Consumer Perceptions, Pathogen Detection, and Removal Rate Determination in Market-style Restaurants

THESIS

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Abstract

Forty-eight million Americans will get a foodborne illness every year. Millions of American consumers eat in market-style restaurants daily, yet food safety in market-style restaurants is poorly understood. The rise in instances of foodborne illnesses presents a need to further understand the role of consumers in food safety in market-style restaurants.

The purpose of this study was to assess the food safety perceptions and behaviors of consumers in market-style restaurants, to determine prevalence of human pathogen indicators (coliforms and generic *Escherichia coli*) and human pathogens (*Listeria monocytogenes*, *Salmonella* spp., and *E. coli* O157:H7) in common areas in market-style restaurants and determine effectiveness of a novel microfiber towel to decrease the risk of foodborne illness.

A convenience sample of 295 consumers was collected in dining areas on an urban, Midwestern university campus. Questionnaires assessed consumer’s perceptions about indicators of food safety, sources of contamination, measures to prevent contamination, safety of different cuisines, and roles of stakeholders in MSR food safety, using a five-point Likert-type scale. Questionnaires also assessed consumers’ food safety behaviors and their potential engagement in preventative food safety behaviors. A total of 391 swab samples were collected from food contact and non-contact surfaces (tables,
salad bars, serving bars, plates, etc). Additionally, 60 cell phone swabs were collected. All samples were tested to enumerate coliforms and generic *Escherichia coli* and determine the prevalence of *Listeria monocytogenes*, *Salmonella* spp., and *E. coli* O157:H7. The efficacy of novel proton microfiber towels to remove human pathogens was determined. A total of 80 experiments were completed to test removal rates of *Escherichia coli* O157:H7 (ATCC® 43888™) and *Salmonella enterica* subsp. *enterica* serovar Typhimurium ATCC (14028GFP) from stainless steel and acrylic surfaces to a microfiber towel. Each pathogen was tested on each surface under conditions of both wet and dry (60 minute drying time) inoculum 10 times.

Consumers perceived employee hand hygiene (wt. mean=4.6) as the most important indicator of food safety in MSR over food preparation (4.4), restaurant cleanliness (4.3), food type (4.0), and posted food safety reminders (3.5). Consumers perceived people (food handlers and other patrons, wt. mean=4.4) to be the most likely source of contamination, and perceived food contact surfaces (4.2) and foods (4.2) to be less likely. They also believed that restaurant owners and employees should be the most responsible for food safety (median=5, Q1=4, Q4=5) and that patrons were the least responsible (median=3, Q1=3, Q4=4). Consumers reported seldom engaging in table/utensil sanitation (wt. mean=2.98) or hand sanitation (2.98).

A total of 141 surfaces and 8 cell phone swabs were positive for coliforms and 19 surfaces and 2 cell phone swabs were positive for generic *E. coli*. The majority of *E. coli* positive samples were from salad bars (39/75 samples) and tables (36 /139 samples). Of the samples that were positive for generic *E. coli*, seven were from salad bar counters and
utensils and three were from cereal serving counters. Total coliform counts ranged from 1-6.6 log CFU/mL.

There were no differences between removal rate of *Salmonella* Typhimurium (55±14%) when compared to removal rates of *E. coli* O157:H7 (52±17%, *P* > .05). The treatment of the inoculum on the surface did not significantly affect the removal rate. When the inoculum was allowed to dry for 60 minutes prior to wiping the removal rate was slightly lower (48±18%) than when the surface was wiped immediately after inoculation (58±10%, *P* > .05). Overall, the log CFU reduction was greater for *Salmonella* (4.6±0.9) than it was for *E. coli* (4.0±1.2, *P* = .02). As expected the log CFU reduction was greater for both *E. coli* and *Salmonella* when the inoculum was wiped while wet (5.0±0.3) rather than wiped after 60 minutes of drying (3.6±1.2, *P* < .001).

The findings of this study highlight the importance of food safety in dining areas. The consumer survey gives us a better understanding of how consumers perceive food safety in market-style restaurants, which will allow for development of more effective interventions to reduce food safety risk. While no pathogens were detected on food contact and non-contact surfaces, the high level of samples that tested positive for human pathogen indicators show that there is the potential for contamination of surfaces in market-style restaurants. Early work on removal rates with a novel microfiber towel indicate that greater than three log pathogen removal from stainless steel and acrylic surfaces, and removal rates average between 41% and 59%. Novel proton microfiber towels may be an effective intervention to prevent foodborne illness in MSR.
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Table of Contents

Abstract .................................................................................................................................................. ii

Acknowledgements .............................................................................................................................. v

Vita ........................................................................................................................................................ vii

Table of Contents .................................................................................................................................... viii

List of Tables ........................................................................................................................................... xi

List of Figures .......................................................................................................................................... xii

Chapter 1: Introduction .......................................................................................................................... 1

Chapter 2: Review of Literature ............................................................................................................ 4

  2.1 Importance of Food Safety ................................................................................................................. 4

  2.2 Occurrence of Outbreaks ...................................................................................................................... 4

  2.3 Indicators of Contamination with Foodborne Pathogens ................................................................. 5

    2.3.1 Coliforms and generic E. coli ......................................................................................................... 5

  2.4 Bacterial Human Pathogens that Cause Foodborne Illnesses ....................................................... 6

    2.4.1 Escherichia coli O157:H7 .............................................................................................................. 6

    2.4.2 Salmonella spp. ........................................................................................................................... 7

    2.4.3 Listeria monocytogenes ................................................................................................................ 7

      2.4.3.1 Persistence on Inanimate Surfaces .............................................................................................. 8

  2.5 Market-style Restaurants .................................................................................................................. 8
2.6 Consumers’ Food Safety Practices in Market-style Restaurants .................. 9
2.7 Food Contact Surfaces and Cross-contamination ...................................... 10
2.8 Effectiveness on Microfiber Towels .......................................................... 12
   2.8.1 Introduction ......................................................................................... 12
   2.8.2 Use of Microfiber Towels ................................................................. 13

Chapter 3: Material and Methods ...................................................................... 15
3.1 Consumer Survey in MSR ........................................................................... 15
   3.1.1 Restaurant Recruitment ................................................................. 15
   3.1.2 Survey Design ................................................................................ 16
   3.1.3 Data Analysis ................................................................................ 17
3.2 Microbial Sampling in MSR ........................................................................ 18
   3.2.1 Pathogen Sampling and Detection .................................................. 18
   3.2.2 Coliforms and Generic *E. coli* ....................................................... 18
   3.2.3 *Salmonella* spp. .......................................................................... 19
   3.2.4 *Listeria monocytogenes* ................................................................. 19
   3.2.5 *E. coli* O157:H7 .......................................................................... 20
3.3 Effectiveness of Proton Towels .................................................................... 21
   3.3.1 Surface Coupon Preparation .......................................................... 21
   3.3.2 Microfiber Towel Preparation ......................................................... 21
   3.3.3 Strain Selection .............................................................................. 21
   3.3.4 Inoculum Preparation .................................................................... 21
   3.3.5 Data Analysis ................................................................................ 22
# Chapter 4: Results

4.1 Consumer Survey ........................................................................................................ 24
   4.1.1 Participants and Restaurants ............................................................................... 24
   4.1.2 Consumers’ Food Safety Attitudes and Practices .............................................. 26

4.2 Pathogen and Pathogen Indicator Testing ................................................................. 29
   4.2.1 Surfaces ................................................................................................................. 29

4.3 Effectiveness on Microfiber Towels .......................................................................... 32
   4.3.1 Removal of *E. coli* O157:H7 from Surfaces .................................................. 32
   4.3.2 Removal of *Salmonella* Typhimurium from Surfaces ................................. 36

# Chapter 5: Discussion ...................................................................................................... 42

# Chapter 6: Conclusions .................................................................................................. 48

# References ..................................................................................................................... 49

# Appendix A .................................................................................................................... 56

Survey: Consumer perceptions, behavior and expectations in market-style restaurants .......................................................................................................................... 56
List of Tables

Table 1. Demographic characteristics and MSR frequency ........................................... 25
Table 2. Ranking of most important indicators of food safety ........................................ 27
Table 3. Ranking of most likely sources of microbial contamination ............................. 27
Table 4. Ranking of stakeholder responsibility for food safety ....................................... 28
Table 5. Surfaces testing positive for coliforms ............................................................... 31
List of Figures

Figure 1. Flow diagram showing the surface, treatment, and inoculum for each experiment (each repeated 10 times) ................................................................. 22

