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Reducing risk of foodborne illness in older adults: interventions targeting at-home and foodservice handling behaviors

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Reducing risk of foodborne illness in older adults: Interventions targeting at-home and foodservice handling behaviors

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DEDICATION

This thesis is dedicated to my husband and best friend, Rahul Roy, without whom I would not have had the courage to continue into graduate school in a field completely outside my comfort zone. Rahul, you are an amazing human being and an inspiring teacher and mentor. I feel so blessed to have you by my side as we face challenges and joys together. You have always believed in my abilities, and told me so. I think that only other graduate students couples with a baby could understand fully what you have done for me. You sacrificed your own sleep and time, working late nights in your lab so that I could complete experiments in mine. You stayed with me in the hospital day and night whenever you could for those frightening and exhausting two weeks when our daughter was in the NICU, typing manuscript revisions in the middle of the night and rocking little Freya in her bassinet so I could get a couple hours of sleep. You have always dropped everything for Freya and I whenever we needed you, even while you were working on your own thesis and trying to graduate and find a job to help support our family. You are a wonderful husband and father, and I look forward to future adventures with you!

This thesis is also dedicated to Freya Karuna Roy, who sleeps in my arms as I type this. Freya, my little one, you should know that if you work hard and keep hope in your heart, you can accomplish anything.

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NOMENCLATURE

APC	Aerobic Plate Count
CDC	Centers for Disease Control and Prevention
CFU	Colony Forming Units
DRI	Dietary Reference Intake
ERS	Economic Research Service
FC	Fecal Coliform
FDA	United States Food and Drug Administration
FSIS	United States Food Safety and Inspection Service
GAP	Good Agricultural Practices
GMP	Good Manufacturing Practices
HUS	Hemolytic Uremic Syndrome
MPN	Most Probable Number
RAC	Raw Agricultural Commodities
RTE	Ready-to-eat
SFP	Staphylococcal Food Poisoning
SMT	Social Marketing Theory
STEC	Shiga Toxin-Producing Escherichia coli
TCS	Time and Temperature Control for Safety
USDA	United States Department of Agriculture

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ABSTRACT

The United States population is aging, creating a higher number of people and proportion of the population at increased risk for foodborne illness. OA awareness and behavior when purchasing and preparing foods inside the home affects food safety risk in this population. A national trend in eating outside the home also places foodservice workers in a key role for interventions focused on foodborne disease prevention in OA. By targeting both OAs and foodservice workers, both projects in this thesis intend to reduce food safety risk in OAs by increasing familiarity and knowledge about food safety and food handling.

For the first project, three SMT-based online food safety mini-modules were created for and pilot-tested with community-dwelling OAs. The modules were developed based on a needs assessment of OAs. The mini-modules were effective in promoting familiarity with food safety behaviors and were well-received, supporting the development of future SMT-based online education in this target audience. For the second project, a minimal-text poster intervention was placed in 8 foodservice operations with sample collection before, 1 month after, and 3-4 months after the intervention. LG samples were taken at three stages of preparation. Samples were screened for *Listeria monocytogenes*, *Escherichia coli* O157 and *Staphylococcus aureus* and enumerated for aerobic plate counts (APC), coliforms, and fecal coliform (FC) counts. All samples were negative for pathogens tested; APC and coliform counts were not significantly different before and after intervention (P <0.05). After intervention, FC counts in samples of LGs from hospitals and restaurants were significantly lower than before intervention ($P < 0.0004$). The reduction in FC after intervention suggests that minimal-text food safety posted messages may decrease food safety risk in foodservice establishments. Overall APC results combined with behavioral compliance results, however, suggest that further research and more education is needed to improve effectiveness of the intervention and improve food handling behavior in the participating sites.

CHAPTER 1: INTRODUCTION

Background

Both the United States and the global population are aging, creating a higher number of people and a greater proportion of the population at increased risk for foodborne illness. Older adults may not be aware that they are at increased risk for foodborne illness. Additionally, a national trend of increasing consumption of fresh leafy greens, along with an increase in foodborne pathogen outbreaks related to the consumption of fresh fruits and vegetables make this vulnerable population a key target for foodborne disease prevention in general and related to leafy greens consumption. A national trend in eating outside the home also places foodservice workers in a key role for targeted interventions focused on foodborne disease prevention. Interventions targeting both foodservice workers and older adults are important to reduce food safety risk in this growing population.

Goal and Objectives

The overarching goal of this thesis is the reduction of food safety risk in the older adult population. The two projects that make up this thesis complement each other as two approaches toward reaching this goal. The online education mini-module project directly targeted older adults as key stakeholders and players in their own food safety risk. The objectives of this project were to determine needs as defined by knowledge gaps in self-reported food handling behaviors, and to develop and assess educational tools addressing these topics. For this project, we hypothesized that need-based online mini-modules would be well accepted and increase food safety knowledge among older adults.

The objectives of the leafy greens project were to determine the current food safety risk status of older adults eating at sites commonly serving this population in Iowa and Kansas, and to evaluate educational materials for the improvement of safe leafy green handling practices among foodservice workers at these sites (e.g., restaurants, assisted living facilities, long-term care facilities, and hospitals). For this project, we hypothesized that microbial testing would indicate a need for improved food safety leafy greens handling practices, and also that a minimal-text food safety messaging intervention would improve the safety of food handling practices in participating foodservice sites by reducing microbial load.

Thesis Organization

This research-based thesis begins with a review of literature regarding older adults' health, food safety risk and behaviors, leafy greens health benefits, consumption and food safety risk, foodservice handling of and microbial testing in leafy greens, and targeting education for food safety in older adults and foodservice workers. Following the literature review are two complete manuscripts. I am the author for correspondence on the first manuscript. Dr. Angela Shaw is the author for correspondence on the second manuscript. Authors of the second manuscript are part of an interdepartmental collaborative grant-committee team based on a grant funded by United States Department of Agriculture, National Institute of Food and Agriculture (AFRI #2013-68003-2194). Each chapter includes an introduction and references. The two manuscript chapters are expanded versions of manuscripts that have been accepted for publication, and these chapters also include methods, results, summary and/or conclusions. The final chapter provides general conclusions for this thesis.

CHAPTER 2: REVIEW OF LITERATURE

Introduction

This review of literature begins with a discussion of the growing and increasingly diverse population of older adults, including nutritional health, immunity, food safety risk, awareness and behaviors related food safety risk in this population. Next, it discusses the nutrition and health benefits, consumption patterns, regulations, and foodborne outbreaks related to leafy green vegetables. It continues with a discussion on how bacteria attach to food contact surfaces and leafy greens, and then with specific pathogens of concern in fresh produce and leafy green vegetables. Additionally, it discusses indicator organisms used to determine food safety risk in foodservice and processing. It continues with foodservice handling as a source of foodborne illness, outbreaks related to foodservice handling, diversity in foodservice, foods of special concern in foodservice handling, barriers and motivators to safe food handling, hygiene, cleaning and sanitation, and the use of behavioral studies and compliance rates as a measure of food safety risk in foodservice environments. The literature review concludes with a discussion of targeting food safety education, including the use of SMT for development of educational tools, online food safety education, older adult and foodservice worker education, food safety messaging, targeted messaging for older adults and the use of minimal-text messaging to overcome educational barriers.

Older Adults

Aging population

The United States population is aging, and the older population is becoming more diverse *(3)*. According to the U.S. Department of Health and Human Services' Administration on Aging, the percentage of older Americans (age 65 and over) in 1900 was 4.1%, and since that time has more than tripled to 13.7% of the population in 2012 *(3)*. Since 2002, this older population has increased 21% while the rest of the population increased only 7% *(3)*. By 2040, the proportion of older Americans is expected to exceed one in five (21%) of the population, and include about 79.7 million Americans *(3)*. The State Data Center of Iowa and the Iowa Department of Aging report that in 2010 older adults comprised 15% of the state population, and this is expected to increase to 19.8% by 2040 *(226)*. In 2012, ethnic or racial minorities made up about 21% of the national population of older Americans, 9% are African-American, 7% Hispanic, 4% Asian or Pacific Islander, 0.7% two or more races, and 0.5% are Native American *(3)*. In the same year, the older population was 55.7% female and 44.2% male *(3)*. The racial and ethnic diversity of the older population has increased from 17% to 21% since 2002, and this trend is expected to continue to increase to 28% by the year 2030 *(3)*. This increasingly diverse aging population presents unique needs and challenges in health promotion and disease prevention, creating a need for targeted interventions.

In addition to racial and ethnic diversity, income varies widely among older adults, impacting the health and food safety of this population. The U. S. Census bureau's American Community Survey found that between 2011 and 2013 the average income in the older population was $49,467, and that 90.8% of this population received social security income, 48.3% received retirement income, and 8.7% received Supplemental Nutrition Assistance Program benefits *(241)*. In Iowa, the median household income for older adults was $34,731 in 2012 *(226)*. Lower income levels can lead to tough choices between food and other necessities. Adults age 60 and over who were food insecure, without reliable access to nutritious and safe food, have been shown to have poorer diets and health than other older adults *(153)*. Income level can predict an individual's perception of food safety and health related risk, with lower income individuals less likely to perceive risks *(63)*.

Poverty rates are increasing among older adults *(3)*. The U.S. Census bureau reported that the poverty rate in the older American population increased from 8.7% in 2011 to 9.1% in 2012, a statistically significant increase *(3)*. The percentage of older Iowans living in poverty is lower than the nation, at 7.8% *(226)*. Level of educational attainment and residence in rural or urban areas are linked to income, thereby influencing poverty among older adults *(3)*. Fewer older Americans have a college degree (23.2%) compared to the general population (29.1%) *(239)*. This was also true in Iowa, where 18.4% of older adults held bachelor degrees compared to 26.3% of the total state population *(226)*. In 2012, the majority of older Americans lived in metropolitan areas (81%) *(3)*. More older Iowans live in rural areas than the national population of older adults, with 17.8% of older Iowans living in major cities and 37.4% in metropolitan counties in 2010 *(226)*. Frequently, rural-residing individuals have higher health and food safety related risk than urban-dwellers due to higher risks, lower income, and less access to health care *(65)*. Income, level of education, and living in urban or rural areas can also influence nutritional status in older adults *(3, 153, 226)*.

Nutritional status

Both obesity and under-nutrition are nutritional concerns in older Americans. A study of older adults in multiple settings (nursing homes, hospitals, community, rehabilitation facilities) and found that 22.8% were malnourished and 46.2% were at risk for malnutrition *(133)*. In 2011-2012, 71.6% (67.0-75.8%) of National Health and Nutrition Examination Survey (NHANES) participants aged 60 and over were overweight or obese *(193)*. Both over-nutrition and under-nutrition fall within the spectrum of malnutrition, and both are associated with negative health-related consequences *(263)*.

In additional to obesity and under-nutrition, American dietary patterns have been associated with chronic disease risk in adults *(49)*. Diet quality may be linked to increased mortality risk in those over age 70 *(240),* but this does not seem to apply to all groups of older adults *(120)*. Dietary patterns of older Americans show that many are not eating enough nutrient-rich food to support healthy aging *(243)*. Americans aged 65 and over eat 86% of fruit and vegetables and only 36% of dark green and orange vegetables and legumes recommended in the United States Department of Agriculture's (USDA) Healthy Eating Index *(243)*. Though many eat at least one vegetable daily, only 7% of men and 9% of women age 65 and over consume dark greens on any given day *(243)*. This dietary pattern follows a similar trend in the general population of under-consumption of fruits and vegetables *(105, 216)*. Additionally, older Americans are eating about one third of recommended whole grains, 58% of milk, and 77% of recommended oils *(75)*. This under-consumption of nutrient-rich foods among older adults is paired with over-consumption of nutrient-poor foods such as added sugar, alcohol, and solid fats, with 59% of total calories coming from these sources *(75)*. A study of rural-residing older adults found that 40% ate a diet high in calorie-rich convenience foods (commonly high in added sugar and fat), and that this was associated with obesity and low nutrient intake *(152)*. This dietary pattern contributes to malnutrition in older adults and puts this population at increased risk for disease and mortality *(110).*

Aging and immunity

Immune function declines during aging in various ways, including changes in the mucosal barrier and immune cells of the gut, a reduction in stomach acid, gut motility, and physical activity, and a decline in health due to chronic disease *(58, 112, 138, 220)*. Studies have found that *bifidobacteria*, a beneficial probiotic species, attaches less easily to the mucosal lining of the gastrointestinal (GI) tract in older adults *(111,195)*. These beneficial bacteria have been shown to protect against colonization of pathogenic bacteria in the gut *(262)*. In addition to changes in mucosa and immune-related microflora, it has been proposed that aging leads to a reduction in the number and functionality of immune cells in the GI tract *(139)*.

Stomach changes impact immunity and food safety risk during aging by limiting the effectiveness of a natural barrier against pathogens *(220)*. Studies have demonstrated that a reduction in, or absence of, the normal production of stomach acid increases susceptibility to pathogenic bacterial infection *(212, 235)*. Normal human stomach acid has a pH less than or equal to 1 *(130)*, and a pH up to 2 has been shown to kill or at least inactivate food pathogens such as *Vibrio cholera, Vibrio vulnificus, Salmonella* species, and *Listeria monocytogenes (L. monocytogenes)* in various studies *(93, 142, 208)*, though pathogens such as *Salmonella* species and *Escherichia coli (E. coli) O157:H7* have shown tolerance to acidic conditions *(8, 207)*. A reduction in stomach acid is not likely a part of normal aging, but rather a result of the comorbidities associated with aging *(135)*. Otherwise healthy older adults have been shown to produce similar amounts of stomach acid to healthy young adults *(135)*. The use of stomach acid neutralizing or reducing medications such as antacids, proton-pump inhibitors, and H_2 antagonist may increase risk of foodborne pathogenic bacterial infection *(116, 184)*. Proton-pump inhibitors have also been implicated in increasing risk for other bacterial infections, such as *Clostridium difficile* and pneumonia *(57, 106)*. Despite these concerns, the use of acid reducing medication is common and continues to rise in the United States *(122)*. Whether due to age-related disease or medication use, a reduction in stomach acid in older adults can reduce immunity and increase disease risk.

Another natural barrier to infection is the movement of smooth muscle lining of the gut, called peristalsis, which expels food waste and pathogens from the body *(261)*. Chronic constipation, a slowing of colonic motility, has been linked with increased bacterial pathogens in the GI tract *(138)*. Similar to reduced stomach acid, abnormal GI motility is not likely part of normal aging, but rather linked to several age-related diseases and dysfunctions, such as diabetes mellitus, stroke, and Parkinson's disease *(47, 192)*.

Another potential contributing factor to reduced immunity during aging is sedentary behavior (sitting) in older adults. Sedentary behavior has been linked to metabolic disease in U.S. adults aged 60 and over *(112)*, while higher activity levels have been found to improve immune response in older adults *(140, 217)*. Older adults are more likely to participate in sedentary behavior than younger adults. Analyses of the 2003-2006 NHANES have found that U.S. adults aged 60 and over spend an average of 8.5 hours per day in sedentary activities, with the highest hours (9.0) in those aged 80 and over *(72)*, which were both higher than the 8.4 hour average for adults over age 20 *(112)*.

In addition to sedentary behavior, chronic disease may contribute to lowered immunity in older adults. A study of otherwise healthy individuals with diabetes discovered that participants had a reduced neutrophil response, which is an important part of the innate immune system *(58)*. The same study also found that this part of the immune system was activated when not needed and therefore less responsive to stimuli *(58)*. Individuals with diabetes have been shown to have an increased risk for several types of infections, including urinary tract, skin, and some respiratory infections *(179)*. Sometimes both the chronic disease and the medications used to treat it may weaken the immune system and increase infection risk. For example, certain types of cancer and chemotherapy cause neutropenia, a dangerous condition of abnormally low neutrophil white blood cells *(156)*.

Food safety risk

Whether due to a reduction in immune response through natural aging or disease factors, older adults are more susceptible to, and experience higher severity of, foodborne illness *(19, 41, 90)*. A 1996 study identified higher mortality rates for foodborne illness among individuals age 65 and over, especially those living in nursing homes *(90)*. An analysis of Centers for Disease Control and Prevention (CDC) data from 1996 to 2005 revealed that most foodborne illness-related deaths (58%) occurred in adults age 65 and over *(19)*. Additionally, the CDC Foodborne Diseases Active Surveillance Network (FoodNet) data indicate that adults age 60 and over have consistently higher hospitalization and mortality rates for all the major food pathogens tracked, and higher rates of *Listeria* species and *Vibrio* infection than other age ranges *(41)*. Older adults are also more susceptible to *Salmonella* and *E.coli* O157:H7 infection than younger adults *(41)*. For these reasons, older adults are recognized as part of a population that is at increased risk for foodborne illness *(90, 137, 219)*.

Food safety awareness and behavior

The United States Food Safety and Inspection Service (FSIS) recommendations for older adults include general food safety behaviors such as washing hands, sanitizing surfaces, and cooking foods to safe temperatures, and also additional precautions such as avoiding foods from higher risk sources, including unpasteurized milk and soft cheeses, cold deli meats, and undercooked eggs *(81, 137, 174, 265)*. One potential challenge to meeting these recommendations is that older adults may not be aware of their higher food safety risk *(31, 92)*. Cates et al. *(31)* found that 41% of older adult respondents to a survey of food safety knowledge and behaviors disagreed that they were at higher risk for foodborne disease due to age. In a study of food safety-related trends and perceptions, adults age 65 and over had a lower perception of food-safety related risk than young adults aged 18-29 years old *(76)*. United States polling data revealed that older adults were also less likely to be concerned or change food related behaviors after publicized foodborne outbreaks *(227)*. Those age 65 and over may also be cooking, handling, and storing food in ways that increase risk of foodborne illness *(92)*. For example, Gettings and Kiernan *(92)* found that several participants in a focus group study used visual, touch, or time (without a thermometer) to determine doneness of cooked foods.

Leafy Greens

Nutrition and health benefits

Increased leafy greens consumption is being promoted for a variety of health benefits. Leafy green vegetables, which include spinach, lettuce, cabbage, and arugula, among others, are an important dietary source of vitamins A, C, K, and E, as well as folate, iron, magnesium, potassium, calcium, and dietary fiber *(6, 16, 107, 145, 258)*. Many Americans are under-eating these nutrients *(244)*. Regular consumption of a variety of fruits and vegetables, including leafy greens, is associated with a reduced risk of mortality and chronic illnesses such as heart disease, cancer, and diabetes *(4, 54, 89, 229)*. An inverse relationship between consuming leafy greens and risk for Type 2 Diabetes Mellitus was identified in a 2010 meta-analysis of fruit and vegetable intake and diabetes *(29)*. Both total vegetable intake and leafy green vegetable intake have been associated with decreased risk of coronary heart disease (CHD) in American men and women *(20)*. Dark leafy greens are also a good dietary source of lutein *(223)*. This antioxidant pigment is thought to protect the retina of the eye from macular degeneration, an age-related disease that leads to blindness *(91)*. Due to these many health benefits, the United States Department of Agriculture (USDA) Dietary Guidelines for Americans recommend that Americans increase overall fruit and vegetable consumption *(244)*. The Guidelines recommend eating dark leafy greens such as spinach as a source of folic acid and iron *(244)*. MyPlate, an educational tool that incorporates the Dietary Guidelines for Americans and the Dietary Reference Intakes (DRI's), recommends adults age 19 and over eat 2 to 3 cups of vegetables, 1.5 to 2 cups of fruit, 3-8 ounce-equivalents of whole grains, 5-6 ounce-equivalents of protein foods such as meat and beans, and 3 cups of dairy foods daily *(242)*. One of the key messages from the MyPlate campaign is "Vary your veggies," with a recommendation to eat vegetables from each subgroup (dark green, red and orange, beans and peas, starchy, other) at least once per week *(242)*.

