A MICROBIOLOGICAL COMPARISON OF POULTRY PRODUCTS OBTAINED FROM FARMERS’ MARKETS AND SUPERMARKETS IN PENNSYLVANIA

A Thesis in
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by
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Abstract

The popularity of farmers’ markets in the United States (U. S.) continues to rise, with an increase from 1,755 in 1994 to 7,175 in 2011. Although farmers’ markets represent a minimal portion of the agricultural market, farmers’ markets have become a significant source of food products for many Americans. Potentially hazardous foods, such as milk, meat, and poultry are popular items sold at farmers’ markets and require specific processing and handling to ensure the safety of the product. Meat and poultry items make up a large portion of potentially hazardous foods sold at farmers’ markets, but only meat products (beef, lamb, pork) are required by federal law to be processed in a USDA-inspected facility. Poultry however, can be grown and processed by individual farmers under exemption status afforded to farmers by the Poultry Products Inspection Act (PPIA). Currently, little to no data have demonstrated the microbiological profile of poultry (chicken or turkey) sold at farmers’ markets and/or compared the findings to conventionally-processed, organic and non-organic poultry sold in supermarkets. Additionally, no study has explored the processing practices, as well as the knowledge and attitudes of poultry vendors in food safety, poultry processing, and regulatory requirements. The purpose of this study was to determine the presence/absence of foodborne pathogens, as well as hygiene indicators, in fresh or frozen whole chicken purchased at farmers’ market and conventionally-processed, organic and non-organic chicken sold in supermarkets. A needs assessment was conducted to evaluate general practices and food safety knowledge and attitudes of poultry vendors at farmers’ markets throughout Pennsylvania.

Whole chicken carcasses from farmers’ markets and supermarkets throughout Pennsylvania were obtained and transported back to the Penn State Muscle Foods Laboratory at 4°C until further analysis. Each chicken carcass was rinsed and levels of aerobic plate counts
(APC), generic *E. coli*, and total coliforms were measured. Resulting rinses also were evaluated for presence/absence of *Campylobacter* spp. and *Salmonella* spp. following standard culture and confirmation methods. Results demonstrated that 28% (28/100) and 90% (90/100) of whole chicken from farmers’ markets, 20% (10/50) and 28% (14/50) of conventionally-processed organic, and 8.0% (4/50) and 52% (26/50) of non-organic chicken, were positive for *Salmonella* spp. and *Campylobacter* spp. respectively. Additionally, among the 90% of *Campylobacter* spp. positive farmers’ market whole chicken, 67% of rinses were enumerable, with a mean count of $1.6 \log_{10}$ CFU/ml.

The needs assessment survey consisted of a 32-question, paper-based survey that was administered to poultry vendors at their respective farmers’ markets during market hours. The needs assessment consisted of four sections which assessed the processing methods, knowledge, attitudes, and demographics of poultry vendors at farmers’ markets in the areas of poultry processing, food safety, and regulation. The results highlighted that 52% (11/21) of vendors slaughtered and processed their own poultry, while 48% (10/21) had their poultry processed at a separate farm or facility. Among those vendors who knew of their processing conditions, 33% (7/21) processed their poultry outside, 38% (8/21) processed their poultry inside a fixed or dedicated processing area, while the remainder either used a combination of both, or did not know. The majority of vendors appeared to have a good understanding of correct temperature control of poultry during processing. However, more than 50% (11/21) incorrectly answered questions related to pathogens and cross-contamination during processing. Additionally, the attitudinal section revealed that 100% (21/21) of vendors agreed that their poultry was safe and 95% (20/21) of vendors believed their poultry products to be safer than poultry sold in retail supermarkets. 70% (14/20) of vendors recognized that antimicrobial sprays and washes can
reduce pathogens on poultry. Interestingly, 25% (5/20) agreed that additional food safety interventions were needed and 33% (7/21) utilized an antimicrobial spray or wash on their poultry before packaging.

These data suggest that whole chicken purchased from farmers’ markets in Pennsylvania were more likely to be contaminated with *Salmonella* spp. and *Campylobacter* spp., as compared to conventionally-processed poultry sold at supermarkets. The results revealed critical vendor practices and identified important vendor knowledge gaps and attitudes on food safety and poultry processing, while also highlighting the need for training and educational materials for poultry vendors. The data obtained from the vendor needs assessment surveys will aid in the development of future farmers’ market research, as well as generating recommendations, guidelines, fact sheets, and outreach material on food safety issues for vendors selling meat and poultry products at farmers’ markets.
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Chapter 1
Literature Review
Salmonella spp.

Historical information

Salmonella was first discovered in 1885 by Daniel Elmer Salmon and Theobald Smith while studying pigs infected with a disease known as hog cholera (Brands, 2005). Scientists originally named the causative agent hog-cholerabacillus. In the early 1900s, the bacterium was renamed after its discoverer, Salmon, to Salmonella cholera-suis (Brands, 2005). Over the last century, numerous other identified bacteria have been reclassified as Salmonella. Currently, the Salmonella group contains over 2500 subtypes (Brands, 2005). Salmonella infections are widespread throughout the United States (U. S.) and have been known to be influenced by numerous factors, including: human demographics, lifestyles, human behavior, food processing technology, changes in travel and commerce, microbial adaptation, public health, and the lack of consumer knowledge on food safety (Foley et al., 2007). Historically, foodborne illness outbreaks caused by Salmonella spp. have been traced to various foods, including, fresh produce, eggs, milk, seafood, and various meats, although poultry products typically remain the primary source of the pathogen.

Foodborne pathogens continue to be a major cause of disease in the U. S. with over 9.4 million illnesses, 55,961 hospitalizations, and 1,351 deaths reported in 2010 (Scallan et al., 2011). Among the 3.6 million illnesses caused by bacteria, non-typhoidal Salmonella have continued to be the leading cause of bacterial foodborne illness, responsible for an estimated 1 million or 11% of all foodborne illnesses occurring in the U. S. in 2010 (Scallan et al., 2011). Salmonella spp. also were responsible for 29 deaths in 2010, comprising 42% of the total deaths caused by laboratory-confirmed bacterial and parasitic infections (Anonymous, 2011b).
During the past two decades, foodborne illness outbreak detection and reporting has become more sophisticated. Programs, such as the Foodborne Diseases Active Surveillance Network (Food Net) conducted by the Centers for Disease Control and Prevention (CDC) and The National Salmonella Surveillance System, have provided medical and scientific professionals with up-to-date statistics, surveillance, and cluster data on laboratory-confirmed *Salmonella* infections. Since the 1970s, the incidence of disease-causing *Salmonella* serotypes has fluctuated, with a dramatic increase in infections during the early 1980s. In fact, the number of *Salmonella* infections reported in 2010 were not significantly different from those reported during 1996-1998, but higher than those reported from 2006-2008 (Anonymous, 2011b).

Although it has been over a 100 years since the discovery of *Salmonella*, human and animal infections caused by the bacterium continue to be a major public health issue, both domestically and globally.

**Characteristics of *Salmonella* spp.**

The genus *Salmonella* is comprised of over 2500 serovars which consists of two main species: *Salmonella bongori* and *Salmonella enterica*. *Salmonella enterica* is further divided into 6 subspecies: S. *enterica* subsp. *enterica*, *salamae*, *arizonae*, *diarizonae*, *indica*, *houtenae*, or commonly labeled as I, II, IIIa, IIIb, IV, and VI (Brenner et al., 2000). *Salmonella* are Gram-negative, straight rods, typically measuring 0.7-1.5 x 2-5 μm and capable of producing colonies of approximately 2-4 mm in diameter on agar plates (Holt et al., 1994). Salmonellae are facultative anaerobes, as well as chemoorganotrophs, having the ability to utilize both fermentative and respiratory metabolisms (Holt et al., 1994). Most salmonellae also are considered aerogenic, producing hydrogen sulfide under certain metabolic growth conditions (Holt et al., 1994). Optimal growth temperatures for the majority of Salmonellae are 37°C.
However, several studies have demonstrated an increased recovery of *Salmonella* at incubation temperatures of 43°C (Andrews et al., 2001). Salmonellae found in food products generally require a pH between 6.6 and 8.2, but can grow in pH conditions as low as 4.05 (Jay, 2000). Salmonellae growth in foods also becomes inhibited when water activity (a_w) values are ≤ 0.94 (Andrews et al., 2001). *Salmonella* are similar to other Gram-negative bacteria in the *Enterobacteriaceae* family, since they are non-spore forming and motile, although non-motile mutants have developed under certain conditions (Andrews et al., 2001). Historically, *Salmonella* have been classified based on metabolic characteristics and subdivided into five subgenera, (I-V) (Le Minor, 1984). Although this classification system is useful in certain applications, utilizing metabolic characteristics like the *inability of Salmonella* to ferment lactose, can be misleading, since class III *Salmonella* have demonstrated variable abilities to ferment lactose and other fermentable sugars (Andrews et al., 2001). Due to the variability among and within subgenera, most modern microbiological analyses utilizes the Kauffman-White scheme, which separates salmonellae are separated into serovars and subtypes, based on surface antigens (Bell and Kyriadkides, 2002).

