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Cross Contamination during Simulated Food Pantry Handling of Apples, Oranges and Potatoes

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Abstract

Food pantries receive, store, distribute and serve food to hundreds of people throughout a community. Safe food handling during all these activities is of paramount importance or food may support growth of pathogens and result in foodborne illnesses after consumption. Year round, and more frequently during holiday seasons, food pantries are seeking food donations to support people in need. Since most food pantries products are donated, the safety of these products from a health perspective can be tricky. The quality of food donations coupled with the way food is handled in these facilities can pose major safety concerns. To determine the potential for transfer of bacteria during handling of food at food pantries, apples, potatoes and oranges were inoculated with a non-pathogenic, fluorescently-labeled strain of *Escherichia coli*, then handled with gloved hands after which another non-inoculated apple, potato or orange was handled. *E. coli* was then enumerated from each piece of food and gloves to determine the transfer rate from the inoculated piece of food to gloves and the non-inoculated food. The average transfer rate from the inoculated food to gloves was 36.4%, from glove to un-inoculated food was 42.4% and from the inoculated food to un-inoculated food was 15.2%. Whether it be from surfaces or hands, cross-contamination of food and surfaces can readily occur and can result in increased likelihood of illness unless proper hygiene is employed. Food pantries can reduce the likelihood of microbial cross-contamination using proper handwashing techniques, and sanitation of surfaces and utensils. Proper hygiene is critical for food pantries to reduce the likelihood of bacterial transfer to previously uncontaminated surfaces.

Keywords: food pantries, bacteria, bacterial transfer, *Escherichia coli*, cross-contamination

1. Introduction

1.1 Food Safety

Food safety is important in emergency food programs such as food pantries, food banks, soup kitchens, shelters, meal programs, and emergency shelters. Emergency food programs handle large quantities of food, and most of the food they handle and distribute is not fresh from the manufacturer or producer. Thus, emergence food program faces a great challenge of safely distributing food to a large wide variety of people, including many of those who are at a higher risk for foodborne illness. Two of the population groups that have the highest rate of food insecurity are also more susceptible to foodborne illness, and that is elderly individuals and young children. In a study conducted in 2020 by Feeding America, the nation's largest domestic hunger-relief organization, out of 76 million persons aged 60 and over, 6.8% were categorized as food insecure, while 2.6% were considered to have very low food security. This translates into 5.2 million and 2.0 million seniors, respectively. In South Carolina, more than half a million individuals are facing hunger, 9.3% of persons over 60 are considered food insecure, and 4.2% are categorized as having very low food security (Zilliak, 2022). Furthermore, in South Carolina, 27% of those individuals who face hunger are children, which equates to one out of eight children in South Carolina that are facing hunger (Hunger in South Carolina). Feeding America serves more than 40 million people annually, and 12 million of those are children (Child hunger in America).

Food distributed through emergency food programs moves through the traditional food supply chain plus many different other points-of-contact including volunteers before it is consumed. According to Feeding America, food is collected, sorted, and distributed to local food pantries, soup kitchens, shelters, and meal programs. Food at pantries can be from direct donations from the public, grocery stores, bakers, food manufacturers and farmers, or if can pass through a food bank from all these sources first before making its way to the food pantry. Once at the final designated emergency food program location, there often is more sorting that is involved from more volunteers. If volunteers do not have proper training on food safety or do not follow proper hand washing, this can increase the risk of foodborne illness. In addition, foodborne illness could result if the product has not been transported or stored properly during any of these transitions. The more points a product moves through before reaching the consumer, the greater the risk of foodborne illness due to unknown safety practices and more points of possible contamination. Due to the number of people served in emergency food programs and the number of volunteer hands the food passes through, food safety is extremely important.

A concern that also arises with food pantries is the large variety of food and the cross contamination that can arise from the mixture of products during collection, storage and transportation. Research has shown that food borne pathogens are often passed from certain raw foods to ready-to-eat foods through improper food safety techniques. A technique that was enforced after being proven to be effective was reported in a study done using clean cutting boards when dealing with raw meat and fresh vegetables (Ravishankar, S, 2010). Being well aware of proper handling and cooking techniques can also make a difference in the likelihood of cross contamination and ultimately an outbreak of foodborne illness.