Figure 2. A schematic of samples testing positive for generic E. coli (indicated by red dot) and coliforms (indicated by # of positive samples out of # of samples tested) ...... 30

Figure 3. Reduction of E. coli O157:H7 from stainless steel and acrylic surfaces using a microfiber towel ............................................................ 33

Figure 4. Reduction of E. coli O157:H7 from stainless steel and acrylic surfaces under wet and dry conditions using a microfiber towel ................................. 34

Figure 5. Removal rate of E. coli O157:H7 from stainless steel and acrylic surfaces using a microfiber towel ......................................................... 34

Figure 6. Removal rate of E. coli O157:H7 from stainless steel and acrylic surfaces under wet and dry conditions using a microfiber towel ............................................. 35

Figure 7. Reduction of E. coli O157:H7 from stainless steel and acrylic under wet and dry conditions using a microfiber towel ............................................. 35

Figure 8. Reduction of E. coli O157:H7 from stainless steel and acrylic under wet and dry conditions using a microfiber towel ............................................. 36
Figure 9. Reduction of *Salmonella* Typhimurium from stainless steel and acrylic surfaces using a microfiber towel ........................................................................................................ 38

Figure 10. Reduction of *Salmonella* Typhimurium from stainless steel and acrylic surfaces under wet and dry conditions using a microfiber towel.................................................. 38

Figure 11. Removal rate of *Salmonella* Typhimurium from stainless steel and acrylic surfaces using a microfiber towel ........................................................................................................ 39

Figure 12. Removal rate of *Salmonella* Typhimurium from stainless steel and acrylic surfaces under wet and dry conditions using a microfiber towel.................................................. 39

Figure 13. Reduction of *Salmonella* Typhimurium from stainless steel and acrylic under wet and dry conditions using a microfiber towel........................................................................................................ 40

Figure 14. Removal rate of *Salmonella* Typhimurium from stainless steel and acrylic under wet and dry conditions using a microfiber towel........................................................................................................ 40

Figure 15. Reduction of *E. coli* O157:H7 and *Salmonella* Typhimurium using a microfiber towel................................................................................................................................. 41

Figure 16. Removal rate of *E. coli* O157:H7 and *Salmonella* Typhimurium using a microfiber towel................................................................................................................................. 41
Chapter 1: Introduction

Every year one in six (48 million) Americans get sick from a foodborne illness (6). It is estimated that 48% of reported foodborne illness outbreaks occur in restaurants or delis (5). Americans are eating in restaurants three or more times each week and an increasing number of consumers are eating in market-style restaurants (MSR) everyday. The market-style dining platform is characterized by a number of food vendors located in the same venue with joint dining areas. These dining platforms are becoming increasingly popular due to convenience and the convenience of an array of choices offered in one location attracting a diversity of consumers. Commonly found in education and entertainment centers, shopping malls, hospitals, airports, grocery stores, market-style restaurants serve all consumer categories including the general population and at-risk populations (young children, elderly, and immunocompromised). While MSR continue to be desirable from economic perspectives due to high table turnover and reduced employee labor in self-serve dining areas, this type of foodservice includes a number of high-risk foodservice options such as holding buffets, salad bars, dessert bars, condiment bars and other similar services. In addition, food safety responsibility in this setting is shared and may create a culture in which the food safety roles are undefined and unclear, especially to the consumer. Furthermore, shared dining areas in MSR may introduce
additional food safety hazards due to an increased risk of cross-contamination, highlighting the need to further investigate food safety challenges specific to this type of foodservice. Finally, novel strategies are required to ensure cleanliness of surfaces in dining areas in MSR and to reduce the risk of cross-contamination.

While the number of foodborne illnesses linked to restaurants remains high, the data on consumer behaviors and their food safety perceptions in MSR is lacking (33). The role of consumers in ensuring food safety has not been investigated. Successful interventions are necessary to reduce the number of foodborne illnesses. This will only be possible if the consumer’s perceptions and behaviors are better understood. The findings of this study will enable development of effective interventions to increase food safety in MSR and reduce the number of foodborne illnesses.

Aim 1. To assess food safety attitudes, practices, and culture among consumers in market-style restaurants.

Hypothesis 1. Consumers’ food safety attitudes and practices in MSR are not adequate to reduce the risk of foodborne illnesses.

Outcome Measures for 1. Attitudes, practices, and culture will be assessed through self-reported data with the use of a questionnaire-based survey.

Aim 2. To detect and enumerate of human pathogen indicators (coliforms and generic *E. coli*) and human pathogens (*Listeria monocytogenes, Salmonella* spp., and *Escherichia*
coli O157:H7) from food contact and non-contact surfaces (tables, salad bars, serving bars, plates, etc) in MSR.

**Hypothesis 2.** Food contact and non-contact surfaces found in dining areas in MSR are contaminated with human pathogen indicators (coliforms and generic *E. coli*) and human pathogens such as *Listeria monocytogenes, Salmonella* spp., and *Escherichia coli* O157:H7

**Outcome Measures for 2.** Enumeration of *E. coli* and coliforms will be performed using culturing techniques on Tryptone Bile X-Glucuronide (TBX). Pathogen detection will be performed by culture, serological tests, and molecular tests.

**Aim 3.** To determine the effectiveness of a novel microfiber towel in removing human pathogens (*Salmonella* Typhimurium and *E. coli* O157:H7) from stainless steel and acrylic surfaces.

**Hypothesis 3.** The novel microfiber towel is effective in removing *Salmonella* Typhimurium and *E. coli* O157:H7 from stainless steel and acrylic surfaces and pathogen removal rate increases with moisture.

**Outcome Measures for 3.** Removal rate and log reduction will be calculated as previously reported (24). When the source of contamination is the surface (coupon), removal rate (%) = (CFU/microfiber towel)/(total CFU) x 100.
Chapter 2: Review of Literature

2.1 Importance of Food Safety:

Food safety continues to be of the highest importance to public health. Every year 48 million foodborne-related illnesses occur in the United States (15% of the American population). Of those, 128,000 people are hospitalized and 3,000 people die due to foodborne diseases. Foodborne illnesses are preventable and by reducing them by 10% we could keep five million Americans from getting sick every year (7).

The economic burden of foodborne illnesses is estimated to cost $77.7 billion in healthcare related expenses and an average of $1,626 per case (48). Additional research found that the cost of foodborne illnesses in Ohio annually was between $1.0 billion or between $91 and $624 per capita, translating to $1,663 per foodborne illness cases in Ohio (49). Salmonella spp. alone results in more deaths and hospitalizations than any other bacteria in food and leads to $365 million in direct medical costs each year (7).

2.2 Occurrence of Outbreaks:

While reported foodborne illness outbreaks occur in restaurants 45% of the time (52), the public continues to consume food away from home at increasing rates (4). According to the USDA, Americans spent one-half of all of their food expenses on food consumed away from their homes in 2011 (57). Certain strains of L. monocytogenes are capable of persisting for long periods of time on food contact and non-contact surfaces and have caused multiple outbreaks (41). A recent L. monocytogenes outbreak in deli meat was
responsible for over 100 reported illnesses and 14 fatalities (34). This was the second largest *L. monocytogenes* outbreak in history. Between 1982 and 2002 49 states have reported 350 outbreaks of *E. coli* O157:H7 leading to 8,598 cases, 1,493 (17%) hospitalizations, 354 (4%) hemolytic uremic syndrome cases, and 40 (0.5%) deaths (42). *Salmonella* outbreaks cause more than 1 million illnesses, 23,000 hospitalizations, and 450 deaths each year in the United States (45). In 2012 alone, *Salmonella* was responsible for 106 foodborne illness outbreaks and led to the most hospitalizations (9). Shiga toxin producing *E. coli* has been a major food safety concern of late due to multiple outbreaks occurring at Chipotle restaurants across more than 10 states (13). From 1973 to 1997 there were more than 600 foodborne illness outbreaks in schools at a median of 25 outbreaks annually. Additionally, *Salmonella* was the most commonly identified pathogen in those outbreaks (16).

2.3 Indicators of Contamination with Foodborne Pathogens:

2.3.1 Coliforms and generic *E. coli*:

Coliforms are a large class of bacteria that are indicative of sanitation quality. The class includes the genera *Citrobacter, Enterobacter, Escherichia, Hafnia*, and *Klebsiella*. Presence of these organisms indicates fecal contamination, and the potential presence of enteric pathogens (50). A strong correlation exists between presence of coliforms and presence of enteric pathogens, but the absence of coliforms is not necessarily indicative of the absence of fecal contamination (50).