*Salmonella* confirmation and serotyping

*Salmonella* confirmation and serotyping methods have continued to progress and change throughout the last century. Traditionally, biochemical identification of *Salmonella* is performed in conjunction with serological confirmation (Andrews et al., 2001). Serological identification of *Salmonella* isolates involve the use of *Salmonella*-specific antibodies and their associated surface antigens, resulting in an agglutination reaction that can be observed through various laboratory techniques. *Salmonella* classification is based on the unique combination of three major groups of surface antigens (O, H, Vi). These include: somatic antigens (O) from the
lipopolysaccharide (LPS) found on the surface of the outer membrane; flagellar antigens (H) on the peritrichous flagella; and capsular antigens (Vi), found only in those *Salmonella* spp. containing a capsule (Doyle and Beuchat, 2007).

The methodology for *Salmonella* subtyping can vary between laboratories. However, both the CDC and the United Kingdom National Standard Methods begin with traditional culture methods and biochemical confirmation tests using a stepwise decision tree procedure to identify subspecies biochemically (CDC, 2008; NSM, 2007). Various selective media, such Xylose Lysiene Deoxycholate (XLD), Cysteine Lactose Electrolyte Deficient Agar (CLED), Deoxycholate Citrate Agar (DCA), and Blood Agar, are used to isolate presumptive-positive colonies of *Salmonella* (NSM, 2007). Subsequently, presumptive-positive colonies are tested using the oxidase test, agglutination test with polyvalent O and Vi antiserum, and/or urease test (NSM, 2007). Depending on the results from each of these tests, *Salmonella* isolates are further analyzed using single factor and polyvalent O and H antisera (NSM, 2007). This process is complex, labor-intensive, and typically requires the skills of an experienced laboratory technician to complete and analyze (Doyle and Beuchat, 2007).

Due to the complexity and labor-intensive process of *Salmonella* subtyping, many microbiological laboratories utilize commercially-available *Salmonella* detection kits that rely on various technologies and exhibit wide ranges of sensitivity. The most common of these detection methods include API 20E, VITEK (bioMérieux, Marcy l’Etoile, France), and Micro-ID (Remel, Lenexa, KS) which apply the combination of numerous biochemical tests to produce a rapid *Salmonella* identification assay (Bell and Kyriakides, 2002). Other systems employ antibody and antigen reactions like latex agglutination kits or immunomagnetic separation. Yet, biochemical- and antibody-based identification kits still require the isolation of presumptive
Salmonella isolates. Other commercially available methods utilize technologies such as electrical conductance, a chemiluminescent immunoassay, immune-chromatography, immunoprecipitation, enzyme-linked immunosorbent assay (ELISA), nucleic acid hybridization probes, or polymerase chain reactions (PCR) (Bell and Kyriakides, 2002).

In the last decade, PCR assays and technologies have been used in combination with traditional Salmonella identification methods (Doyle and Beuchat, 2007). Although PCR is rapidly gaining acceptance and popularity, it is unlikely that it will replace culture-based methods for Salmonella detection (Doyle and Beuchat, 2007). Currently, PCR assays have been developed to detect the invA gene, which is unique to the genus Salmonella (Salyers and Whitt, 2002). Many other PCR approaches employ serovar-specific genes or combinations of genes, in the case of multi-locus sequence typing (MLST), pulsed field gel electrophoresis (PFGE), and multiple-locus variable-number tandem-repeats analysis (MLVA) (Bell and Kyriakides, 2002). Although these methods are highly specific and rapid methods for surveillance and outbreak strain tracking, they are limited to specific serovars and cannot differentiate between DNA originating from vegetative or dead bacterial cells. The selection of Salmonella detection, confirmation, and serotyping methods will depend greatly on the need for speed, specificity, and laboratory skills. Although numerous technologies exist to serotype Salmonella, traditional biochemical and serological methods continue to be the proven and trusted methods used by microbiological laboratories.

Detection of Salmonella spp. in food

There are numerous methods used for the isolation of Salmonella from foods. The microbiological media and sampling schemes selected can depend on the food, resources and needs of the agency or laboratory performing the isolation. Currently, federal agencies like the
Food and Drug Administration (FDA) and United States Department of Agriculture, Food Safety and Inspection Service (USDA-FSIS) follow *Salmonella* isolation schemes using standard methodologies and referenced in FDA Bacteriological Analytical Manual (BAM) (CDC, 2012) and the USDA-FSIS Microbiological Laboratory Guidebook (MLG) (USDA-FSIS, 2012), respectively. Both references are based on current research as well as the Association of Analytical Communities (AOAC) approved methods and those validated in the Compendium of Methods for the Microbiological Examination of Foods (Downes and Ito, 2001). Although different *Salmonella* isolation schemes exist, the methods utilize similar microbiological media, biochemical tests, and confirmation methods, as well as pre-enrichment, selective enrichment, selective plating, and confirmation steps.

*Salmonella* found in foods are often present in low numbers and in an injured state (Andrews et al., 2001). Therefore, a pre-enrichment step utilizing incubation temperatures between 35-37°C is typically performed during the isolation of *Salmonella* from foods to recover and promote the growth of injured cells (Andrews et al., 2001; Wray and Wray, 2000). Lactose broth is commonly used in the pre-enrichment step for *Salmonella* isolation from foods, even though the majority of *Salmonella* spp. do not ferment lactose. Previous studies have concluded that replacing lactose with sugars fermented by *Salmonella* does not increase the efficacy of Lactose Broth (Andrews et al., 2001). Other pre-enrichment media used by the FDA and USDA-FSIS include Tryptic Soy Broth (TSB) and Buffered Peptone Water (BPW), usually utilized in combination as a buffer and pre-enrichment broth (USDA-FSIS, 2012; CDC, 2012). Following pre-enrichment, samples are transferred to selective enrichment broths that contain nutrients and antimicrobials that favor the growth of *Salmonella* while retarding the growth of non-*Salmonella* organisms present in the sample (Andrews et al., 2001). Historically, Tetrathionate Brilliant
Green (TBG) and Selenite Cystine (SC) broths have been used as selective enrichments for Salmonella isolation. Although effective in the recovery of Salmonella, during incubation of SC, the reduction of sodium acid selenite can lead to the production of selenium, which is considered toxic to humans (Andrews et al., 2001). As such, the regulatory agencies now recommend Rappaport-Vassiliadis broth (RV) for enrichment of Salmonella (CDC, 2012; USDA-FSIS, 2012; Andrews et al., 2001). Additionally, the incubation temperature used for these selective enrichments has been disputed over time. McCoy and Aleksic reported that for some species of Salmonella, 43°C could inhibit recovery (Aleksic, 1973; McCoy, 1962; Andrews et al., 2001). Currently, the FDA and USDA-FSIS utilize different selective enrichment incubation temperatures (CDC, 2012; USDA-FSIS, 2012; Andrews et al., 2001). For example, enrichments from food products with high microbial loads are incubated at 43°C to provide enhanced recovery of the pathogen, while an incubation temperature of 35°C is most suitable for foods containing low microbial loads (CDC, 2012; Andrews et al., 2001).

The FDA-BAM currently follows similar methodology, thereby allowing the technician to determine which incubation temperatures are most suitable for each food product. The USDA-FSIS-MLG recommends selective enrichment incubation temperatures of 42°C for Salmonella isolation from all meat and poultry products (CDC, 2012; USDA-FSIS, 2012). Following the use of selective enrichments, samples are transferred to selective plating media in order to isolate discrete colonies of Salmonella spp. present in the food product. These media are formulated with various indicator dyes, bile salts, and other selective agents that promote the growth of Salmonella but reduce or inhibit the growth of competing microflora (Andrews et al., 2001). Numerous selective plating media exist for the isolation of Salmonella. Currently, the FDA utilizes a combination of Hektoen enteric agar (HE), Bismuth sulfite agar (BS),
MacConkey agar, and XLD, depending on the type of analysis and food product (CDC, 2012). The USDA-FSIS MLG currently recommends the use of Brilliant green sulfa agar (BGS), Xylose Lysine Tergitol agar (XLT4), or Double Modified Lysine Iron agar (DMLIA) for the isolation of *Salmonella* from meat and poultry products (USDA-FSIS, 2012). Greater understanding and research on these selective plating media have led to modifications of their original formulations.

The addition of antibiotics or other antimicrobials has led to greater media selectivity in some cases, but media selectivity may be affected by freshness of the media, incubation temperature, and *Salmonella* species (Andrews et al., 2001). The addition of novobiocin can enhance the selectivity of XLD and HE and increase *Salmonella* recovery (Hoben et al., 1973; Restaino et al., 1977; Andrews et al., 2001). Previous research by McCoy (1973) also found that freshly poured BS agar recovered fewer *Salmonella* spp. as compared to BS agar stored under refrigeration for 48 hours (Andrews et al., 2001). Wilson et al. (1980) reported that incubation of BG agar at 43°C could result in small atypical *Salmonella* colonies; while recovery of *Salmonella* on XLD and HE improved at incubation temperatures of 41.5°C (Andrews et al., 2001). Due to the numerous and complex factors affecting the recovery of *Salmonella* from food, the majority of standard methods employed by government agencies and recommended by certifying institutions rely on the combination of multiple selective enrichments, selective plating media, and incubation temperatures to address the complexity of *Salmonella* growth conditions.