Leafy green vegetable consumption

Recommendations to increase consumption and growing public awareness of health benefits have been accompanied by increasing consumption of fresh leafy greens in the United States. Spinach consumption increased by 66% from 1990 to 2000, with 60 percent consumed as fresh spinach *(158)*. Unfortunately, despite the increase in some types of greens consumption, Americans are still not eating recommended total amounts of leafy greens, and overall consumption of fruits and vegetables has not significantly increased in the past two decades *(30, 105, 216)*. According to an analysis of 2009-2010 NHANES data, American women consume only 1.5 cups and men only 1.7 cups of vegetables on average daily, which falls significantly short of the 2 to 3 cup daily USDA recommendations *(119, 242)*. Older adults are also not consuming enough leafy green vegetables, with only 36% eating the USDA's Healthy Eating Index recommended amounts of dark green and orange vegetables, and less than 10% eating a dark green vegetable on any given day *(75, 243)*. With health benefits in mind, if promotion of and increased consumption of leafy greens in older adults continues, so must an emphasis on safe preparation and handling to mitigate food safety risks.

Dining out

The safety of food eaten outside the home has become an increasing concern for Americans, including older adults. Americans eat out more often and spend more on food outside the home than ever before *(84, 222)*. Data from the United States Bureau of Labor and Statistics shows that between 2004 and 2005, Americans in the lowest income categories spent about one quarter of their food dollars on food eaten or purchased away from home, and those in the higher income categories spent almost half their food dollars on these foods *(84)*. Data from the Economic Research Service (ERS) showed that in 2012, for every dollar spent on food, 43 cents was spent on food outside the home *(69)*. ERS data also showed that in the same year, 44.8% daily leafy vegetable and lettuce consumption took place outside the home *(68)*. This is an increase from 2007 to 2010, during which time 27.3% of dark green vegetables were eaten outside the home *(70)*. This trend has translated into an increase in produce sales through foodservice organizations *(136)*. According to an ERS report, produce sales through foodservice increased from $12 billion in 1987 to $35.4 billion in 1997 *(67)*. Older adults are contributing to this dining out trend more than ever *(178)*. According to research done by NPD group (formerly National Purchase Diary), from 2008 to 2012, adults aged 55 to 64 increased meals and snacks purchased at foodservice establishments by 1.85% per capita and adults aged 65 and over increased purchases by 7.73% *(178)*. This trend of older adults' increasing leafy green consumption outside the home brings a potential increase in food safety risk for this population, especially if foodservice workers are not properly handling leafy greens.

Regulation

An increase in concern over the safety of leafy green vegetables has prompted regulatory changes. In 2011, the United States Food and Drug Administration (FDA) Food Safety Modernization Act (FSMA) of 2010 (21 USC 2201), was signed into law *(10)*. In addition to providing increased authority and mandatory recall power to the FDA, the FSMA mandates that the FDA create minimum acceptable standards for how produce is grown, harvested, packaged, and held, with the intent to reduce and prevent biological, physical, chemical, hazards in food *(10)*. In response to FSMA, the FDA published a proposed rule in 2013, which was followed by a supplemental proposed rule in November 2015, Standards for Growing, Harvesting, Packing, and Holding of Produce for Human Consumption (21 CFR. 11, 16, 112) *(234, 252, 255)*. The final rule based on these went into effect on January 26, 2016 *(252)*. There are several exemptions included in the rule, including produce not usually consumed raw, produce grown for personal use, raw agricultural products, and produce that later receives adequate processing to reduce microbial growth *(252)*. Under this definition, leafy greens grown for commercial use are included in the standards.

The standards outlined in the rule encompass four areas related to food safety: employee health, hygiene, and training, water for agricultural use, biological soil amendments, and domestic and wild animals *(252)*. The standards require that workers handling produce must be trained, with documentation, on good handling practices (21

CFR 112.21, 112.22, 112.23) *(252)*. Hygiene and cleanliness standards must also be in place and monitored for both employees and visitors (21 CFR 112.31, 112.32, 112.33) *(252)*. Agricultural water must be inspected, with documentation, for safety and sanitation (21 CFR §§ 112.41, 112.42, 112.46, 112.50) *(252)*. Samples of this water must contain a geometric mean of no more than 126 colony forming units (CFU) per 100 mL or a statistical threshold value of no more than 410 CFU of generic *Escherichia coli* (21 CFR § 112.44(c)) *(255)*. A provision to this standard states that a 0.5 log reduction per day since last irrigation or a reduction rate with a time interval between harvest and end of storage can be calculated to meet this standard (21 CFR § 112.50(b)(8)) *(254)*. Biological soil amendments such as manure and compost must include documentation of methods used to control microbial and chemical hazards (21 CFR § 112.60) *(252)*. Biological soil amendments must be tested periodically and found to contain no *L. monocytogenes*, less than 3 most probable number (MPN) per 4 grams total solids of *Salmonella* species, less than 0.3 MPN per gram analytical portion *Escherichia coli* O157: H7, and less than 1,000 MPN per gram total solids fecal coliform bacteria (21 CFR § 112.55(b)) *(252)*. Periodic testing as well as dates of application and harvest must be documented (21 CFR § 112.60) *(252)*. Compost must be made using approved FDA standards (21 CFR § 112.54(c)), and human waste is prohibited from use (21 CFR § 112.53) *(252)*. The presence of both domestic and wild animals must be monitored and documented, and an adequate amount of time between grazing and harvest must be allowed if animals are working the land (21 CFR § 112.83(a)) *(252)*. This time period is currently under consideration, along with the soil amendment harvest time periods *(255)*. Monitoring and control of wild animals must not threaten or kill endangered species, destroy animal habitats, or exclude animals from outdoor growing areas (21 CFR § 112.84) *(255)*.

2013 Food Code

In contrast to FSMA, the FDA's 2013 Food Code is regulation targeting the foodservice section of the food industry. The Food Code is designed as a model to provide evidence-based, current best practice recommendations for state and local legislation. Food code recommendations include overall personal health and hygiene of the food handler, hand-washing and glove use, handling of Time and Temperature Control for Safety (TCS) and "ready-to-eat" (RTE) foods, and sanitation of utensils, equipment, and food-contact surfaces. The Food Code has several recommendations for food service handling that relate to the handling of leafy greens. According to the Food Code, leafy greens are defined as varieties of lettuce, spinach, kale, escarole, endive, spring mix, cabbage, chard, and arugula (¶ 1-201.10(B)) *(251)*. Herbs, such as parsley, mint, and cilantro are not defined as leafy greens *(251)*. Cut leafy greens are defined as leafy greens that have been "cut, shredded, sliced, chopped, or torn (¶ 1-201.10(B)) *(251)*. These definitions were added in the 2009 edition of the Food Code (¶ 1-201.10(B)) *(247)*. Additionally, cut leafy greens are categorized as a TCS food, meaning that cut leafy greens (as purchased or cut in house) must be kept at 41°F or lower to minimize growth of microbes and must be discarded if not served within seven days of opening or cutting (¶ 3-501.17(A)) *(251, 254)*.

Leafy greens that are washed and/or cut and do not require any further steps to ensure food safety before service to the customer are also defined as RTE foods *(251)*.

Under most circumstances, food employees may not touch RTE foods, such as RTE leafy greens, with bare hands or arms except under specific circumstances, including prior approval from regulatory authorities and detailed documentation (¶¶ 3-301.11(B), (D)). Employees serving "highly susceptible populations" (including older adults) are not included in this exception (¶ 3-301.11 (D)). The rule against bare hand contact does not apply to RTE ingredients that will be mixed with raw ingredients before cooking to proper temperatures (¶ 3-301.11 (D)). Additionally, the 2013 Food Code states that raw produce should be thoroughly washed, and that unwashed produce should be kept separate from RTE food (§ 3-302.15).

In addition to the Food Code, the FDA has released guidelines with specific recommendations for the safe foodservice handling of leafy greens. These recommendations include avoiding the use of leafy greens with obvious damage or decay and washing RAC leafy greens with water of appropriate microbial quality before cutting or processing. The guidelines do not recommend re-washing packaged pre-washed or RTE leafy greens, since this can increase the risk of cross-contamination *(245, 248, 249)*.

The 2013 Food Code incorporated these guidelines, stating that pre-washed, bagged produce items should be considered RTE and should not be rewashed before use (§ 3-302.15) *(253)*. Other changes from the 2009 to 2013 editions of the Food Code are generally formatting, terminology, and clarification updates *(253)*. For example, the term "Potentially Hazardous food (Time/Temperature Control for Safety Food) (PHF/TCS)" was changed throughout the Food Code to "Time/Temperature Control for Safety Food (TCS)" and "Enterohemorrhagic *Escherichia coli* (EHEC)" was changed to "Shiga toxin-producing *Escherichia coli* (STEC)" *(253)*. Both Iowa and Kansas have currently adopted the 2009 United States Food Code as state food codes. Iowa has also adopted the 2011 Food Code Supplement. This means that both state codes include the added definitions of leafy greens and cut leafy greens mentioned previously, and both states include cut leafy greens as a TCS food *(251)*. This also means that both state codes lack the additional recommendation included in the 2013 Food Code to avoid rewashing pre-washed, bagged produce items *(253)*.

Foodborne Illness and Leafy Greens

The CDC estimates 48 million foodborne illnesses leading to 128,000 hospitalizations and 3,000 deaths in the United States yearly *(38)*. Historically, foods from animal sources have been the primary focus of food safety and foodborne illness prevention efforts, however, fresh produce, including leafy green vegetables, has been recognized as an emerging source of foodborne outbreaks *(38)*. An analysis of foodborne outbreaks from 1998 to 2008 included 22% of illnesses, 14% of hospitalizations, and 6% of deaths linked to the consumption of leafy green vegetables, making this commodity the number one cause of foodborne illnesses, number two cause of hospitalizations, and placing it in the top five causes of death *(196)*. The CDC's most recent annual report on foodborne disease outbreaks highlighted that in 2012, 12% of outbreaks with an identified food vehicle were linked to vegetable row crops, with Shiga toxin-producing (STEC) *E. coli* and norovirus as associated pathogens *(38)*. This is an increase from the CDC's 2011 report, which identified vegetable row crops as the food vehicle in 5% of outbreaks *(36)*. In that same year, the pathogen most commonly associated with vegetable row crops was STEC *E. coli (36)*. From 2009 to 2010, the CDC reported that 3% of total outbreaks were attributed to vegetables, and 1% specifically attributed to leafy vegetables

(41). There was a significant increase in outbreaks associated with vegetables between 1998 and 2008, from 2% to 4% *(41)*. Populations most severely affected by foodborne outbreaks include children, pregnant women, immune-compromised individuals, and older adults, with the highest foodborne illness hospitalization and mortality rates among older adults aged 65 and over *(19, 40, 168)*.

According to CDC reports from 2011 and 2012, the most common sites associated with foodborne outbreaks in the United States are sit-down restaurants *(36, 38)*. In 2012, restaurants (sit-down, fast food and others) accounted for 60% of foodborne outbreaks and 41% of foodborne illnesses *(38)*. Other sites associated with outbreaks included private homes, institutions, grocery stores, farms, nursing homes, hospitals, and churches *(38)*. Another CDC report covering 1998 to 2008 stated that over the 10 year period, 68% of foodborne outbreaks were linked to restaurants or delis, with private residences at 9%, caterers at 7%, and institutions (such as schools) at 5% *(39)*.

Pathogens

The CDC reports that bacterial pathogens account for four of the top five foodborne pathogens causing illness in the United States annually, as well as three of the top five leading to hospitalization and three of the top five leading to deaths *(34)*. From 1998 to 2008, 18% of bacterial foodborne illnesses were linked to vegetable consumption, and 5.2% to leafy green vegetable consumption *(196)*. Bacterial pathogens that have been associated with outbreaks in leafy green vegetables include *E. coli* O157:H7, *L. monocytogenes*, *Salmonella* species, and *Shigella sonnei (175)*. According to the CDC, *E. coli* O157 leads to an estimated 2,138 hospitalizations in the United States yearly, and *L. monocytogenes* leads to an estimated 255 foodborne illness-related deaths in the United States yearly *(34)*. *Staphyloccocus aureus* (*S. aureus)* is also an important foodborne pathogen in the United States, leading to an estimated 241,148 illnesses yearly *(34)*. In a survey of foods recalled due to microbial pathogens between 2003 and 2011, 33 vegetables and products were recalled for potential contamination with *L. monocytogenes*, 78 for *Salmonella*, 11 for *Clostridium botulinum*, 3 for *S. aureus*, and 12 for *E. coli* O157: H7 *(61)*.

Viral pathogens also contribute greatly to foodborne illness in the United States *(38)*. According to the CDC's annual surveillance report 41% of foodborne outbreaks were caused by viruses in 2012 *(38)*. Of those outbreaks, 172 of 175 were caused by norovirus, making it the single most common cause of foodborne outbreaks that year *(38)*. Painter et al. *(196)* similarly found that from 1998 to 2008, norovirus was the most common cause of both foodborne outbreaks and related illnesses. Also the most common cause of acute stomach and intestinal inflammation in the United States, norovirus leads to diarrhea, stomach pain, and vomiting *(82)*. The CDC estimates that 20 million people in the United States become ill from norovirus every year *(42)*. Norovirus is a single-stranded RNA virus surrounded by a protein capsid that protects it from environmental stress *(250)*. The virus can be spread from person-to-person contact, through contaminated food, and from contaminated surfaces *(82)*.

Bacterial attachment to food contact surfaces

Bacteria use various methods of attachment to surfaces *(166)*. There are also different levels of attachment, such as individual cells and biofilms *(109)*. Level of attachment is important in the food industry, because biofilm formation provides a protective environment that potentially lowers the effectiveness of sanitation techniques *(229)*. Hall-Stoodley et al. *(109)* describe biofilms as "populations of microorganisms that are concentrated at an interface (usually solid-liquid) and typically surrounded by an extracellular polymeric substance (EPS) matrix." Biofilm formation in food environments is influenced by surface type and frequency of sanitation procedures *(94)*. The method and level of bacterial attachment is influenced by the physical characteristics of the surface such as hydrophobicity and texture, as well as environmental factors, such as temperature and nutrient availability *(17, 60, 80, 100, 132)*. Different bacterial species vary in varieties and types of adhesion and structural characteristics, such as fimbriae and flagella, which aid in attachment to surfaces *(125)*. Attachment also varies by bacterial strain, contributing to virulence of individual strains *(80, 159)*. Pathogenic bacteria are known to attach to both hydrophobic and hydrophilic surfaces *(161)*. Mafu et al. *(161)* found that *Salmonella* Enteritidis, *E.coli* O157: H7, and *S. aureus* can all attach to both polystyrene and glass. Pathogenic bacterial attachment is of special concern in foodservice environments, because biofilm formation can make pathogens more difficult to remove and therefore more likely to contaminate food *(224)*. *L. monocytogenes* has been shown to attach to stainless steel, plastic, rubber, and glass, and is known to form biofilms on food equipment and environmental surfaces *(28, 162)*. *E. coli* O157:H7 is also known to attach to, and form biofilms on, various types of surfaces, including stainless steel, glass, plastic, and wood *(17, 64)*.

Bacterial attachment to leafy greens

Attachment to and effective removal of bacterial pathogens from fresh produce is a growing public health concern due to foodborne outbreaks *(34, 175)*. Produce grown in close contact with soil, such as leafy green vegetables, often have high native bacterial loads *(85, 87, 131, 141, 189, 215, 256)*. Pathogenic bacteria, though not part of a plant's normal microbiota, can survive and grow on plant surfaces *(266)*. Unlike abiotic surfaces, plants often respond to bacterial presence using defensive mechanisms *(201, 225)*. Bacteria form biofilms on plant surfaces as a form of protection from plant defensive mechanisms and environmental stress, and also for improved access to nutrients *(109)*. Biofilm formation increases the difficulty of removing bacteria from plant surfaces by limiting the effectiveness of both the host defenses and antimicrobial agents *(55)*. Fresh fruits and vegetables are cleaned and sanitized using a variety of physical and chemical treatments *(95)*. The mostly commonly used method in the leafy greens industry is currently chlorinated water *(95, 191)*. The physical characteristics of leafy greens create challenges for effective washing and sanitation. Leafy green surfaces may be folded or layered, may have natural crevices, and may be easily bruised or torn, providing a protective environment for bacteria to attach and grow, as well as preventing antimicrobial treatments adequate contact with bacteria for effective reduction *(266)*. Torn or cut leafy greens release organic substances which interact with sanitizers, neutralizing them and further reducing effectiveness *(191)*.

***Escherichia coli* O157:H7**

Since its discovery as a foodborne pathogen in 1982, *E. coli* O157:H7 has become a growing global public health concern due to the severity of symptoms, increasing number and increasing size of outbreaks associated with this pathogen *(171)*. The *E. coli* O157:H7 serotype produces shiga toxin, which causes damage to the stomach epithelia and intestinal microvilli *(171)*. A gram-negative, rod-shaped, facultative anaerobe, *E. coli* O157:H7 grows in acidic foods at a pH as low as 4.4, and at water activity as low as 0.95 a_w *(259)*. It grows at temperatures ranging from 10°C to 44°C, with optimal growth at 42°C. This pathogen's tolerance of acidic conditions contributes to its low infectious dose of 2-2,000 cells *(23)*. The major symptom of infection is gastroenteritis, which is often characterized by vomiting, abdominal cramping and diarrhea, beginning 1-8 days after infection and progressing to bloody diarrhea *(259)*. The majority of cases resolve, but about 5% of those with bloody diarrhea progress to a more life-threatening condition called hemolytic uremic syndrome (HUS), which can cause renal failure and neural damage *(171)*. Older adults are also more susceptible to *E.coli* O157:H7 infection than younger adults *(40)*.

***Escherichia coli* O157:H7 outbreaks**

E.coli O157:H7 has been found in the intestinal tracts of cattle, sheep, deer, and recently, swine *(127)*. Food sources of outbreaks range from undercooked ground beef, raw milk and cured meats to unpasteurized juice, sprouts, and fresh produce *(23)*. There have been several notable recent multi-state *E. coli* O157 outbreaks attributed to leafy greens. In 2013, an outbreak involving ready-to-eat (RTE) salad mixes led to 33 illnesses, 7 hospitalizations, and 2 cases of HUS *(37)*. In 2012, a five-state outbreak involving RTE organic spinach and spring mix led to 33 illnesses, 13 hospitalizations, and 2 cases of HUS. The source of contamination was not identified *(37)*. A 2011 outbreak included 9 states, leading to 58 illnesses, 34 hospitalizations, and 3 cases of HUS. A single farm was identified as the source of romaine lettuce, but the specific source of contamination was not found *(218)*. A multi-state *E. coli* O157 outbreak in 2006 led to increasing public concern about leafy greens food safety *(14)*. Linked to bagged, fresh spinach, this major outbreak involved 26 states and led to 205 illnesses and 3 deaths *(32, 246)*. Though the exact source of contamination was never determined, one suspected source was feral swine entering the spinach field *(127)*. Nearby cattle were also implicated, and problems were identified with surface water interacting with irrigation water *(26, 88)*. Another *E.coli* 0157:H7 outbreak in Montana and Washington states in 1995 involved leaf lettuce and resulted in 40 confirmed cases and 52 suspected additional cases of illness. The possible sources of contamination in this case were improperly composted manure, contaminated irrigation water, runoff from a nearby cattle pasture, and contaminated irrigation water *(1)*. These cases highlight the concern and need for interventions to prevent future *E.coli* 0157:H7 outbreaks.

