was informed that the vinyl-covered tables are not typically used for field-packing netted melons, such as cantaloupe, but are used for smoot melons, such as honeydew (apparently a few harvesters had been borrowed from the honeydew portion of their operation). Overall, the field sampling performed in June 2016 was very informative. The PI and research technician were able to develop an artificial fouling procedure to simulate a realistic amount of "dirt" for surface coupons. Briefly, cantaloupe leaves were rubbed on the coupon surface for 20 seconds to artificially foul the coupon surface to simulate real-world conditions observed in a field-pack operation. A small number of swabs were collected after sanitation procedures had been performed by the three operations (only swabbing of harvester pack tables was allowed, n=69; no swabbing was performed on cardboard-covered pack tables as the cardboard is thrown out after use). Coliforms and generic *E. coli* were undetectable in all swab samples post-sanitation.

Objective 2. Compare the effect of different sanitizers on *Salmonella* and *L. monocytogenes* survival on potential cross-contamination surfaces.

This objective compared the effect of different sanitizers on *Salmonella* and *L. monocytogenes* inoculated on selected contact surfaces. First, a series of survival studies for *Salmonella* and *L. monocytogenes* was performed in the laboratory to determine the rates at which the respective pathogen survived on each contact surface over the course of a day. A day (8 h) was the maximum time point, as most CA/AZ field-packing melon operations clean and sanitize at the end of each operational run (Russell et al., 2014). Cleaning consisted of removing all debris and dirt from contact surface materials by water and a detergent. After cleaning, a sanitizer (i.e., chlorine or peroxyacetic acid) is sprayed on the contact surface to decontaminate it from potential pathogens. Therefore, contact surfaces on which *Salmonella* and *L. monocytogenes* were observed to survive throughout the day were subjected to efficacy tests with the sanitizers used in field-pack operations. The goal of this objective was to determine (i) which contact surfaces have the greatest pathogen survival throughout the day (time points 0, 2, 4, 6 and 8 h) if contaminated, and (ii) the most effective sanitizer to reduce the likelihood of cross-contamination (or transfer of pathogen between contact surface and melon) for the targeted contact surface.

Survival of the pathogens on fouled and clean contact surfaces when using dry and wet inoculums is shown for *L. monocytogenes* (**Figure 2.1–2.4**) and *Salmonella* (**Figure 2.5–2.8**) on the different gloves and stainless steel. In general, while both pathogen populations declined on the contact surfaces over the 8 h, pathogen survival was greater when contact surfaces were fouled versus clean. (A surface was rubbed with a cantaloupe leaf for 20 seconds to simulate a "fouled" surface.) Additionally, pathogen survival was greater when contact surfaces were inoculated with a wet versus dry inoculum. For example, *L. monocytogenes* and *Salmonella* survival was higher over 8 h ($P \leq 0.05$) on stainless steel surfaces inoculated using a wet inoculum compared to a dry inoculum (Figure 2.4 and 2.8, respectively). This result is of particular interest as several studies have been performed using wet inoculums. A dry inoculum was used to simulate real-world conditions since West Coast cantaloupe production is typically dry (i.e., minimal water is used during cantaloupe harvest), therefore contamination events

would occur in a dry environment. When using a wet inoculum, *L. monocytogenes* survival was significantly higher at 8 h ($P \leq 0.05$) on fouled rubber and nitrile gloves compared with clean rubber and nitrile gloves (Figure 2.2 and 2.3); however, when using a dry inoculum, this trend was only observed for rubber gloves, as no significant difference in survival was observed on fouled and clean nitrile gloves at 8 h. Also, no significant difference in *L. monocytogenes* survival was observed on fouled or clean cotton gloves at 8 h, regardless of inoculum type (Figure 2.1). Interestingly, when using a wet inoculum, *Salmonella* survival was significantly higher ($P \leq 0.05$) at 8 h on fouled cotton gloves than on clean cotton gloves (Figure 2.5), but this trend was not observed when using a dry inoculum. This result was likely due to the wet inoculum soaking into the cotton material (and influencing survival). No significant difference in *Salmonella* survival was observed over 8 h between fouled and clean rubber and nitrile gloves, regardless of inoculum type (Figure 2.6, 2.7). Typically during harvest, gloves are changed daily (as the team observed and through personal communication with cantaloupe stakeholders). For example, nitrile gloves are single-use and changed during any breaks or stoppage of work; cotton and rubber gloves are collected daily and laundered. The data collected as part of this project provides evidence that rubber gloves are more likely to be associated with contamination events as they become fouled over the course of a work day (8 h). Therefore, rubber gloves should be used with caution or used sparingly (as a last choice in protective glove attire). Data showed that rubber gloves were associated with the highest transfer potential of *Salmonella* and *L. monocytogenes* from contaminated cantaloupe to surfaces or from contaminated surfaces to cantaloupe.

Similar trends were observed for the plastic-type contact surfaces. Populations of both pathogens declined on plastic bristle brushes and polyethylene over the 8 h (with both populations significantly declining between 0 and 8 h). When a wet inoculum was used, *Salmonella* and *L. monocytogenes* survival was significantly greater at 8 h ($P \leq 0.05$) on fouled plastic bristle brushes and polyethylene surfaces compared with clean plastic bristle brushes and polyethylene surfaces. When a dry inoculum was used, no significant difference in *Salmonella* and *L. monocytogenes* survival was observed between fouled and clean plastic bristle brushes and polyethylene at 8 h. This result was similar to that for nitrile gloves, and may reflect the similar smooth nature of the contact surfaces.

Since gloves are single-use or laundered daily, sanitation of stainless steel contact surfaces was targeted for further study. Stainless steel is a common contact surface in cantaloupe harvest, handling, and packing operations, and includes pack tables and knives. Comparisons of the effect of different sanitizer treatments on the pathogens on stainless steel are shown in **Figure 2.9–2.14**. Experiments were performed to investigate sanitation of stainless steel with no treatment, a water treatment, chlorine treatment (150 ppm), and peroxyacetic acid (PAA) treatment (80 ppm). Two contact times were selected: 30 minutes and 15 hours (based on direct input from stakeholders). Sanitation of cantaloupe harvesters generally occurs at the end of operation (overnight, 15 h) and directly before operations begin (30-min contact time). *Salmonella* and *L. monocytogenes* populations inoculated on clean stainless steel surfaces showed larger reductions after treatment compared with populations on fouled surfaces. Thus, fouled surfaces were more difficult to sanitize, which stresses the importance of cleaning surfaces prior to sanitizing. This finding was most evident when analyzing the data from the sanitizer chlorine. After a 30-min chlorine treatment, the survival of *Salmonella* and *L. monocytogenes* populations was greater ($P \leq 0.05$) on fouled stainless steel surfaces than on clean stainless steel surfaces (Figure 2.9 and 2.12, respectively). For fouled stainless steel surfaces contaminated with *Salmonella*, a 30-min treatment with PAA decreased *Salmonella* populations more than treatment with chlorine (Figure 2.10). However, the same trend was not observed for *L. monocytogenes*, as populations remained high on fouled stainless steel surfaces regardless of 30-min sanitizer treatment (chlorine or PAA) (Figure 2.13).