*Salmonella* infections in humans

Symptoms and infection characteristics

Since its discovery, *Salmonella* has been identified as one of the most important causative agents of foodborne illness in human history (Bell and Kyriakides, 2002). *Salmonella* infection
Salmonella infections alone are responsible for $365 million annually in direct medical costs in the U.S., and continue to cause significant societal costs, having been responsible for 29 deaths in 2010 (Anonymous, 2011c). Salmonella ser. Typhi and Salmonella ser. Paratyphi, are clinically important serotypes which continue to cause disease and death in the developed world (CDC, 2012b). These serotypes are not typically associated with foodborne illness, since humans are their main reservoirs (Riemann and Cliver, 2006). Rather, S. Typhi and S. Paratyphi infections are typically spread through the consumption of water contaminated by sewage or from food and water handled by infected persons (CDC, 2012b). Non-typhoid Salmonella infections are caused by Salmonella serovars found in the Salmonella enteritidis species. Salmonella ser. Enteritidis and Salmonella ser. Typhimurium typically have been the agents of non-typhoidal foodborne illness since the 1980s (Riemann and Cliver, 2006). Non-typhoid Salmonella infection can be acquired through the consumption of raw or undercooked food products such as eggs, poultry, meat, unpasteurized milk, vegetables, and fruits (Riemann and Cliver, 2006). Other sources of infection also can originate from contact with animals such as chickens, pigs, reptiles, and birds colonized by Salmonella (Riemann and Cliver, 2006).

As discussed, Salmonella infections can be acquired through several means, including the fecal-oral route, swallowing contaminated aerosols, or by consumption of contaminated food, ingredients, and water (Grunnet and Hansen, 1978; Fannin et al., 1985; Riemann and Cliver, 2006). The infectious dose of Salmonella can vary depending on the serovar, host-specific interactions, and vehicle transmission properties. Susceptibility to infection of Salmonella may be increased in patients taking antacids, who have had gastrectomies (partial or full removal of the stomach), and who are achlorhydric (unable to produce stomach acid) (Blaser and Newman,
1982). Age and the condition of the immune system also can increase susceptibility to *Salmonella*. It has been suggested that young children may have rapid emptying of gastric contents, which may increase the chances that low dosages of *Salmonella* could cause infection (Silverio, 1964; Blaser and Newman, 1982). Foods containing fat and higher buffering capacities also may contribute to increased *Salmonella* susceptibility, as the salmonellae may be protected from gastric acids (D’Aoust et al., 1975; Blaser and Lee, 1982). In previous human studies performed before the 1970s, researchers concluded that ingestion of approximately $5 \log_{10}$ CFU/mL organisms of *S.* Typhi was sufficient to cause disease. Investigation of an outbreak of *S.* Typhimurium infection associated with chocolate concluded that approximately 10 cells were responsible for infection (Kapperud et al., 1998). Similarly, investigation of an outbreak of *S.* Enteritidis caused by the transportation of ice cream mix in a tanker used for liquid eggs, determined that the probable level of contamination was 6 cells per half cup of ice cream (Hennessy et al., 1996). This information suggests that low levels of *Salmonella* can cause infection, but also can be influenced by many biological and extrinsic factors related to the source of contamination.

Non-typhoid *Salmonella* infection is typically described as an acute gastrointestinal illness which occurs within 6-48 hours of ingestion of contaminated food or water. Patients also can experience diarrhea (sometimes bloody), fever, abdominal cramps, fever, chills, nausea, vomiting, joint pain, headache, and general malaise (Riemann and Cliver, 2006; CDC, 2012b). In most cases, fever subsides within 48-72 hours, with diarrhea typically lasting for less than a week (Riemann and Cliver, 2006). Non-typhoid *Salmonella* infection is generally known to be self-limiting. However, approximately 5% of infections lead to bacteremia or bloodborne infections, and in the developing world, non-typhoidal salmonellae sequeale commonly result in
acute bacterial meningitis (Hohmann, 2001; Molyneux et al., 2008). Other complications also can lead to clogged arteries, pseudoappendicitis, and localized urogenital infections, while further sequelae such as reactive arthritis can also be caused by Salmonella intestinal infections. (Miller et al., 1995; Hohmann, 2001; Riemann and Cliver, 2006; Leirisalo-Repo, 2007; Arnedo-Pena et al., 2010).

Salmonella Typhi is responsible for causing the human illness typhoid fever, or enteric fever (Riemann and Cliver, 2006). Salmonella Paratyphi can cause symptoms similar to enteric fever as well as gastrointestinal illness resembling non-typhoid gastroenteritis (Riemann and Cliver, 2006). Both typhoid and paratyphoid fevers are severe illnesses causing symptoms of fevers as high as 40°C, abdominal pain, loss of appetites, and in some cases, development of a flat rash of rose-colored spots (CDC, 2012). The incubation period of S. Typhi and S. Paratyphi is less clear, but can range from 3 days to 1 month, with typical onset of symptoms occurring between 8-14 days (Riemann and Cliver, 2006). Complications, such as intestinal perforation, gastrointestinal bleeding, and typhoid encephalopathy, can occur in 10-15% of patients in those countries where typhoid fever is endemic (Connor and Schwartz, 2005). In countries where medical care may be much less accessible, case fatality rates have been reported as high as 30% (Connor and Schwartz, 2005). In rare instances, S. Typhi can enter a carrier state in certain infected individuals who are capable of shedding high levels of the bacteria for decades without showing symptoms of infection (Roumagnac et al., 2006). McLarty and Dance, (1999) summarized the reports of at least two cases of infected individuals who had been suspected in carrying Salmonella for over 50 years. Although these individuals were not considered “healthy carriers” their cases have led many researchers to speculate that these long term carrier states may play a significant role in the evolutionary history of Salmonella (Roumagnac et al., 2006;
McLarty and Dance, 1999).

The mechanisms behind *Salmonella* infection and cause of diarrhea is not yet fully understood; much of what is known stems from *in vitro* studies on animal intestinal loop models (Riemann and Cliver, 2006). Numerous pathogenicity islands have been identified that house virulence gene clusters in *Salmonella*. The SP11 pathogenicity island in particular contains a group of genes identified as *inv* genes, which are responsible for invasion and subsequent intestinal membrane ruffling associated with *S.* Typhimurium infection (Salyers and Whitt, 2002). Membrane ruffling involves changes in the actin cytoskeleton and actin filaments of the cellular membranes that form protrusions or ruffles, which are believed to lead to the engulfment of *Salmonella* following the translocation of bacterial effectors via the type III secretion apparatus (Doughman et al., 2003; McCormick, 2004). The SP11 pathogenicity island also encodes genes producing a type-three secretion system which is thought to secrete effector molecules into the host cell, possibly playing a crucial role in inflammation, damage to mucosa, attraction of neutrophils, and increased secretion (Riemann and Cliver, 2006). Other research has focused on the adhesion and attachment of *Salmonella*, since bacterial adherence and colonization are necessary for invasive infection (Sakarya et al., 2010). Studies on *S.* Typhi have revealed that adherence to M cells of the intestinal epithelium is necessary for adherence to absorptive enterocytes (Takeuchi et al., 1967; Kohbata et al., 1986; Sakarya et al., 2010). Increasing evidence also suggests that bacterial fimbriae play a crucial role in the pathogenesis of *Salmonella*, although the exact mechanisms are still controversial or unknown (Sakarya et al., 2010). As research methods and technologies improve, the precise mechanisms by which *Salmonella* causes disease may be understood.
Outbreaks

As the U. S. food supply continues to evolve and change, the steps to counter contamination of foods has become extremely complex. More ingredients are being sourced globally, vertically-integrated and centralization of food production is increasing, and more U. S. consumers are eating meals outside the home (Todd et al., 2010; Anonymous, 2011b). The previous decade and recent experiences have highlighted the continued difficulties of *Salmonella* control in foods. Although numerous smaller outbreaks and recalls of contaminated products often occur, many of these outbreaks are isolated and do not cross into multiple states. Since 2006, *Salmonella* has been responsible for outbreaks originating in tomatoes, peanut butter, pot pies, spices, cantaloupes, alfalfa sprouts, turkey burgers, ground turkey, ground beef, and shelled eggs (CDC, 2012b). These foods do not encompass all products *Salmonella* has contaminated, but these outbreaks run counter to the notion that *Salmonella* is only associated with poultry. Although *S. Enteritidis* and *S. Typhimurium* are consistently the top two serovars causing outbreaks in the U.S.; the majority of major multi-state outbreaks occurring since 2006 have been caused by a variety of *Salmonella* serovars (CDC, 2012c). In 2007, *Salmonella* serovars Tennessee, Wandsworth, Schwarzengrund, and (I 4,[5],12:i:-), (pronounced “four five twelve eye minus), were responsible for the combined illnesses of 824 people, with the largest outbreak associated with peanut butter, spanning 44 states (CDC, 2012c). In 2008-2010, a combined total of 984 persons fell ill in multi-state outbreaks resulting from *Salmonella* serovars Litchfield, Agona, Saintpaul, Montevideo, Newport, Hartford, Baildon, Chester, and (I 4,[5],12:i:-) (CDC, 2012c). In 2010, one of the largest *Salmonella* outbreaks in U. S. history originated from shelled eggs contaminated with *S. Enteritidis* (CDC, 2012c). The investigation concluded that 1,939 reported illnesses were associated with the outbreak, with over a half of a million eggs being
recalled nationwide (CDC, 2012c).