Presence of indicator organisms does not necessarily mean that the pathogens are present. It does mean, however, the presence of fecal matter, which means that human
pathogens could also be present. Coliforms and generic *E. coli* are often criticized as indicators. However, currently they are used as reliable indicators for drinking water and the food industry.

In order to prevent the dissemination of foodborne pathogens and reduce the risk of foodborne outbreaks we must design effective risk communication material for both consumers and employees, and to do so we must better understand the microbial quality of food contact and non-contact surfaces in market-style restaurants and the pathogen transfer and dissemination routes.

2.4 Bacterial Human Pathogens that Cause Foodborne Illnesses:

2.4.1 *Escherichia coli* O157:H7:

Enterohemorrhagic *Escherichia coli* is a gram-negative, facultative anerobe that causes disease in humans. Enterohemorrhagic *E. coli*, which includes *E. coli* O157:H7, is a major public health problem due to the prevalence of numerous outbreaks in the last two decades. It produces shiga toxin. Due to the production of this toxin, infection can lead to hemolytic uremic syndrome (HUS). *Escherichia coli* O157:H7 causes 265,000 illnesses in the United States annually and 8% of those cases lead to HUS. It is estimated that 3-5% of those who develop HUS die (11). Very young children and the elderly are at greater risk to develop HUS than other, but people of all ages can become seriously ill. The CDC also estimates that Enterohemorrhagic *E. coli* causes 3,200 hospitalizations each year. The major source of contamination with *E. coli* is due to the consumption of beef (10).
2.4.2 Salmonella spp.: 

*Salmonella* is a gram-negative, rod-shaped bacteria that causes disease in humans. The CDC estimates that *Salmonella* causes 1.2 million foodborne illnesses in the United States every year. Additionally, it causes 19,000 hospitalizations and 450 deaths annually. *Salmonella* is the number one cause of death among foodborne pathogens (28%). Children are at great risk for *Salmonella* infections. The CDC reports that children under 5 years of age have greater rates of infections than any other age group (11). In 2012 alone, there were 831 *Salmonella* outbreaks. Recent research found that as organic load increased on surfaces such as stainless steel so did the survival of *Salmonella* spp. (17). The major sources of contamination with *Salmonella* include eggs and poultry (12).

2.4.3 Listeria monocytogenes:

*Listeria monocytogenes* is a gram-positive, facultative anaerobe that causes listeriosis in humans. It is found in soil, water, and some animals. *Listeria monocytogenes* is unique due to its ability to grow at refrigeration temperatures. While the general population can develop listeriosis, it is most common in older adults, pregnant women, newborns, and adults with weakened immune systems. The major sources of contamination with *Listeria monocytogenes* include uncooked meat and vegetables and unpasteurized milk or cheese (8).
2.4.3.1 Persistence on Inanimate Surfaces

It has been shown that *Listeria monocytogenes* was second most likely to cling to stainless steel just behind granite/marble. Additionally, it has been reported that the highest number of viable cells could be recovered from polypropylene surfaces (51). Both of these surfaces are commonly found in food service establishments. Only one study has assessed the distribution of coliforms on both foods and surfaces in a Rutgers University cafeteria (36). To date information on the prevalence of *Listeria* spp. is missing (28), even though it causes some of the most costly foodborne illnesses (47). The United States has implemented a zero tolerance policy for *L. monocytogenes* in read-to-eat (RTE) foods. Processing plants must have *Listeria* prevention programs in place, but retail establishments, including restaurants are currently not required to have those same programs in place. Risks of contamination of RTE foods with *L. monocytogenes* increases with operations such as slicing, mixing, and packaging since *L. monocytogenes* is able to survive on meat slicers and serve as a contamination source (29).

2.5 Market-style Restaurants:

Market-style restaurants are becoming increasingly popular. This style of restaurant offers consumers a variety of cuisines in one location. Market-style restaurants may have small scale, large scale, or fast food restaurants. Additionally they may contain only a few units or over 20 restaurants in one location. Dining areas in market-style
restaurants are communal, leading to sanitation in dining areas to be overseen by the site management. Market-style restaurants continue to be found in locations such as shopping malls, hospitals, airports, school and universities, and entertainment centers. Due to their locations and types of cuisines offered, market-style restaurants serve all types of consumers including at-risk populations. A large variety of foods are offered at market-style restaurants, including many ready-to-eat (RTE) foods made from raw (salad bar) and mixed raw/cooked ingredients (sushi). Currently, the safety of these products is assured by cold storage, employee hygiene, and prevention of cross-contamination. Since each individual vendor holds the responsibility for food safety in their unit, markets style restaurants present a set of unique and troublesome food safety challenges. Due to the nature of market-style restaurants each vendor may implement different levels of food safety measures in their unit. Additionally, dining areas may also be cleaned differently. Since the vendors are not held responsible for cleanliness in the dining areas, there are likely gaps in food safety practices and surface sanitation. Each vendor’s unit is close to one another, which may influence the employees’ food safety behaviors at each unit.

Currently, the state of Ohio requires that “managers must ensure that employees are trained in food safety as it relates to their assigned duties”, and ServSafe® or comparable certification for one manager per shift is require by Ohio Department of Health (39).

2.6 Consumers’ Food Safety Practices in Market-style Restaurants:

Food safety perceptions of consumers in restaurants have been previously investigated. Williamson and Granani, (1991) found that 33% of consumers indicated
that problems related to food safety were due to unsafe practices at the restaurants (59). Other studies have linked having a foodborne illness with the belief that consumption of contaminated food outside of the home was the cause (20). Additionally, the consumers’ level of hygiene and cross-contamination in dining areas are greatly influenced by other consumers’ food safety handling practices. The level that consumers influence one another is greater in this type of restaurant when compared to other restaurant types. Several studies reported consumer behaviors at home (2, 30, 53), but to our knowledge consumer behaviors and food safety perceptions in market-style restaurants have not been studied. While several studies have been done to describe the practices of consumers in different restaurant types (30, 44), there is scarce information on the practices of consumers, specifically in market-style restaurants.

The objective of this study is to assess food safety attitudes, practices, and culture among 300 consumers in three different market-style restaurants on a university campus using questionnaires.

2.7 Food Contact Surfaces and Cross-contamination:

When controlling the spread of pathogens, food contact surfaces are of the utmost importance and require more attention (15). The survival of foodborne pathogens is affected by the amount of organic residue on a surface as well as the composition of the surface itself (17, 51).

Not only do employee food handling practices influence how cross-contamination can occur, but consumers’ behaviors, knowledge, perceptions, and attitudes also play a
role along with the degree of contamination in market-style restaurants. Currently few studies have been done to link self-reported consumer behaviors with microbiological data from the same restaurants (25). In market-style restaurants the level of contamination and pathogen transfer routes have not yet been studied. Although, the use of shared dining areas increases the likelihood of cross-contamination.

Foodborne illness outbreaks are most frequently associated with restaurants. Frequent cleaning of surfaces in foodservice kitchens as well as surfaces in consumer dining areas is necessary in order to prevent foodborne illness outbreaks. Restaurant employees must focus both on the prevention of cross-contamination in the kitchen as well as proper cleaning and sanitation in public dining areas in order to prevent the spread of pathogenic organisms (55). Cross-contamination due to poor personal hygiene and contaminated tools and equipment during food preparation is a major factor that affects the dissemination of foodborne illnesses (40, 55).