Interestingly, chlorine and PAA were effective against *Salmonella* and *L. monocytogenes* with a 15-h contact time (Figure 2.11 and 2.14, respectively). Therefore, if stainless steel surfaces are clean, both chlorine and PAA are effective against *Salmonella* and *L. monocytogenes* with a 30-min contact time; however, if stainless steel surfaces are fouled, a shorter contact time (like 30 min) is not recommended, especially when using a chlorine treatment.

Objective 3. Assess melon handling practices at retail through case study methodologies including interviews and observation to identify potential risk factor points.

This objective focused on different tools to utilize both quantitative and qualitative data to provide a complete picture of cantaloupe handling in the retail sector, from distribution to display (environmental monitoring at retail and surveys of food safety managers at major retailers). This objective included investigation into both whole cantaloupe and fresh-cut cantaloupe that was handled within the retail setting (not processed by a supplier).

Meetings were held with industry representatives from two retail partners to facilitate the identification of contact surfaces. A tour of a retail location was provided by a Retail Food Safety Specialist to assist in identification and confirmation of surfaces—for ability to sample and for surfaces that cantaloupe actually contacted). Surface usage rates and sanitation procedures were cataloged for the five associated retail locations. With industry assistance from the retail partners, seven and six surfaces were ultimately selected as final sampling sites for retail partner 1 and 2, respectively. Several contact surfaces were excluded, including cardboard shipping containers, gloves, and packaging materials that were used only once prior to disposal (or recycling). For retail partner 1, the seven surfaces that were to be sampled included (1) wash sinks, (2) plastic lugs used to transport whole melons, (3) drying racks used to dry melons after washing, (4) knives used to cut melons, (5) cutting boards, (6) foam padding used in displays of whole melons, and (7) melon-holding display structures (i.e., the front and side material used to contain melons in the display bins). For retail partner 2, the six surfaces that were to be sampled included (1) plastic carts used to cart melons to the retail floor, (2) reusable plastic containers (RPCs) used for display, (3) wood holding display structures, (4) mesh used in displays, (5) styrofoam fruit cups used in displays, and (6) plasticor sheeting used in displays. The retail partners provided access to five stores (retail partner 1 in a southern state between mid-October and late-November 2016, and retail partner 2 in a northern state in fall 2017). At each location, a 10×10 cm area was sampled for each contact surface. For retail partner 1 sampling occurred over four time points: before store opening (~5 am), before mid-day cleaning (~12 pm), after mid-day cleaning (~2 pm), and before closing (~10 pm); and for retail partner 2 sampling occurred over five time points: 6–7 am, 10–11 am, 2–3 pm, 6–7 pm, and 10–11 pm. Contact surfaces were swabbed using 3M swab sticks with Dey-Engley neutralizing broth. Swabs were stored on ice, packed into coolers, and shipped overnight to collaborators at the University of Florida for processing. Swabs were tested for *Listeria* species, *L. monocytogenes*, total coliforms, *Escherichia coli* (*E. coli*), and total aerobic count.

For retail partner 1, 141 swabs were collected and processed. Only one sample (0.7%) tested positive for *E. coli*. Approximately 32% (45/141) of the swabs tested positive for *Listeria* species (**Figure 3.1**). No swabs tested positive for *L. monocytogenes* from any of the contact surfaces. Interestingly, five of the seven surfaces tested positive for *Listeria* spp. at least once during the study. *Listeria* spp. were detected in 100% (19/19) of the swabs collected from the foam contact surface across all stores. The foam contact surface (**Figure 3.0**) was observed in whole cantaloupe displays, where the melons were placed on top of the foam to provide cushioning and to limit bruising (since most displays were constructed of wood or plastic). Surfaces associated with whole cantaloupe contact had a higher prevalence of *Listeria* spp. (~74%, 28/38) compared with surfaces associated with fresh-cut cantaloupe contact (~18%, 17/95). The frequency of *Listeria*–positive samples varied by time point: for example, the

frequency of *Listeria*–positive samples decreased after mid-day cleaning. Most surfaces also showed a decrease in coliform counts after the mid-day cleaning (**Figure 3.2**). Of particular note, surfaces associated with whole cantaloupe display (foam and sides of display structures), which were not part of the mid-day cleaning, had the highest coliform counts during the study.

For retail partner 2, 200 swabs were collected and processed. Only whole cantaloupe contact surfaces were sampled (none for fresh-cut cantaloupe). No samples tested positive for *E. coli*. Approximately 33% (65/200) of the swabs tested positive for *Listeria* spp. All surfaces were *Listeria*–positive at least once (6/6; **Figure 3.3**). One *L. monocytogenes*–positive sample was found but was negative upon retest three consecutive times (demonstrating the sporadic nature of *Listeria* in environments). Plastic carts had the lowest prevalence of *Listeria* spp. but were cleaned and sanitized daily. The next lowest prevalence of *Listeria* spp. was from external displays (wood and RPCs) where cantaloupe were in indirect contact with surfaces. The three contact surfaces that were in direct contact with cantaloupes at retail partner 2 were mesh (30%), plasticor (54%), and styrofoam fruit cups (46%). Interestingly, those three contact surfaces were only cleaned and sanitized on an as-needed basis. Additionally, the frequency of *Listeria*–positive samples decreased toward the end of the day (**Figure 3.4**). Possible reasons for this reduction in positive samples include less customer traffic, and time of day that workers typically re-stock and/or new workers arrive (i.e., shift change; also the second shift focuses more on cleaning and sanitizing, and tidying the store). Unlike at retail partner 1, none of the contact surfaces at retail partner 2 had drastically higher frequencies of *Listeria*–positive samples; *Listeria* spp. prevalence on all six contact surfaces at retail partner 2 was less than 50%, compared with 100% prevalence on foam at retail partner 1 (**Figure 3.5**).

Additionally, a survey was designed to determine the risk perceptions and risk rankings surrounding washed and unwashed cantaloupe, as well as retail handling and supplier procedures. Participants for the survey were chosen based on their employment and involvement with the International Association for Food Protection (IAFP). Recruitment began by identifying the largest retail and wholesale chains by total sales. Retail and wholesale chains were then 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. IAFP members employed by these companies were then identified using the IAFP membership directory. Twenty individuals were chosen based on their employer and familiarity with the company's produce handling procedures. Individuals were emailed with requests to take the survey over the phone or online through SurveyMonkey; all participants chose to take the survey online. Results were analyzed using the built-in analysis tools provided by SurveyMonkey as well as Microsoft Excel. In total, eight individuals participated in the survey.

Survey results indicated that cantaloupes are seen as a moderate to high risk product. Participants were asked to rank the safety of various produce on a 5-point scale, with 1 = low risk and 5 = high risk. The average risk rankings obtained were as follows: cantaloupes, 3.875; tomatoes, 3.375; cabbage, 2.875; and sweet potatoes, 2. Eastern and western cantaloupes had a similar risk, as ranked by survey participants. The survey found that washing had a significant effect on the perceived safety of cantaloupes, with the risk for unwashed cantaloupes ranked at 4.25 and unwashed cantaloupes ranked at 3.125. Interestingly, all eight participants (100%) from the retail organizations stated that washing may increase the risk of foodborne pathogen contamination if not done properly. In fact, six (75%) of the participants claimed their employers required cantaloupe suppliers to provide washed product. Five (62.5%) of the participants said their employers changed cantaloupe washing guidelines after the 2011 and 2012 cantaloupe-borne outbreaks. When asked for further details on washing policies, some followed 3rd party standards (e.g., GFSI), while others followed the FDA guidelines for cut melon or simply required sanitizer use. For example, six participants (75%) said their employer required the use of sanitizers in the rinse water in order to purchase cantaloupe from suppliers.