Although less frequent, four *Salmonella* outbreaks occurring in the last six years resulted from contact with animals (CDC, 2012c). In 2010, water frogs and frozen rodents used as snake feed were responsible for a combined 119 illnesses (CDC, 2012c). In 2011, chicks, ducklings, and African dwarf frogs were responsible for two multi-state outbreaks causing 309 illnesses, with the largest outbreak spanning 42 states (CDC, 2012c). These unique outbreaks highlight the importance of hand washing after handling animals known to harbor *Salmonella* and the risks of shipping animals and other biological agents across the country.

Low moisture or dry products have also been associated with large *Salmonella* outbreaks in the past. Although outbreaks with these items are rare, illnesses have occurred in large populations (Chen et al., 2009). *Salmonella* has been the cause of outbreaks in numerous low-moisture products such as raw almonds, infant formula, cereal, dry seasonings, potato chips, dried coconut, peanut butter, puffed rice and corn snacks, and chocolate (Chen et al., 2009). Between 1971 and 2003, 21 recalls were initiated due to contaminated spices and herbs, with 12 of the more recent outbreaks originating from spices imported globally. It has also been observed that low-moisture foods contaminated with *Salmonella* can exhibit extremely low infectious doses. In an outbreak involving paprika and paprika-powdered potato chips, *Salmonella* isolated from the products was found at 0.04-0.05 CFU/g (Lehmacher et al., 1995; Chen et al., 2009). Previous studies have demonstrated that exposure to conditions of low $a_w$ for short periods of time can dramatically increase the heat resistance of *Salmonella* (Kirby and Davies, 1990). In fact, Mattick et al. (2000) observed a significant increase in heat resistance among *S. Typhimurium* DT104 cells previously exposed to $a_w$ as low as 0.95. It is clear that *Salmonella* is highly adaptable, and that processing conditions such as drying should be followed
by other further antimicrobial processing steps to ensure the safety of dry food products.

These outbreaks demonstrate that Salmonella control in foods is not just an issue for the poultry industry, but for all food producers. The CDC estimates that each year foodborne illness caused by Salmonella is responsible for over one million illnesses, 19,336 hospitalizations, and 378 deaths (CDC, 2012c). It is crucial that future investments and innovations in food safety continue to develop, as Salmonella will likely continue to be a significant public health issue well into the future.

Prevalence of Salmonella spp. in poultry

Since 1910, consumption of chicken and turkey has increased 5.7 fold and 17.5 fold per capita, respectively (Buzby and Farah, 2006; Foley et al., 2008). Due to the increased demand and subsequent production of poultry products in the U.S., the risk of Salmonella has increased and fluctuated dramatically throughout the century (Foley et al., 2008). Advancements in poultry processing have improved the microbiological quality of poultry significantly throughout the decades. However, with an increased understanding of the ecological niche that Salmonella may play in the biology of poultry, efforts to control Salmonella have shifted towards a focus on pre-harvest and on-farm practices in conjunction with traditional poultry processing intervention controls (Foley et al., 2008).

Chicken

Salmonella is a versatile and opportunistic bacterium, in which numerous serovars are capable of colonizing and infecting live chickens or broilers (Foley et al., 2008). This information is of particular concern, considering the U. S. processed 36.9 billion pounds of broiler meat and 9.28 billion broiler hatching eggs in 2010 (U.S. Census, 2009). Susceptibility of chicken to colonization of Salmonella can be affected by numerous factors including: age of
the birds, *Salmonella* serotype, stress, presence of feed additives like antimicrobials, competition of gut microflora, presence of compatible colonization sites, and host genetic background (Bailey, 1988). Vertical transmission of *Salmonella* from infected layer hens, as well as horizontal transmission through contaminated hatcheries, are key factors contributing to *Salmonella* infection in the chicken industry (Foley et al., 2008). In the past century, the trends of the most commonly isolated *Salmonella* serotypes from chicken have shifted. Programs like the National Poultry Improvement Plan (NPIP), implemented in 1935, focused on eradicating pullorum and fowl typhoid disease, caused by *Salmonella* ser. Pullorum and *Salmonella* ser. Gallinarum, from the chicken industry (Foley et al., 2008). It has been proposed that eradication of these serotypes allowed *S.* Enteritidis, a rare serotype prior to 1960, to fill the ecological niche following the eradication of *S.* Pullorum and *S.* Gallinarum (Rabsch et al., 2000; Velge et al., 2005; Foley et al., 2008).

As poultry processing intervention technologies improved and the strict control of *S.* Enteritidis became an integral part of the NPIP control plan, other *Salmonella* serovars previously considered rare, are now found to not only infect chicken, but cause foodborne outbreaks nationwide (CDC, 2012c; Foley et al., 2008). It is suspected that natural immunity, as well as vaccine use for the control of *S.* Enteritidis, has allowed serovars like *S.* Heidelberg, and *S.* Kentucky to fill the ecological niche following the reduction of *S.* Enteritidis in broilers (Foley et al., 2008). A USDA study in 2006 concluded that 11.4% of broilers and 45.0% of raw ground chicken were positive for *Salmonella* (USDA-FSIS, 2007). Alternatively, testing performed on 147 broiler establishments, analyzing 6,829 samples, concluded the percentage of *Salmonella* prevalence on broilers was 6.7% in 2010 (USDA-FSIS, 2010). Since 2006, the USDA-FSIS has focused its sampling on raw carcass product classes in an effort to improve process control in
raw ground products, as well as increase sampling and testing of poultry processors (USDA-FSIS, 2010). The reduction in Salmonella prevalence could provide evidence that these regulatory practices are effective, but also highlight the efforts of the poultry industry to utilize more stringent intervention technologies in their processing.

**Turkey**

Like chicken, turkey products are an important and common vehicle for human Salmonella infections (Foley et al., 2008). During the past two decades, six different Salmonella serovars have predominated in turkey (Foley et al., 2008). Although the prevalence of certain serovars differ between clinical and non-clinical isolates, Salmonella serovars Senftenberg, Heidelberg, Hadar, Bredeney, Reading, and Brandenburg make up the top six serovars associated with turkeys and were able to cause human disease for over 20 years (Foley et al., 2008). Turkey processing and production has become considerably centralized such that 68% of turkeys raised in the U.S. in 2007 were produced from 827 farms, rearing more than 100,000 turkeys (U.S. Census, 2007). As such, specific serovars may be spreading rapidly and prevalent in these large, geographically-separated flocks, possibly skewing the actual prevalence of certain serovars and causing difficulties in tracking Salmonella in turkeys (Foley et al., 2008). From 1996-2006, Salmonella prevalence in ground turkey samples decreased by 60% (McNamara and Levine, 1998; Foley et al., 2008), presumably due to implementation of the Pathogen Reduction Act and Hazard Analysis Critical Control Point programs (USDA-FSIS, 1998). Approximately one decade ago, ground turkey sold at retail had variable Salmonella prevalence, ranging from 11-36%, and 2.6% in breast meat (Rose et al., 2002; Zhao et al., 2001; Foley et al., 2008). USDA testing in 2010 revealed that of 1,444 turkey samples tested, 4.6% were positive for Salmonella, a 0.8% increase from 2009 (USDA-FSIS, 2010). Ground turkey sampling resulted in a
Salmonella prevalence rate of 10.2%, 0.5% lower than in 2009. These data demonstrated that efforts to control Salmonella in turkey have been effective. However, with over 7.11 billion pounds of turkey produced in 2010, efforts to prevent Salmonella illness from the consumption are warranted (U.S. Census, 2010).

**Campylobacter spp.**

**Historical information**

Campylobacter was first described by Theodore Escherich during the end of the nineteenth century, having observed the spiral bacteria in the colonic mucus of a child who had died of “cholera infantum” (Nachamkin and Blaser, 2000). Eighty years later, Campylobacter was recognized as a human pathogen. In 1931, veterinarians isolated an unknown “vibrio” from cattle with “winter dysentery” without the use of selective medium and subsequently named the bacterium Vibrio jejuni since it was isolated from the jejunal mucosa (Nachamkin and Blaser, 2000). In 1972, Dekeyser developed culture methods for the isolation of V. fetus from sheep and cattle with vibrionic abortions (Nachamkin and Blaser, 2000). In 1979, the first report of Campylobacter enteritis in humans was published, beginning a new era in Campylobacter research (Nachamkin and Blaser, 2000). As selective culture methods were developed, numerous Campylobacter-like bacteria were discovered; yet, classification was troublesome and complex since researchers relied solely on phenotypic characteristics (Nachamkin and Blaser, 2000). As such, the term "Campylobacter-like organisms” (CLO) was used to describe organisms that produced negative or variable biochemical results within the Campylobacter species (Nachamkin and Blaser, 2000). In an attempt to address these taxonomic issues, Romaniuk and Lau presented the first phylogenetic data on Campylobacter spp. in the late 1980s utilizing 16S rRNA sequences (Romaniuk et al., 1987; Lau et al., 1987; Nachamkin and Blaser,
One year later, Paster and Dewhirst (1988) also published 16S rRNA sequences of *Campylobacter* spp., *Wolinella* spp., and *Bacteroides* spp., resulting in the reorganization of these distinct bacterial genera (Nachamkin and Blaser, 2000). Following subsequent taxonomic studies and the discovery of *Helicobacter pylori* as the causative agent of peptic ulcers, the family *Campylobacteraceae* was created to include the genera *Campylobacter* and *Arcobacter*, while the genera *Helicobacter* and *Wolinella* are of the family *Helicobacteraceae* (Nachamkin and Blaser, 2000). Since its discovery as a human pathogen, *Campylobacter* is considered the most common cause of bacterial gastroenteritis in the U.S. and is linked to contaminated food, water, and infected animals (CDC, 2010). The CDC estimates that 2.4 million persons are affected annually by *Campylobacter*, resulting in approximately 124 deaths per year.