The objective of this study is to detect and enumerate human pathogen indicators (coliforms and generic E. coli) and human pathogens (Listeria monocytogenes, Salmonella spp., and Escherichia coli O157:H7) from food contact and non-contact surface (tables, salad bars, serving bars, plates, etc) swabs collected from three MSR on a university campus. Due to the limited number of employees for cleaning in the dining area of market-style restaurants, organic load on surfaces may increase the risks of human pathogens.
2.8 Effectiveness of Microfiber Towels:

2.8.1 Introduction:

Both Salmonella (35%) and Escherichia coli (4%) are among the top five pathogens that cause domestically acquired foodborne illnesses resulting in hospitalization. Additionally, Salmonella is the number one foodborne pathogen resulting in death (28%), and outbreaks caused by Salmonella increased by 39% from 2012 to 2013. In 2013, restaurants accounted for 60% of outbreaks (6, 7). The roll that cross-contamination plays in foodborne illness outbreaks has been well documented (18). There are a number of cross-contamination routes contributing to contamination with human pathogens in foodborne illness outbreaks. These include hand to surface, surface to hand, food to hand, hand to food, and other combinations (56). Some studies have investigated the transfer rates between various surfaces (cutting boards, foods, worker’s hands, and utensils) found in a kitchen environment, but few have examined transfer rates between specific food and consumer contact surfaces and microfiber cleaning towels (14, 32, 35, 58). Surfaces can easily become contaminated when touched by an infected food handler or by contact with raw foods (19, 61). From dirty surfaces, pathogens can easily be transferred from surfaces to foods at high rates (56). Proper cleaning and sanitizing of both food contact surfaces and dining areas is essential to prevent foodborne illnesses. Pathogenic microorganisms can easily be transferred from surfaces to foods at high rates. Salmonella spp. can survive for weeks on many different surfaces (56).
2.8.2 Use of Microfiber Towels:

Microfiber towels have been shown to remove greater amounts of *Listeria monocytogenes* than scouring pads, nonwoven, and terry towels from stainless steel and Formica (26). The current towel of choice in most foodservice establishments is the terry towel due to the inexpensive nature of these towels. In order to determine successful cleaning and sanitation interventions new technologies must be examined. Microfiber is a fiber with a weight/length ratio < 1 decitex (1 decitex = 1 g/10,000 m). In order to make microfiber towels small fibers are split from larger polyester and polyamide synthetic fibers (38). Stitchbonded, non-woven fabric, novel microfiber proton towel has been on the market as of recently. While the manufacturers label states the proton towels may remove 99.9% of pathogens from hard surfaces prior to using an approved sanitizer (54), the effectiveness of the towels has not been validated on stainless steel, acrylic, or other surfaces in restaurants and retail. By removing the vast majority of pathogens from a surface with a microfiber towel, appropriate sanitizing agents may be more effective. In addition, if effective against human pathogens, towels can be a possible cleaning alternative between sanitation periods in market-style restaurants.

Pathogenic organisms such as *Salmonella* have been shown to require a greater concentration of sodium hypochlorite solution for deactivation when in a towel than in suspension (27). It has been reported that microfiber towels are able to remove over 90% of deposits from highly contaminated surfaces (38). Additionally, other studies have
demonstrated the ability of microfiber towels to remove greater levels of viruses from stainless steel and other nonporous surfaces than other types of towels such as the terry towel (22). Microfiber towels look to have similar knitting patterns to terry towels under the microscope but have smaller loops and are denser (26). In addition to being made from 70% polyester and 30% polyamide, microfibers are 1/100th the size of a human hair and have 40 times more surface area than cotton fibers (43). It is the combination of these properties that makes microfiber towels more effective at removing pathogenic organisms from surfaces than traditional terry towels. Researchers have demonstrated that different strains *E. coli* and *Salmonella* have different rates of adhesion to stainless steel (3).

Proton towels come in light duty, medium duty, and heavy duty. For this project, we chose the medium duty towel as it is recommended for use in both the front and back of the house (54). In order to determine the efficacy of these microfiber towels for use in a food service setting, we aimed to understand transfer rates of *Escherichia coli* O157:H7 Migula, Castellani and Chalmers (ATCC® 43888™) and *Salmonella enterica* subsp. *enterica* serovar Typhimurium GFP ATCC (14028GFP) from two common food contact surfaces (stainless steel and acrylic) to a microfiber Tietex proton towel. This study will test the efficacy of the Tietex proton towel while dry. We anticipate that the transfer rates may be strain dependent and not necessarily representative of *E. coli* O157:H7 or *Salmonella* Typhimurium.
Chapter 3: Material and Methods

3.1 Consumer Survey in MSR

3.1.1 Restaurants and Recruitment:

This study was conducted in October 2014–November 2015 in three different market-style restaurants on an urban, Midwestern university campus. The restaurants on average employed two managers, seven fulltime employees and 85 student employees. Each restaurant served approximately 500 consumers during lunch and 700-900 consumers for dinner. The MSR were selected based on their location and willingness to participate in the study. Restaurants included at least four food-vending units including serving/holding tables, buffet foods, salad bars, sushi bar, sandwich assemblies and warm meals. Featured foods included ethnically diverse choices such as Mexican, Chinese, Italian, Middle Eastern, and Mediterranean foods. All restaurants had common dining areas with shared condiments, utensil, drink dispensers and garbage bins. Consumers in MSR were recruited by convenience sampling. They were approached to participate in a study while in the restaurants with an incentive of a drawing for an iPad mini. All study procedures were approved by the Ohio State University Institutional Review Board, Social and Behavior Research with Humans (protocol 2014B0137).
3.1.2 Survey Design:

A questionnaire was developed in collaboration between researchers with expertise in food safety, microbiology, and hospitality management. Previously validated and published measurement tools were modified and adjusted to fit a MSR setting and the target population in this study (37). The questions were organized into four sections. The first section contained demographic questions including age, gender, education level, ethnicity, and frequency of dining in MSR. The second section was designed to assess consumers’ perceptions about hygiene indicators in MSR, sources of contamination, measures to prevent contamination, food safety of different cuisines, and their own or other stakeholders’ roles in food safety. The perceptions of hygiene indicators were assessed using an 18 item five-point Likert-type scale with responses from 1=not important to 5=very important. A 15 item five-point Likert-type scale was used to rank the importance of different sources of microbial contamination of the consumers. The scale included questions related to contaminations from surfaces, foods, and people. Consumer’s perceptions of effectiveness of preventative measures were assessed using a six item five-point Likert-type scale (1=not effective to 5=effective). In addition, food safety behaviors and consumers’ willingness to engage in preventative behaviors in MSR were assessed using a five-point Likert-type scale measuring the frequency of engagement (1=never to 5=very often) in relevant practices. Lastly, the fourth section of the questionnaire was designed to assess consumers’ food culture in MSR using a five-
point Likert-type scale as follows: 1) the influence of other patrons in MSR on consumer behaviors using from 1=strongly disagree to 5=strongly agree and 2) the consumer’s willingness to engage in the same food safety behaviors if they see others engaging in that behavior with responses ranging from 1=not likely to 5=very likely. The complete questionnaire is available by request from the authors (Appendix A).

3.1.3 Data Analysis:

Missing and erroneous data from questionnaires was not included for data analysis. Questionnaire data were recorded and analyzed using SPSS Statistical Package for the Social Sciences (version 22.0; IBM Corp., Armonk, NY). Questions with grouped items were treated as continuous data and analyzed using independent samples t-tests and analysis of variance (ANOVA) tests. Questions containing only one item were analyzed as ordinal data using Chi-Square tests. Descriptive statistics and frequencies were used to analyze the sample characteristics such as age, gender, education, and ethnicity. Additionally, weighted averages were compared for all grouped questions. The questionnaire items were grouped before data analysis so that items assessing the consumer’s perceptions of specific topics were analyzed together. A question assessing important food safety indicators included five groups (food characteristics, food preparation, surface cleanliness, employee hand hygiene, and consumer food safety indicators). A question assessing sources of microbial contamination included three groups (surfaces, foods, and people). A question assessing consumer food safety
behaviors included two groups (hand sanitation practices and table/utensil practices). A question assessing the effectiveness of measures to prevent microbial contamination included two groups (hand practices and table/utensil practices). Finally, a question assessing consumers’ willingness to engage in certain food safety behaviors was grouped into three groups (hand sanitation behaviors, table sanitation behaviors, and sanitation messages.

3.2 Microbial Sampling in MSR

3.2.1 Pathogen Sampling and Detection

Surfaces in the common dining area in three MSR were swabbed using pre-moistened Speci-Sponge® (3M, Maplewood Minnessota) four times over a 9 month period. Mobile phone swabs were collected from consumer in one MSR location over two different time periods. Surfaces were swabbed for 30 seconds to ensure uniform sampling of different surfaces. The samples were transported on ice packs to the laboratory for immediate processing. Samples were processed by adding BPW (10:1) in an EasyMIX® lab mixer (bioMerieux, Marcy l’Etoile, France) for 120 seconds and then sonicated in ultrasonic bath (VWR, Radnor, Pennsylvania) for 120 seconds to dislodge the bacteria.

3.2.2 Coliforms and Generic E. coli

Serial dilutions were made and plated onto Tryptone Bile X-Glucuronide (TBX) (Oxoid, Basingstoke, UK) and incubated at 37°C for 24-48 hours for detection and
quantification of coliforms and generic *E. coli*, and in order to enrich the samples to test for *Salmonella* spp., *Listeria monocytogenes*, and *E. coli* O1057:H7 (60).