1.2 Spread of Bacteria

Bacterial cross-contamination can result from factors like moisture, contact time, and pressure. Factors affecting bacterial transfer can be categorized into two groups: 1) environmental (surface properties, biofouling, moisture, pressure, contact time) and 2) intrinsic (bacterial features like exopolysaccharides, biofilm formation, clumping, extracellular structures). Surface roughness influences bacterial attachment, with rough surfaces having lower initial transfer but stronger adhesion (Pérez-Rodríguez et al., 2007). Additionally, the concentration of bacteria on surfaces or in an inoculum affects transfer, with higher inoculum sizes leading to lower transfer rates (Montville and Schaffner, 2003; Dawson et al, 2010).

Bacteria can be found on hands, leading to the risk of cross-contamination, and contaminated hands are a significant source of bacterial transfer in food processing and preparation. Microflora found on hands can be classified into two categories: resident and transient (Price, 1938). The resident microflora is typically naturally occurring on the skin's surface, residing beneath the superficial cells of the stratum corneum (Montes and Wilborn, 1969). While they are not usually considered harmful, they can potentially cause infections in places like the eyes and can persist longer on intact skin compared to gram-negative transient species. On the other hand, transient skin flora includes bacteria, fungi, and viruses that are not part of the normal skin microbiota and may include harmful pathogens. They typically do not reproduce on the skin but can survive and potentially cause diseases. Transient bacteria can easily transfer to food or other surfaces during food handling, and their ability to spread depends on factors such as the specific species, the number of cells on the hand, how long they survive on the skin, the duration of contact, and the moisture content of the skin. Temporary resident microorganisms multiply and stay on the skin for a limited period (Kampf and Kramer, 2004). Practicing good personal hygiene and thorough hand washing can help reduce the transfer of fecal microorganisms from the hand to the mouth, thereby minimizing the spread of potentially harmful transient organisms (Allwood et al., 2004; Daniels et al., 2002; Dawson et al., 2010; Shojaei et al., 2006; Sneed et al., 2004).

Contamination of fresh produce that leads to foodborne illnesses occurs in all steps of growing and processing including harvesting, transporting, washing and further processing, distribution and handling at retail, food service establishments and kitchens. Food-contact surfaces host diverse bacterial communities that can differ between location and surface types.

The most diverse bacterial communities in the kitchen were found on infrequently cleaned surfaces such as fans above stoves, refrigerator/freezer door seals, and floors. On the other hand, sinks had the least diverse communities dominated by biofilm-forming gram-negative lineages (Flores et al., 2013).

Cross contamination by microbial pathogens in the kitchen environment plays an important role in sporadic and epidemic food borne illnesses. Hands are potentially a critical control point for reducing or preventing bacterial cross contamination from ill and asymptomatic food workers who might shed high levels of pathogens particularly those originating from the nasal cavity. In some cases, the disease-causing microorganisms can remain with the person after recovery. Fingers can transfer bacteria through touching equipment, contaminated food, clothing, or other areas of the body. Fingernails, jewelry, nose, eyes, ears can also lead to bacterial transfer since these can be reservoirs for pathogens. It is important to take the utmost precautions when preparing and serving food because of the high probability of contamination during those activities. Infections of certain microorganisms can lead to illness, hospitalizations, and death which is why it is extremely important to uphold proper hygiene and sanitizing techniques when handling food.

E. coli is a gram negative, diverse species of bacteria commonly found in the human intestines and environment. It is considered the most abundant facultative anaerobe of human intestinal microflora (Ejrnæs, 2011). Illness caused by this pathogen has cost the healthcare system a significant amount (Lim, 2010). When someone becomes ill from E. coli, for example E. coli O157:H7, it is easily spread to other surfaces and people through improper hygiene. Therefore, it is important that this pathogen is detected and treated properly and efficiently to prevent illness and harm. This experiment helps observe the content and spread of E. coli from gloves and bare hands through food including apples, oranges, and potatoes.

1.3 Research Objective

The purpose of this research was to evaluate three transfers of generic *E. coli* from humans to food or contaminated food to other non-contaminated food using items and procedures commonly used in food pantries. Through testing for bacteria on food pantry items, safety can be ensured, as safety is a number one priority in food pantries due to the volume of people they see and serve. This research was done to measure the level of transmission of *E. coli* from produce to the glove or hand and then to another piece of produce. The impact of hand or glove transfer on the survival of *E. coli* on apples, oranges, or potatoes was to be analyzed by using TSA agar in a laboratory setting.