Complications arising from *Campylobacter* infection, including Guillain-Barre syndrome (GBS), also affects thousands of people per year, demonstrating that *Campylobacter* infection is a serious pathogen, capable of causing more than just acute gastroenteritis (CDC, 2010).

**Characteristics of *Campylobacter* spp.**

The genus *Campylobacter* is part of a group of helical or vibroid Gram-negative bacteria, consisting of 18 species and subspecies (Holt et al., 1994). *Campylobacter* measure 0.2-0.5 µm wide and 0.5-0.5 µm long (Holt et al., 1994). *Campylobacter* can appear S-shaped and gull-wing-shaped, with one or more helical turns (Holt et al., 1994). In certain circumstances (ex. old cultures), *Campylobacter* appears as a spherical, coccoid body (Holt et al., 1994). Identification of *Campylobacter* typically includes observing the characteristic cork-screw-like motion caused by an unsheathed polar flagellum located at one or both ends of the cells (Holt et al., 1994). *Campylobacter* are microaerophilic bacteria that require an environment consisting of low oxygen concentration (3-15%), as well as a carbon dioxide concentration (3-5%) for growth.
Campylobacter spp. are non-carbohydrate fermenting chemoorganotrophs, requiring the breakdown of amino acids and tricarboxylic acids intermediates for energy production (Holt et al., 1994). Campylobacter are sensitive to certain environmental factors that make them difficult to culture outside the host. The bacterium is sensitive to desiccation, low pH, freezing; yet most campylobacters remain viable and grow in bile when incubated at 37°C (Holt et al., 1994). The two most prevalent human pathogenic strains, C. jejuni and C. coli, grow optimally under thermophilic conditions (42°C) (Nachamkin and Blaser, 2000). Campylobacter are naturally found in the reproductive organs, intestinal tract, and oral cavity of human and animals, as well as poultry (Holt et al., 1994). Food products typically implicated in Campylobacter infections include raw milk, raw or undercooked poultry, fresh beef and pork, as well as produce, seafood, shellfish, and water. While most cases of campylobacteriosis are considered sporadic and originate from unknown sources, many outbreaks are linked to consumption of poultry products, contaminated water, and raw milk (Doyle and Beuchat, 2007).

**Detection of Campylobacter spp. in food**

The unique and fastidious growth conditions necessary to culture Campylobacter outside the host reservoir, made it difficult to isolate and identify the pathogen. In fact, initial methods for the isolation of campylobacters from human feces utilized differential filtration of a saline extract through a 0.65 μm filter (Dekeyser et al., 1972). Soon after, selective agars supplemented with Campylobacter-resistant antibiotics could inhibit the growth of background microflora and were introduced as validated methods for isolation of Campylobacter from feces. Skirrow’s medium and Preston medium were accepted widely as suitable selective media well into the 1980s. Although these media were effective, researchers like Bolton, continued to develop and modify selective media for a more effective isolation of Campylobacter from other...
sources, such as food. Today, there are numerous selective enrichments, selective plating agars, and confirmation tools that aid in the isolation of *Campylobacter* from various food products. Currently, the FDA-BAM and the USDA-FSIS MLG both employ the use of Bolton broth as a selective enrichment broth (USDA-FSIS, 2012; CDC, 2012). Bolton broth was developed to resuscitate sub-lethally-injured *Campylobacter* cells found in foods, while actively inhibiting the growth of background microflora through the use of multiple antibiotics (Bolton and Robertson, 1982). Sodium metabisulphite and sodium pyruvate present in Bolton Broth quench toxic compounds that may form in the medium, as well as increase the aero-tolerance of injured cells (Anonymous, 2001). The addition of antibiotic supplements containing vancomycin, cefoperazone, trimethoprim, and cyclohexmide serve to collectively inhibit the growth of Gram-positive and Gram-negative bacteria, as well as yeasts (Anonymous, 2001).

The FDA-BAM recommends stomaching food samples in a specified dilution of Bolton broth, incubating for 4 hours at 37°C, then further incubating at 42°C for 24-48 hours. The FDA utilizes this 4-5 hour pre-enrichment for samples known to be kept in storage for more than 10 days. Previous research has demonstrated that recovery of *Campylobacter* subjected to heat stress requires longer enrichment times (Kim et al., 2009). The pre-incubation period is not utilized by the USDA-FSIS presumably due to high levels of *Campylobacter* present in meat and poultry samples. Other selective enrichment broths described in the Compendium of Methods for the Microbiological Examination of Foods include Park and Sanders, and Hunt broths that contain varying quantities of ferrous sulphate, sodium meta-bisulphate, and sodium pyruvate, while also utilizing nutrients specific for *Campylobacter* metabolism (Andrews et al., 2001; Kim et al., 2009). Following the enrichment of blended or stomached food samples in a selective enrichment, aliquots are streaked onto selective plating media.
Commonly used plating media for the isolation of *Campylobacter* include *Campylobacter* Charcoal Differential Agar or Charcoal Cefoperazone Deoxycholate Agar (CCDA), as well as modified CCDA (mCCDA), Campy-Cefex agar, Campy-Line agar, and Abeyta-Hunt Bark Agar (AHB). All of these plating media are effective for the isolation of *Campylobacter* from foods, since all utilize similar antibiotic supplements. The FDA BAM currently recommends the use of both AHB and mCCDA agars, while the USDA-FSIS MLG employs Campy-Cefex agar for all meat and poultry analyses. Although their modes of selectivity differ, all three of these selective agars are supplemented with cefoperazone, an active and effective antibiotic against Gram-positive bacteria commonly present with *Campylobacter* (Anonymous, 2001). mCCDA is based on the original formula described by Bolton, which uses charcoal rather than blood as the decontaminant agent, sodium pyruvate as a growth stimulant, and ferrous sulfate to aid in the aerotolerance of the cells (Anonymous, 2001). Campy-Cefex, described by Stern is similar to mCCDA, but does not contain charcoal and instead, uses laked horse blood as a decontaminant (Stern et al., 1992; Anonymous, 2009b). A similar combination of sodium bisulfate, sodium pyruvate, and ferrous sulfate are used to increase the aerotolerance and growth of *Campylobacter* (Anonymous, 2009b). AHB agar consists of a simple agar base of heart infusion agar (HIA) and yeast extract, but is supplemented by sodium cefoperazone, rifampicin, amphotericin B, and the combination of sodium pyruvate, ferrous sulfate, and sodium metabisulfite (FBP) (CDC, 2012).

Confirmation of presumptive colonies can be performed using a combination of traditional biochemical tests and microscopic identification. However, numerous rapid methods are now employed for identification of *Campylobacter* spp. Catalase, oxidase, hippurate hydrolysis, and glucose utilization tests can be used to identify major species of *Campylobacter*, since *C. jejuni* and *C. coli* are catalase- and oxidase-positive, and glucose-negative, while *C.*
jejuni is hippurate hydrolysis-positive (Holt et al., 1994). Triple Sugar Iron (TSI) slants also can be used for further biochemical differentiation since C. coli and C. lari produce hydrogen sulfide, while C. jejuni does not (Holt et al., 1994). Recently, microbiological laboratories employ a combination of biochemical tests coupled with rapid identification kits, such as latex agglutination kits, VIDAS, and API Campy strips (bioMérieux, Marcy l’Etoile, France) for identification. Although these kits are useful tools for confirming the genera of Campylobacter, more precise subtyping methods have been developed using various PCR and molecular methods.

**Polymerase Chain Reaction (PCR)**

Molecular methods for the detection and identification of bacteria in foods has progressed significantly since the early 1990s. With an increased sensitivity and accuracy of molecular confirmation or subtyping methods, many laboratories are utilizing PCR methodologies to detect and confirm Campylobacter spp. Detection of Campylobacter using molecular methods is particularly useful due to the difficulty and time consuming process of culturing Campylobacter, which can take up to 7 days (Denis et al., 1999). Discriminating between Campylobacter isolates also can be variable and difficult to interpret using biochemical identification, since false positives and false negatives occur using rapid methods like latex agglutination (Miller et al., 2008). PCR affords rapid and species-specific identification for Campylobacter, while reducing the time, necessary biochemical reagents, and media necessary for traditional confirmation.

The hippurate hydrolysis test is used widely in the biochemical confirmation of C. jejuni, since it is the only species of Campylobacter able to hydrolyse hippurate (Holt et al., 1994). Therefore, researchers have targeted the gene encoding the enzyme hippuricase for use in PCR identification (Caner et al., 2008). In numerous studies however, the use of the hipO gene
primers may not identify those rare *C. jejuni* that lack hippuricase, leading to misinterpretation of the species when targeting *hipO* in PCR assays (Caner et al., 2008). Other studies have identified membrane associated protein (*map*) genes, flagellin protein (*fla*) genes, cytolethal distending toxin (*cdt*) genes, and polysaccharide capsule (CPS) genes, as targeted sites for use in the identification of *Campylobacter* using PCR methodologies (Stucki et al., 1995; Caner et al., 2008; Meinersmann et al., 1997).