Listeria monocytogenes

L. monocytogenes is also a pathogen of food safety concern in leafy greens. The monocytogenes species of the gram-positive, non-spore forming, rod shaped *Listeria* genus is pathogenic and particularly virulent *(128)*. With a hospitalization rate over 90%, *L. monocytogenes* is among the top five deadly foodborne pathogens in the United States, causing an estimated 255 deaths annually *(34, 172)*. Though its optimal growth temperature is 30 to 37°C, *L. monocytogenes* grows at temperatures as low as 1°C, making refrigeration an ineffective control measure for this pathogen *(128)*. Depending on other environmental factors such as temperature, salt concentration, and inoculation level, *L. monocytogenes* has been shown to grow at a pH ranging from 4.0-9.5, high salt concentration, and a water activity as low as 0.92 a_w. *(52, 73, 86)* The infectious dose for *L. monocytogenes* is thought to be between 10^2 and 10^9 CFU *(128)*. Symptoms of listeriosis, the disease caused by *L. monocytogenes* infection, usually begin within 1 to 90 days of ingestion, and range from influenza-like fever, headache, vomiting, and diarrhea to inflammation of the central nervous system *(2).* As with other foodborne pathogens, infants, pregnant women, older adults, and the immune-compromised are at most risk of infection. Pregnant women are a population of added concern due to the risk of miscarriage and infection of the fetus and newborn infant *(2)*. Adults aged 60 and over have higher rates of *L. monocytogenes* infection than any other age range *(40)*.

Listeria monocytogenes **outbreaks**

L. monocytogenes is found naturally in water, soil, and on plant life, and has been found in the fecal matter of symptom-free humans, cattle, swine, sheep, poultry, flies, and ticks *(2)*. *L. monocytogenes* has ability to survive and persist in food processing facilities at refrigeration temperatures (2-4°C) making this pathogen a concern in RTE foods *(28)*. The first outbreak that identified *L. monocytogenes* as a foodborne pathogen happened in Nova Scotia, Canada in 1981, and was traced to cabbage contaminated by sheep manure *(73)*. The outbreak led to 49 illnesses and 18 deaths, including 9 stillbirths *(74)*. An earlier 1979 *L. monocytogenes* outbreak that sickened 23 patients in Boston area hospitals was reported years later, and though an exact food source could not be identified, the most common foods eaten by all affected patients were raw salad ingredients *(116)*. *L. monocytogenes* outbreaks in the United States most commonly involve dairy products, however, a 2011 outbreak involving fresh cantaloupe raised increasing concern for this foodborne pathogen in fresh produce. This major outbreak involved 28 states and led to 147 illnesses, 33 deaths, and 1 miscarriage *(35)*. More recently, a *L. monocytogenes* outbreak linked to prepackaged caramel apples that began in October of 2014 involved 35 illnesses in 12 states, 2 possible illnesses in Canada, 34 hospitalizations, and 7 deaths, including 1 fetal death *(44)*. Investigations identified the likely source as environmental contamination at an apple processing facility, and the company issued a voluntary recall of Gala and Granny Smith apples packed at the facility *(44)*. Another recent outbreak of *L. monocytogenes* involved contaminated ice cream. In March of 2015, Blue Bell Creameries issued a voluntary recall of multiple ice cream products, and later all ice cream products, after *L. monocytogenes* was detected in ice cream products *(43)*. Further investigation linked the detected strains to illnesses as far back as 2010. The outbreak resulted in 10 cases, 10 hospitalizations, and 3 deaths in 4 states *(43)*. As these cases highlight, prevention of *L. monocytogenes* contamination in food processing and foodservice environments is a continued and growing concern. Additionally, a current *L. monocytogenes* outbreak in packaged salad mixes processed at a Dole facility provides an example of the *L. monocytogenes* risk associated with leafy greens *(45)*. To date, this ongoing outbreak includes 12 cases in 6 states, leading to 12 hospitalizations and one death *(45)*. The outbreak was traced to a Dole packaging facility in Springfield, Ohio, leading to a withdrawal from the market of all salads produced at the site *(45)*.

Staphylococcus aureus

S. aureus is a gram-positive, catalase-positive, facultative aero-anaerobic, spherical, non-spore-forming bacterium that can be found as a single cell or in clusters *(113)*. It can grow at temperatures between 7°C and 48.5°C, pH of 4.2 to 9.3, and water activity as low as 0.86 *(150, 213)*. Among the most common foodborne pathogens, *S. aureus* causes an estimated 241,148 illnesses annually in the United States *(34)*. Staphylococcal food poisoning (SFP) is caused by enterotoxins produced in contaminated food *(113)*. The intoxication dose of these enterotoxins is generally understood to be <1 mcg *(113, 250)*. Recent research showing that cell survival and enterotoxin production vary greatly depending on the food environment (temperature, competing microbes, etc.) has made pinpointing an infectious dose even more difficult *(211)*. Though *S. aureus* can be inactivated by heat, any enterotoxins already produced are heat resistant *(113, 150)*. Both uncooked and cooked foods that are further processed or stored are of concern, especially because a common source of *S. aureus* contamination in food is poor hygienic practices during handling and processing *(15, 150)*. Another concern with this common foodborne pathogen is its potential for antibiotic resistance *(121)*. Symptoms of SFP, including abdominal cramps, nausea, vomiting, and sometimes diarrhea, usually begin within eight hours and resolve within 48 hours. As with most other food pathogens, groups at most risk for severe illness include infants, older adults, and immune-compromised individuals *(13)*.

***Staphylococcus aureus* outbreaks**

S. aureus is part of the normal human micro flora, and is commonly found on and in the living environments of humans, poultry, cattle, sheep, and goats *(113)*. Foods most commonly associated with SFP include meat, poultry, dairy, and bakery products *(250)*. An outbreak in 2010 involved pastries at an Illinois bakery and led to at least 100 illnesses. During the investigation several on-site surfaces, both food-contact and non-food-contact, were found contaminated with *S. aureus* strains capable of producing enterotoxins. Poor hygienic and sanitary practices, temperature abuse, and cross-contamination were cited as potential causes of contamination *(108)*. Though *S. aureus* does not usually lead to illness as severe as *E. coli* O157:H7 or *L. monocytogenes*, this foodborne pathogen can serve as an important hygiene and sanitation indicator in foodservice environments, as in the Illinois bakery case.

Indicator Organisms

Indicator organisms are often utilized in the microbial assessment of foods and food contact surfaces. The organisms, when present above established limits, indicate a lack of proper hygiene, handling of food, sanitation, and/or overall cleanliness.

Aerobic plate counts

Aerobic plate counts (APC) indicate the number of total aerobic bacteria on a surface or food sample. Though not an indication of food safety, when APC levels are above acceptable standards, this can indicate contamination issues on food contact surfaces *(177)*. Proposed standards for food contact surfaces in foodservice organizations serving older adults include APC counts of <1.3 log_{10}CFU *(221)*. APC levels are not used as food safety, but rather food quality indicators in foods *(238)*. Though APC levels are influenced by handling and temperature control, standards have not been set for APC levels in fresh leafy greens due to the high naturally occurring microbial counts in these foods *(46, 187, 239)*. For this same reason, enumeration of specific spoilage microorganisms, such as *Pseudomonas* and *Erwinia spp.* are typically studied as shelf life and quality indicators in leafy greens *(163, 189)*. APC levels on fresh produce have been used to indicate differences in microbial quality for various types of produce, as well as indicate changes in microbial quality throughout food processing and handling *(131)*. Typical APC on leafy greens range from around 4 to 9 log_{10} CFU/gram *(87, 131, 141, 189, 257)*.

Coliform counts

Coliforms are gram-negative, facultative anaerobic, lactose-fermenting rod-shaped bacteria which grow and produce gas at 35°C *(78, 239)*. The coliform group includes genera *Citrobacter*, *Enterobacter*, *Yersinia*, *Erwinia*, *Serratia*, *Hafnia*, Klebsiella, and *Escherichia (151)*. Coliform counts have historically been used to indicate fecal contamination of foods, however these bacteria are now recognized as a part of the natural environment and not necessarily from fecal sources, and therefore coliform counts are no longer used for this purpose *(78)*. Specifically, some enteric coliform bacteria, including *Enterobacter*, *Klebsiella*, and *Citrobacter*, have been found naturally in soil and water, greatly limiting the coliform count's effectiveness as a test for drinking water quality *(151)*. Like APC, coliform counts on fresh produce have been used to indicate both differences between, and changes in, microbial quality throughout food processing and handling *(131)*. Typical coliform counts on leafy greens range from 2 to >6 log_{10} CFU/gram *(85)*. Coliform detection on surfaces has been used to indicate general sanitation and cleanliness in food environments *(78)*.

Fecal coliform counts

Fecal coliforms (FC) are a heat tolerant subset of coliform bacteria, which can grow and ferment at 45.5°C *(77)*. *E. coli* make up the vast majority of FC, though this subset does include *Klebsiella*, which (as mentioned) are naturally found in the environment *(239)*. *E. coli* counts are used to detect fecal contamination of foods and food contact surfaces because these bacteria are commonly found in human and animal feces and do not naturally occur in soil or on produce *(46, 78)*. There are no FC or *E. coli* standards set for leafy greens in the United States, however other countries have set acceptable FC limits at <2 log_{10} CFU/gram and E. coli at <2 log_{10} CFU/gram and <3 log_{10} CFU *(46, 85, 236)*.

Food Handling in Foodservice Establishments

Food safety is a national and global public health priority. The Food and Agriculture Administration (FAO) and the World Health Organization (WHO) are encouraging all countries to address and improve food safety *(71)*. Foodservice workers play an important role in improving food safety and preventing foodborne illness. The CDC's 2012 Foodborne Disease Outbreak Surveillance report identified restaurants as the most common site of food preparation involved in foodborne outbreaks *(38)*.

Foodservice worker hygiene and sanitary food preparation practices have been identified as major factors contributing to outbreaks *(99, 108)*. Four of the five practices identified by the WHO as keys to food safety include food handling behaviors: proper hygiene, prevention of cross-contamination, cooking to correct temperatures, and maintaining proper temperature control of food *(265)*. Observational studies of foodservice workers have identified low rates of hand-washing as a major issue *(111, 147, 233)*.

Bacterial contamination of foods may also occur when foods come into direct or indirect contact with contaminated surfaces; according to the CDC's 2012 surveillance report, 12.8% of foodborne outbreaks with reported contributing factors included factors related to contaminated surfaces *(38)*. Lubran et al. *(157)* noted a common occurrence of contact between non-food contact surfaces, gloved hands, and RTE foods. Researchers in this study also noted that, although compliance with cleaning and sanitation at required times was observed at 100%, there were 110 additional occasions during which cleaning and sanitation was attempted and inappropriately executed *(157)*.

Foodservice outbreaks

According to the CDC, in 2012 restaurants and other foodservice operations were the most commonly identified sites of food preparation involved in outbreaks in the United States *(38)*. A notable *S. aureus* outbreak that led to over 100 illnesses, was tied to a retail bakery in 2010 and highlighted the importance of compliance with good manufacturing practices (GMP) related to food safety *(108)*. An investigation following the outbreak found antibiotic resistant, toxic strains of *S. aureus* on several surfaces, including food preparation surfaces, below a mixer and on a computer keyboard, as well as in a whipped topping concentrate *(108)*. The retail foodservice establishment was cited for lack of proper cleaning and sanitation, holding foods at improper temperatures, procedures that failed to prevent contamination, and improper hand hygiene *(108)*. In addition to cross-contaminating foods via environmental surfaces, foodservice employees can contaminate foods by working when they are ill. A 2014 CDC report claimed that 70% of foodborne norovirus outbreaks are caused by foodservice workers *(42)*. A 2006 norovirus outbreak traced to a Michigan restaurant that led to at least 364 illnesses was linked to employees working while ill, including cooking staff *(33)*. A 2013 *Salmonella* outbreak at a restaurant in Las Vegas, Nevada sickened 336 people and led to 50 hospitalizations *(188)*. The outbreak investigation did not reveal the original source of *Salmonella*, however the food item linked to the outbreak was cooked chorizo sausage that was likely contaminated after it was cooked in the restaurant *(188)*.

Cultural diversity

One major challenge that must be addressed in any food safety program for foodservice workers is cultural diversity and the various attitudes and behaviors culturally related to food safety. According to the National Restaurant Association, more than 25% of foodservice workers in the United States are born in other countries *(181)*. Several studies of food sellers around the world have revealed a variety of attitudes and knowledge towards food safety and related behaviors *(164, 194, 238)*. For example, level of education has been directly related to both attitude and knowledge of food safety in Malaysian food vendors *(238)*. In a study of Nigerian street food vendors, participants often lacked awareness and resources for proper hand-washing *(194)*. Cultural differences can also lead to language barriers when communicating food safety information. In a 2008 study of 154 outbreak investigations, 58% of foodservice workers spoke primarily Spanish, but only 41% of managers could speak Spanish, leading researchers to identify language barrier as a potentially contributing factor for the outbreaks studied *(59)*. Furthermore, in a risk assessment case study of 40 ethnic foodservice operations, oral and written language were identified as major barriers in successfully communicating information about food safety *(209)*.

TCS foods

In addition to general hygiene and sanitation, certain foods must be kept at proper temperatures to prevent growth of microbial contaminants. These foods, known as Time and Temperature Control for Safety (TCS) foods, are considered more likely to become unsafe if left out unrefrigerated, due to microbial growth or toxin formation *(251)*. Cut leafy greens, such as cut salad mixes, are considered TCS foods *(251)*. These foods usually contain proteins, which serve as the nutrients micro-organisms need to survive and grow *(182)*. TCS foods also contain moisture, another factor that contributes to bacterial growth *(214)*. They often have a higher pH, since most bacteria do not grow well in low pH foods *(21)*. In addition to cut leafy greens, TCS foods include cut melons and tomatoes, baked potatoes, raw meat, poultry, and fish, dairy products, and eggs, among others *(182)*. Leafy green vegetables that have not been processed beyond cutting at the root for harvesting are considered raw agricultural commodities (RAC), and are not considered a TCS food *(251)*. Because TCS foods support microbial growth, they must be handled appropriately to prevent foodborne disease.

According to the 2013 Food Code, raw fruits and vegetables should be washed in water before being cut (§ 3-302.15). Though recent recommendations do not encourage soaking cut leafy greens in water *(22)*, the Food Code does still permit this practice (¶ 3-302.12(C)). Once cut, leafy greens are considered a TCS food, and must be kept at or below 41°F during storage and display (§ 3-202.11). Additionally, once washed, leafy greens are considered RTE foods (¶ 1-201.10(B)) *(251)*. RTE foods are those that can be safely eaten in the present form without further cooking or processing (¶ 1-201.10(B)) *(251)*. Employees must not touch this RTE food with bare hands (¶ 3-301.11(B)) *(251)*.

Foodservice environment

The foodservice environment plays a key role in foodservice handling behavior. Specifically, the food safety culture of a foodservice organization can play a role in prevention of foodborne illness, and has recently been identified as a risk factor for outbreaks *(103, 199)*. Since other priorities can compete for resources, foodservice organizations must actively create a positive food safety culture that encourages employee compliance with food-safe behaviors *(267)*. The CDC recommends employers offer paid sick time, make use of on-call staffing, and provide food safety training for employees and managers to help support a positive food safety culture *(42)*. In a qualitative study of factors that contribute to a positive food safety culture, Neal et al. *(184)* identified consistency, accountability, and active participation of management as key factors influencing food safety culture. In addition to managerial participation, communication of food safety messages is an essential part of establishing a food safety culture *(104)*. This type of communication is best kept brief, highly visual, strategically placed in target areas, and rotated to keep messages novel *(267)*.

Foodservice environments may include barriers to appropriate food handling. Studies of food handling behaviors in foodservice workers have identified some of these barriers, including lack of training and time, inconvenience, and inadequate resources *(101, 117)*. In a 2005 qualitative study of food safety behaviors and related barriers, lack of convenient access to a sink, lack of time, and time spent drying hands were identified as barriers to hand-washing *(101)*. A 2008 study also reported these three barriers to hand-washing *(117)*. Lack of time, ill-fitting gloves, and inconvenience have been identified as barriers to glove use *(101)*. Foodservice workers have reported lack of time, resources, training, and managerial participation as barriers to cleaning and sanitization *(117)*. In a focus group study, restaurant workers have also identified an unsupportive organization as a barrier to proper hand hygiene *(200)*. In a risk-assessment study that included forty foodservice establishments, workers listed cultural, knowledge, and communication issues as major influences on food safety behaviors *(209)*. Furthermore, targeting these barriers has proven to increase training effectiveness *(268, 269)*. An intervention addressing identified barriers significantly improved both behavioral compliance and perception of control over behaviors related to food safety, such as hand-washing and thermometer use *(268, 269)*. Identifying and addressing barriers may be key to improving food safety within the context of the foodservice environment.

In addition to barriers, several motivators have been identified that promote proper food safety practices in foodservice environments *(12, 129)*. In a 2014 focus group study foodservice employees reported that managers who were present often, held employees accountable, relayed correct information, and modelled appropriate behavior promoted proper food safety practices *(12)*. In the same study, employees also noted adequate training and co-workers modeling correct behavior as motivators to promoting proper food safety behaviors *(12)*. A positive correlation was identified between foodservice workers' satisfaction with interpersonal relationships at work and good hygiene practices *(129)*. These findings support the idea that positive manager-employee and coworker relationships motivate proper food safety behaviors, and are therefore an important part of the foodservice environment related to food safety.

Hygiene

The Food Code recommends restricting ill employees from working with food, including specific restrictions based on symptoms and diagnosis (§ 2-201.13). Employees must keep clothing (§ 2-304.11), hands and arms clean, and follow specific hand washing procedures such as scrubbing vigorously with a "cleaning compound" for 10 to 15 seconds (§ 2-301.12). Hand hygiene is required after touching body parts or animals, using the restroom, coughing or sneezing, eating or drinking, touching dirty utensils or equipment, switching between raw and RTE foods, and before putting on gloves (§ 2-301.14). Gloves should be changed between tasks, when damaged, or soiled, and whenever handling RTE foods (§ 3-304.15) *(251)*.

Cleaning and sanitation

The 2013 Food Code states that food contact surfaces and utensils should be cleaned before and between uses with raw produce and TCS foods, when changing between raw and RTE foods, after any potential contamination (¶ 4-602.11(A)), and every four hours during use (¶ 4-602.11(C)). These same surfaces and utensils should be sanitized before use after cleaning (§ 4-702.11). Sanitization is defined as "the application of cumulative heat or chemicals on cleaned food-contact surfaces that, when evaluated for efficacy, is sufficient to yield a reduction of 5 logs, which is equal to a 99.999% reduction, of representative disease microorganisms of public health importance" (¶ 1-201.10(B)) *(251)*.