Outcomes and Accomplishments

The transfer of *Salmonella* and *L. monocytogenes* from a contaminated cantaloupe to surfaces or from a contaminated surface to cantaloupe was low when using both a dry and wet inoculum. The data highlighted the importance of using the most real-world inoculum application (dry versus wet inoculum). For example, pathogen transfer rates were higher for cotton gloves when using a wet inoculum compared with using a dry inoculum due to the wet inoculum soaking into the cotton. Western cantaloupe production is typically very dry (due to the CA and AZ climates), and water is only used when cleaning and sanitizing surfaces post-operational run. Additionally, all surfaces are not created equal and the risk of cross-contamination is not equally distributed. Some contact surfaces, such as foam, harbor pathogens more. Also, rubber gloves have more *Salmonella* and *L. monocytogenes* transfer than other contact surfaces such as nitrile gloves or stainless steel. Transfer of pathogens also was influenced by contact time and pressure, but when standardized, similar results were observed. Fouled or dirty surfaces aided in transfer (or cross-contamination) of both pathogens, highlighting the importance of sanitation practices.

While both pathogen populations declined on contact surfaces over the 8 h, pathogen survival was greater when contact surfaces were fouled versus clean. It is recommended that cantaloupe growers and packers do not leave dirty surfaces for prolonged periods of time, as this may increase pathogen harborage. Pathogen survival also was greater when contact surfaces were inoculated using a wet versus dry inoculum, thus water should be avoided or limited, if possible, in dry environments. Experiments were performed to investigate sanitation of stainless steel with no treatment, a water treatment, chlorine treatment (150 ppm), and peroxyacetic acid (PAA) treatment (80 ppm). Contact times of 30 minutes and 15 hours were selected based on direct input from stakeholders. The most effective sanitation for fouled stainless steel was an overnight (i.e., 15 h) contact time; both chlorine and PAA were effective. It is important to note that when stainless steel was clean, a 30-min contact time with the sanitizer was effective (because cleaned surfaces are easier to sanitize); however, stainless steel pack tables will rarely be clean after a full day of packing operations.

At retail, contact surfaces also impacted the likelihood of *Listeria* spp. detection. For example, *Listeria* spp. prevalence was 100% on a foam surface used to cushion cantaloupe on display tables or bins during longitudinal sampling. Also, contact surfaces in indirect contact with cantaloupe, such as wood or plastic bins (RPCs), had significantly lower prevalence of *Listeria* spp. compared with contact surfaces in direct contact with cantaloupes. This result may be due to fouled surfaces promoting greater survival of *Listeria* than clean or less dirty surfaces. In general, contact surfaces that were cleaned and sanitized had lower prevalence of *Listeria* spp. Based on observation and interviews, sanitation protocols were very robust for fresh-cut cantaloupe and as a result the *Listeria* spp. prevalence was low. On the other hand, sanitation protocols were fluid and or non-existent for whole cantaloupe, and as a result the *Listeria* spp. prevalence on contact surfaces was significantly higher. Cleaning and sanitizing protocols must be in place for whole cantaloupe at retail. Sanitation “as needed” does not seem sufficient to limit the prevalence of *Listeria* species. Surfaces should be changed frequently when cleaning and sanitizing is not possible. Lastly, it is important to note that uniformity of handling practices and contact surfaces may exist within retail chains, but retail chains differ markedly between each other. In this study several differences were observed between retail partner 1 and 2; for example, different contact surfaces or sanitation protocols.

The survey data also indicated that washed cantaloupe was perceived to be a safer product than unwashed cantaloupe. The majority of survey participants said their retail chain required suppliers to provide washed product, despite the belief that improper washing can/may increase the risk of foodborne pathogen contamination. While this survey was limited by the number of participants, it demonstrates the need for future work to focus on uniform handling of cantaloupe throughout the supply chain.

Summary of Findings and Recommendations

- Transfer of *Salmonella* and *L. monocytogenes* was highest for rubber gloves compared with all other field-pack contact surfaces. Over time, due to wear, the rubber gloves cracked and allowed better attachment of pathogens.
- Less transfer of *Salmonella* and *L. monocytogenes* was observed between contaminated cantaloupe and surfaces (or vice versa) with shorter contact times.
- Less transfer of *Salmonella* and *L. monocytogenes* was observed between contaminated cantaloupe and surfaces (or vice versa) with smoother surfaces (e.g., stainless steel or nitrile gloves).
- Pathogen survival was greater on fouled compared with clean contact surfaces, highlighting the importance of robust, frequent sanitation.
- The most effective sanitation protocol for fouled contact surfaces was an overnight application of either chlorine or PAA.
- *Listeria* spp. were present in retail whole cantaloupe display environments.
- Retail contact surfaces in whole cantaloupe areas that were cleaned and sanitized on a regular basis (e.g., daily) had lower *Listeria* spp. prevalence than those surfaces that were cleaned and sanitized on a variable schedule (or as needed basis).
- Foam had the highest prevalence of *Listeria*–positive samples (100%), and is not recommended for use in whole cantaloupe displays (despite its ability to cushion product).

APPENDICES

Publications and Presentations

As of January 2018, no papers have been submitted for publication, but the team expects to submit three papers for peer review in 2018.

Presentations:

2018

Friedrich, L.M., L.L. Dunn, B. Chapman, L.K. Strawn, and M.D. Danyluk. 2018. Survival of *Listeria monocytogenes* on Cantaloupe Field Pack Food Contact Surfaces. International Association of Food Protection Annual Meeting (Salt Lake City, Utah). *Submitted*

Pfuntner, R., L. Truitt, M.D. Danyluk, B. Chapman, and L.K. Strawn. 2018. *Listeria monocytogenes* Transfer Potential during Field-pack Handling of Cantaloupe. International Association of Food Protection Annual Meeting (Salt Lake City, Utah). *Submitted*

Strawn, L.K. 2018. Control of Cross-Contamination during Field and Retail Handling of Cantaloupe: FINAL REPORT UPDATE. California Melon Symposium (San Diego, California).

2017

Rupert, C., L.K. Strawn, M.D. Danyluk, L.M. Frederick, and B. Chapman. 2017. Control of Cross Contamination during Retail Handling of Cantaloupe. International Association of Food Protection Annual Meeting (Tampa, Florida). Abstract P3-39.

Pfuntner, R., L. Truitt, M.D. Danyluk, B. Chapman, and L.K. Strawn. 2017. *Salmonella* Transfer Potential during Field-pack Handling of Cantaloupe. International Association of Food Protection Annual Meeting (Tampa, Florida). Abstract P3-70.

Strawn, L.K. 2017. Control of Cross-Contamination in Field and Retail Handling of Cantaloupe. Center for Produce Safety Research Symposium (Denver, Colorado).

Strawn, L.K. 2017. Control of Cross-Contamination during Field and Retail Handling of Cantaloupe: PROGRESS REPORT UPDATE. California Melon Symposium (San Diego, California).

2016

Strawn, L.K. 2016. Control of Cross-Contamination in Field and Retail Handling of Cantaloupe. Center for Produce Safety Research Symposium – Lighting Round (Seattle, Washington).