### 3.2.3 *Salmonella* spp.

The samples were pre-enriched at 37°C for 24 hours in original sampling bags with BPW. *Salmonella* detection was performed as previously reported (31). Briefly, a 1-mL aliquot of incubated pre-enrichment was added to 10 mL of Rappaport-Vassiliadis *Salmonella* enrichment broth (RV broth; Neogen, Lansing, Michigan) and incubated at 37°C for 24 hours and 10 µL was streaked onto Xylose Lysine Tergitol-4 agar (XLT4; Neogen Lansing, Michigan). Colonies were confirmed on Triple Sugar Iron, Urea, and Citrate slants (TSI agar, Urea agar, Citrate agar; Neogen, Lansing, Michigan) 37°C for 24 hours and serotyped using Salmonella O Antiserum Poly A and Poly B (Difco, Becton Dickinson, Detroit, Michigan). Salmonella was captured on antibody-coated paramagnetic beans using Dynabeands (Invitrogen, Grand Island NY, USA) microspheres. Dynabeands (50 µL) were added and used according to the manufacturers’ instructions. Following IMS, beads (10 µL each) were plated onto XLT4.

### 3.2.4 *Listeria monocytogenes*

Detection of *Listeria monocytogenes* was performed as previously described (21). First, 1 mL of the 10⁻¹ dilution from each sample was inoculated into 9 mL of Fraser Broth (FB, Neogen, Lansing, Michigan) and incubated at 35°C for 24 and 48 hours. Positive samples were streaked onto PALCAM Agar plates (PA, Neogen, Lansing, Michigan) and incubated at 35°C for 24 hours. Positive colonies were transferred onto
blood agar (Remel, Lenexa, Kansas) and incubated at 35°C for 24 hours. *Listeria monocytogenes* was plated on each media as a positive control while uninoculated plates were used as negative controls. Colonies were confirmed, using Rapid L’mono plates (Bio-Rad, Hercules, California) and incubated at 35°C for 24 hours.

3.2.5 *E. coli* 0157:H7

*E. coli* O157:H7 was captured on antibody-coated paramagnetic beads using Dynabeads (Invitrogen, Grand Island, New York). Dynabeads (50 µL) were added and used according to the manufacturers’ instructions. Immunomagnetic Separation (IMS) was performed on samples with the highest coliform counts and samples that were positive for generic *E. coli*. After IMS was performed, each sample was streaked onto Sorbitol MacConkey with cefixine and tellurite (Neogen) and incubated at 37 °C for 24 hours. Plates were then compared to positive and negative controls. Positive colonies were then transferred to tubes of 5 mL of EC MUG (Neogen) broth and incubated 37 °C for 24 hours. Each tube was screened for fluorescence using UV light. Positive samples did not fluoresce and were streaked onto MacConkey (Neogen) agar plates and incubated at 37 degrees for 24 hours. MacConkey plates were screened for purple colonies (indicating suspect O157:H7). Suspect colonies were confirmed by using Oxoid *E. coli* O157:H7 Latex tests.
3.3 Effectiveness of Proton Towels:

3.3.1 Surface Coupon Preparation:
Two different surfaces typically found in restaurants: acrylic and stainless steel (type 304) were obtained from GlobePharma (New Brunswick, New Jersey). Surface coupons were 5 x 5 cm squares for cleaning validation. Prior to inoculation all coupons were rinsed with boiling water and then soaked in 70% ethanol for 1 hour to sterilize. Coupons were then allowed to air dry in a biological safety level 2 laboratory hood prior to inoculation.

3.3.2 Microfiber Towel Preparation:
Microfiber Proton Towels were supplied by Tietex (Spartanburg, SC). Towels were cut into 5 x 5 cm squares and sterilized by autoclaving at 121°C for 15 minutes.

3.3.3 Strain Selection and Inoculum Preparation:
*Escherichia coli* O157:H7 Migula, Castellani and Chalmers (ATCC® 43888™) and *Salmonella enterica* subsp. *enterica* serovar Typhimurium GFP ATCC (14028GFP) were chosen. These two strains were chosen so that future projects using food slurries and antibiotics in LB agar media can be done to build on this study since both strains are resistant to ampicillin.

3.3.4 Inoculum Preparation:
Before each experiment, frozen cultures of each strain were streaked onto LB agar (Difco, Becton Dickinson, Detroit, Michigan) and incubated at 37°C for 24 hours. A
single isolated colony of each strain was selected and transferred to 1 ml of LB broth and incubated at 37°C for 24 hours. Finally, 10 ml of LB broth was inoculated with the previously inoculated 1 ml and incubated at 37°C for 24 hours. The \textit{E. coli} was then diluted to 2.4 x 10^6 CFU/ml and the Salmonella strain was diluted to 1.4 x 10^6 CFU/ml. These concentrations were confirmed by enumeration on LB agar at the time of experimentation and optical density at 600nm. Additionally, the towel was inoculated with both \textit{E. coli} and \textit{Salmonella} and five recovery experiments were run for each microorganism. These experiments were performed to understand how much bacteria the microfiber towel retained after processing. \textit{E. coli} had a 31% retention rate and \textit{Salmonella} had a 67% retention rate.

![Flow diagram showing the surface, treatment, and inoculum for each experiment (each repeated 10 times)](image)

\textbf{Figure 1.} Flow diagram showing the surface, treatment, and inoculum for each experiment (each repeated 10 times)

3.3.5 Data Analysis

Data were compiled and log transformed using Microsoft Excel (Microsoft, Redmond, WA). Previous studies that have been done in a similar manner reported the necessity to log transform the data in order to make it normally distributed (14, 46). Removal rates
from surfaces to towels and reduction of pathogen load on the surfaces were calculated as previously reported (24). The inoculated source is defined as the sum of the amount on both surfaces after the transfer has taken place, so total CFU = CFU/microfiber towel + CFU/surface coupon. When the source of contamination is the surface (coupon), transfer rate (%) = (CFU/microfiber towel)/(total CFU) x 100. Independent samples t-tests were used to determine differences between treatments, surfaces, and microorganisms. All statistical tests were performed using SPSS Statistical Package for the Social Sciences (version 22.0; IBM Corp., Armonk, NY).
Chapter 4: Results

4.1 Consumer Survey

4.1.1 Participants and Restaurants:

A total of 295 consumers from three MSR at a large, Midwestern university campus participated in the study. **Table 1** shows demographic characteristics and dining frequency at MSR. Average age of participants was 20±4.5 years and 59% were female. The majority were Caucasian (61%), 21% Asian, 3.7% African American, 14% other. The majority of participants were undergraduate students (81% High School Diploma, 7.1% Bachelor’s Degree, 2.4% Graduate Degree, 2% Associate’s Degree). This was similar for three sampled restaurants (A, B, and C). Overall, most consumers in this study (76.6%) reported eating at MSR between two and three times per week. However, the frequency of eating in MSR was different among the patrons of three tested restaurants (*P* < .001). Location A attracted consumers that ate in MSR least frequently (1.18), while location B attracted consumers that ate in MSR most frequently (1.88).
Table 1. Demographic characteristics and MSR frequency

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>172</td>
</tr>
<tr>
<td>Male</td>
<td>122</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td></td>
</tr>
<tr>
<td>Some High School</td>
<td>1</td>
</tr>
<tr>
<td>High School Diploma</td>
<td>260</td>
</tr>
<tr>
<td>Associate’s Degree</td>
<td>6</td>
</tr>
<tr>
<td>Bachelor’s Degree</td>
<td>21</td>
</tr>
<tr>
<td>Graduate Degree</td>
<td>7</td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>203</td>
</tr>
<tr>
<td>African American</td>
<td>11</td>
</tr>
<tr>
<td>Black non-African American</td>
<td>7</td>
</tr>
<tr>
<td>Hispanic</td>
<td>4</td>
</tr>
<tr>
<td>Asian</td>
<td>61</td>
</tr>
<tr>
<td>American Indian or Alaska Native</td>
<td>1</td>
</tr>
<tr>
<td>I would rather not say</td>
<td>8</td>
</tr>
<tr>
<td><strong>Dining Frequency in MSR</strong></td>
<td></td>
</tr>
<tr>
<td>Everyday</td>
<td>64</td>
</tr>
<tr>
<td>4-5x per week</td>
<td>84</td>
</tr>
<tr>
<td>2-3x per week</td>
<td>78</td>
</tr>
<tr>
<td>Once week per week</td>
<td>29</td>
</tr>
<tr>
<td>Less than once per week</td>
<td>22</td>
</tr>
<tr>
<td>Less than once per month</td>
<td>18</td>
</tr>
</tbody>
</table>
4.1.2 Consumers’ Food Safety Attitudes and Practices

Most MSR consumers (68%) reported having none to moderate concern about food safety, and only 32% reported being concerned about food safety when eating in MSR. This was similar in all restaurants ($P > .05$). The most important indicator of food safety as perceived by the consumer was employee hand hygiene (wt. mean 4.64), followed by food preparation (4.40), overall cleanliness (4.32), the type and source of food (4.04), and food safety reminders (3.5) (Table 2). Accordingly, people, food handlers, and other patrons were considered to be the likely sources of microbial contamination (4.36), followed by foods (4.15) and surfaces (4.20) (Table 3). Consumers perceived that food serving counters were the most likely source of contamination of all surfaces. Although the majority perceived surface sanitation and hand washing to be the most effective measure to prevent microbial contamination (4.00), MSR patrons very rarely practiced table/utensil sanitation (2.98) or hand washing/sanitation (2.98), themselves. However, the consumers indicated that they would be very likely to engage in proper hand sanitation if they saw other patrons doing so (3.75). They also indicated they would very likely clean the table prior to eating if sanitary wipes were placed on the table (3.73). Almost one-half (46.8%) of consumers believed they were not responsible for food safety and 92.5% believed that the owner of each restaurant has the responsibility for food safety (Table 4). The majority of consumers (56%) reported
keeping leftovers for later or the next day and 33% reported keeping leftovers often or very often.