Observational studies and compliance rates

Assessment of food safety behaviors in foodservice sites often utilizes observation and analysis of compliance rates for recommended handling, hygiene, and sanitation behaviors *(48, 166, 207, 269)*. York et al. *(269)* and Roberts et al. *(207)* made use of direct (in-person) observation of foodservice worker behaviors during food preparation to evaluate the effectiveness of food safety educational interventions. Chapman et al. *(48)* recorded video observations of foodservice worker behaviors to evaluate effectiveness of an informational intervention. Researchers noted that this indirect form of observation is less intrusive and allows for more than one researcher to review the data *(48)*.

Observed food safety behavior does not always match up with self-reported behavior *(206)*. In a 2003 review of 87 studies of consumer food safety behavior which included observational and self-reported behavior, although 100% of participants in the reviewed studies identified why and how to wash hands and 82% of those interviewed identified the importance of hand-washing, compliance with appropriate hand-washing behaviors in observational studies was only 0 to 25% *(205)*. This suggests that self-report alone may not be the most reliable means of measuring outcomes for food safety messaging interventions, and the use of more than one method may provide a more complete evaluation.

Compliance rates for appropriate food safety behaviors are still a major issue in foodservice environments. From 1998 to 2008 the FDA conducted a study of common risk factors for foodborne disease in 800 foodservice facilities based on compliance with the 1997 Food Code *(256)*. The first two reports released from the study identified poor compliance with employee hand-washing, keeping temperature-sensitive foods cold, recording dates on RTE foods, and proper cleaning and sanitizing of food contact surfaces *(256)*. The third report, released in 2009, identified time and temperature control of foods, employee hygiene, and prevention of contamination as risk factor areas still in poor compliance *(256)*. Specifically, full service restaurants were found out of compliance with proper hand-washing 75.8% of the time, fast food restaurants 38.8% of the time, hospitals 35.6% of the time, nursing homes 34.4% of the time, and elementary schools were out of compliance 27.5% of the time *(256)*. The same study also found poor compliance rates for proper cooling and holding of foods, with full service restaurants out of compliance 54.7% of the time, fast food restaurants 38.3% of the time, hospitals 36.2% of the time, nursing homes 29.2%, and elementary schools out of compliance 27.5% of the time *(256)*. In study of retail deli departments, compliance with 2005 Food Code recommendations for hand washing was only 11% for frequency overall *(157)*.

Targeted Food Safety Education

Social marketing theory

One strategy used in the development of health interventions targeting behavior change is social marketing theory (SMT). In practice, SMT makes use of marketing strategies and tools to influence behavior change *(154, 186)*. The SMT cycle can be described in steps: planning, choosing content and delivery method(s), developing and testing tools, implementing, assessing, and revising *(5, 96, 155)*. A mini symposium of reviews on SMT-based public health programs included multiple examples of successful interventions targeting a variety of socio-demographic groups *(98)*. The first step to designing an SMT-based intervention, planning, involves collecting information about the needs and preferences of the target population *(198)*. Following SMT, once needs and preferences are determined the educational intervention should be customized to the target audience *(154)*. According to Kreuter et al. *(144)*, this means that both the content of the intervention and the method(s) of delivery should be customized to the audience, as part of the second and third steps of SMT. One example of this is the use of peer educators or mentors, a strategy Buman et al. *(25)* found effective in ensuring older adults' maintenance of increased physical activity levels after a targeted intervention. After the fourth stage, implementation, the fifth stage in an SMT-based intervention involves evaluation of outcomes for effectiveness of the intervention *(186)*. This can be accomplished using validated tools to assess measurable objectives *(228)*. The program can then be redesigned as needed based on evaluation, and the cycle continues *(5)*.

Online and computer-based food safety education

Online and computer-based tools can be an effective method for delivery of educational materials in a variety of settings *(66, 77, 160, 197)*. A six-week computer-based training intervention was determined both feasible and effective in improving health outcomes for consumers at a primary care clinic *(97)*. Campbell et al. *(27)* found that online educational tools increased self-efficacy (confidence to perform a certain behavior) and led to nutrition-related behavior change in a limited-resource consumer audience. ServSafe® Online was shown to significantly improved food safety knowledge in foodservice workers and hospitality student participants who scored below passing (75%) on a pre-exam *(77)*. Online Extension-delivered programs have previously been shown to increase food safety knowledge and familiarity *(83)*. A nine-week computer-based educational program increased employee knowledge and improved observed behavior related to workplace safety *(66)*. In a study of food safety manager training methods, foodservice participants using computer-based training methods scored as well or better than participants using a face-to-face method in a post-assessment of knowledge *(231)*.

Older adult education

Educational interventions targeting older adults should be theory-based and tailored to the needs and preferences of the particular audience of older adults *(210)*. Theory-based health interventions targeting older adults have been shown to increase self-efficacy (confidence to perform specific heath behavior), knowledge, and result in behavior change. A diabetes educational program for older adults based on the Theory of

Meaningful Learning and Social Cognitive Theory led to a significant reduction in blood glucose levels after 10 weekly sessions *(176)*. An educational intervention based on Social Cognitive Theory changed older adults' beliefs and increased self-efficacy, perception of risk and intent to speak with a health care provider about the prescribed use benzodiazepine medications *(167)*. A three-year nutrition education program based on United States Department of Agriculture, American Heart Association, and American Diabetes Association recommendations via individual counseling resulted in weight, blood glucose, cholesterol, and blood pressure for those who participated in at least four counseling sessions *(260)*. A food safety educational booklet targeting older adults and healthcare workers caring for older adults was favorably received by study participants, and one quarter of participants reported sharing it with an older adult and 59% reported passing on information to older adults about safe food choices, handing, and storage *(264)*. A theory-based 10-week extension nutrition education program focusing on dietary fat and fruit and vegetable intake significantly increased nutrition knowledge and improved self-reported dietary behaviors in older adults *(169)*. A targeted Extension wellness program for older adults in Nevada led to significant decreases in loneliness, and increases mastery and knowledge related to nutrition, safety, and wellness *(53)*.

During first steps of SMT, content and methods of delivery should be tailored to the needs and preferences of the target group of older adults, and surveys have been used successfully for this purpose *(114)*. Studies have shown that older adults are willing to utilize food safety educational materials that use information technology and do actively seek health information online *(24, 79, 143)*. When seeking information online, older adults are sometimes challenged by the amount and variety of information available, which can be confusing and overwhelming *(165)*. It is not surprising, then, that some older adults prefer printed educational materials. Cates et al. *(31)* identified printed materials and health care providers as most preferred methods of learning about food safety in this audience. Offering both online and printed food safety education materials may help address the needs and preferences of today's and tomorrow's older adult.

Another important part of the planning stage of SMT is identifying and addressing barriers and motivators of the target audience. In a review of research on nutrition education programs for older adults, it was determined that widely varying attitudes, abilities, ethnicity, and socioeconomic status of the older adult population can all serve as barriers that need to be addressed during educational program planning for this audience *(115)*. Some motivators identified included an interest in staying well and opportunities for social interaction *(115)*. For these reasons, any educational intervention targeting food safety in older adults should take into account the specific needs, preference, barriers, and motivators of the group of older adults it is designed for.

Foodservice worker education

Research on the effectiveness of food safety training and education for foodservice workers has had varying results, with some studies finding that food safety behaviors improved post-education, and other studies finding no improvement. In a study of 55 food service organizations and 137 foodservice workers in the United Kingdom, 63% of workers reported that they did not always use food safety behaviors when necessary, and lack of training was associated with likeliness of falling into this category *(50)*. Cohen et al. *(51)* tested microbial quality of foods prepared by foodservice workers before, during, and after a month-long food safety training program which focused on GMP's and Hazard Analysis and Critical Control Points (HAACP); results indicated that the microbial quality of food improved during and after the training program *(51)*. In a pre-and post-ServSafe® training study, and increase was noted in both hand-washing knowledge and observed hand-washing behavior among foodservice workers, but this improvement was not found in other personal hygiene, cross-contamination, or time and temperature control behaviors *(207)*. In a study of 69 foodservice workers taking at home food safety training, training significantly increased awareness and knowledge of hand-washing, but this did not translate into improved hand-washing behavior *(118)*.

Successful food safety educational programs are often continuous and combine more than one mode of dissemination. In a review of research on food safety educational programs, ongoing training was identified as important to preventing unsafe food handling practices *(173)*. In the same review, programs resulting in an improvement in food safety made use of both in-person training and visual media, such as posters *(173)*.

Several food safety training methods for foodservice workers are currently used in foodservice establishments in the United States, including ServSafe®, GMP and HAACP-based courses, as well as informal training. There are currently no national standards for food safety training of foodservice managers in the United States, and regulations vary at the state level. In a 2004 review of state food codes, only 17 states required a specific food safety manager certification *(7)*. According to the National Registry of Food Safety Professionals, this number has since increased to about half of all states, including Iowa *(180)*. Iowa requires at least one employee to be certified as a food safety manager. Kansas does not yet require certification, but does require foodservice managers demonstrate food safety knowledge, allowing food safety manager certification as proof of compliance. Several local, regional, and state food safety programs exist. Two examples of larger programs used in multiple regions include ServSafe® (United States) and FOODSAFE (British Columbia, Canada). Both Iowa and Kansas accept ServSafe® Food Protection Manager as proof of food safety manager certification *(123, 134)*.

ServSafe®

ServSafe® is a food safety educational program by the National Restaurant Association Educational Foundation (NRAEF) and accredited by the American National Standards Institute (ANSI). According to the NRAEF *(183)*, more than five million people are certified as ServSafe® Food Protection Managers. In addition to the Food Protection Manager Program™, the NRAEF offers ServSafe® Food Handler™ and ServSafe® Alcohol™ training and certification *(183)*. The Food Protection Manager Program™ is a lecture-based course that requires a certified instructor and covers topics such as hygiene, foodborne illnesses, safe storage and preparation of foods, sanitation, temperature control, at-risk populations for foodborne illness, training and monitoring personnel *(183)*. The NRAEF also offers an online version covering the same material, which Feinstein et al. *(77)* found increased participant certification exam scores over the instructor-based scores. For either course delivery method, participants must score greater than 75% on a proctored exam to receive certification ServSafe® *(77)*.

FOODSAFE

The FOODSAFE training program is a collaborative project of the Province of British Columbia (BC) Canada, along with the BC Centre for Disease Control, BC Regional Health Authorities, BC Restaurant and Foodservices Association, and WorkSafe BC. The program consists of two levels of certification, and contains information on hygiene, foodborne illnesses, safely receiving, storing, and preparing food, cleaning and sanitation. The level one certification is required for all foodservice operators and at least one foodservice worker in the foodservice operation *(170)*.

Improving current programs

Current food safety training programs in place may not be adequate to ensure safe food handling practices in a diverse workplace *(62)*. Though most programs address similar food safety topics, such as workplace hygiene, many do not address barriers to food safe behaviors such as hand washing, cleaning, sanitizing, and thermometer use*(173)*. Some of these barriers have been identified as a lack of training, time, accessible equipment, and convenience *(101, 117)*. Focus groups with foodservice managers have also identified employee turnover, a lack of time and a lack of "user friendly" resources as barriers to improving food safety in foodservice establishments *(11)*. Food safety training programs and educational materials may need to address these barriers to improve effectiveness. A theory-based educational intervention that addressed perceived barriers was as effective (46.4% food safety behavior compliance) as food safety training alone (47.8% compliance), and both were more effective than the control (37.1% compliance) *(268)*. The intervention involved providing resources and a small monetary incentive, as well as the use of minimal-text posters targeting the perceived barriers identified in focus groups and a needs assessment survey *(268)*. Targeted barriers included a lack of resources (thermometers), lack of incentive for performing tasks, lack of time, lack of reminders, inconvenience, and a lack of understanding the seriousness of outcomes if behaviors are not performed *(268)*. In the same study, a combination of the intervention with training had the greatest impact (56.2% compliance) *(268)*. In a pilot study of another theory-based intervention targeting Hispanic workers, lessons focusing on food handling and personal hygiene, as well as management supervision improved hand-washing behavior *(190)*. Identifying and addressing barriers of the targeted group of foodservice workers may improve current food safety program effectiveness.

Food safety messaging

Effective food safety messaging is a key component in improving food safety. In a 2010 review of food safety messaging campaigns, it was determined that effective food safety messages targeted a specific audience, were based on the knowledge and perceptions of that audience, were easy to understand and distribute, were repeated, made use of modern media, and involved risk communication *(124)*. Risk communication involves understanding the needs, perceptions, and knowledge-base of those affected, and developing messaging based on this information *(55, 126)*. In a study of a risk communication messaging intervention to prevent salmonellosis, participants who read the campaign material scored 88.2% correct on a test evaluating knowledge about preventing salmonellosis compared to 60.4% correct for those who had not received the material *(237)*. Jacob et al. *(124)* cite social marketing as an effective tool for development of food safety messaging. One example of a successful food safety messaging campaign based on SMT is the FSIS's Thermy™ campaign *(205)*. Six years after the Thermy™ campaign began in 2000, Americans ownership of food thermometers increased by 21%, use of thermometers to check the temperature of chicken pieces increased by 9%, and use of thermometers increased when cooking hamburgers by 2% *(149, 206)*. Use of thermometers with chicken and hamburgers continued to increase over the next four years *(148)*.

One aspect of targeting messaging for culturally diverse audiences is cultural competence. Culturally competent messaging includes appropriate language and nonverbal communication that incorporates cultural perceptions and behavior *(9)*. The American restaurant industry employs a diverse population of individuals, many of whom were born in other countries *(181)*. The National Adult Literacy Survey estimated that 11 million Americans aged 16 and over are non-literate in English, and 30 to 40 million have "Below Basic" literacy *(146)*. Messaging designed to reach the widest audience contains minimal text and includes images to portray a clear, direct message *(56)*. The CDC has developed a tool, called the "Clear Communication Index" to help in the development of health messages and educational materials *(18)*. Jacob et al. *(124)* proposed that effective messaging increases perception of personal risk and responsibility.

Targeted messaging for older adults

Older adults may have both lower awareness of foodborne illness risk and unsafe food handling practices, providing both reason and focus for targeted food safety messaging designed to decrease risk of foodborne illness in this group. Cates et al. *(31)*

found that 41% of older adult respondents to a survey of food safety knowledge and behaviors disagreed that they were at higher risk for foodborne disease due to age. In a study of food safety-related trends and perceptions, adults age 65 and over had a lower perception of food-safety related risk than young adults aged 18-29 years old *(76)*. Additionally, the food preparation practices (e.g., cooking, handling, storage) of older adults may be placing them at risk of foodborne illness *(92)*.

Minimal-text interventions

Effective communication of food safety messages in a food service environment is important for the creation of a positive food safety culture *(104)*. One strategy for communicating food safety messages is use of a minimal-text intervention, such as a poster. The use of minimal text addresses language and reading barriers. Additional elements that can increase effectiveness of a minimal-text food safety intervention include providing messages with specific behaviors rather than broad goals, placing messaging in the area where the behavior is desired, and rotating the intervention to keep food service employees' attention *(267)*. Minimal-text food safety interventions targeting foodservice workers have been found effective in a variety of settings and with different populations. A minimal-text food safety "infosheet" intervention posted in an operation's high-traffic areas led to an increase in hand-washing and reduction in cross-contamination behaviors in food service workers *(48)*. A minimal-text intervention including visuals improved food safety knowledge in Spanish speaking and immigrant, Hispanic foodservice workers *(202, 203)*. Furthermore, in a study of 2,600 college students, implementation of a minimal-text food safety-training program led to a 90.7% pass rate on a food safety assessment *(243, 232)*.

Summary

Both the United States and the global population are aging, creating a higher number of people and proportion of the population of older adults at increased risk for foodborne illness. Additionally, a national increase in the consumption of fresh leafy greens, along with an increase in foodborne pathogen outbreaks related to the consumption of fresh fruits and vegetables make the older adult population a key target for foodborne disease prevention related to leafy greens. Older adults' awareness and behavior when purchasing and preparing foods inside the home affects food safety risk in this population. A national trend in eating outside the home also places foodservice workers in a key role for interventions focused on foodborne disease prevention in older adults. By targeting both older adults and foodservice workers, both projects in this thesis intend to reduce food safety risk in older adults by increasing knowledge about food safety and food handling.

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CHAPTER 3: PROMOTING FOOD SAFETY AWARENESS FOR OLDER ADULTS USING ONLINE EDUCATION MODULES

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Abstract

Older adults are susceptible to and at greater risk for foodborne illness in comparison to other adult age groups. Online education is an underutilized method for the delivery of food safety information for this population. Three social marketing theory-based online mini-modules were created for and pilot-tested with older adults. These mini-modules were effective in promoting familiarity with food safety behaviors and were well-received, supporting the development of future SMT-based online education in this target audience.

Introduction

Adults aged 65 and over are susceptible to and at greater risk for foodborne illness than other adults *(22, 32)*. Immune function declines during aging in various ways, including changes in the mucosal barrier and immune cells of the gut, a reduction in stomach acid, gut motility, physical activity, and a decline in health due to chronic disease *(8, 15, 17, 33)*. Behravesh et al. *(2)* report that most foodborne illness-related deaths (58%) occur in adults aged 65 and over. Similarly, the Centers for Disease Control and Prevention (CDC) reported that in 2012 adults aged 60 and over had consistently higher hospitalization and mortality rates for all the major food pathogens tracked than other age groups *(6)*.

The United States Food Safety and Inspection Service (FSIS) recommends, in addition to general food safety behaviors such as washing hands, sanitizing surfaces, and cooking foods to safe temperatures, that older adults should avoid foods from higher risk sources such as unpasteurized milk and soft cheeses, cold deli meats and undercooked eggs *(11, 16, 25, 37)*. One potential challenge to meeting these recommendations is that older adults may not be aware of their higher food safety risk *(5, 14)*. Cates et al. *(5)* found that 41% of older adult respondents to a survey of food safety knowledge and behaviors disagreed that they were at higher risk for foodborne disease due to age. In a study of food safety-related trends and perceptions, Fein et al. *(9)* found that adults age 65 and over had a lower perception of food-safety related risk than young adults aged 18-29 years old. Additionally, the food preparation practices (e.g., cooking, handling, storage) of older adults may also be placing them at risk of foodborne illness *(14)*. The lowered awareness of foodborne illness risk and unsafe food handling practices of older adults warrants the creation of Extension-delivered, theory-based food safety education programming. Particularly since public health interventions have successfully targeted this population *(23, 24, 36)*.

Food safety educational interventions targeting older adults should be theory-based and tailored to the needs and preferences of the particular audience of older adults *(30)*. Older adults are a socio-economically and culturally diverse group, and this diversity is projected to increase over the next decade *(1, 27)*. The racial and ethnic diversity of the older population has increased from 17% to 21% since 2002, and this trend is expected to continue to increase to 28% by the year 2030 *(1)*. This highlights the need for culturally sensitive, targeted interventions for older adults. Theory-based health interventions for older adults have been shown to increase self-efficacy (confidence to perform specific heath behavior), knowledge, and result in behavior change *(7, 23, 26, 35, 36)*.

Social Marketing Theory

One theory used in the development of public health interventions targeting behavior change is social marketing theory (SMT). In practice, SMT makes use of marketing strategies, tools, and theory to influence behavior change *(20, 28)*. Lefebvre and Rochlin *(21)* describe the steps of SMT: planning, choosing content and delivery method(s), developing and testing tools, implementing, assessing, and revising. The planning step involves collecting information about the needs and preferences of the target population and using this information to customize both the content of the intervention and the method(s) of delivery *(19, 20, 29)*. Francis, Martin, and Taylor *(13)* found that tailoring an online nutrition education program to the target audience's needs and preferences led to appealing and relevant program perceptions.