Budget Summary

Virginia Tech spent $96,487.64 (*see Note*); subcontractor University of Florida spent $64,038; and subcontractor North Carolina State University spent $56,273; for a combined funding expenditure of $216,798.64 (of total grant award $217,066).

Note: As of January 31, 2018, all charges made by us have posted by Virginia Tech, leaving a balance of $267.36. The balance of $267.36 was due to the budget including one extra pay period in 2017 that could not be used before December 31st, 2017 (grant end date).

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Figures

Objective 1:

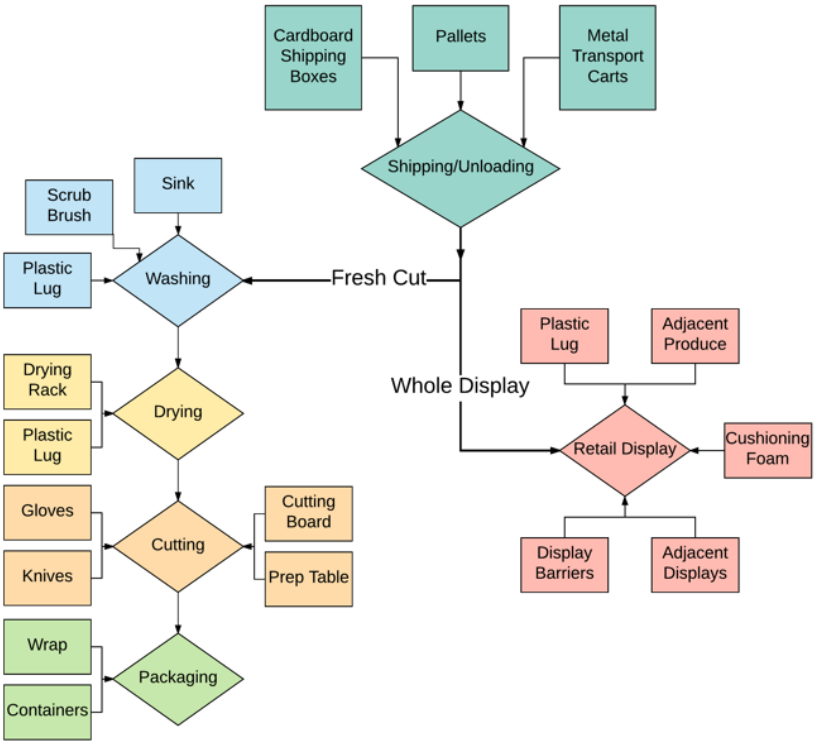

Figure 1.0. Cantaloupe contact surfaces throughout the supply chain.

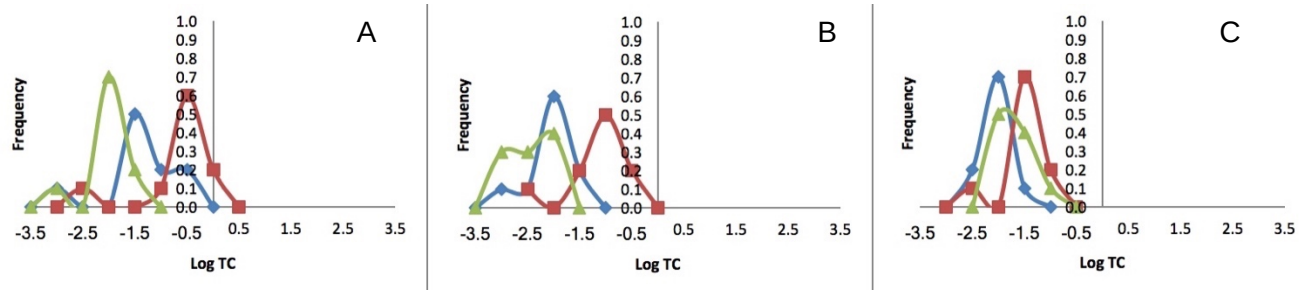

Figure 1.1. Distribution of coefficients of *Salmonella* transfer from cantaloupe to glove contact surfaces with mild pressure using 5 seconds (A), 10 seconds (B), and 20 seconds (C) for cotton blend (blue line), rubber (red line), and nitrile (green line) gloves (n=10).

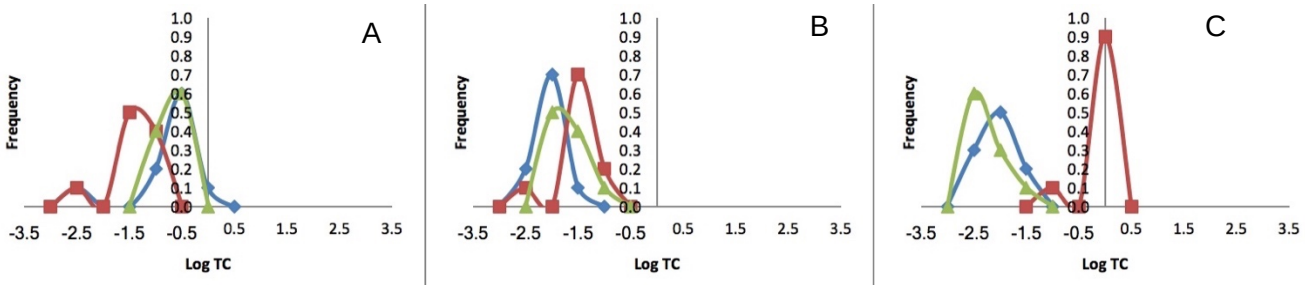

Figure 1.2. Distribution of coefficients of *Salmonella* transfer from cantaloupe to glove contact surfaces with 20-second contact time using no pressure (A), mild pressure (B), and vigorous pressure (C) for cotton blend (blue line), rubber (red line), and nitrile (green line) gloves (n=10).

Figure 1.3. Glove contact surfaces (rubber [left], nitrile [middle], and cotton blend [right]).