2. Methods

2.1 Inoculation and Recovery

A non-pathogenic, ampicillin-resistant strain of *Escherichia coli* JM109 with a gene displaying a green-fluorescent color under UV light was used as the test organism for this study. Apples, oranges, and potatoes were purchased weekly to be used in weekly replications of testing. Each subject tested one type of food each week by inoculating the surface of one food item with 0.2 ml of a ~6 log cfu/ml *E. coli* inoculum. After 5 min, the inoculated food was picked up with a gloved hand or bare hand and held for 5-10 s. Then, the food was placed in the sterile plastic bag with 40 ml of 0.1% peptone water (sample 1). Without touching anything else, the same gloved hand or bare hand was used to pick up a non-inoculated food item of the same type (for example inoculated apple followed by non-inoculated apple). This non-inoculated item was held for 5-10 s and then it was placed into another sterile bag containing 40 ml of 0.1% peptone water (sample 2). Recovery of bacteria remaining on the glove or hand was determined by placing the hand with the glove or bare hand in the third bag containing 20 ml of 0.1% peptone water (sample 3). Individuals were asked to swirl their hands in the peptone for 1 min. Bacteria were enumerated using serial dilutions and standard plate count methodology.

2.2 Enumeration of Bacteria

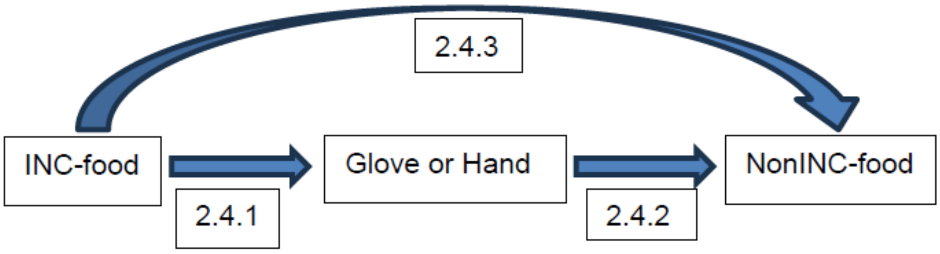
Bacteria were enumerated by making serial dilutions and plating samples of 0.1 ml on TSA containing 0.5% ampicillin (DIFCO™ tryptic soy agar, Becton Dickinson and company Sparks, MD, USA) followed by incubating at 37 ℃ for 24 hours. Colony forming units (CFU) were counted under UV light on plates containing 25-250 colonies and converted to CFU per sample and $\log_{10}$ of CFU per sample.

2.3 Research Design and Statistical Analysis

The experiment was replicated 3 times on separate days by 12 subjects yielding 36 observations for each food type per treatment (gloved hand or bare hand) and a total of 216 observations. The effect of bare hands vs gloved hands for each food type on the percentage of and log CFU of bacteria transferred from; inoculated food to gloves/hands, gloves/hands to non-inoculated food and inoculated food to non-inoculated food was determined using the proc univariate command of PCSAS (2022) to obtain mean, median, range and standard deviation. The student’s t-test was also performed, and different commands were used to determine if significant differences existed between the use of gloves or bare hands and food type.

2.4 The Percentage of Bacteria Transfer

The percentage of bacteria transferred was calculated using the following methods.



2.4.1 Percent Transfer from Inoculated Food (INC-food) to Gloves (G) or Hands (H)

$$= \frac{(\text{NonINC}-\text{food})+(\text{Bacteria recovered from G or H})}{(\text{INC}-\text{food})+(\text{nonINC}-\text{food})+(\text{Bacteria recovered from G or H})} X100$$

2.4.2 Percent Transfer from Gloves (G) or Hands (H) to Non-inoculated Food (nonINC-food)

$$= \frac{(\text{nonINC}-\text{food})}{(\text{nonINC}-\text{food})+(\text{Bacteria recovered from G or H})} X100$$

2.4.3 Percent Transfer from Inoculated Food (INC-food) to Non-inoculated Food (nonINC-food)

$$= \frac{(\text{nonINC}-\text{food})}{(\text{INC}-\text{food})+(\text{nonINC}-\text{food})+(\text{Bacteria recovered from G or H})} X100$$

3. Results and Discussion

Previous studies investigated the bacterial populations in various indoor settings, including public restrooms (Flores et al., 2011), hospitals (Kembel et al., 2012), office buildings (Hewitt et al., 2012), kitchens (Flores et al., 2013), and fitness centers (Mukherjee et al., 2014). Human skin was identified as the primary source of bacteria in all these places, whereas other sources like soil and outdoor air have proven to be far less influential.