Online education

Today's older adults are using technology, which offers educational opportunities *(3, 10)*. Online educational tools can increase self-efficacy (confidence to perform a certain behavior) and lead to behavior change *(4)*. Furthermore, online Extension-delivered programs have previously been shown to increase food safety knowledge and familiarity *(12)*.

When developing education programs for older adults, online opportunities typically are not explored due to misperceptions about older adult use of technology. Flynn et al. *(10)* and Bujnowska-Fedak and Pirogowicz *(3)* report older adults actively seek health information online; in fact adults age 65 and older have increased internet usage from 53% to 59% since 2012 *(31)*. Additionally, older adults are willing to utilize technology-based food safety educational materials *(18)*. This presents a unique opportunity for Extension to provide older adults with online food safety education. The goal of this project was to develop and evaluate online SMT-based food safety education modules targeting the food safety education needs for older adults.

Methods

Needs assessment

Older adults attending local congregate meal-sites (n=29) and residing in retirement communities (n=58) completed a 10- question food safety quiz *(34)* to identify areas for food safety education. This quiz asked about the participant's frequency of completing certain food safety behaviors (Table 1). Quiz responses were tabulated using descriptive statistics. Those with higher frequencies of "no" or "sometimes" responses (35% or higher) were identified as "areas of need" and subsequent food safety education modules were developed.

Development and evaluation of modules

The results from the needs assessment indicated a major knowledge gap related to safe thawing practices, with 64% of participants answering “No” or “Sometimes” to this question (Table 1). In response, three five-to-eight minute online modules were developed addressing temperature control of foods: “Thaw Safely!” (safe thawing practices), “It’s All About the Temperature!” (thermometer use), and “Freeze Smart!” (freezing foods).

Each mini-module highlights the key recommendations temperature-related behaviors and will be posted on the older adult focused Extension website, Mid Life and Beyond (http://www.extension.iastate.edu/humansciences/midlife-and-beyond). Each mini-module includes hyperlinks to additional online resources. The mini-modules were created using PowerPoint with voice-over recordings in Adobe Presenter *(12, 13)*.

Mini-module evaluations were conducted at one of the retirement communities which had participated in the needs assessment. Participants watched the online modules in a group setting and completed evaluation post-pre surveys. Survey results were entered into the online survey system, Qualtrics (Provo, Utah), where they were analyzed using descriptive statistics.

Results

Demographics

Eighty-seven older adults (57 females, 27 males, 3 no response) ages 64 to 92 years (81.3 years average) completed the needs assessment. The online module evaluations were completed by residents at one of the needs assessment retirement communities, primarily females ages 73 to 92 years (81.4 years average; Table 2).

Post-pre evaluation

All participants reported an increase in familiarity after viewing the modules for each of the topics addressed (Table 2). Additionally, the majority reported being "very likely" to apply the advice mentioned during the module (Table 2).

Summary

The online food safety education mini- modules were well-received by participants and were effective in promoting awareness of recommended food safety practices for older adults. These findings support the development of additional online food safety education opportunities for older adults. Based on the needs assessment data collected future topics may include food packaging dates and purchasing of refrigerated and frozen foods.

Author Contributions

Amber L. Roy collected and analyzed data and drafted the manuscript. Sarah Francis assisted with survey design, module design, statistical analysis and drafting of the manuscript. Angela Shaw and Lakshman Rajagopal were involved with decisions related to module design, data interpretation, writing, and review of the manuscript.

Tables

Table 1: Needs assessment results collected from adults aged 64 and over at congregate meal sites and retirement communities

Food Safety Quiz Question	Number[a]	Percent(%)[b]
When grocery shopping, I pick up refrigerated and frozen foods just before checking out. [a]		
Yes	55	63.2
No/Sometimes	31	35.6
No response	1	1.1
I check "sell-by" or "use-by" dates on packages when shopping or eating.		
Yes	51	58.6
No/Sometimes	36	41.4
When I bring my groceries home, I refrigerate cold foods immediately. [a]		
Yes	86	98.9
No/Sometimes	1	1.1
I wash my hands before I prepare food.		
Yes	74	85.1
No/Sometimes	13	14.9
I keep raw meat or poultry juice away from other foods by using separate cutting boards.		
Yes	60	69.0
No/Sometimes	27	31.0
I wash cutting boards that have touched raw meat or poultry between uses.		
Yes	80	92.0
No/Sometimes	6	6.9
No response	1	1.1
I always thaw meat in the refrigerator.[a]		
Yes	30	34.5
No/Sometimes	56	64.4
No response	1	1.1
I refrigerate my leftovers immediately. [a]		
Yes	73	83.9
No/Sometimes	13	14.9
No response	1	1.1
Spoiled leftover food does not always smell, taste, or look bad, so when I'm in doubt, I throw it out.		
Yes	74	85.1
No/Sometimes	12	13.8
No response	1	1.1
I keep kitchen towels and sponges clean.		
Yes	74	85.1
No/Sometimes	11	12.6
No response	2	2.3

[a]Topic relates to food temperature [b]Percentages do not always add up to 100 due to rounding

Table 2. Participant evaluation post-pre survey results collected from older adults aged 73 and over at a retirement community

Post-Pre Survey Question	It's All About the Temperature! (n=15)	Freeze Smart! (n=15)	Thaw Safely! (n=16)
Gender			
Male	3	3	3
Female	12	12	13
Pre familiarity with mini-module topic			
Not familiar	0 (0.0%)	0 (0.0%)	0 (0.0%)
Somewhat familiar	9 (60.0%)	6 (40.0%)	11 (68.8%)
Very familiar	6 (40.0%)	9 (60.0%)	5 (31.2%)
Post familiarity with mini-module topic			
Not familiar	0 (0.0%)	0 (0.0%)	1 (6.2%)
Somewhat familiar	3 (20.0%)	3 (20.0%)	4 (25.0%)
Very familiar	12 (80.0%)	12 (80.0%)	11 (68.8%)
Likelihood of applying some advice mentioned in the lesson			
Not likely	1 (6.7%)	0 (0.0%)	0 (0.0%)
Somewhat likely	2 (13.3%)	3 (20.0%)	0 (0.0%)
Very likely	12 (80.0%)	12 (80.0%)	16 (100.0%)

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CHAPTER 4: USE OF MINIMAL TEXT POSTERS TO IMPROVE THE MICROBIAL STATUS OF LEAFY GREENS AND FOOD CONTACT SURFACES IN FOODSERVICE SITES SERVING OLDER ADULTS

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Abstract

An aging population, a trend toward eating away from home, and an increase in foodborne outbreaks associated with leafy greens has spurred food safety concerns with foodservice operations serving older adults. The objective of this study was to determine effectiveness of a minimal-text food safety poster intervention in changing microbial status of leafy greens and food contact surfaces at selected foodservice sites. A minimal-text poster intervention was placed in foodservice operations within Iowa and Kansas. Samples were collected before, 1 month after, and 3-4 months after the intervention (n=48, N=144). Leafy green samples were taken at three stages of preparation. Samples were screened for *Listeria monocytogenes*, *Escherichia coli* O157 and *Staphylococcus aureus* and enumerated for aerobic plate counts (APC), coliforms, and fecal coliform (FC) counts. All samples were negative for pathogens tested; APC and coliform counts were not significantly different before and after intervention ($P < 0.05$). After intervention, FC counts in samples of leafy greens from hospitals and restaurants were significantly lower than before intervention ($P < 0.0004$). The reduction in FC after

intervention suggests that minimal-text food safety posted messages may decrease food safety risk in foodservice establishments.

Introduction

Centers for Disease Control and Prevention (CDC) found that 46% of reported foodborne illnesses were linked to fresh produce and nuts, with 22% linked to leafy greens *(30)*. Economic Research Service (ERS) data from 2012 and 2014 showed that among all Americans, 44.8% of dark leafy vegetable and lettuce consumption took place away from home; this is an increase from 2007-2010 (27.3%) *(11)*. CDC data from 1996 to 2005 found most foodborne illness-related deaths (58%) occurred in adults aged 65 and over *(4)*. Epidemiological data suggests older adults also suffer higher hospitalization and mortality rates than other adults with foodborne illnesses *(6, 15)*.

The United States population is aging. According to the U.S. Department of Health and Human Services' Administration on Aging (2013), the percentage of older Americans (age 65 and over) has more than tripled from 4.1% in 1900 to 13.7% of the population in 2012. By 2040, this proportion is expected to exceed one in five, or represent about 21% of the population *(2)*. This population presents unique needs and challenges in health promotion and disease prevention. Age-associated loss of immune function, poor nutrition, lower activity levels, and disease contribute to an increase in older adults' vulnerability to foodborne illness. Additionally, older adults are dining out more frequently. Results from an NPD Group, Inc. (formerly National Purchase Diary) study indicate that between 2008 and 2012, the percentage of adults aged 55 to 64 (compared to total customers) purchasing meals and snacks at foodservice establishments increased by 1.85% and the percentage of adults aged 65 and over purchasing meals and snacks at foodservice establishments rose by 7.73% *(27)*.

As a sector of the food industry, foodservice facilities are challenged with maintaining compliance with food safety regulations. From 1998 to 2008, the United States Food and Drug Administration (FDA) found in a trend investigation with 800 foodservice facilities that the most common non-compliant behaviors, based on Food Code 1997, included employee hand-washing, keeping temperature sensitive foods cold, recording dates on ready-to-eat foods, and proper cleaning and sanitizing of food contact surfaces, employee hygiene, and prevention of contamination *(43)*. This report shows there is a need for more effective food safety training options to reach employees in foodservice.

One strategy for communicating food safety messages is a minimal-text intervention, such as a poster. The use of minimal text addresses language and reading barriers. Additional elements that can increase effectiveness of a minimal-text food safety intervention include providing messages with specific behaviors rather than broad goals, including detailed images, placing messaging the area where the behavior is desired, and rotating the intervention to keep food service employees' attention *(45)*. Minimal-text food safety interventions targeting foodservice workers have been found effective in a variety of settings and with different populations. Chapman et al. determined that a minimal-text food safety "infosheet" intervention posted in an operation's high-traffic areas led to an increase in hand-washing and reduction in cross-contamination behaviors in institutional foodservice workers *(8)*. Rajagopal found that a minimal-text intervention including visuals improved food safety knowledge in Spanish-speaking and immigrant, Hispanic foodservice workers *(32, 33)*. In a study of 2600 college students, Strohbehn and Rajagopal determined that implementation of a minimal-text fundamental food safety-training program led to a 90.7% pass rate on a food safety assessment *(34, 38)*.

One theory used in the development of health interventions targeting behavior change is social marketing theory (SMT). In practice, SMT makes use of marketing strategies and tools to influence behavior change *(24, 28)*. The SMT cycle can be described in steps: planning, choosing content and delivery method(s), developing and testing tools, implementing, assessing, and revising *(3, 16, 25)*. In a mini symposium of reviews on SMT-based public health programs, Gordon and others *(17)* discovered multiple examples of successful interventions targeting a variety of socio-demographic groups. The first step to designing an SMT-based intervention, planning, involves collecting information about the needs and preferences of the target population *(31)*. Following SMT, once needs and preferences are determined the educational intervention should be customized to the target audience *(24)*. According to Kreuter and others *(22)*, this means that both the content of the intervention and the method(s) of delivery should be customized to the audience and pilot tested, as part of the choosing content/methods of delivery and developing/testing tools steps of SMT. The implementation step, the assessing step in an SMT-based intervention involves evaluation of outcomes for effectiveness of the intervention *(28)*. This can be accomplished using validated tools to assess measurable objectives *(37)*. The tool can then be revised and the cycle of steps can begin again.

The increasing number of outbreaks associated with leafy greens, as well as the growing trend of eating meals away from home and an aging population creates a need for interventions targeting foodservice workers in facilities serving older adults. The objectives of this study were to assess the current microbial status of leafy greens and food contact surfaces in establishments serving older adults in the Midwest and assess effectiveness of a minimal-text poster intervention targeting behaviors in improving the microbial safety of these.

Materials and Methods

The intervention

Behavioral (observational and interview) data and microbial data were collected during all site visits (before, 1 month after, and 3-4 months after intervention). Microbial analysis data are the focus of this manuscript. Following SMT, the initial site visits served as a needs assessment for tool development, part of the planning and choosing content and delivery methods steps. During the developing and testing tools stage, nine minimal-text poster interventions (Fig. 1) were developed based on the initial comprehensive behavioral and microbial assessment of leafy green handling in the foodservice operations (http://www.extension.iastate.edu/foodsafety/content/leafy-greens-safe-handling). The posters targeted foodservice workers with messages focused on hand-washing, proper handling of whole and bagged leafy greens, food safety for older adults, and prevention of cross-contamination through proper glove use and hand-washing as well as cleaning practices by workers in the foodservice operations. Posters were full color and included large high-definition images depicting correct behaviors, behaviors indicated as incorrect with a prohibitory symbol, and images of microbial colonies on plates representing contamination of hands (Example in Fig. 1). As part of the testing of tools SMT step, the posters were initially evaluated for feedback by a combination of foodservice workers, foodservice managers, undergraduate dietetics and hospitality students, and food safety/foodservice experts. After evaluation and revision, the minimal-text poster intervention was implemented; All nine posters were sent or hand delivered to each of the eight foodservice operations; a rotation schedule was recommended. Posters were placed at locations in the kitchens chosen by the person in charge. Verification of poster display and placement was done at follow-up visits. Posters were displayed at locations such as: employee bulletin board, preparation station where leafy greens were being prepared, and refrigeration unit door where leafy greens were stored. All nine posters were later translated into Mandarin Chinese and Spanish (Fig. 2). Evaluation of posters for effectiveness was carried out using observational, interview, and microbial data.

Leafy greens sample collection

Site visits occurred at eight foodservice operations serving older adult populations (four in Iowa and four in Kansas). Microbial evaluation of the leafy greens occurred once before intervention, 1 month after, and 3-4 months following intervention at each foodservice type for a total of three site visits at each of the eight foodservice locations, or 24 times. Samples of leafy greens were collected at receiving, at the beginning of food preparation, and as the leafy greens were served (three different sampling points); thus, a total of 72 samples were collected. A minimum of 250 grams of leafy greens per sample was collected with washed and gloved hands and placed into a coded sterile sampling bag. The samples of leafy greens were delivered under refrigeration (below 5˚C) and analyzed within 24 hours of collection. A temperature abuse indicator, 3M™ MonitorMark™ Time Temperature Indicator, (St. Paul, MN) was placed into the coolers to quantify any temperature abuse during transport and holding.

Surface sample collection

Microbiological testing of food contact surfaces was done on the same three occasions as collection of leafy greens – once before intervention, and 1 month and 3-4 months after intervention using a specified protocol in which all researchers were trained. A total of 72 surface samples were collected. Surface swabs were collected on three different direct contact surfaces (i.e. cutting board, knife blade, spinner, strainer, portioning utensil, pan, leafy greens bag, produce brush, and preparation surface) and indirect contact surfaces (cart, produce sink, refrigerator handle, hand-washing sink handle) in each operation *(36)*. The direct surfaces were those used to prepare the leafy green products. A 30 cm^2 surface was swabbed using a sterile 10 cm^2 template and a coded swab, Quantiswab® (bioMérieux, Marcy l'Etoile, France). The template and swab were moved three times to cover the 30 cm^2 to represent the 250 gram area the leafy greens would occupy. Samples were transported in the same manner as the leafy green samples. A total of 72 contact surface samples were collected.

Microbial analysis

All samples were coded prior to arrival at the food microbiology facility to ensure blindness of the study. The leafy green samples and food contact swabs were received into a Biological Safety Level 1 laboratory for sorting and initial sample data entry. Once the samples had been initially processed, they were transported to a Biological Safety Level 2 laboratory for microbial analysis. The 3M™ MonitorMark™ (St. Paul, MN) Time Temperature Indicator was checked and amount of temperature abuse occurring during transport was recorded. The three-250 gram bags of leafy greens and three swabs were removed from the cooler and refrigerated. From each of the samples of leafy greens, sub samples were weighed and placed into sterile stomacher bags. All samples of leafy green were homogenized using a Seward Stomacher® 400 Circulator (Worthing, West Sussex, UK). For surface swab samples, the additional diluent was added to the swab tube to make 10 mL.

General microbiological quality of the leafy greens and food contact swabs were determined by enumeration of the total aerobic plate counts (APC), coliform counts and fecal coliform (FC) counts. Half of the leafy greens and surface swabs sub samples had the addition of buffered peptone water (BPW) for APC, coliform, and FC analysis. Serial dilutions occurred in the samples followed by plating on Aerobic Count Plate Petrifilm™ and Coliform/*E.coli* Petrifilm™, respectively (3M™, St. Paul, MN). APC plates were counted after 48 hours and red colonies were recorded as aerobic plate counts. Coliform and FC plates were incubated at 35°C and observed for changes at 24 and 48 hours. Blue to red-blue colonies associated with gas at 48 hours were counted as FC colonies. Red colonies associated with gas were counted as coliform colonies.

The rest of the sub samples were enriched for detection of the presence of *E.coli* O157, *Listeria monocytogenes,* and *Staphylococcus aureus*. For enrichment of *E.coli* O157, EC broth with Novobiocin (20mg/L) was utilized, *Listeria monocytogenes* was enriched using buffered listeria enrichment broth (BLEB), and *Staphylococcus aureus* was enriched using Staph broth with Tween (4% Polysorbate 80). All broths were pre-warmed to 20-25°C before combining with samples. EC broth samples were incubated at 42°C for 18-24 hours; BLEB samples and Staph broth were incubated at 36°C for 24 hours. ELISA kits and latex agglutination were utilized for the detection of *E.coli* O157 (3M™ Tecra™ E. coli O157 Visual Immunoassays) and *Staphylococcus aureus* (3M™ Tecra™ Staph aureus Visual Immunoassays). BAX® PCR assay was utilized for detection of *Listeria monocytogenes* (Dupont™ BAX® System PCR assay 24E). Protocols for the represented tests were utilized after the initial incubation periods. All test results indicated positive or negative for the presence of the pathogen of concern. Conventional plating techniques were performed for indeterminate results with the enrichment on selective media based on FDA Bacteriological Analytical Manual (BAM).

Statistical analysis

Data were entered into Microsoft® Excel® (Redmond, WA) and independently validated. Data were then imported into SAS® software (IBM®, Armonk, NY). Mixed model methodologies were used to evaluate specific response variables to determine the amount of change in APC, coliforms, and FC (*E.coli*) at the three time points (as received, handling, and service) in the leafy greens and on the different contact surfaces. Leafy green sample data and surface sample data were analyzed separately. Independent variables (state, foodservice type, sample type, point in intervention process) were analyzed for potential interactions. A significance level was determined to be $P < 0.05$.

Behavioral data collection and analysis

Behavioral data collected at all three site visits included observation of food safety behaviors related to the production and service of leafy greens, including personal hygiene, storage, time and temperature control, sanitation, and prevention of cross-contamination. During analysis, the number of observed behaviors in compliance with food safety standards was divided by the total number of observed behaviors to calculate compliance rates for each site visit. Chi-square analysis of compliance rates was performed using SAS® software (IBM®, Armonk, NY). Additionally, follow-up interviews were conducted with observed employees, and questions were asked about how and why behaviors were conducted. This qualitative data were coded into themes for later analysis, which is not reported in this paper.