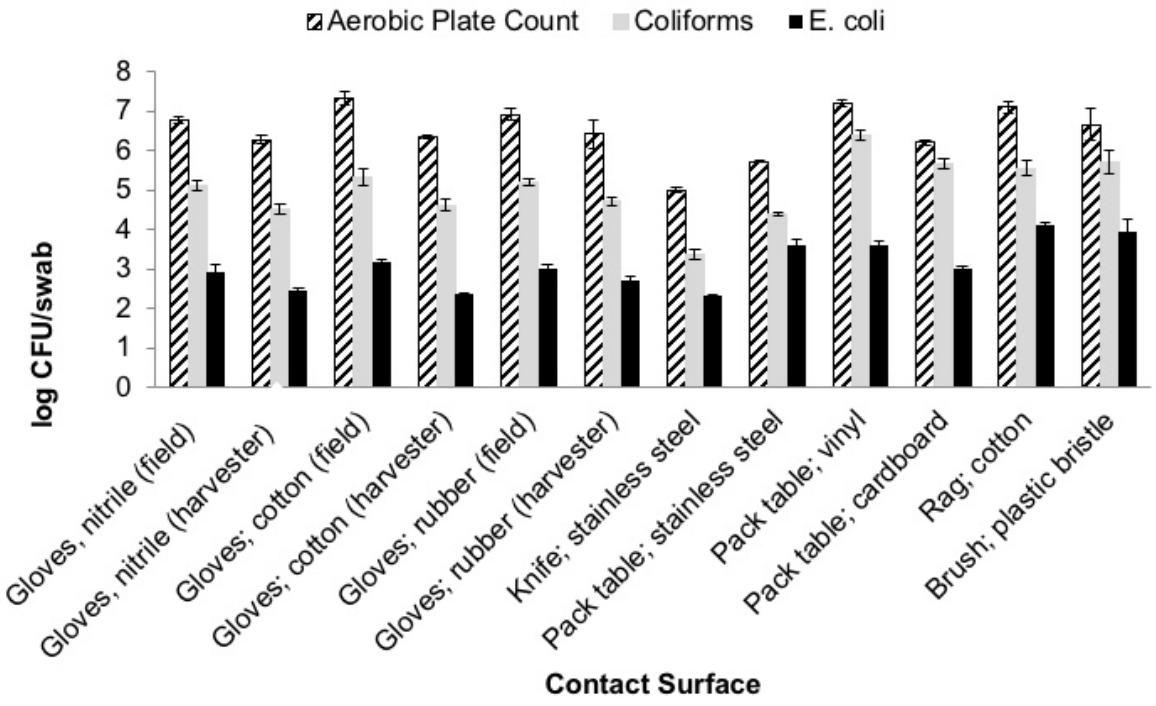

Figure 1.4. Comparison of microbial loads (aerobic plate count, coliforms, and generic *E. coli*) on field-pack contact surfaces collected between 7 and 10 am (morning timeframe). Each contact surface, if present, was swabbed. Up to three swabs were collected per contact surface for each harvester (n=3), except rags and brushes (n=2 per harvester). As many different harvesters/crews were sampled within the 3-hour timeframe as possible (AZ1 = 5 harvesters, CA1 and CA2 = 6 harvesters each). Harvesters/crews were tagged to perform an afternoon sampling, but no significant differences between times were observed in log CFU/swab counts.

Objective 2

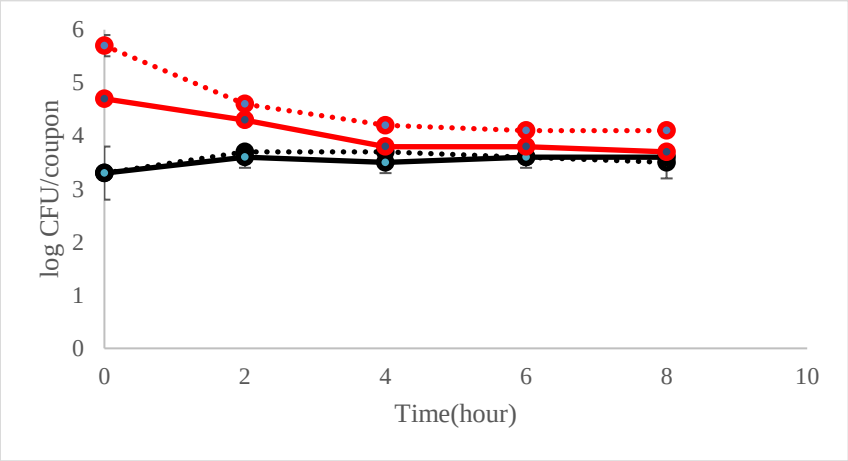

Figure 2.1. *L. monocytogenes* survival using a dry (black lines) and wet (red lines) inoculum on new (solid lines) and fouled (dashed lines) cotton gloves.

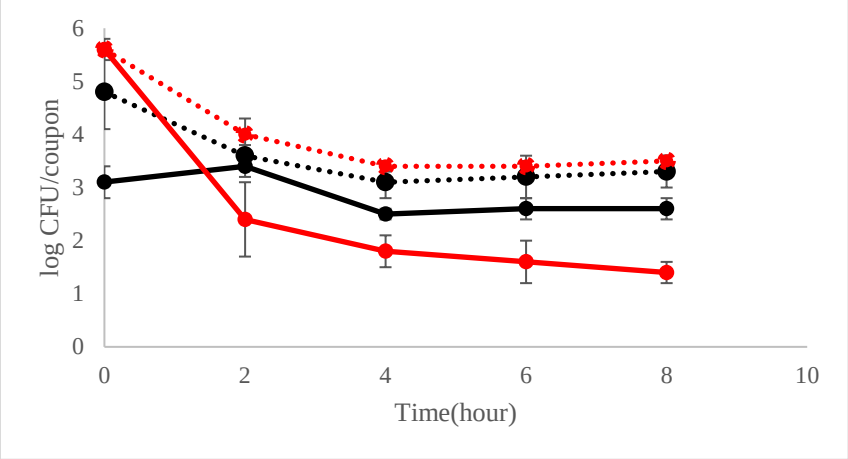

Figure 2.2. *L. monocytogenes* survival using a dry (black lines) and wet (red lines) inoculum on new (solid lines) and fouled (dashed lines) rubber gloves.

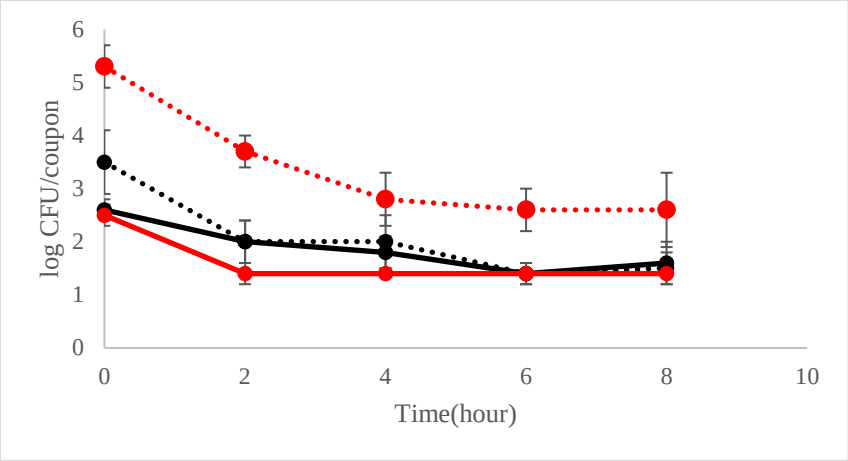

Figure 2.3. *L. monocytogenes* survival using a dry (black lines) and wet (red lines) inoculum on new (solid lines) and fouled (dashed lines) nitrile gloves.

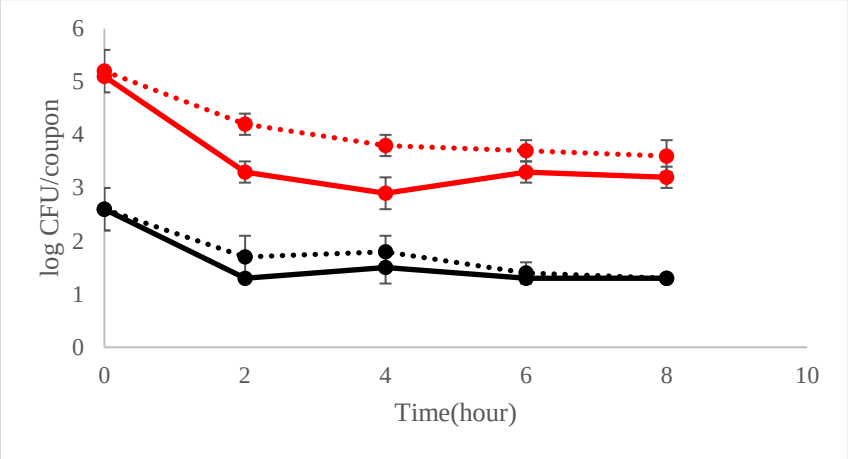

Figure 2.4. *L. monocytogenes* survival using a dry (black lines) and wet (red lines) inoculum on new (solid lines) and fouled (dashed lines) stainless steel.