Serotyping *Campylobacter* has been performed traditionally using the Penner or Lior schemes based on heat-stable or heat-labile antigen subtyping (Ketley and Konkel, 2005). This method has identified roughly 65 separate Penner serotypes for both *C. jejuni* and *C. coli* (Ketley and Konkel, 2005). Twenty-two of the 47 *C. jejuni* Penner serotypes fall into complexes that are structurally related CPS types (Poly et al., 2011). Since CPS of *C. jejuni* is the major serodeterminant of the Penner serotyping scheme, primers were developed, specific for each capsule type, based on the variable capsule loci of 8 strains of major serotypes (Poly et al., 2011). Poly et al. (2011) confirmed previous research that suggests CPS are highly mosaic, likely due to horizontal gene transfer among strains. This observation suggests that Penner complexes are highly related. Yet, possible phase variation or other unknown factors requires more sequencing of CPS loci to judge the specificity of PCR schemes targeting CPS genes (Poly et al., 2011).

In other studies, the *mapA* gene exhibited a high degree of conservation among 161 *C. jejuni* human and animal isolates, with no amplification among 126 non *C. jejuni* isolates (Stucki et al., 1995). Additionally, Stucki et al. (1995) observed no restriction fragment polymorphism formations in the amplified product when digested with multiple restriction enzymes, suggesting the gene is well conserved among *C. jejuni* (Stucki et al., 1995). The CDT, having been a widely characterized virulence factor in *Campylobacter* spp., is encoded by three linked genes known as
**cdtA**, **cdtB**, and **cdtC** (Nachamkin and Blaser, 2000). These genes have been targets for numerous PCR schemes, since *C. jejuni*, *C. coli*, and *C. fetus* are known to harbor these genes in a species-specific manner (Lutful-Kabir et al., 2011). In one study, a *cdt* multiplex PCR assay evaluated 112 CLO organisms and determined that the *cdtB* gene-based multiplex PCR appeared to be more reliable compared to *cdtA* or *cdtC* gene based multiplex PCR (Samosornsuk et al., 2007; Lutful-Kabir et al., 2011). Martinez et al. (2006) also reported deletions and mutations on the *cdtC* gene, but not the *cdtA* and *cdtB* genes, suggesting *cdtB*-based PCR schemes might be most suitable for species identification (Lutful-Kabir et al., 2011). AbuOun et al. (2005) reported a 667-bp deletion between *cdtA* and *cdtB* genes from 3 strains isolated from infected patients. In another study, 4 strains of *C. jejuni* strains did not yield specific PCR products due to the same deletion (AbuOun et al., 2005; Lurful-Kabir et al., 2011). While mutations and variations can occur among *cdt* genes from various *Campylobacter* species, these genes may be useful targets for species identification (AbuOun et al., 2005; Lurful-Kabir et al., 2011, Martinez et al., 2006).

**Campylobacter infection in humans**

**Symptoms and infection characteristics**

*Campylobacter* infection is widespread throughout the world and continues to be the leading cause of bacterial-induced acute gastroenteritis in the U.S., responsible for an estimated 124 deaths per year and nearly $1.3 billion in U.S. medical costs (CDC, 2010; Batz et al., 2011). *Campylobacter* infection is clinically indistinguishable from acute gastrointestinal infections caused by other bacterial pathogens such as *Salmonella*, *Shigella*, and *Yersinia* species (Allos, 2001). *Campylobacter* infection is typically characterized by loose, watery, and bloody diarrhea, fever, and abdominal cramps (Allos, 2001). In some cases, diarrhea and abdominal pain are
minimal; however, 8-10 bowel movements can occur at the peak of illness (Blaser et al., 1983). In rare cases, patients can develop a relapsing diarrheal illness, lasting several weeks (Allos, 2001). The incubation period for *Campylobacter* infections can range from 18 hours to 8 days, although symptoms typically occur within 3 days (Nachamkin and Blaser, 2000). Although rare in developed countries, infection of *C. jejuni* is common in healthy asymptomatic individuals living in low income populations (Glass et al., 1983). Developing countries such as South Africa, India, China, Indonesia, and Bangladesh are common areas where *C. jejuni* infection is endemic, and asymptomatic carriage rates of *C. jejuni* is high (Glass et al., 1983). Numerous factors can affect the infectious dosage, including type of food consumed, health of the individual, and *Campylobacter* species. Interestingly, it has been observed in human experimental infections that doses as low as 500 *C. jejuni* can cause illness (Nachamkin and Blaser, 2000). Some evidence also suggests that the pathogen may be responsible for appendicitis since the organism has been isolated from inflamed appendices (Nachamkin and Blaser, 2000). Other more rare complications of *Campylobacter* infections include: meningitis, endocarditis, septic arthritis, osteromyelitis, neonatal sepsis, and transient bacteremia, and Guillain-Barré syndrome. 

**Guillain-Barré Syndrome**

Guillain-Barré Syndrome (GBS) was first recognized by three French neurologists in 1916 after diagnosing two soldiers with acute areflexic paralysis (Hughes and Cornblath, 2005). Two subtypes of the syndrome have been observed. The first syndrome is described as acute inflammatory demyelinating polyradiculoneuropathy (AIDP), while the second is known as acute motor axonal neuropathy (AMAN) (Hughes and Cornblath, 2005). Both of these subtypes involve a form of the degradation of the protective myelin sheath surrounding the nerve in the
peripheral nervous system, which results in paralysis lasting several weeks to years (Vucic et al., 2008). The incidence of typical GBS has been reported to be approximately 0.6-4 cases per 100,000 per year throughout the world (Hughes and Cornblath, 2005). Studies have reported that most cases of GBS in the U.S. occur after an infection with C. jejuni serotype 0:19. It has been proposed that C. jejuni 0:19 may cause GBS through a mechanism of molecular mimicry (Vucic et al., 2008). In this scenario, the immune response seen in GBS is caused by antibodies specific to C. jejuni lipo-oligosaccharides which are identical in molecular structure to certain gangliosides in human nerve cell membranes (Vucic et al., 2008). It is through the resulting nerve damage that paralysis, characteristic of GBS, can occur. Two-thirds of GBS patients experience gastroenteritis within the previous 6 weeks of diagnosis. However, case-controlled studies also have implicated Mycoplasma pneumoniae as a possible trigger of the syndrome as well (Hughes and Cornblath, 2005). GBS typically peaks within 4 weeks, with recovery lasting weeks or months (Hughes and Cornblath, 2005). In 25% of the GBS cases, weakness of the respiratory muscles requires artificial ventilation, a death rate of 4-15%, and up to 20% are left disabled permanently (Hughes and Cornblath, 2005).

Outbreaks

Campylobacter spp. are commensal organisms in many animal reservoirs (Doyle and Beuchat, 2007). These reservoirs include chicken, duck, turkey, geese, cows, pigs, sheep, goats, wild birds, as well as domestic animals (Doyle and Beuchat, 2007). Animal food products typically make up the majority of vehicles responsible for campylobacteroisis each year, although the food vehicles common to Campylobacter outbreaks continue to change (Doyle and Beuchat, 2007). Campylobacter was responsible for over 30,000 cases of campylobacteroisis in approximately 900 outbreaks in the U.S. from 1978-2003 (Doyle and Beuchat, 2007). Between
1978 and 1987, half of the outbreaks originated from water and unpasteurized milk. Between 1981 and 1990, 20 outbreaks affecting 1,013 individuals were attributed to raw milk, making up 45% of the outbreaks over the 10 year span (Doyle and Beuchat, 2007). In a separate study, researchers reported *Campylobacter* spp. were responsible for 80 U.S. outbreaks between 1996 and 2005, with 18 originating from chicken and other poultry, and 37 originating from dairy products (Greig and Ravel, 2009). During a comprehensive review of waterborne diseases spanning the years of 1997-2006, it was reported that *Campylobacter* was responsible for 19 outbreaks causing 5,565 cases of campylobacteroisis; 17 of those outbreaks were caused by *C. jejuni* (Craun et al., 2010). Data obtained from the CDC Foodborne Outbreak Online Database (CDC, 2011) reports that between 2005 and 2009, 105 confirmed U.S. foodborne outbreaks were caused by *Campylobacter* spp., and among the 79 foodborne vehicles confirmed in those outbreaks, 14 were caused by poultry products and 41 by dairy products (CDC, 2011). Since 1996, and the implementation of the PR/HACCP system, the USDA-FSIS, in conjunction with other government agencies, have sought to reduce *Campylobacter* contamination from meat and poultry products.

Over the last decade, the USDA-FSIS has increased the testing and inspections of meat and poultry specifically, seeking to ensure processing plants are implementing procedures to reduce and/or eliminate *Campylobacter* from their food products. In May 14, 2010, the USDA-FSIS announced the implementation of new performance standards for both *Salmonella* and *Campylobacter* for chilled broiler carcasses and turkey establishments (USDA, 2010). Similarly, FDA standards for processed pasteurized milk continue to list *C. jejuni* as an adulterant. Although federal regulations and inspections can be effective in reducing the prevalence and outbreaks associated with contamination of *Campylobacter* in raw animal commodities, there is
still a need for consumers to cook and handle foods properly.