Mukherjee et al., (2014) investigated the bacterial diversity found on surfaces in public fitness centers in a metropolitan area of the United States. Samples were collected from skin-contact surfaces such as exercise equipment, toilet handles, and handrails and were analyzed to identify the bacterial taxa present. The results indicated the presence of 17 bacterial families and 25 bacterial genera, with *Firmicutes*, *Proteobacteria*, and *Actinobacteria* being the dominant phyla. Most bacterial genera originated from humans and the environment, including air, dust, soil, and water. The most abundant bacterial families on these surfaces were *Bacillaceae*, *Staphylococcaceae*, *Enterobacteriaceae*, *Aerococcaceae*, and *Microbacteriaceae*.

The study also detected the presence of some pathogenic or potentially pathogenic bacterial genera, including *Salmonella*, *Staphylococcus*, *Klebsiella*, and *Micrococcus*. Specifically, *Staphylococcus* was found to be the most prevalent genus. Some of the identified *Staphylococcus* species in the fitness centers were *S. saprophyticus*, *S. epidermidis*, and *S. aureus* (Mukherjee et al., 2014). *Staphylococcus saprophyticus* is commonly found in the human urogenital and gastrointestinal tract, as well as in food products such as cheese, meat, and vegetables and the environment. *S. epidermidis* is a common inhabitant of human skin (Huebner and Goldmann, 1999) and is known to produce biofilms, which protect it from antibiotics and host immune defenses (Raad et al., 1998; Vuong and Otto, 2002). *S. aureus*, including methicillin-resistant *Staphylococcus aureus*, is known to transmit from person to person through skin contact or touching contaminated surfaces (Eady and Cove, 2003; Mukherjee et al., 2014). Furthermore, methicillin-resistant *S. aureus* can survive on inanimate surfaces for an extended period, further increasing the risk of transmission (Desai et al., 2011; Sanford et al., 1994).

Flores et al., (2013) determined the bacterial communities in over 80 surfaces within the kitchens of four households. The results showed that 34 bacterial and two archaeal phyla were identified in residential kitchens, with most sequences belonging to the *Actinobacteria*, *Bacteriodetes*, *Firmicutes*, and *Proteobacteria*. While potential food-borne pathogens were low in abundance, they were broadly distributed throughout the kitchens. this part is already added in the introduction part if you want to remove from here. Human skin was identified as the primary source of bacteria on kitchen surfaces, with contributions raw food and faucet water in certain locations.

Additionally, certain research has outlined how environmental surfaces play a part in the spread of bacteria. To illustrate, surfaces found in public spaces, such as computer, phones, telephone receivers, headsets, desks, automated teller machines (ATMs), cash machines, and elevator buttons, have all been identified as potential sources for transmitting disease-causing microorganisms (Brooke et al., 2009; Bures et al., 2000; Reynolds et al., 2005; Zhang et al., 2012).

Ekanem et al., (1983) found that contamination of hands, shared toys, and other items in classrooms appeared to contribute to the spread of enteropathogens during diarrhea outbreaks in daycare centers. Over a nine-month period from December 1980 to August 1981, they tested hands and objects in five Houston daycare centers monthly and during outbreaks of diarrhea.

They discovered that fecal coliforms were present on hands (17%) and classroom objects (13%) during routine testing. However, during diarrhea outbreaks, these coliforms were more commonly found on hands (32%) and objects (36%) than during non-outbreak periods, indicating a significant association.

The present research determined the extent of *E. coli* transfer from produce to either a glove or hand and subsequently to another piece of produce. Results show that that contamination from apples, oranges and potatoes can not only be transferred to gloved or bare hands, but can be passed to a second, previously non-contaminated food item (Table 1). The recovery of E. coli from apples, oranges, and potatoes immediately after inoculation ranged from 6 to 6.6 log cfu/item (Table 1). Recover and transfer to hands or other previously non-inoculated items followed the same pattern for apples and oranges. However, potatoes had significantly fewer cells recovered from gloved hands (13% transfer of original 6.4 log/item to hands at 5.5 log/hand level) and food samples touched by gloved hands compared to apples and oranges (Table 1). The rate of transfer was also similar for the apples and oranges with a decreasing rate of transfer from the inoculated food to gloved hand, gloved hand to non-inoculated food and then the overall transfer from the inoculated food to the non-inoculated food. Potatoes differed in the transfer rate having the highest rate of transfer from the gloved hand to the non-inoculated food (Table 2). When a contaminated gloved hand was used to pick up a previously non-contaminated apple or orange, approximately 70% of the original level of contamination was transferred to the item compared to an approximate 50% transfer rate with a bare hand. (Gloved hand with apple or orange= 700,000/1 million x 100 = 70%

Bare hand Apple transfer is 1 million/2million x 100 = 50%).