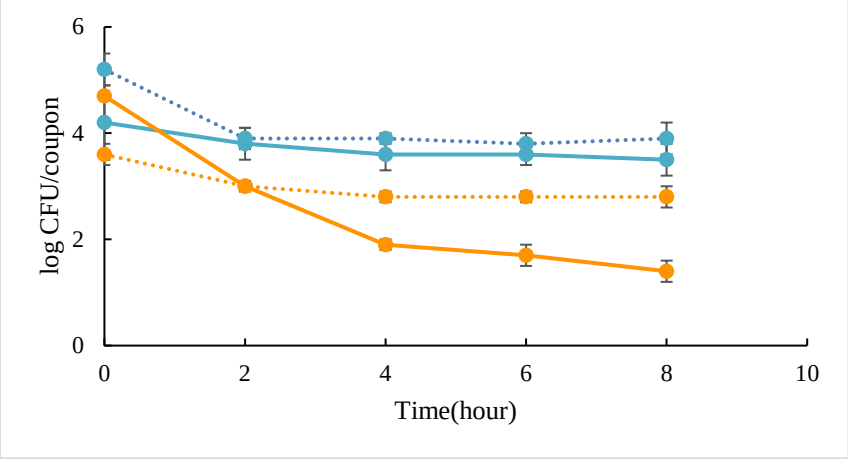

Figure 2.5. *Salmonella* survival using a dry (blue lines) and wet (orange lines) inoculum on new (solid lines) and fouled (dashed lines) cotton gloves.

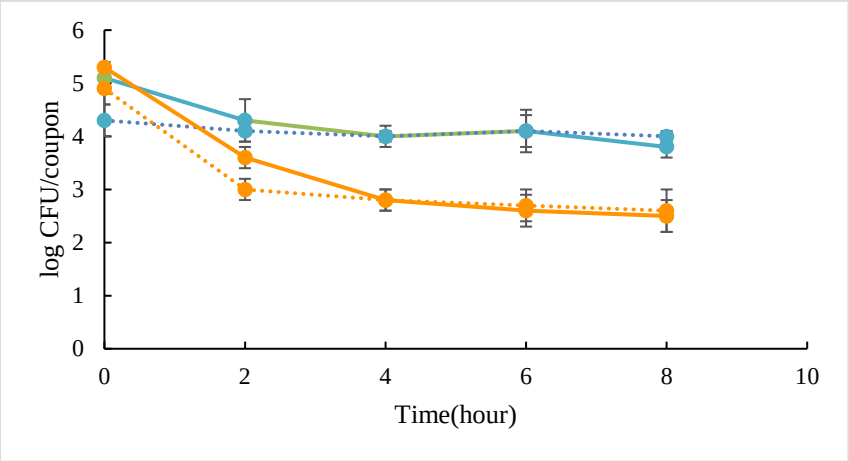

Figure 2.6. *Salmonella* survival using a dry (blue lines) and wet (orange lines) inoculum on new (solid lines) and fouled (dashed lines) rubber gloves.

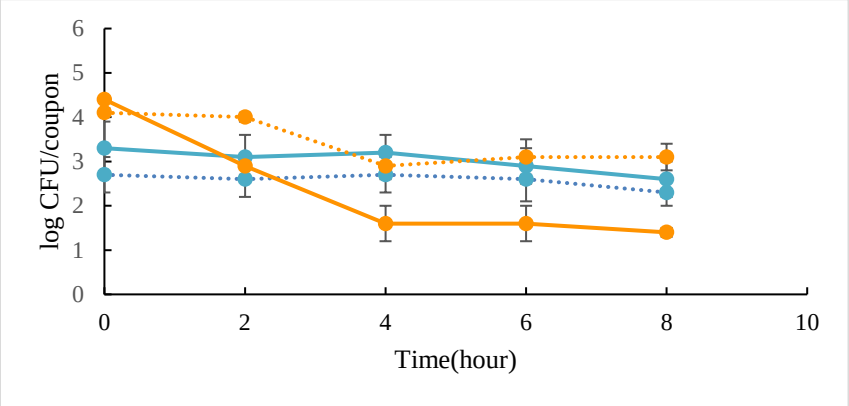

Figure 2.7. *Salmonella* survival using a dry (blue lines) and wet (orange lines) inoculum on new (solid lines) and fouled (dashed lines) nitrile gloves.

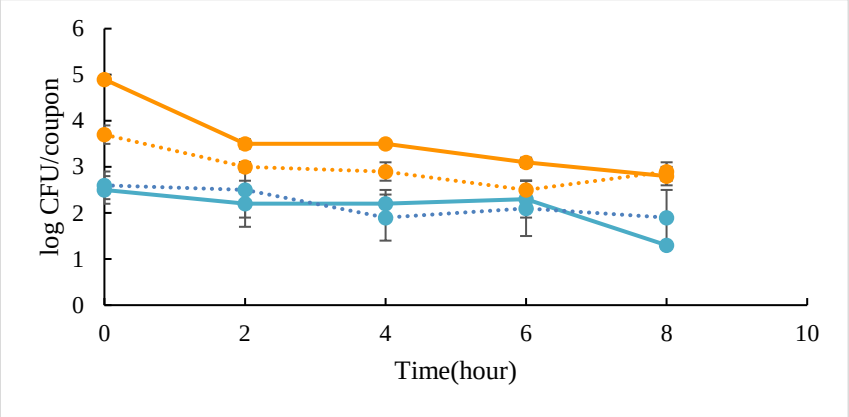

Figure 2.8. *Salmonella* survival using a dry (blue lines) and wet (orange lines) inoculum on new (solid lines) and fouled (dashed lines) stainless steel.

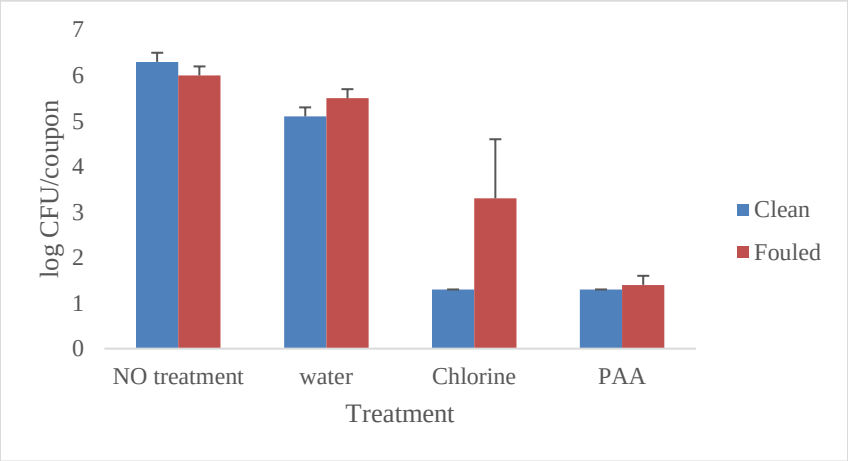

Figure 2.9. Effect of 30-minute sanitizer contact on *Salmonella* inoculated on stainless steel.