**Table 2.** Ranking of most important indicators of food safety

<table>
<thead>
<tr>
<th>Food safety indicator</th>
<th>Rank</th>
<th>Weighted mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employee hand hygiene</td>
<td>1 (Most important)</td>
<td>4.64</td>
</tr>
<tr>
<td>Food preparation</td>
<td>2</td>
<td>4.40</td>
</tr>
<tr>
<td>Overall cleanliness</td>
<td>3</td>
<td>4.32</td>
</tr>
<tr>
<td>Food type/source</td>
<td>4</td>
<td>4.04</td>
</tr>
<tr>
<td>Food safety reminder messages</td>
<td>5 (Least important)</td>
<td>3.50</td>
</tr>
</tbody>
</table>

**Table 3.** Ranking of most likely sources of microbial contamination

<table>
<thead>
<tr>
<th>Source</th>
<th>Rank</th>
<th>Weighted mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>People</td>
<td>1 (Most likely)</td>
<td>4.36</td>
</tr>
<tr>
<td>Surfaces</td>
<td>2</td>
<td>4.20</td>
</tr>
<tr>
<td>Foods</td>
<td>3 (Least likely)</td>
<td>4.15</td>
</tr>
</tbody>
</table>
Table 4. Ranking of stakeholder responsibility for food safety

<table>
<thead>
<tr>
<th>Rank</th>
<th>Stakeholder</th>
<th>Median</th>
<th>Q1</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Most Responsibility)</td>
<td>Restaurant Owner</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Restaurant Employees</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>Food Court Owner</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Janitors</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Government</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6 (Least Responsibility)</td>
<td>Patrons</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
4.2 Pathogen and Pathogen Indicator Testing:

4.2.1 Surfaces:

A total of 451 samples were collected from 20 different surfaces. Surfaces sampled include tables, chairs, plates, bowls, utensils, utensil dispensers, napkin dispensers, condiment counters, condiment dispensers, soup counters, soup utensils, salad bars, salad bar utensils, dessert counters, yogurt bars, yogurt bar utensils, cereal counters, trash counters, beverage counters, and consumer cell phones. Sampled surfaces include food contact and non-contact surfaces in MSR dining areas, including surfaces that consumers may touch during food consumption.

A total of 141 surfaces swabs (36%) and 8 cell phone swabs (13%) were positive for coliforms. Generic *E. coli* was isolated from 19 surface swabs and 2 cell phone swabs. Of the samples that were positive for coliforms, the majority were from salad bars (39/75) and tables (36/139). Of the samples that were positive for generic *E. coli*, seven were from salad bars or salad bar utensils (33%) and three were from cereal serving counters (14%). On the first sampling the average coliform count was 4.2 log CFU/ml. On the second sampling the average coliform count was 3.0 log CFU/ml. On the third sampling the average coliform count was 2.3 log CFU/ml. On the fourth sampling the average coliform count was 3.1 log CFU/ml. Total coliform counts ranged from 1 to 6.6 log CFU/ml. Human pathogens, *E. coli O157:H7*, *Salmonella* spp., and *Listeria monocytogenes* were not detected on any surface in MSR in this study.
Figure 2. A schematic of samples testing positive for generic E. coli (indicated by red dot) and coliforms (indicated by # of positive samples out of # of samples tested.)
**Table 5.** Surfaces testing positive for coliforms

<table>
<thead>
<tr>
<th>Surface</th>
<th>Positive/tested</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beverage Machine/Counter</td>
<td>18/29</td>
<td>62%</td>
</tr>
<tr>
<td>Food Serving Counter</td>
<td>23/41</td>
<td>56%</td>
</tr>
<tr>
<td>Salad Bar (and Utensils)</td>
<td>39/75</td>
<td>52%</td>
</tr>
<tr>
<td>Trash Counter</td>
<td>7/15</td>
<td>47%</td>
</tr>
<tr>
<td>Tables</td>
<td>38/148</td>
<td>26%</td>
</tr>
<tr>
<td>Hand Railing</td>
<td>2/9</td>
<td>22%</td>
</tr>
<tr>
<td>Condiment Counter</td>
<td>4/19</td>
<td>21%</td>
</tr>
<tr>
<td>Plates/Silverware</td>
<td>9/48</td>
<td>19%</td>
</tr>
<tr>
<td>Consumer Cell Phones</td>
<td>8/60</td>
<td>13%</td>
</tr>
</tbody>
</table>
4.3 Effectiveness of Microfiber Towels:

4.3.1 Removal of *E. coli* O157:H7 from Surfaces:

The reduction of *E. coli* O157:H7 was similar between both surfaces (stainless steel, 4.1±0.9 log CFU; acrylic, 3.9±1.6 log CFU; *P* = .592) (Figure 3). The reduction of *E. coli* O157:H7 was much greater from freshly inoculated surfaces (4.9±0.2 log CFU) than after drying (3.0±1.2 log CFU; *P* <.001) (Figure 4).

The removal rate of *E. coli* O157:H7 was similar for both surfaces (stainless steel, 54±12%; acrylic, 49±21%; *P* = .389) (Figure 5). The removal rate of *E. coli* O157:H7 was greater from freshly inoculated surfaces (58±15%) than it was after drying (44±16%; *P* <.05) (Figure 6).

The reduction of *E. coli* O157:H7 from stainless steel was much greater from freshly inoculated surfaces (4.9±0.2 log CFU) than it was after drying (3.2±0.2 log CFU; *P* < .001) (Figure 7). The reduction of *E. coli* O157:H7 from acrylic was much greater from freshly inoculated surfaces (4.9±0.2 log CFU) than it was after drying (2.9±1.7log CFU; *P* < .01) (Figure 7).

The removal rate of *E. coli* O157:H7 from stainless steel was similar from both freshly inoculated surfaces and dried surfaces (wet, 58±15%; dry, 49±2%; *P* = .079) (Figure 8). The removal rate of *E. coli* O157:H7 from acrylic was similar from for both
freshly inoculated surfaces and dried surfaces (wet, 58±15%; dry, 42±22%; \( P = .072 \)) (Figure 8).

**Figure 3.** Reduction of *E. coli* O157:H7 from stainless steel and acrylic surfaces (\( P = .592 \))

![Graph showing reduction of E. coli O157:H7 from stainless steel and acrylic surfaces](image)

**Figure 3.** Reduction of *E. coli* O157:H7 from stainless steel and acrylic surfaces using a microfiber towel
Figure 4. Reduction of *E. coli* O157:H7 from stainless steel and acrylic surfaces under wet and dry conditions using a microfiber towel.

Figure 5. Removal rate of *E. coli* O157:H7 from stainless steel and acrylic surfaces using a microfiber towel.
**Figure 6.** Removal rate of *E. coli* O157:H7 from stainless steel and acrylic surfaces under wet and dry conditions using a microfiber towel

**Figure 7.** Reduction of *E. coli* from stainless steel and acrylic under wet and dry conditions using a microfiber towel
4.3.2 Removal of *Salmonella* Typhimurium from Surfaces:

The reduction of *Salmonella* Typhimurium was similar between both surfaces (stainless steel, 4.5±1.2 log CFU; acrylic, 4.7±0.5 log CFU; *P* = .526) (Figure 9). The reduction of *Salmonella* Typhimurium was much greater for freshly inoculated surfaces (5.1±0.3 log CFU) than after drying (4.1±1.0 log CFU; *P* <.001) (Figure 10).