Results and Discussion

Minimal-text interventions have been shown affective in improving food safety awareness, knowledge, and behavior of foodservice workers, though these studies lacked microbial assessment *(8, 32, 33, 38)*. In these observational studies, researchers identified that bacterial contamination of foods may occur when foods come into direct or indirect contact with contaminated surfaces or by contact with contaminated personnel. A 2009 report released by the FDA based on a ten-year study of 800 foodservice facilities identified time and temperature control of foods, employee hygiene, and prevention of contamination as food safety risk factor areas in poor compliance with Food Code recommendations *(43)*. Specifically, hospitals were found out of compliance with proper hand-washing 35.6% of the time, nursing homes were out of compliance 34.4% of the time, and full service restaurants were out of compliance with proper hand-washing 75.8% of the time *(43)*. The presence of *Staphylococcus aureus*, bacteria naturally found on the skin and nasal cavity of humans, on food and food contact surfaces indicates poor personal hygiene (lack of hand-washing) because the most common source of food contamination is humans *(23)*. *E.coli* O157 is a foodborne pathogen that can cause major health issues in humans, which is categorized as an adulterant in food with the fecal-oral mode of contamination. *Listeria monocytogenes*, like *E.coli* O157, is a foodborne pathogen associated with health hazards and is considered an environmental contaminate. If *E.coli* O157 or *Listeria monocytogenes* are found present in a food item during food processing, the product must be discarded immediately with corrective actions established to ensure the pathogen is eliminated from the processing environment and prevention measures have been taken for further processing of the product *(42)*. In this study, none of the bacterial pathogens tested for in our study (*Listeria monocytogenes*, *Staphylococcus aureus*, *Escherichia coli* O157) were detected in any samples (leafy greens or surfaces), therefore no corrective actions were needed.

Table 1 provides a summary of the microbial counts observed on leafy greens and surfaces at the four foodservice types. There were no significant differences found in results between the two states (Iowa and Kansas), therefore data from all three sampling times for both states were pooled for analysis ($P > 0.05$). APC levels on fresh produce have been used to indicate differences in microbial quality for various types of produce, as well as indicate changes in microbial quality throughout processing and handling steps *(20)*. APC levels on leafy greens for this study (Table 1) were within expected ranges for leafy greens 10^4 to 10^9 CFU/gram *(14, 20, 21, 29, 44)*. Our tests found no significant differences detected for APC or coliform counts for leafy green samples by foodservice type or time of sampling (before, 1 month after intervention or 3-4 months after intervention) (*$P > 0.05$*) (Figs. 5,11). Though not statistically significant, there was a trend noted of increasing APC counts as the leafy greens moved through the flow of food handling (from receiving to service) (Fig. 3). These increases are expected, as foodservices are not sterile environments. No significant differences were detected for APC, coliform counts, or FC counts for different surfaces in the kitchens by intervention stage (Figs. 5, 7, 8, 9, 14, 15, 16), type of contact surface sampled (direct versus indirect food contact surface, such as cutting board versus refrigerator door handle) (Figs. 6, 13, 18) or the interaction between time of sampling and type of surface (*$P > 0.05$*) (Figs. 5, 12, 17).

Although there are no official standards for acceptable APC levels for the foodservice industry for leafy greens or surfaces, APC levels in this study (Table 1) on both direct (1200 ± 3700 CFU per mL) and indirect surfaces (330 ± 1100 CFU per mL) were higher than literature has suggested as appropriate standards for foodservice sites serving older adults (< 20 CFU per mL) and levels commonly used by industry experts (< 100 CFU per mL) *(10, 36)*. However, it must be noted that the surfaces sampled were in the midst of a service day and the standards provided are those of freshly sanitized facilities. These findings suggest that additional studies are needed to provide baseline levels and/or regulatory limits of acceptable microbial levels for foodservice operations.

The role of surfaces contamination on overall food safety has been highlighted in many studies. According to the CDC's 2012 surveillance report, 12.8% of foodborne outbreaks with reported contributing factors included factors related to contaminated surfaces *(5)*. In a study of retail deli departments, Lubran et al. *(19)* noted common occurrences of contact between non-food contact surfaces, gloved hands, and ready-to-eat foods. They noted 100% compliance with cleaning and sanitation at required times but also found 110 additional occasions during which cleaning and sanitation practices were attempted, yet inappropriately executed *(26)*. The finding of improper handling, cleaning and sanitation, and cross-contamination may be possible reasons for increasing APC and coliform counts from receiving through preparation to service seen in our study. Results from the work of Lubran et al. (2010) also reveal the importance of training all staff on food safety behaviors, as those researchers found employee job responsibilities changed during the study, which could further explain the high rate of inappropriate cleaning and sanitation behaviors. High rates of employee turnover seen in the foodservice industry may also increase the need for more frequent food safety training *(19)*. Thus, easy to follow messages can be one way to ensure employees new to a specific task are fully informed on proper procedures.

Like APC, coliform counts on fresh produce have been used to indicate changes in microbial quality through processing and handling *(20)*. Coliforms represent bacteria from four genera: *Enterobacteriaceae*: *Citrobacter, Escherichia, Enterobacter*, and *Klebsiella*. Some *Enterobacter* spp and *Klebsiella* spp are found in soil, water or on plants and could be part of natural flora of leafy greens. Coliform counts in samples of leafy greens were not significantly different before or after the intervention (Table 2). There was a trend, though not significant, of decreasing coliform counts on leafy greens from receiving to preparation to service (Fig. 11). Similar to APC, there are no official standards for coliform counts on leafy greens or food contact surfaces in the foodservice, however surface counts in this study (Table 2) were above unofficial standards (10 CFU/mL) commonly used in pre-operational sanitation checks performed in the food processing industry *(10)*. Ideally, coliform counts should remain below these industry standards, but the introduction of soil with leafy greens purchased in unwashed form and cleaned in house can contaminate surfaces during production. Our results indicate the need for more frequent sanitation procedures along with improved procedures for receiving leafy greens to ensure surfaces are not contaminated through indirect contact. Further, foodservices should adhere to the FDA recommendation to not rewash bagged salad greens prior to use; this best practice will lower the risk of cross contamination *(41)*.

While FC is commonly found on surfaces in public environments, there should not be a presence of FC in the food production and processing settings on leafy greens or food contact surfaces. Industry has used fecal coliform testing as a screening tool to indicate possible contamination of foods and food contact surfaces *(7, 12, 35)*. Cutting boards and counter surfaces have been demonstrated as potential vectors for cross-contamination of intestinal bacteria to food *(9, 18, 39)*.

There were no significant differences observed in FC counts from samples of leafy greens between different foodservice types, but a significant interaction for fecal coliform counts between the foodservice type and intervention stage was found ($P < 0.05$) (Fig. 20). Fecal coliform counts from samples of leafy greens collected at hospitals were significantly lower at 1 month and 3-4 months after the intervention ($P = 0.0004$) than samples collected before the intervention (Table 3). Fecal coliform counts from leafy greens collected at restaurants were also significantly lower at 1 month and at 3-4 months after the intervention (*P = 0.0004*) than samples collected before (Table 3). In both cases, counts collected 3-4 months after were not significantly different from samples collected 1 month after the intervention and counts were zero (below the detectable limit) ($P = 1$) (Table 3). Another observation was that fecal coliform counts on leafy greens tended to increase, though not significantly, from receiving to preparation to service ($P = 0.1621$) (Fig. 19), similar to the trend noted with APC (Fig. 3). This finding raises concerns about proper handling, temperature control, and potential for cross-contamination occurring during preparation of leafy greens.

There are no official standards in the United States for FC levels on leafy greens, however other countries and previous studies have set allowable limits for generic *E.coli* and fecal coliforms in ready-to-eat leafy greens at < 100 CFU/gram *(7, 13, 40)*. In this study, fecal coliform counts on leafy green samples were below this limit, and there was a significant reduction observed in fecal coliform counts on leafy greens in restaurants and hospitals after intervention. These results indicate potential effectiveness of a poster intervention in reducing fecal contamination of leafy greens during handling in these types of foodservice operations, however further research is needed to validate the impact of this type of intervention on food safety. Another observation in our study was a lack of significant difference detected in specific direct leafy greens contact surfaces (e.g. knife blade, cutting board, counter top) sampled before the intervention, 1 month after, or 3-4 months after intervention ($P > 0.05$) for any of the tests (aerobic plate counts, coliforms or fecal coliforms). Cutting boards and counter surfaces have been demonstrated as potential vectors for cross-contamination of intestinal bacteria to food *(9, 18, 39)*.

Abdelmassih et al. *(1)* provide an analysis of behavioral compliance rates related to leafy green production and service in the eight participating foodservice sites. Behavioral compliance results were mixed. There was no significant change found in compliance rates 1 month after the intervention in any of the eight sites visited. At 3-4 months after the intervention, there was no significant change in four of the participating foodservice sites, an increase in compliance rates in two sites, and a decrease in compliance rates in two sites *(1)*. Factors that were associated with increasing compliance rates included employees having received previous food safety training, managers involving employees in the implementation of the poster intervention, and rotation of the posters throughout the four week intervention period *(1)*.

Conclusions

To the authors' knowledge, this study is a first attempt to study contamination of leafy greens as it occurs in foodservice operations. This may be in part due to the challenges of collecting data in a working foodservice kitchen (obtaining permissions, avoiding disruptions, etc.). Microbial analysis of surfaces and fresh produce is, by its nature, time and temperature sensitive, therefore separate samples were collected for each site visit, leading to potential individual sample variation that limits implications drawn from the data. Additionally, both bulk and pre-washed, bagged leafy green samples were collected to accommodate menu and delivery differences at the foodservice sites, which could also lead to variations in microbial counts. Future microbial analysis of this type could be strengthened by baseline data collection over a longer period to observe natural variations over time as a potential cause for observed changes in microbial counts.

Our results suggest the potential for a minimal-text food safety intervention to decrease microbial contamination risks in foodservice establishments, however additional microbial and behavioral studies are needed to identify and rule out other potential causes for variations in microbial counts in foodservice settings before the impact of this type of intervention on food safety risk can be determined. Overall microbial counts and mixed compliance rate results suggest that continued education is needed to ensure sanitation of food contact surfaces and safe preparation and service of leafy greens. Posters with visually based, succinct food safety messages related to proper handling of leafy greens appeared to be useful to a diverse and changing workforce. Poster effectiveness may be enhanced by encouraging employee involvement and interaction with the intervention, combining posters with other food safety training methods, and ensuring rotation of posters. Further research is needed to determine whether specific barriers and motivators of employees exist in foodservice settings serving aging populations to practice safe food handling and correct sanitizing procedures. Further research is also needed for development and publication of acceptable levels for APC, coliforms, and FC in the foodservice industry that can be used as a screening tool to assess proper cleaning and sanitation of food contact surfaces.

Acknowledgements

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Author Contributions

Amber Roy collected test data and drafted the manuscript. Angela Shaw designed the microbial protocols for this study and interpreted the results. Lakshman Rajagopal, Susan Arendt, Kevin Sauer and Catherine Strohbehn collected the microbial samples (surface and leafy greens) at the eight foodservice establishments in Iowa and Kansas. Additionally, these individuals were involved with decisions related to study design, data interpretation, statistical analysis, writing, and review of the manuscript.

Tables

Table 1. Least square mean colony forming units of aerobic, coliform, and fecal coliform counts collected on leafy greens and surfaces directly and indirectly in contact with leafy greens in Iowa and Kansas at eight foodservice establishments (n= 72 leafy greens samples, n= 72 surface samples)

	Aerobic Plate Counts[a]	Coliform Counts	Fecal Coliform Counts
Leafy Green Samples			
Location:			
Hospital	4.4e5 ± 1.2e6 (2.0 - 5.1e6)	3.9e3 ± 1.1e4 (0.0 - 3.7e4)	3.9e-1 ± 8.7e-1 (0.0 - 3.0)
Long-term Care	2.6e5 ± 9.9e5 (2.6e2 - 4.1e6)	3.6e3 ± 7.7e3 (0.0 - 2.9e4)	0.0 ± 0.0 (0.0 - 0.0)
Assisted Living	1.2e6 ± 2.9e6 (4.7e2 - 1.1e7)	5.3e2 ± 1.1e3 (0.0 - 3.9e3)	0.0 ± 0.0 (0.0 - 0.0)

Table 1 continued

Restaurant	1.7E6 ± 3.4E6 (5.5e2 - 1.1e7)	2.1e3 ± 3.9e3 (0.0 - 1.5e4)	3.1e-1 ± 8.9e-1 (0.0 - 3.0)
Surface Samples			
Surface Type:			
Direct	1.2e3 ± 3.7e3 (0.0 - 1.8e4)	1.1e2 ± 3.2e2 (0.0 - 1.5e3)	1e-1 ± 6e-1 (0.0 - 4.0)
Indirect	3.3e2 ± 1.1e3 (0.0 - 4.7e3)	8.5e1 ± 3.3e2 (0.0 - 1.5e3)	0.0 ± 0.0 (0.0 - 0.0)
[a]Least square means ± standard deviation (min-max range)			

Table 2. Least square mean colony forming units of aerobic plate and coliform counts collected on direct food contact surfaces in Iowa and Kansas at eight foodservice establishments at different stages of a minimal-text intervention (n=72)

	Before Intervention	1 Month After Intervention	3-4 Months After Intervention
Aerobic plate count ±SD	5.9e2 ± 1.9e3 (0.0 - 7.2e3)	1.7e3 ± 4.3e3 (2.0 - 1.5e4)	1.3e3 ± 4.3e3 (1.0 - 1.8e4)
Coliform count ± SD	2.2e1 ± 5.1e1 (0.0 - 1.7e2)	1.8e2 ± 4.5e2 (0.0 - 1.5e3)	1.2e2 ± 3.1e2 (0.0 - 9e2)
[a]Least square means ± standard deviation (min-max range)			

Table 3. Least square mean colony forming units of fecal coliform counts collected on leafy greens in Iowa and Kansas at eight foodservice establishments at different stages of a minimal-text intervention (n=72)

	Before[a]	1 Month After	3-4 Months After
Location:			
Hospital	1.2±1.2(0-3)[Aa]	0.0±0.0(0-0)[Ab]	0.0±0.0(0-0)[Ab]
Long-term Care	0.0±0.0(0-0)[Ba]	0.0±0.0(0-0)[Aa]	0.0±0.0(0-0)[Aa]
Assisted Living	0.0±0.0(0-0)[Ba]	0.0±0.0(0-0)[Aa]	0.0±0.0(0-0)[Aa]
Restaurant	9.2e-1±1.4(0-3)[Aa]	0.0±0.0(0-0)[Ab]	0.0±0.0(0-0)[Ab]
[a]Least square means ± standard deviation (min-max range) [a,b] represents a significant difference across rows [A,B] represents a significant difference down columns			

Figures


IOWA STATE UNIVERSITY
Extension and Outreach
Wash hands
Cover and label
Store above raw or cooked foods and at 41°F or lower
BAGGED LEAFY GREENS
DOS
DON'TS
No gloves needed if not touching greens
Don't wash
FOOD SAFETY IS IN MY HANDS
GERMS ON YOUR HANDS
When dried on apron
When not washed
After touching phone
After touching face
After touching garbage
Tablet
Kitchen Phone
Cell Phone
Prevent Cross-Contamination:
KEEP HANDS CLEAN!
DO NOT TOUCH
Face
Equipment
Garbage
Hair
Safe Food

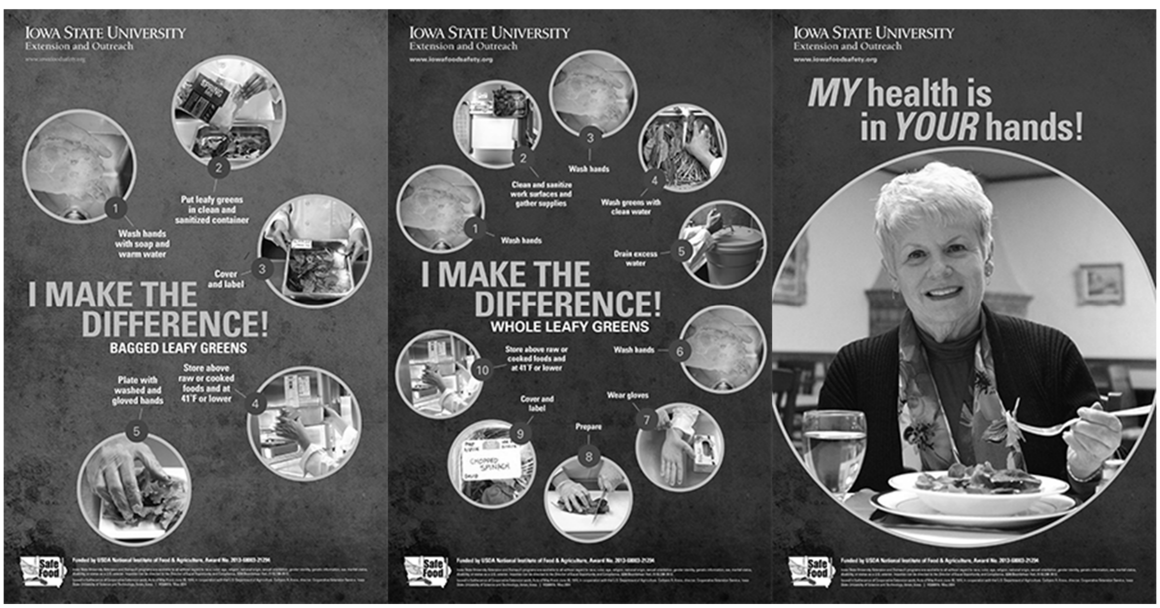
IOWA STATE UNIVERSITY
Extension and Outreach
www.iowafoodsafety.org
Wash hands with soap and warm water
Put leafy greens in clean and sanitized container
Cover and label
I MAKE THE DIFFERENCE!
BAGGED LEAFY GREENS
Plate with washed and gloved hands
Store above raw or cooked foods and at 41°F or lower
Wash hands
Clean and sanitize work surfaces and gather supplies
Wash hands
Wash greens with clean water
Drain excess water
I MAKE THE DIFFERENCE!
WHOLE LEAFY GREENS
Store above raw or cooked foods and at 41°F or lower
Wash hands
Cover and label
Wear gloves
Prepare
MY health is in YOUR hands!
Safe Food

Figure 1. Nine (English) minimal-text food safety posters targeting foodservice workers

Figure 2. Examples of (Mandarin and Spanish) minimal-text food safety poster intervention targeting foodservice workers