This is likely due to the rough surfaces on the bare hand and bacteria remaining in crevices versus transfer from a smooth gloved surface.

Apples and oranges had similar rates of inoculated produce to gloved hands, inoculated produce to non-inoculated produce from gloved hands, and increased food to hand (Figure 1). While potatoes had a significantly lower transferring rate from inoculated produce to gloved hands and inoculated food to hand, compared to apples and oranges (Figure 1). On the other hand, potatoes had a slightly higher percentage of bacteria transferred from gloved hands picking up inoculated produce to non-inoculated produce and hand to non-inoculated food (Figure 1). These results could be to the texture of the skin of each kind of produce allowing for different rates of transfer. Thus, the rate of transfer for all produce is not the same, but all produce is affected, therefore all produce should be handled with the same precautions. A single source of contamination from a glove or hand can lead to subsequent contamination of multiple sources as seen in this experiment. Around 76 million Americans contract a foodborne illness every year according to the Centers for Disease and Control Prevention (CDC). Therefore, it is important for food pantries to practice safe processing and handling to avoid contamination to a large population. Research shows that Americans are aware of proper food handling but need more education on how to achieve and maintain food safety practices. This can go as far as washing hands before consuming or serving produce as well as washing all produce with at least tap water. These two simple steps can largely reduce the number of possible bacteria present on produce. It is necessary to control the spread of contamination through washing hands, disinfection of surfaces, washing food with tap water, and storing food properly sealed or in the refrigerator. In all to help reduce the spread of any plausible pathogenic bacteria.

Table 1. The log of colony forming units per sample recovered from inoculated produce (apple, orange or potato), gloved hands after picking up inoculated produce and produce picked up by gloved hands after picking up inoculated produce samples

	Glove or hand	INC-Apple	G/hand Apple	Apple -2	INC-Orange	G/hand Orange	Orange-2	INC-Potato	G/hand Potato	Potato-2
Log cfu	glove	$6.0^{3b,c}$ (0.08)[1]	$6.0^{b,c}$ (0.09)	$5.8^{b,c}$ (0.09)	6.4^{a} (0.09)	$6.0^{b,c}$ (0.09)	5.8^{c} (0.09)	6.4^{a} (0.09)	5.5^{c} (0.09)	5.5^{c} (0.09)
Log cfu	hand	6.5^{a} (0.09)	$6.3^{a,b}$ (0.09)	6.0^{b} (0.09)	6.5^{a} (0.09)	$6.2^{a,b}$ (0.09)	$6.0^{b,c}$ (0.09)	6.6^{a} (0.09)	$6.0^{b,c}$ (0.09)	$6.0^{b,c}$ (0.09)

a,b,c Means with different letters are significantly different. ($P \leq 0.05$).

INC-apple = inoculated apple, G/hand-Apple = Glove or hand used to pick up inoculated apple, Apple-2 = Apple picked up with the Gloved hand after picking up inoculated apple, INC-Orange = Inoculated orange, G/hand Orange = Glove or hand used to pick up inoculated orange, Orange-2 = Orange picked up with the Gloved hand after picking up inoculated orange, INC-Potato = inoculated potato, G/hand-Potato = Glove or hand used to pick up inoculated potato, Potato-2 = Potato picked up with the Gloved hand after picking up inoculated potato.

[1]The standard error of the mean is in parentheses.

Table 2. Percentage of bacteria transferred from inoculated produce to gloved hands or bare hands (INC food to glove/hand), from gloved hands or bare hands to non-inoculated produce (glove/hand to non-INC food) and from inoculated produce to non-inoculated produce via gloved hands or bare hands (INC food to non-INC food by glove/hand)

treatment	% transfer	Standard Error
INC food to glove	36.4b	1.7
INC food to hand	43.3a	1.7
Glove to non-INC food	42.4a	1.8
Hand to non-INC food	43.8a	1.7
INC food to non-INC food by glove	15.2c	1.6
INC food to non-INC food by hand	17.7c	1.7

a,b,c Means with different letters are significantly different. (P≤0.05).

INC food to glove = inoculated produce to gloved hands, INC food to hand = inoculated food to bare hands, Glove to non-INC food = gloved hands picking up inoculated produce to non-inoculated produce, Hand to non-INC food = bare hands picking up inoculated produce to non-inoculated produce, INC food to non-INC food by glove = inoculated produce to non-inoculated produce via gloved hands, INC food to non-INC food by hand = inoculated produce to non-inoculated produce via bare hands.