**Prevalence of *Campylobacter* spp. in poultry**

**Chicken**

It has been widely established that contamination of chicken products with *Campylobacter* can be traced back to the live bird on the farm (Keneer et al., 2004). Although various on-farm strategies have been employed for control, once *Campylobacter* is introduced to a flock, spread of the bacterium can occur quickly (Keener et al., 2004). Chickens can harbor high levels of *Campylobacter* (9.0 log$_{10}$ CFU/g of cecal content) without symptoms of infection (Keneer et al., 2004). Studies also have demonstrated near complete *Campylobacter* colonization of a flock within 49 days. In another study, 100% flock carriage rate was obtained within 21 days (Gregory et al., 1997; Wallace et al., 1998; Keener et al., 2004). It is suspected that a majority of transmission of *Campylobacter* occurs through horizontal transmission from contaminated water, litter, insects, wild birds, rodents, fecal contact, farm personnel, although feed is not suspected to be a source of contamination (Keneer et al., 2004). Other studies have reported evidence of vertical transmission, where *C. jejuni* isolates from a parent flock were found to be of the same clonal origin as isolates found in the offspring of the broiler flock (Keneer et al., 2004). In a study by Clark and Bueschkens (1985), chicken eggs inoculated with *C. jejuni* resulted in 11% of the hatched chicks to be colonized with *Campylobacter* (Keener et al., 2004).

Controlling *Campylobacter* also extends beyond the farm, since transportation and processing of poultry may lead to contamination. It is suspected that stress during transportation can cause changes in the microflora of the chicken crop. In this scenario, it is thought that stress causes a decrease in the pH of the crop, possibly increasing levels of *Campylobacter* in live birds
(Hinton et al., 2000; Keener et al., 2004). In another study, feed withdrawal resulted in an increase in the number of infected live birds; approximately 45% in 360 birds tested (Hinton et al., 2000; Keener et al., 2004). Northcutt et al. (2003) also reported significant increases in *Campylobacter* spp. in the carcasses of live birds which were withheld feed for 12 hours, resulting in an increase of $0.5 \log_{10}$ CFU/g of cecal droppings. Poultry transport coops have also been viewed as a source of *Campylobacter* contamination, and the effectiveness of coop washing and sanitizing systems have been uncertain (Berrang and Northcutt, 2005). Corry et al. (2002) found that coop washing systems failed to remove all residual feces on cage surfaces, while Slader et al. (2002) was able to detect *Campylobacter* spp. in 4 out of 5 samples collected from commercially-washed transport cages. Northcutt and Jones (2004) reported that a majority of poultry processors do not utilize coop washing systems due to high water costs and the perception of wasting water. Interestingly, Berrang et al. (2004) found that residual *Campylobacter* in unwashed transport coops decreased when placed in dry storage for 24-48 hours (Northcutt and Jones, 2004). In fact, Berrang and Northcutt (2005) reported a 7 log reduction of *Campylobacter* inoculated on fiberglass transport coop flooring squares after 24 hours of drying, with no prior washing. These findings may suggest that extended dry storage of poultry transport coops may impart more of a reduction in residual *Campylobacter* than coop washing.

Contaminated live birds pose a challenge to poultry processors, since live birds entering the processing facility can harbor high levels of *Campylobacter* contamination on their feathers, skin, feet, as well as internally. Equipment (pickers, scalders, chill tanks) and processes (ex. scalding, defeathering, evisceration, chilling) can be sources of *Campylobacter* on chicken carcasses, requiring antimicrobial intervention steps to reduce levels throughout processing.
(Bailey et al., 1987; Keeney et., 2004). The survival of *Campylobacter* has been shown to vary widely throughout the processing, where bacterial reductions can be swiftly followed by increases in pathogen levels due to recontamination. Berrang and Dickens (2000) reported reductions in *Campylobacter* spp. post-scald and post-chill, however increases in *Campylobacter* spp. were observed post-pick and post-evisceration compared to post-scald counts (Berrang and Dickens, 2000). Although the mean log$_{10}$ CFU/mL of *Campylobacter* spp. has typically been shown to decrease post-chill, Berrang and Dickens (2000) found variability in counts between flocks, where one out of the six flocks tested exhibited a 1.6 log$_{10}$ CFU/mL increase from pre-chill to post-chill (Berrang and Dickens, 2000). It is suspected that chicken skin may aid in the survival of *Campylobacter* through processing, presumably due to the changes occurring in the microtopography of the tissue (Chantarapanont et al., 2003). It is suspected that the swelling and exposure of deep crevices within the tissue may trap bacteria and water providing more surface area to contaminate, while also possibly protecting bacteria from physical removal and exposure to sanitizers (Chantarapanont et al., 2003). Several studies have isolated high levels of *Campylobacter* from chicken skin, but not from the underlying muscle (Berrang et al., 2002; Altmeyer et al., 1985; Keener et al., 2004). Using confocal scanning laser microscopy and transformed *Campylobacter* possessing the green fluorescent protein (GFP), Chantarapanont et al. (2003) reported that a greater amount of total GFP-*Campylobacter* cells were located at the 0-10µm depth in feather follicles than on the chicken skin surface. It was also concluded that GFP-*Campylobacter* found at depths of 30-50µm in feather follicles had a greater chance of survival than those present at the skin surface (Chantarapanont et al., 2003). Despite the knowledge of cross-contamination and numerous interventions used in chicken processing, many studies have reported high prevalence rates of *Campylobacter* isolated from retail chicken
samples. In 1992, Stern and Line detected *Campylobacter* spp. in 98% of retail packaged broilers from grocery stores (Stern and Line, 1992; Keener et al., 2004). Out of 212 retail chicken samples taken from supermarkets in the Greater Washington D.C. area, Zhao et al. (2001), reported a 71% *Campylobacter* contamination rate. One survey reported 74% contamination rate of organic carcasses sold at retail (Cui et al., 2005), while another study reported 75% of retail carcasses raised under pre-harvest free range conditions were contaminated with *Campylobacter* spp. (Hanning et al., 2010). The presence of *Campylobacter* in retail chicken continues to remain a significant public health concern. Risk management, research, interventions, and strict practices must continue at all levels of chicken production, with special emphasis to control *Campylobacter* at the farm level.

**Turkey**

Pathogen prevalence in turkey products has focused on *Salmonella*, with a few large scale studies and national data addressing *Campylobacter* prevalence in turkey. Recently, numerous smaller scale studies and national baseline surveys have provided a view into the prevalence and significance of *Campylobacter* infection in turkey. A study performed in the early 1980s reported 100% prevalence rate of *Campylobacter* in cecal contents from 600 freshly slaughtered turkeys (Luechtefeld and Wang, 1981). Luechtefeld and Wang (1981) also reported a mean *Campylobacter* concentration of $2.7 \times 10^6$ CFU/g in turkey feces. Rosef et al. (1984) reported that the carriage rate of the pathogen in one turkey flock was 56.7%. USDA-FSIS collected 1,221 turkey rinse samples from 50 USDA-inspected turkey plants between 1996 and 1997 and reported 90.3% samples were positive for *Campylobacter* spp. (USDA-FSIS, 1998). This study was performed prior to the implementation and enforcement of HACCP in poultry processing facilities. Another study found that intestinal tracts from 230 organic turkeys from five organic
turkey processing facilities in Ohio exhibited *Campylobacter* prevalence rates of 87% (Smith et al., 2004). In a more recent study focusing on the *Campylobacter* prevalence in the viscera of market-weight turkeys, 64% of ceca and 87% of the colon (n=180) were positive for either *C. jejuni* or *C. coli* (Wesley et al., 2008). The latest baseline survey of *Campylobacter* in turkeys, compiled by the USDA-FSIS sampling data from 2008-2009, reported 2,884 samples from 58 establishments exhibited a *Campylobacter* prevalence rate of 23% and 1% from pre-and post-chill turkey carcasses, respectively (USDA-FSIS, 2010b) Although few studies have explored the prevalence of *Campylobacter* in turkey, the data from recent baseline reports suggest that enforcement and implementation of HACCP programs in turkey processing plants appears to be effective in reducing the prevalence of *Campylobacter* on turkey.

**Poultry processing**

**Conventional poultry processing**

In the sixteenth century, chickens were introduced into America from Europe; yet the modern poultry industry did not emerge until the 1900s (Anonymous, 2010). Since 1930, and due to the lack of beef and pork production in the U.S. during World War II, research and technical innovations in poultry housing, feeding, breeding, and processing have led to rapid development and highly successful industries (Anonymous, 2010). Poultry meat accounts for 30% of global meat consumption, with worldwide average per capita consumption quadrupling since the 1960s (Anonymous, 2010). Chickens and turkeys are the most common sources of poultry meat; chicken accounts for approximately 86% of all poultry raised worldwide (Anonymous, 2010). In the last century, poultry production has moved from a decentralized system involving many individual farmers, hatcheries, livestock markets, wholesalers, and small processors, to centralized, vertically-integrated systems (Mead, 2004). Before vertically
integrated farming, farmers would traditionally raise chicks purchased from a hatchery until those chickens had grown to market weight. Farmers would sell their live birds at livestock markets, direct to consumers, or to processors who would slaughter and process the birds for wholesalers and supermarkets (Mead, 2004). During this period, various breeds were raised, different on farm practices were used, and the feed varied. Processors also lacked the knowledge and specialized equipment to slaughter and process poultry in a rapid and sanitary manner. The late 1950s saw many breakthroughs in poultry production, and throughout the following decades, poultry nutrition, genetics and disease control, breeding, husbandry, and processing technologies rapidly improved into the modern poultry industry we know today (Mead, 2004). Figure 1 demonstrates the steps involved with poultry production and processing (Mead, 2004).