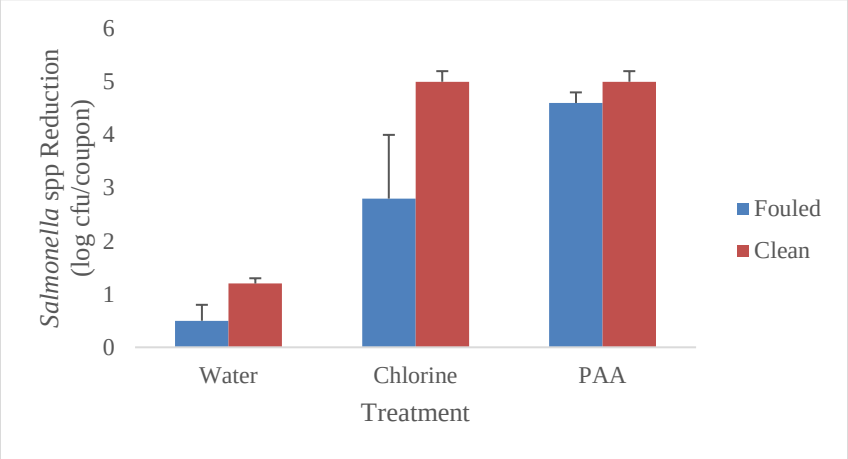

Figure 2.10. Comparison of *Salmonella* reduction with a 30-minute sanitizer contact time.

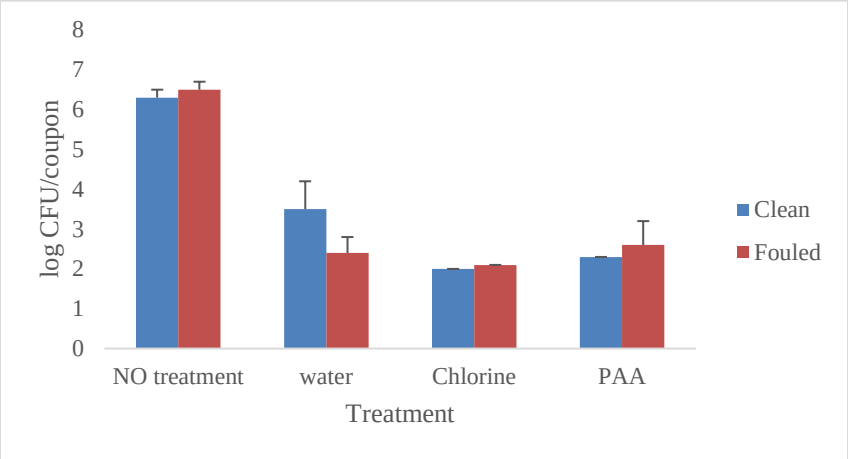

Figure 2.11. Effect of 15-hour sanitizer contact on *Salmonella* inoculated on stainless steel.

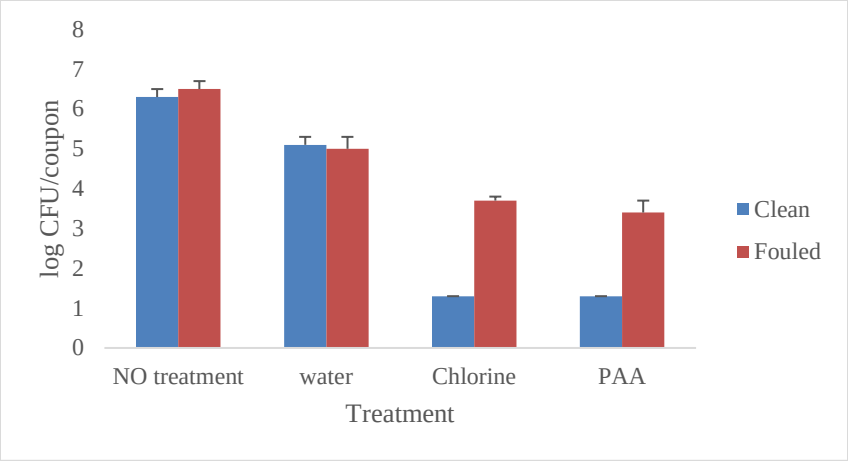

Figure 2.12. Effect of 30-minute sanitizer contact on *L. monocytogenes* inoculated on stainless steel.

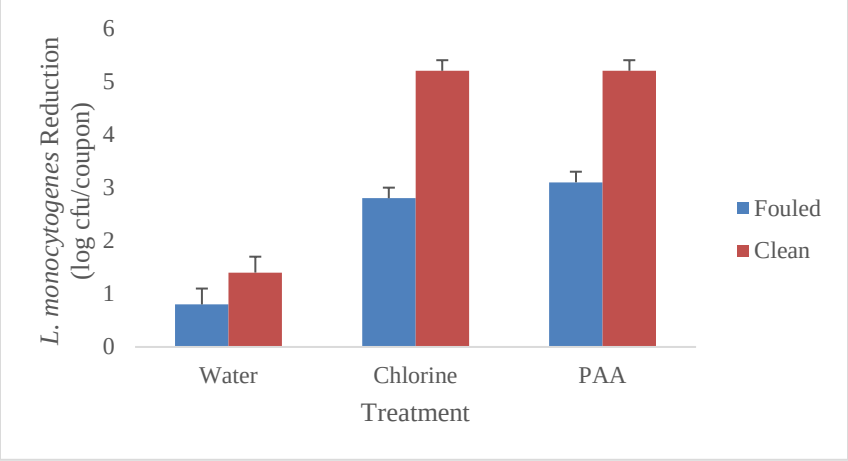

Figure 2.13. Comparison of *L. monocytogenes* reduction with a 30-minute sanitizer contact time.

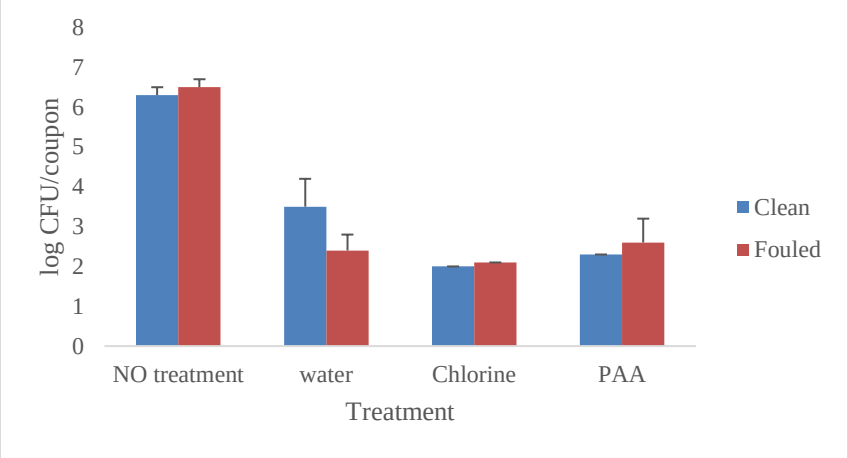

Figure 2.14. Effect of 15-hour sanitizer contact on *L. monocytogenes* inoculated on stainless steel.