The removal rate of *Salmonella* Typhimurium was similar for both surfaces (stainless steel, 54±17%; acrylic, 55±11%; *P* = .745) (Figure 11). The removal rate of *Salmonella* Typhimurium was similar for freshly inoculated surfaces (58±3%) than after drying (52±20%; *P* = .187) (Figure 12).
The reduction of \textit{Salmonella} Typhimurium from stainless steel was much greater under wet conditions (5.2±0.1 log CFU) than it was for dry conditions (3.8±1.4 log CFU; $P < .01$) (Figure 13). The reduction of \textit{Salmonella} Typhimurium from acrylic was much greater for freshly inoculated surfaces (5.0±0.3 log CFU) than after drying (4.4±0.5 log CFU; $P < .01$) (Figure 13).

The removal rate of \textit{Salmonella} Typhimurium from stainless steel was similar for both freshly inoculated surfaces and dried surfaces (wet, 59±3%; dry, 49±24%; $P = .207$) (Figure 14). The removal rate of \textit{Salmonella} Typhimurium from acrylic was similar for both freshly inoculated surfaces and dried surfaces (wet, 57±3%; dry, 54±16%; $P = .601$) (Figure 14).

Overall, reduction of \textit{Salmonella} Typhimurium (4.6±0.9 log CFU) was greater than to \textit{E. coli} O157:H7 (4.0±1.2 log CFU; $P < .05$) (Figure 15). Additionally, removal rate of \textit{Salmonella} Typhimurium (55±2%) was similar to removal rate of \textit{E. coli} O157:H7 (52±3%; $P = .403$) (Figure 16).
**Figure 9.** Reduction of *Salmonella* Typhimurium from stainless steel and acrylic surfaces using a microfiber towel

**Figure 10.** Reduction of *Salmonella* Typhimurium from stainless steel and acrylic surfaces under wet and dry conditions using a microfiber towel
**Figure 11.** Removal rate of *Salmonella* Typhimurium from stainless steel and acrylic surfaces using a microfiber towel

**Figure 12.** Removal rate of *Salmonella* Typhimurium from stainless steel and acrylic surfaces under wet and dry conditions using a microfiber towel
Figure 13. Reduction of *Salmonella* Typhimurium from stainless steel and acrylic under wet and dry conditions using a microfiber towel.

Figure 14. Removal rate of *Salmonella* Typhimurium from stainless steel and acrylic under wet and dry conditions using a microfiber towel.
**Figure 15.** Reduction of *E. coli* O157:H7 and *Salmonella* Typhimurium using a microfiber towel

**Figure 16.** Removal rate of *E. coli* O157:H7 and *Salmonella* Typhimurium using a microfiber towel
One of the objectives of this study was to understand consumers’ food safety attitudes and perceptions in market-style restaurants. We found most consumers have little or no concern for food safety. This is of concern considering the risk for foodborne illness in restaurants and the potential for cross-contamination in shared dining areas. Consumers perceive themselves as the least responsible for food safety in shared dining areas. This indicates the potential for food safety hazards in shared dining areas due to consumers lacking responsibility and concern for food safety. In addition consumers did not think that they bare responsibility for food safety. Consumers’ attitudes and perceptions indicate that food safety is the responsibility of someone other than themselves. This may be because the majority of the participants were young adults, similar to findings of Abott et al, (2012) (1). To our knowledge consumer behaviors and food safety perceptions in settings similar to MSR have been rarely studied. Several studies have been done to describe the practices of consumers in conventional restaurant types (30, 44), but the information is still lacking. Additionally, few studies have been done to characterize food safety perceptions of consumers. Our findings are of special interest because of the shared responsibility for food safety in dining areas highlighting the need for increased responsibility awareness at university dining areas and similar MSR settings.
Consumers in our study perceived the hand hygiene of employees to be important for food safety and perceived other people as likely sources of contamination with human pathogens. However, consumers self-reported hand washing and other sanitary practices were lacking when eating in MSR. Consumers indicate their willingness to engage in sanitary practices such as washing tables if they observed other patrons engaging in those practices and if the environment allowed for such behavior, highlighting the importance of food safety culture in university dining. Installing wipes on tables and hand sanitizers near the entrances and encouraging their usage may be an effective measure to improve food safety in MSR.

Consumers in university dining reported that they would often keep leftovers for later or the next day, which indicates the need for specific guidelines for reheating, storage time, and temperature exposure on food containers. While Abbott et al. (2012) showed that educational campaigns may improve knowledge about proper handling of leftovers among patrons of university dining areas, this study highlights the need for behavioral interventions in addition to food safety education in order to prevent foodborne illnesses (1).

We hypothesized that food contact surfaces in shared dining areas in MSR may contain human pathogen indicators. We found coliforms and generic *E. coli* on a number of different surfaces. These findings indicate that cleaning and sanitation may be insufficient shared dining areas in MSR. The high rate of contamination with coliforms and generic *E. coli* on surfaces such as salad bars and tables (frequent usage surfaces) indicate the potential risks in shared dining areas in MSR and the need for novel cleaning and sanitation strategies. More effective cleaning and sanitation and increased awareness
for shared food safety responsibility among consumers will lead to better control of human pathogens in university dining and similar MSR. It is common for a limited number of employees to be available for cleaning and sanitation in the shared dining area. In addition, in university dining these are usually student employees, presenting a challenge for effective cleaning especially during breakfast, lunch, and dinner rush. In similar MSR setting, this may particularly be the case in shopping malls during the weekend. Additionally, consumers indicated they would be likely to use sanitary wipes for hand and table sanitation if they were supplied at tables. As this is currently not the case in the majority of university dining areas, it may be a cost effective and user-friendly way to improve control of cross-contamination with minimal additional labor.

We also found that nearly 15% of consumers’ cell phones contained coliforms. This is of interest considering the frequency at which consumers have direct hand contact with their cell phones while eating, as observed by Her et al, 2015. In that study conducted in parallel to our group, consumers handled their cell phones while eating (14% of the time) more frequently than any other objects (23). This suggests the need for novel sanitation techniques to accommodate these practices.

The need for novel cleaning and sanitation equipment has been previously established (26). In order to understand how these technologies work in MSR we must consider the type of technologies used and surfaces they are used on. We investigated the effectiveness of a novel microfiber towel to remove human pathogens from stainless steel and acrylic surfaces.

The removal rate was 10% for *E. coli* when the inoculum was wiped fresh compared to 60 minutes of drying, highlighting the importance for frequent cleaning and
sanitation of the surfaces such as tables, salad bar counters, and other food service counters. In addition, we can expect that the addition of moisture to the microfiber towel in the form of a spray (sanitizer or otherwise) would increase the amount of bacteria removal from a surface with the towel. While this remains to be tested in the laboratory, it is important for food service vendors to understand the factors that affect the efficacy of new technologies such as microfiber towels. The removal rate of Salmonella Typhimurium with microfiber towels was similar when wiped fresh and after drying, suggesting that the type and strain of pathogens may affect the efficacy of this cleaning technology. Additional experiments are warranted to test these and other conditions.

The microfiber proton towel was able to remove a much greater amount of both E. coli O157:H7 and Salmonella Typhimurium from surfaces when they were wiped while wet rather than wiped after 60 minutes of drying. Additionally, the removal rate was greater when E. coli O157:H7 was wiped wet, but there were no significant differences in Salmonella Typhimurium wet and dry removal rates. There were no differences in reduction or removal rate of E. coli O157:H7 or Salmonella Typhimurium from stainless steel compared to acrylic surfaces.

While the towel was successful at removing 3.2 to 5.2 log CFU/coupon from surfaces, the highest removal rate was 58% under the conditions of our study. However, concentrations of coliforms/E. coli on surfaces in restaurants is commonly lower. At this rate, it is possible that the novel microfiber towel would be successful at removing a significant amount of the cells. The inoculation rate that we used was greater than the concentration of bacterial contamination that is commonly found on food contact surfaces.
Overall, the reduction of *Salmonella* Typhimurium was greater than the reduction of *E. coli* O157:H7, but the removal rate of *Salmonella* Typhimurium was similar to that of *E. coli* O157:H7. The differences in removal rate were not significant on any surface, indicating that pathogenic microorganisms may be removed at similar rates using the microfiber towel. While the results of this study indicate that the microfiber towel may remove slightly greater amounts of *Salmonella* Typhimurium than *E. coli* O157:H7, it should not be concluded that microfiber towels are better at removing specific bacteria over others until this is further investigated. The benefit of microfiber towels to remove bacteria has been shown, but it is important to understand how to maximize the use of these towels for employees in MSR. Further research must be done in order to fully understand the factors that affect the efficacy of the towels.