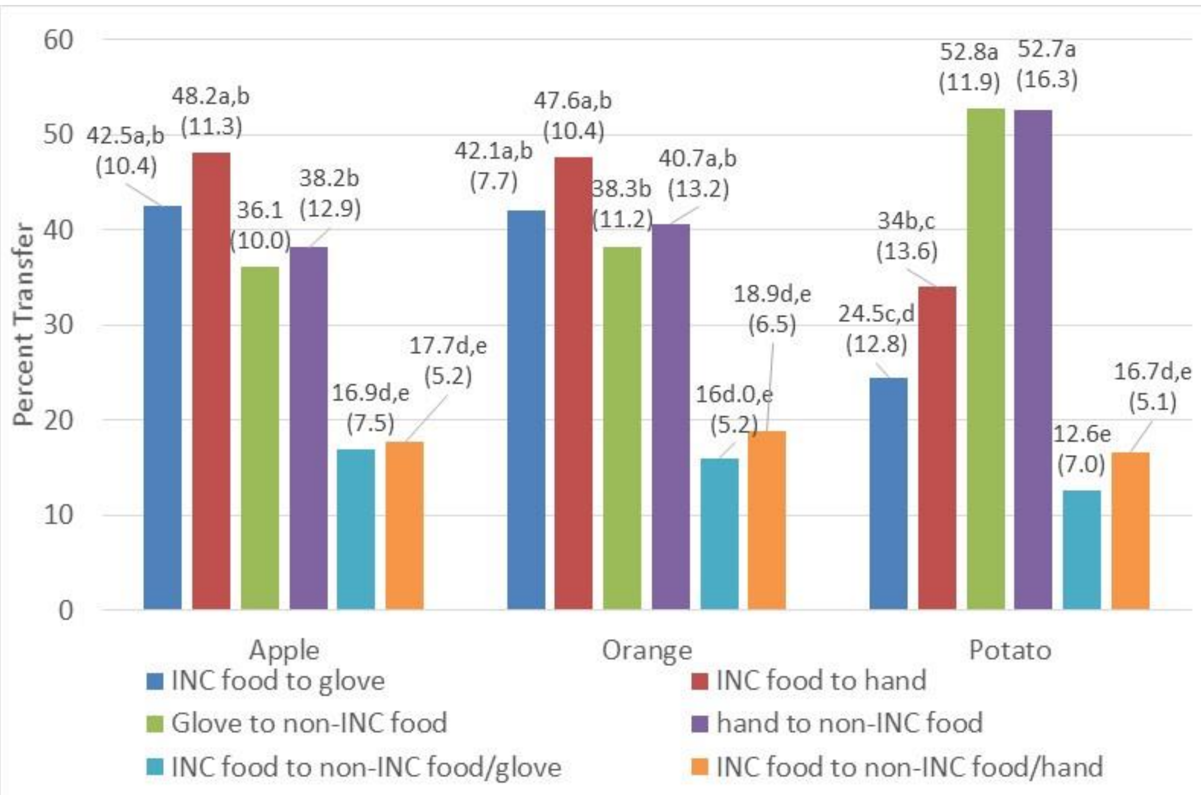


Figure 1. Percentage of bacteria transferred from different types of inoculated produce (apple, orange, or potato) using bare or gloved hands

a,b,c,d,e Means with different letters are significantly different. (P≤0.05). Standard deviation is shown beneath each mean in parentheses.

INC food to glove = inoculated produce to gloved hands, INC food to hand = inoculated produce to bare hands, Glove to non-INC food = gloved hands picking up inoculated produce to non-inoculated produce, Hand to non-INC food = bare hands picking up inoculated produce to non-inoculated produce, glove INC food to non-INC food = inoculated produce to non-inoculated produce via gloved hands, hand INC food to non-INC food = inoculated produce to non-inoculated produce via bare hands.

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Authors contributions

Dr. Dawson, Dr. Buyukyavuz, and Dr. Northcutt were responsible for study design and revising. Dr. Buyukyavuz directed data collection. Dr. Dawson drafted the manuscript and Dr. Northcutt revised it. Authors Burton, Dawsey, Day, Hendershot, Johnson, Kania, Leahy, Manning, Pascarella, Stopka, Strickland, and Thomas were responsible for data collection. All authors read and approved the final manuscript

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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