Objective 3

Figure 3.0. Foam contact surface (padding to cushion cantaloupe and limit bruising on display).

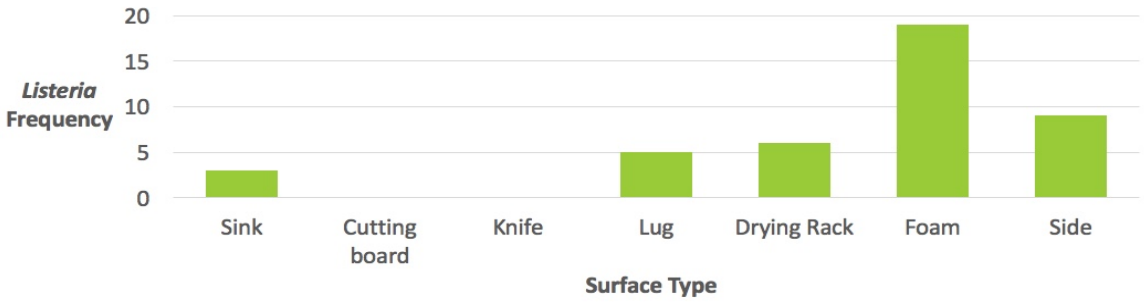

Figure 3.1. Prevalence of *Listeria*-positive samples for each contact surface (Retail Partner 1).

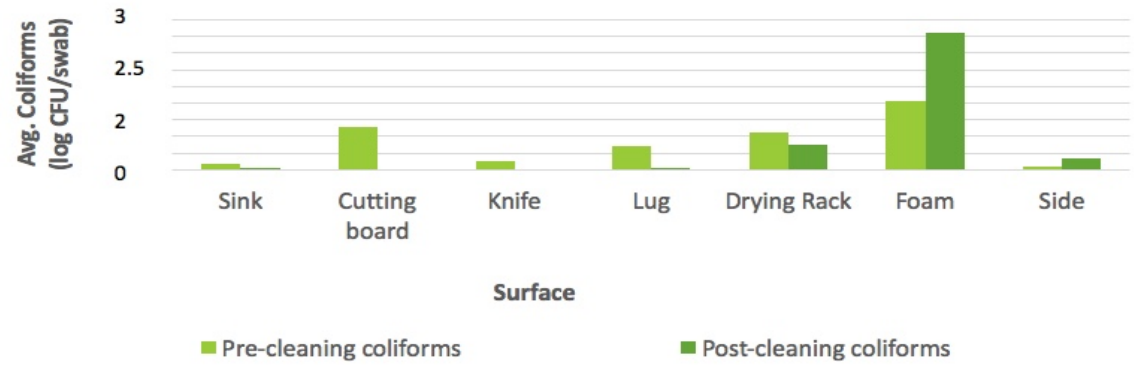

Figure 3.2. Average coliform counts (log CFU/swab) for each contact surface pre- and post-cleaning (Retail Partner 1).

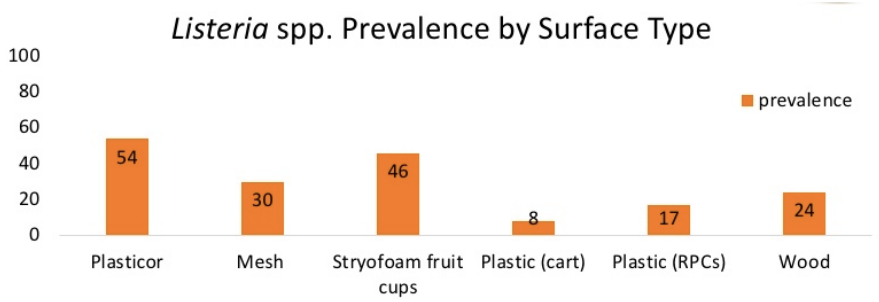

Figure 3.3. Prevalence of *Listeria*-positive samples for each contact surface (Retail Partner 2).

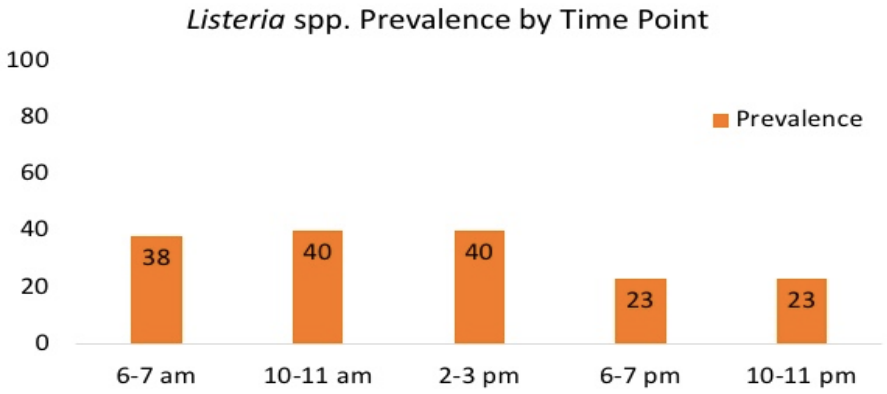

Figure 3.4. Prevalence of *Listeria*-positive samples for each sampling time point (Retail Partner 2).

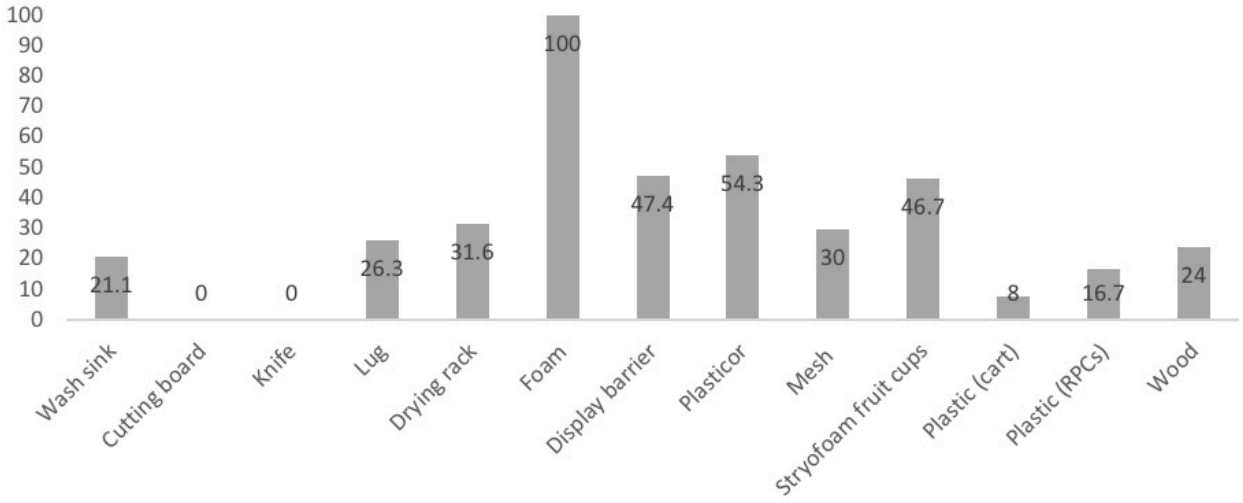

Figure 3.5. Combined data for Retail Partner 1 and 2: *Listeria* spp. prevalence for each retail cantaloupe contact surface.