The studies had limitations. All data from surveys is self-reported by the consumer. University restaurants present specific food safety challenges that differ from other MSR. The majority of consumers were young adults/college-aged students in a university dining setting. All vendors in this MSR are operated by one service, which is not typically the case in typical MSR outside of a university. In addition, the restaurants were aware of the days we were coming to take food contact and non-contact surface swabs, which may have biased their sanitation practices. In the United States it is rare to find human pathogens at detectable rates on surfaces, which was confirmed from our testing. Further testing of the efficacy of a microfiber towel to remove bacteria was performed only with two strains of microorganisms. A mixed inoculum was not used. While each inoculum was allowed to dry on the surface, we did not test both a wet and
dry towel, only a dry towel. We used inoculation rates that are greater than what is usually found on surfaces in order to recover a countable number of cells. Regardless of theses limitations, we believe that the findings of our study contribute to knowledge of food safety in MSR and improve our understanding of specific food safety risks in this and similar settings.
Chapter 6: Conclusions

The results of this study give us a better understanding of the food safety risks in MSR both from the consumer side and from microbiological data. This information can be used to develop effective interventions to prevent foodborne illness in MSR. Furthermore, our results demonstrated the effectiveness of a novel microfiber towel to remove a substantial amount of pathogenic bacteria from food contact surfaces. Further studies should be done to gather more information on the effectiveness of this microfiber towel to remove different bacteria and how it performs under different conditions.
References


5. CDC. 2010. Foodborne Illness Outbreaks.


7. CDC. 2014. Foodborne Illness Outbreaks.


10. CDC. 2015. E.coli (Escherichia coli).


13. CDC. 2016. Multistate Outbreaks of Shiga toxin-producing Escherichia coli O26 Infections Linked to Chipotle Mexican Grill Restaurants (Final Update).


Appendix A

Survey: Consumer perceptions, behavior and expectations
in market-style restaurants

A. DEMOGRAPHICS

1. In what year were you born? ________________

2. What is your gender?
   □ Male   □ Female

3. What is the highest completed education level?

   □ Some High School, but no Diploma
   □ High School Diploma
   □ Associate’s Degree, Please specify major: __________________________
   □ Bachelor’s Degree, Please specify major: __________________________
   □ Graduate Degree, Please specify degree and major:____________________

4. What is your ethnicity? Please select one or more.
   □ White
   □ African American
   □ Black non-African American
   □ Hispanic
   □ Asian
   □ Native Hawaiian or Pacific Islander
   □ American Indian or Alaska Native
   □ I would rather not say

5. How often do you eat in market-style restaurants?
   □ Every day
   □ 4-5 times per week
   □ 2-3 times per week
   □ Once per week
   □ Less than once per week
B. PERCEPTIONS

6. Please tell us to what extent are you concerned with food safety in market-style restaurants?

<table>
<thead>
<tr>
<th>Items</th>
<th>Not at all</th>
<th>Moderately concerned</th>
<th>Very concerned</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am concerned with food safety in the market-style restaurants (e.g., food courts).</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. In your opinion, what are the important indicators of food safety in a market style restaurant?

<table>
<thead>
<tr>
<th>Items</th>
<th>Not important at all</th>
<th>Somewhat important</th>
<th>Very important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleanliness of floors</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleanliness of tables</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleanliness of counters, and other surfaces</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleanliness of food preparation area</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleanliness of condiment area and waste disposal</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of hand sanitizers</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of food safety messages (posters)</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleanliness of salad bar</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature of salad bar</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperatures of displays</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proper cooking and preparation of foods</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food server handling practices</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gloves being worn by food handlers</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The ingredients within food</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Where the food originated before being prepared</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality of food (freshness, ingredients)</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date the food was prepared</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If the food is certified organic</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
8. In your opinion, how likely are the following to be sources of microbial contamination in market-style restaurants:

<table>
<thead>
<tr>
<th>Items</th>
<th>Not important at all</th>
<th>Somewhat important</th>
<th>Very important</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surfaces</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trays</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salad bar counters</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salad bar tongs</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Counters</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utensils</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tables</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash register surfaces</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Foods</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold cut meats</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salsa and guacamole</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sushi</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh vegetable salads</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh cut fruits</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hamburgers</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>People</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food handlers</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other patrons</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. To what extent are you concerned about food safety of following cuisines?

<table>
<thead>
<tr>
<th>Items</th>
<th>Not at all</th>
<th>Moderately concerned</th>
<th>Very concerned</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of cuisine</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese foods (e.g., noodles, soups)</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mexican foods (e.g., taco, burrito)</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>American foods (e.g., hamburger, pizza)</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deli foods (e.g., sandwiches, salads)</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japanese foods (e.g., sushi, roll, teriyaki)</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Chinese foods (e.g., noodles, soups) | 1 - - - 2 - - - 3 - - - 4 - - - 5
Mexican foods (e.g., taco, burrito) | 1 - - - 2 - - - 3 - - - 4 - - - 5

10. Who do you think has the responsibility for food safety in market style restaurants?

<table>
<thead>
<tr>
<th>Items</th>
<th>Not at all</th>
<th>Moderately responsible</th>
<th>Very responsible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food court owner</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Owner of each restaurant unit</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employees in the restaurants</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Janitors</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patrons (consumers)</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C. PRACTICES

11. How often do you practice following behaviors at market-style restaurants?

<table>
<thead>
<tr>
<th>Items</th>
<th>Never</th>
<th>Sometimes</th>
<th>Very often</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wash hands before entering</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use hand sanitizer after washing hands</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use hand sanitizer without washing hands</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wipe table before eating</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wipe table after eating</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use utensils, wrappers and other barriers</td>
<td>1 - - - 2 - - - 3 - - - 4 - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>eating.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Items</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>-----------------------------------------------------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Wash hands after eating.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use hand sanitizer without washing hands after eating.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eat on the table without a tray</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eat with your hands without barriers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Keep left overs for later/next day</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12. How effective are the following measures to prevent microbial contamination at market-style restaurants (MSR)?

<table>
<thead>
<tr>
<th>Items</th>
<th>Not effective ▼</th>
<th>Moderately effective ▼</th>
<th>Very effective ▼</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washing hands before entering.</td>
<td>1 - - - - - 2 - - - - - 3 - - - - - 4 - - - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sanitizing hands with sanitizer.</td>
<td>1 - - - - - 2 - - - - - 3 - - - - - 4 - - - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wiping tables before eating.</td>
<td>1 - - - - - 2 - - - - - 3 - - - - - 4 - - - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wiping tables after eating.</td>
<td>1 - - - - - 2 - - - - - 3 - - - - - 4 - - - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using utensils/barriers when eating.</td>
<td>1 - - - - - 2 - - - - - 3 - - - - - 4 - - - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washing hands after eating.</td>
<td>1 - - - - - 2 - - - - - 3 - - - - - 4 - - - - - 5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

D. CULTURE
13. How much do you think the behaviors of other patrons at the market-style restaurant influence your own behavior?

<table>
<thead>
<tr>
<th>Items</th>
<th>Strongly Disagree</th>
<th>Neither agree nor disagree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I believe other patrons in market-style restaurant will influence my own behavior.</td>
<td>1 - - - - 2 - - - - 3 - - - - 4 - - - - 5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

14. How likely would you engage in the same behavior if you would see following?

<table>
<thead>
<tr>
<th>Items</th>
<th>Not likely</th>
<th>Moderately likely</th>
<th>Very likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food handler sanitizing their hands</td>
<td>1 - - - - 2 - - - - 3 - - - - 4 - - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other patrons sanitizing hands</td>
<td>1 - - - - 2 - - - - 3 - - - - 4 - - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of hand sanitizers</td>
<td>1 - - - - 2 - - - - 3 - - - - 4 - - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patrons wiping tables before use</td>
<td>1 - - - - 2 - - - - 3 - - - - 4 - - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patrons wiping tables after use</td>
<td>1 - - - - 2 - - - - 3 - - - - 4 - - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of sanitary wipes at the tables</td>
<td>1 - - - - 2 - - - - 3 - - - - 4 - - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Picture or other messages to wipe the tables</td>
<td>1 - - - - 2 - - - - 3 - - - - 4 - - - - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Picture or other messages to wash hands</td>
<td>1 - - - - 2 - - - - 3 - - - - 4 - - - - 5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Thank you for your response to this survey. Your information is vital to the success of this project.