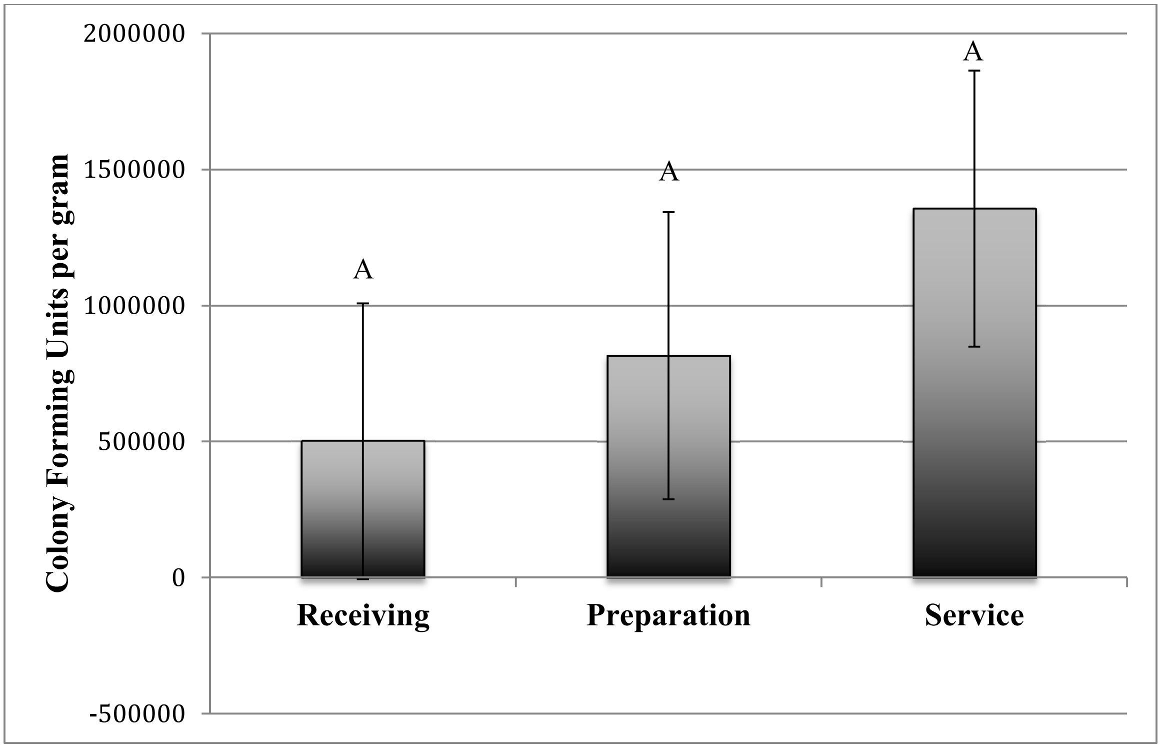

Figure 3. Colony Forming Units of aerobic bacteria collected on leafy green samples at three stages in the flow of food in Iowa and Kansas at eight foodservice sites

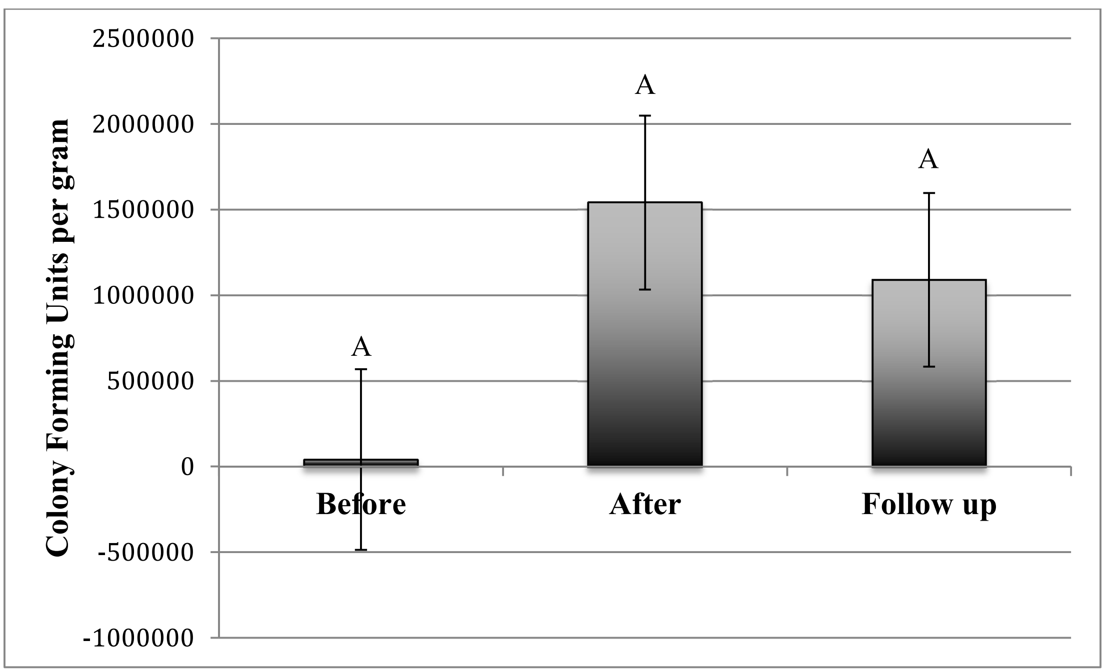

Figure 4. Colony Forming Units of aerobic bacteria collected on leafy green samples by stage of intervention in Iowa and Kansas at eight foodservice sites

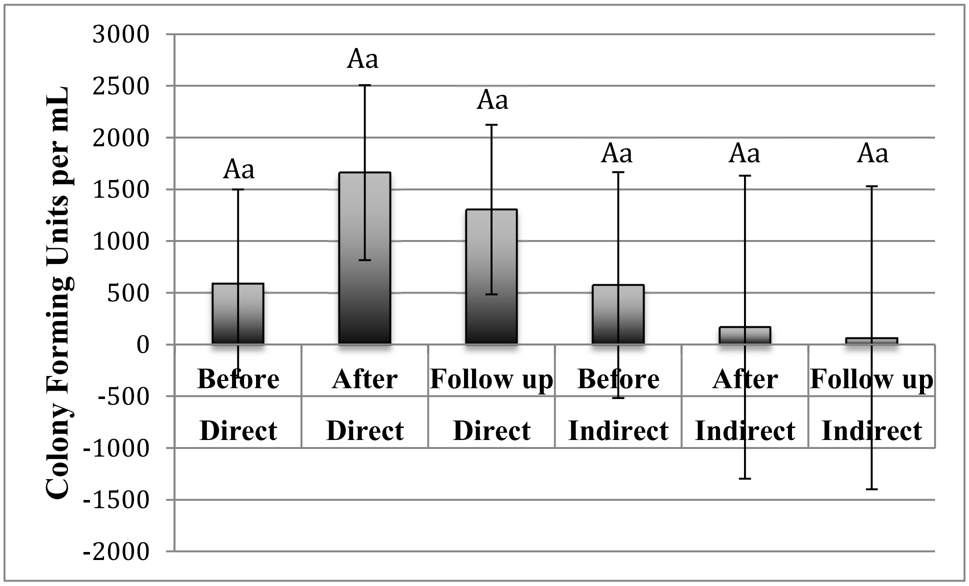

Figure 5. Colony Forming Units of aerobic bacteria collected on direct and indirect surfaces by stage of intervention in Iowa and Kansas at eight foodservice sites

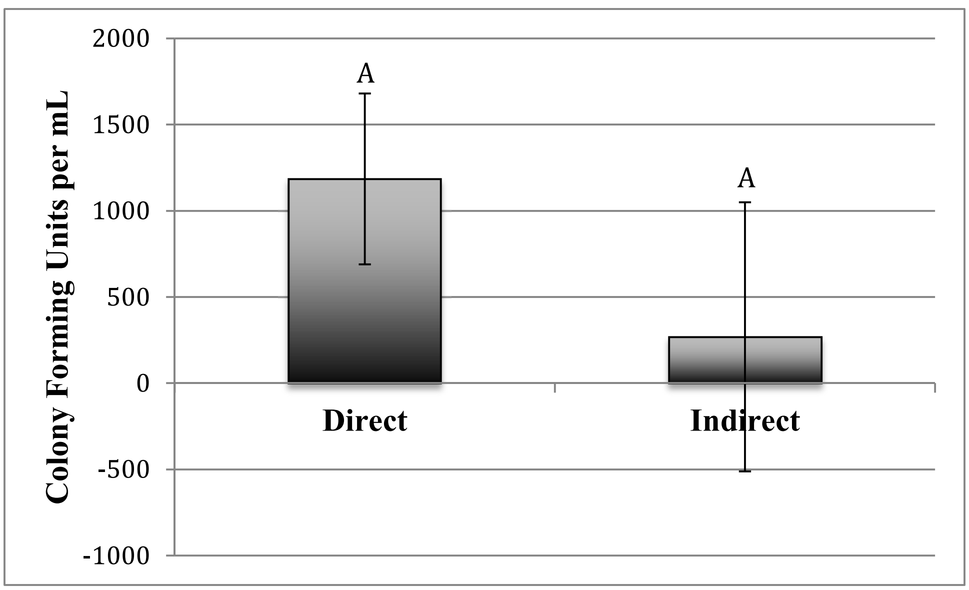

Figure 6. Colony Forming Units of aerobic bacteria collected on direct and indirect surfaces in Iowa and Kansas at eight foodservice sites

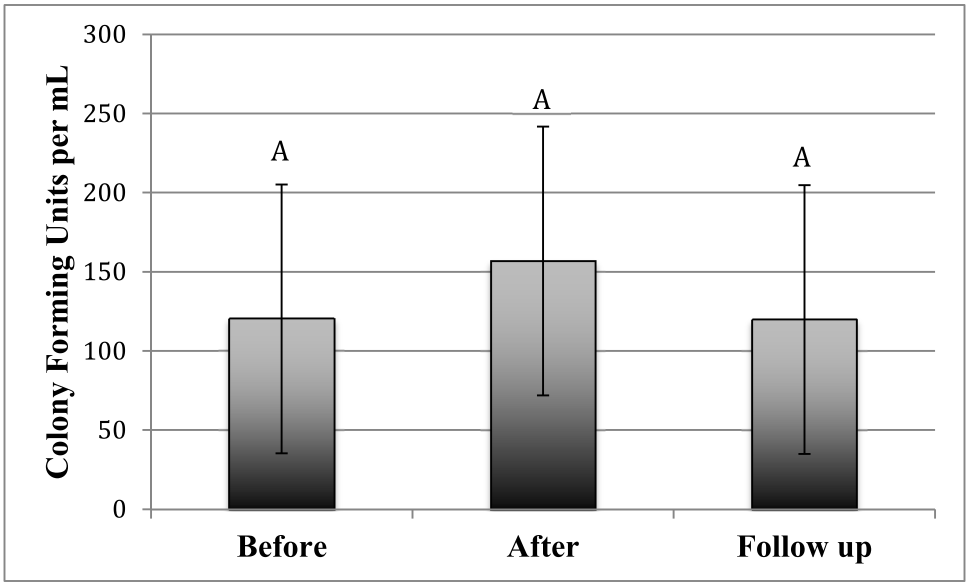

Figure 7. Colony Forming Units of aerobic bacteria collected on knife blade surfaces by stage of intervention in Iowa and Kansas at eight foodservice sites

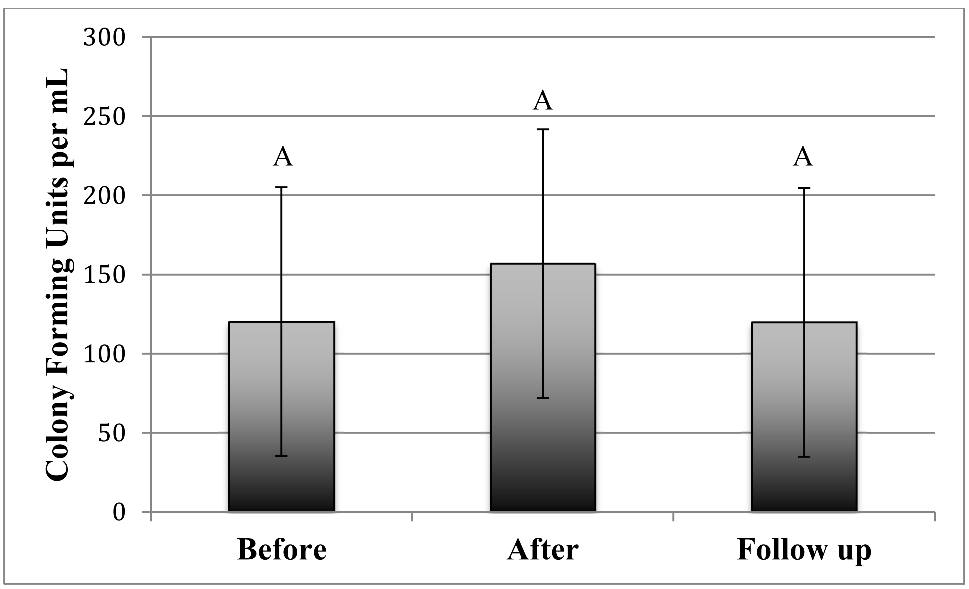

Figure 8. Colony Forming Units of aerobic bacteria collected on cutting board surfaces by stage of intervention in Iowa and Kansas at eight foodservice sites

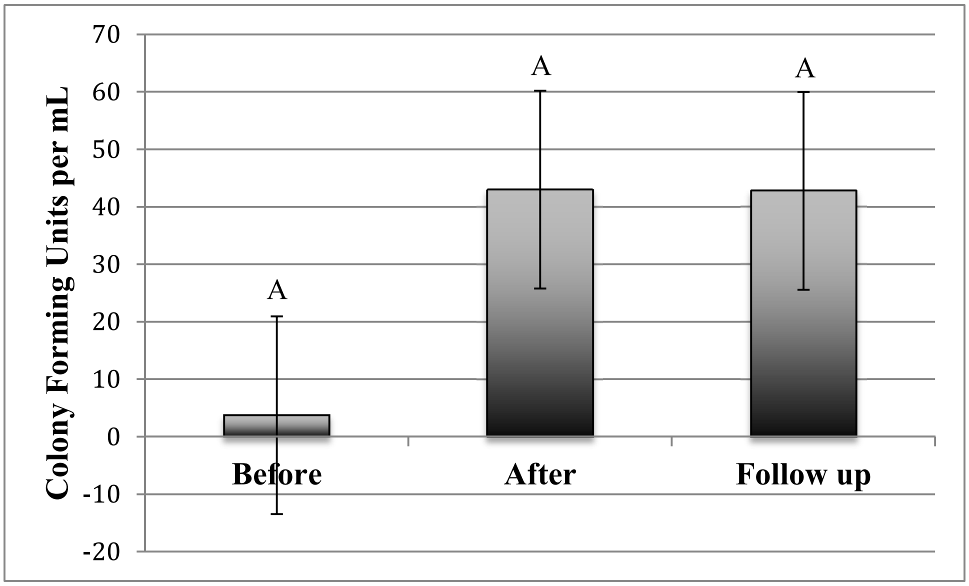

Figure 9. Colony Forming Units of aerobic bacteria collected on counter top surfaces by stage of intervention in Iowa and Kansas at eight foodservice sites

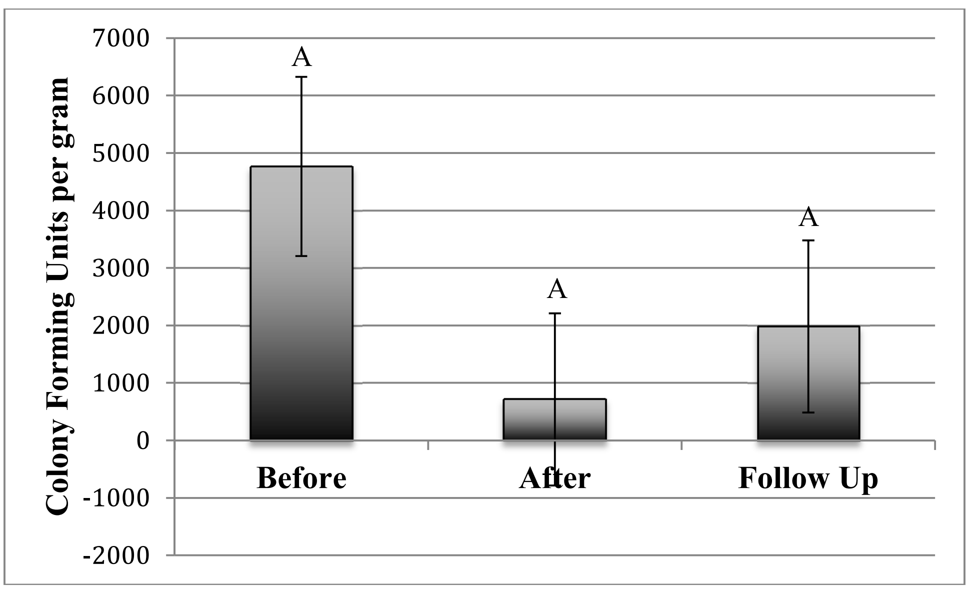

Figure 10. Colony Forming Units of coliform bacteria collected on leafy greens by stage of intervention in Iowa and Kansas at eight foodservice sites

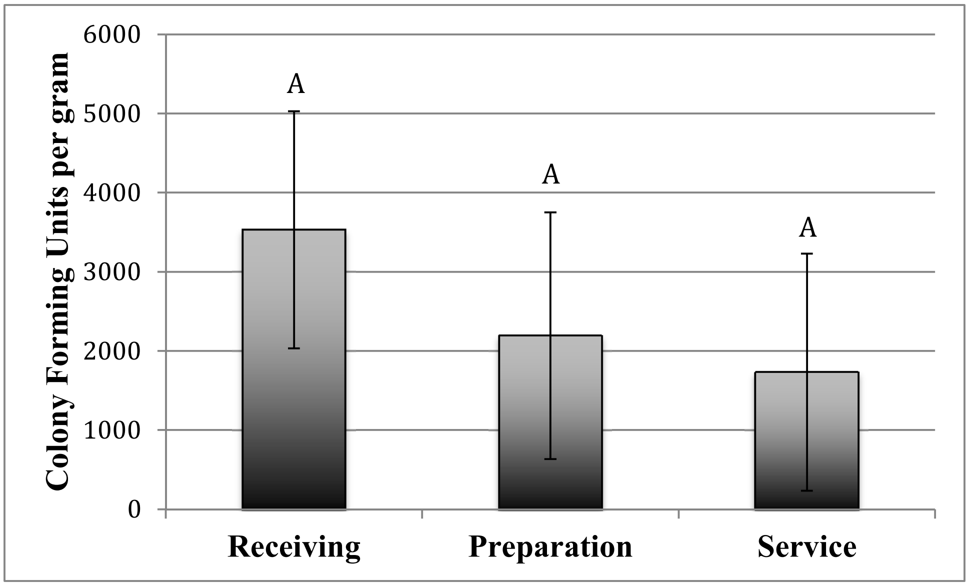

Figure 11. Colony Forming Units of coliform bacteria collected on leafy greens by stage in the flow of food in Iowa and Kansas at eight foodservice sites

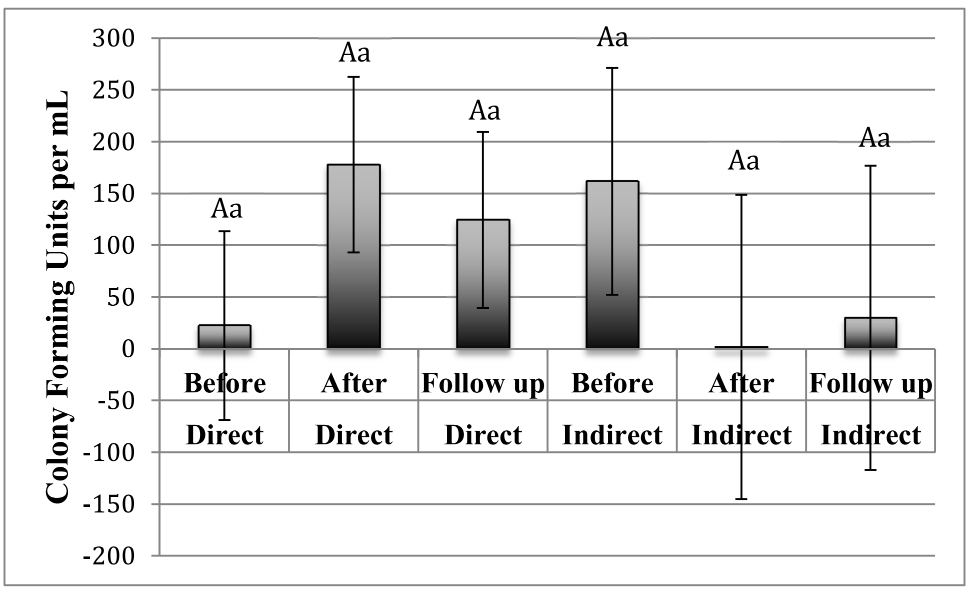

Figure 12. Colony Forming Units of coliform bacteria collected on direct and indirect surfaces by stage of intervention in Iowa and Kansas at eight foodservice sites

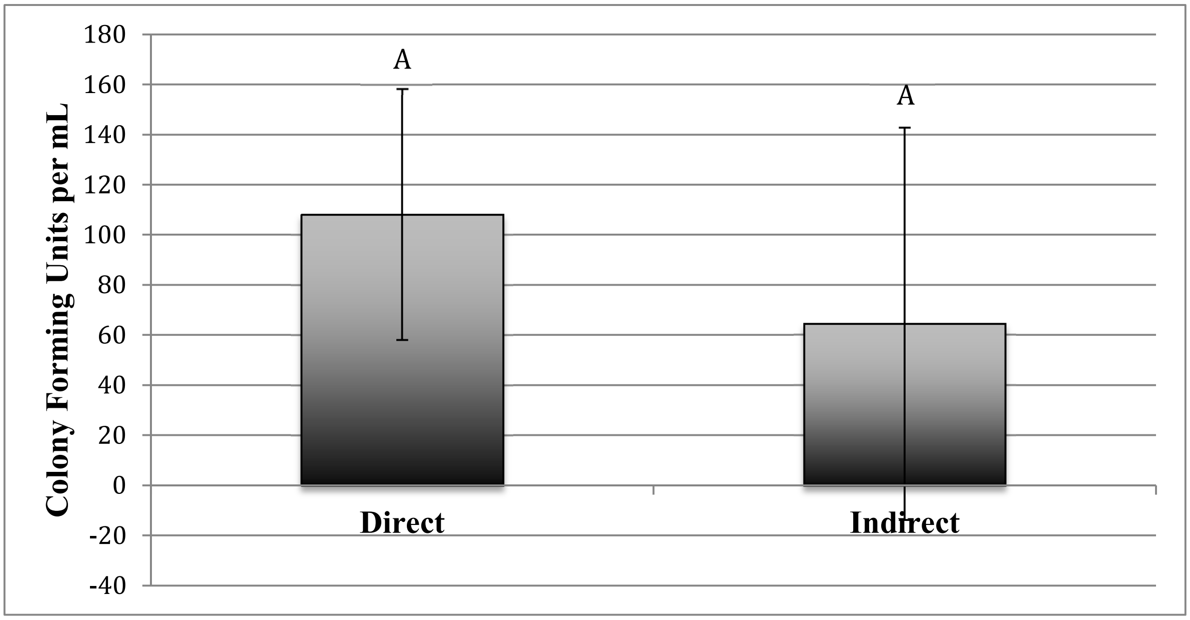

Figure 13. Colony Forming Units of coliform bacteria collected on direct and indirect surfaces in Iowa and Kansas at eight foodservice sites

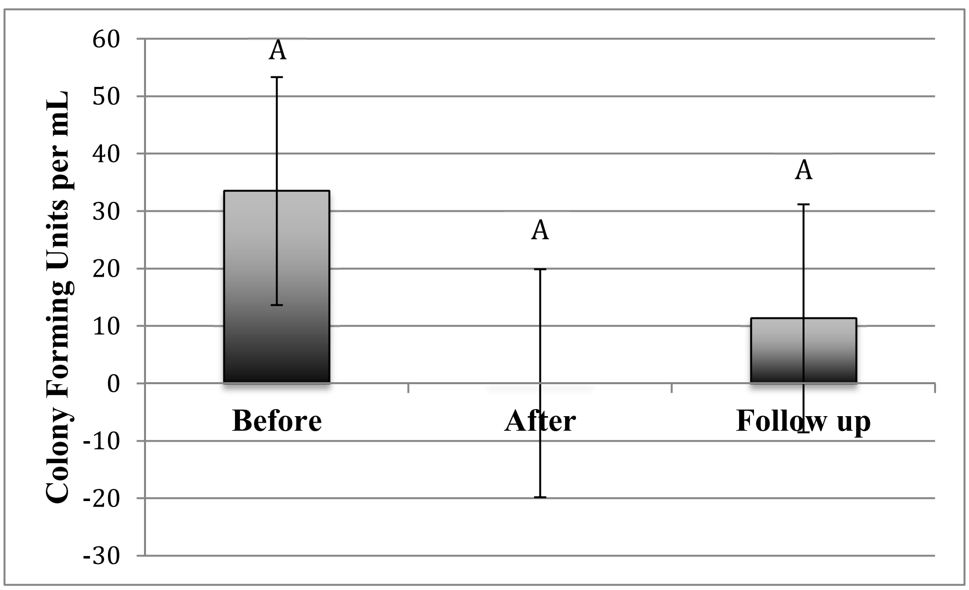

Figure 14. Colony Forming Units of coliform bacteria collected on knife blade surfaces by stage of intervention in Iowa and Kansas at eight foodservice sites

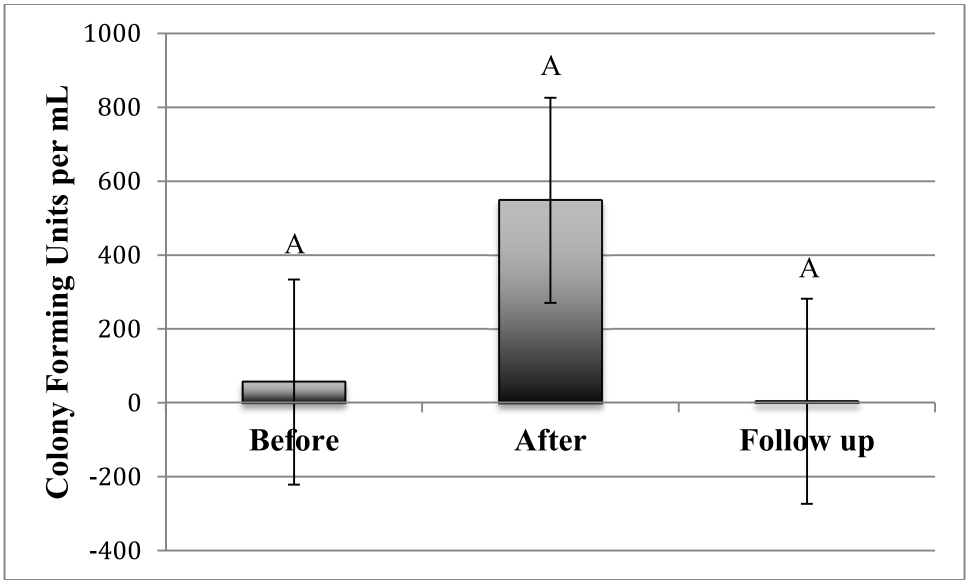

Figure 15. Colony Forming Units of coliform bacteria collected on cutting board surfaces by stage of intervention in Iowa and Kansas at eight foodservice sites

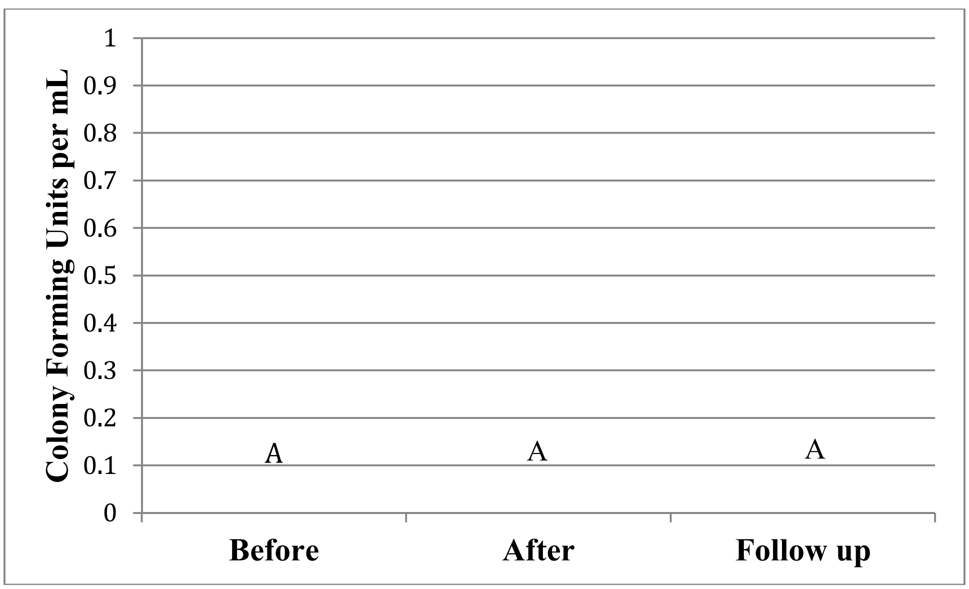

Figure 16. Colony Forming Units of coliform bacteria collected on counter top surfaces by stage of intervention in Iowa and Kansas at eight foodservice sites

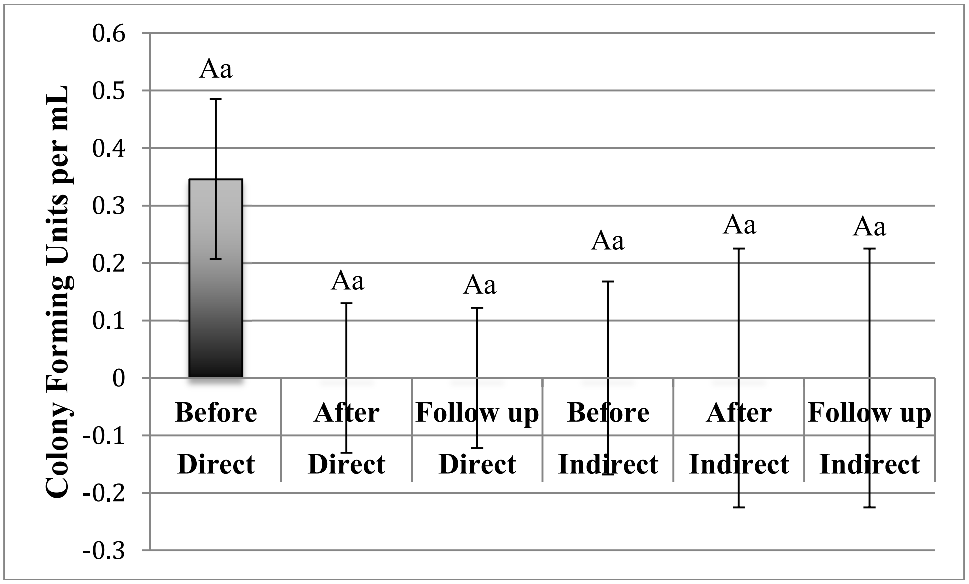

Figure 17. Colony Forming Units of fecal coliform bacteria collected on direct and indirect surfaces by stage of intervention in Iowa and Kansas at eight foodservice sites

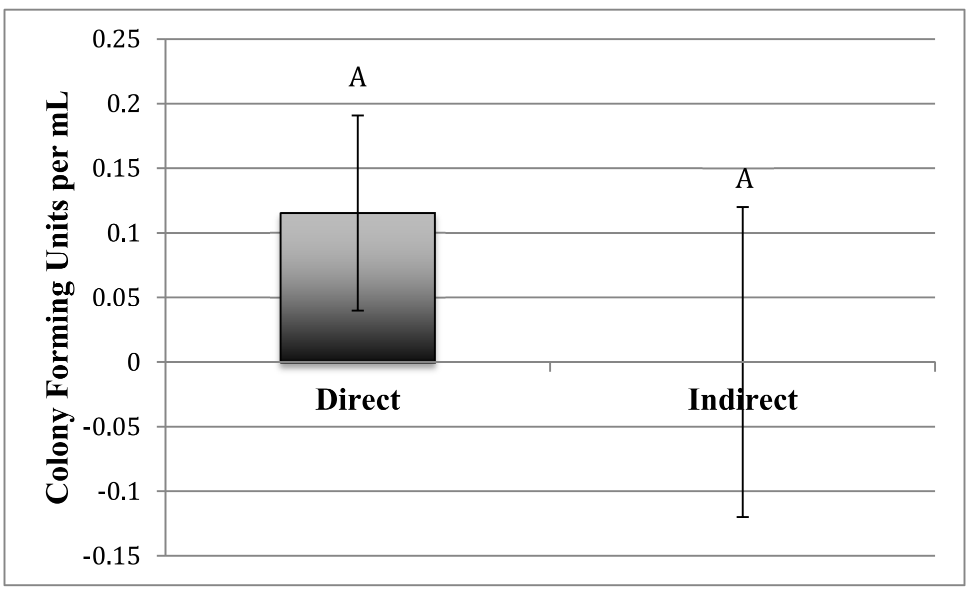

Figure 18. Colony Forming Units of fecal coliform bacteria collected on direct and indirect surfaces in Iowa and Kansas at eight foodservice sites

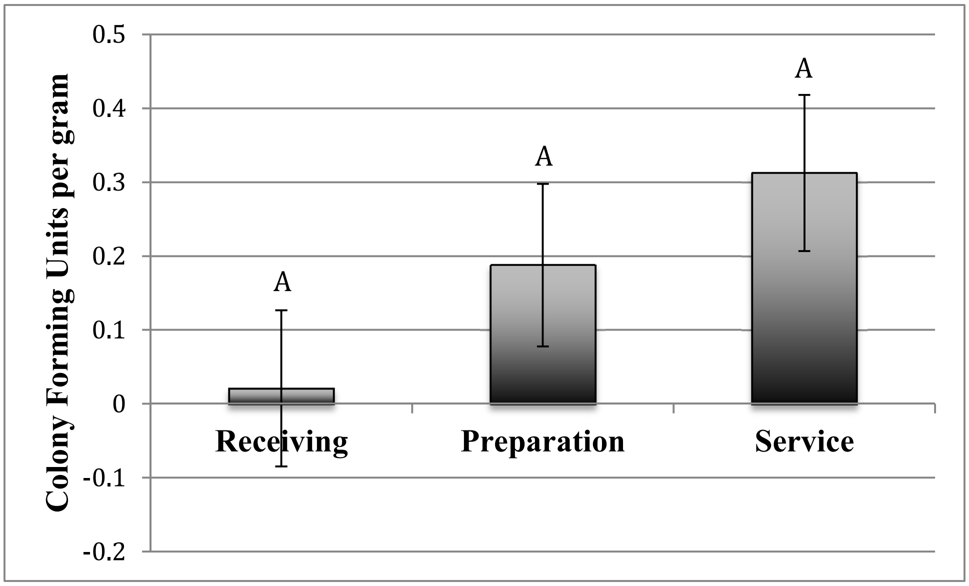

Figure 19. Colony Forming Units of fecal coliform bacteria collected on leafy green samples by stage in the flow of food in Iowa and Kansas at eight foodservice sites

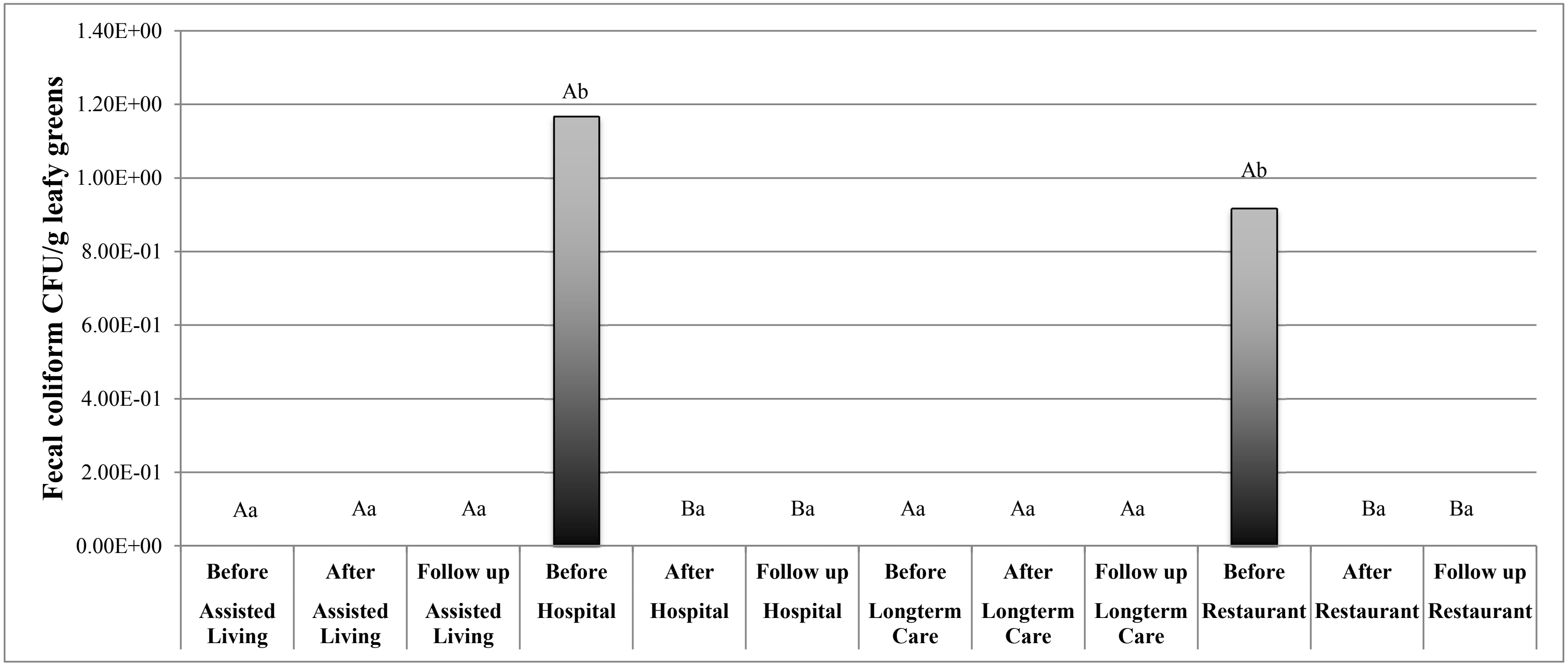

Figure 20. Colony Forming Units of fecal coliform bacteria collected on leafy green samples by foodservice type and stage of intervention in Iowa and Kansas at eight foodservice sites

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CHAPTER 5: GENERAL CONCLUSIONS

Both projects included in this thesis focused on reducing food safety risk for older adults using educational interventions. The intervention in the first project directly targeting older adults resulted in an increase in familiarity, but further research is needed to determine if that will translate into behavior change. The intervention in the second project focused on food service workers had mixed results. More research is needed to determine if the intervention was truly effective. Creating effective tools to bring about behavior change is a major challenge in food safety for the home and in foodservice kitchens. A multi-dimensional approach will likely be the best overall strategy for reducing food safety risk for older adults, and both of these educational interventions may provide one tool to help reach this goal.