Organic poultry processing

Since the USDA established the National Organic Program (NOP) in 2002, the distinction between what was deemed conventional and organic food and agricultural production was codified into law and regulation. What is now considered conventional processing follows the same regulatory and inspection requirements that have existed and evolved through the hundreds of years of U.S. agricultural production. Although organic food production must follow specific guidelines to be certified as organic, much of the same farming and processing methods are used, and both conventional and organic processing fall under many of the same regulatory and inspection requirements required in the U.S. Although numerous regulatory requirements exist for the production of different processed poultry products, the overarching regulations for conventional poultry processing are dictated by the U.S. Poultry Products Inspection Act. Other regulations that large processors may follow are Environmental Protection Agency (EPA) regulations for Concentrated Animal Feeding Operations (CAFO) and USDA
Agricultural Marketing Service (AMS) poultry and eggs quality grading, certification, and verification.

The organic meat industry is relatively young in the U.S., but it has been built upon basic philosophical requirements that focus on the welfare of the animal, minimal use of man-made or synthetic chemicals, and reduction of artificial contamination of the environment (Fanatico, 2008). In the U.S, the NOP acts as the overarching regulation for the production of all organic foods, including poultry and other livestock. The organic regulations begin at the origin of the livestock. In the case of poultry or edible poultry products, those products must be from poultry that has been under continuous organic management, beginning no later than the second day of life (Anonymous, 1990). Producers of organic poultry also must utilize feed produced from agricultural products, including pasture and forage that have been organically produced by a certified NOP operation (Anonymous, 1990). Growth of poultry must not be promoted with the use of animal drugs, added hormones, feed supplements or additives above those needed for adequate nutrition (Anonymous, 1990). Feed produced from animal by-products must not be used, and growers must provide pasture of a sufficient quality and quantity to graze throughout the grazing season (Anonymous, 1990).

Major housing and living conditions for organic poultry production include: provisions to allow for exercise, freedom of movement, reduction of stress, establishment of housing and pasture conditions, and sanitation practices to minimize the spread of disease and parasites (Anonymous, 1990). Organic poultry production most notably prohibits the use of animal drugs, other than vaccination, in the absence of illness (Anonymous, 1990). This approach includes antibiotics, parasiticides, and other veterinary drugs that contain synthetic substances prohibited in the NOP (Anonymous, 1990). Those poultry that require the use of medical treatment outside
the purview of organic standards must receive proper care and cannot be sold or slaughtered as organic until a drug-specific prescribed withdrawal period, typically lasting at least a month (Anonymous, 1990).

One major distinction between organic and conventional poultry production is the prevention of continuous confinement. Conventional poultry may be confined to a broiler house to control for environmental conditions, pest control, disease management, and feeding regimens known to be most beneficial to the health and production of poultry (Mead, 1994). Alternatively, organic poultry producers must allow year-round access to the outdoors, shade, shelter, exercise areas, fresh air, clean water for drinking, and direct sunlight. Rodent, fly, and other pest controls are typically managed using multilevel approaches utilizing physical and mechanical exclusion methods such as tarps, electric fences, adhesives, and fans (Anonymous, 1990).

Certain synthetic rodenticides are allowed under the NOP, such as cholecalciferol and sulfur dioxide (Fanatico, 2008).

Much of the difference between conventional and organic poultry production occurs within pre-harvest measures, focusing on the live bird. Little differences exist between organic and conventional poultry processing; however those differences can have food product quality and food safety implications. The major processing distinctions focus on the use of detergents, sanitizers, pest control methods, disinfectants, and other chemicals commonly used in poultry processing (Fanatico, 2008; Anonymous, 1990). All other aspects involved with processing including slaughtering, cutting, evisceration, dehydrating, freezing, chilling, packaging, or any other preparation for the purpose of retarding spoilage and preparing the agriculture product for market is the same for conventional as it is for organic poultry processing (Anonymous, 1990). Sanitizers and disinfectants that are allowable in organic processing include peroxyacetic acid,
ozone, acetic acid, alcohols, ammonium sanitizers, detergents, hydrogen peroxide, carbon
dioxide, and any other approved organic acids (Anonymous, 1990). Although chlorine
compounds are allowable under organic processing standards, they must not exceed 4 ppm of
residual chlorine, which is a major distinction between conventional and organic poultry
processing (Anonymous, 1990). The use of antimicrobial compounds other than chlorine-based
sanitizers may affect pathogen control in organic processing plants. Therefore, the use of non-
typical sanitizers and cleaners should be validated and monitored frequently as part of a
sanitation program.

Sanitizers

Chlorine sanitizers

Poultry processors have been using chlorine to reduce spoilage bacteria and control
pathogens for more than 40 years (Keener et al., 2004). Hypochlorous acid is the form of
chlorine responsible for antimicrobial action and is generated when sodium hypochlorite is
injected into water (Keener et al., 2004; Gavin and Weddig, 1995). Controlling the amount of
free and active chlorine can be difficult with the addition of organic impurities that react with
chlorine to form chloramines and other chloro-nitrogen compounds that weaken chlorine’s
germicidal properties (Keener et al., 2004; Gavin and Weddig, 1995). In the presence of organic
impurities, chlorine will react until all impurities are completely reduced and oxidized, requiring
continuous addition of free chlorine to the system (Keener et al., 2004). The bactericidal
properties of chlorine are proportional to the concentration of free residual chlorine, as the pH of
the water after addition of chlorine will determine the rate at which microorganisms are killed
(Keener et al., 2004). It has been observed that increasing water pH decreases the germicidal
effects of chlorine, due to the loss of (HOCL) or free chlorine in the system, as (OCL-) is less
toxic to microorganisms. Although the action of chlorine has been extensively studied, the exact mode of action and killing effects are still a continuing area of study. It is generally accepted that the antimicrobial activity of chlorine is partly due to the change in pH imparted by the influx of hydroxyl ions (Estrela et al., 2002). This influx is thought to interfere with cytoplasmic membrane integrity, cause irreversible enzymatic inhibition, and interfere with cellular metabolism and phospholipid degradation (Estrela et al., 2002). The formation of chloramines will disrupt cellular metabolism, while individual chlorine molecules interact with amino groups and can cause irreversible oxidation of sulphydryl groups of enzymes in the bacterial cell (Estrela et al., 2002).

An alternative to chlorine is chlorine dioxide (C\textsubscript{2}O\textsubscript{2}), a synthetic, yellowish-green gas with chlorine-like odor (Keener et al., 2004). The action of chlorine dioxide is independent of pH and does not form hypochlorous acid (Keener et al., 2004). The killing effects are due to the disruption of the transport of nutrients across the cell wall (Keener et al., 2004). Chlorine dioxide is an effective sanitizing agent and has been reported to be effective in reducing bacterial counts at concentrations of 3-5 ppm (Lillard et al., 1979). Lillard et al. (1979) demonstrated that chlorine and chlorine dioxide at concentrations of 34 ppm and 5 ppm respectively, were equally successful in eliminating \textit{Salmonella} spp. from treated poultry chiller water. Blaser et al. (1986) studied the effects of chlorine in water on \textit{C. jejuni} and demonstrated free chlorine levels of 0.25 mg/L completely inactivated \textit{C. jejuni} within 30 seconds \textit{in vitro} (Blaser et al., 1986). Blaser et al. (1986) also observed a 1 log\textsubscript{10} CFU/ml reduction in \textit{C. jejuni} strains within 5 minutes when using a 0.1 mg/L of free chlorine.

Although \textit{in vitro} experimental studies have demonstrated the effectiveness of chlorine, under commercial processing conditions, many studies have not demonstrated significant
reductions in pathogens using chlorinated washes and baths (Keener et al., 2004). One study previously reported minimal *Salmonella* reductions of 0.5 and 0.6 log using 20 ppm of chlorine in a chill tank (Waldroup et al., 1992). Similarly, Kotula et al. (1967) reported little effect in reducing the proportion of positive *Salmonella* on carcasses, post-water chill, using a 50 mg/L chlorinated carcass washer. Alternatively, Mead (2004) reported statistically significant reductions in *Campylobacter* spp. using chlorinated sprays at various stages of processing. Evidence has suggested that the poultry skin aids in the protection of certain bacteria when exposed to a chlorinated treatment. Other studies have suggested that attached or entrapped bacteria are not readily accessible to chlorine and therefore, are unaffected while attached to chicken skin (Lillard, 1995; Mead, 2004). Mead (2004) also demonstrated that *Campylobacter* attached to stainless steel was reduced to undetectable levels using chlorine concentrations as low as 10 mg/L. However, *Campylobacter* inoculated on chicken skin were virtually unaffected when exposed to free chlorine concentrations of 250 mg/L (Mead, 2004). Chlorine treatment of chill water and washes continue to be utilized in poultry processing despite conflicting reports of its effectiveness. Currently, USDA-FSIS requires the application of chlorinated water containing a minimum of 20 ppm available chlorine on all surfaces of carcasses when the inner surfaces of poultry have been reprocessed (USDA-FSIS, 2010c). Although conventional poultry processing utilizes chlorine, certified organic and smaller poultry processors have identified alternative sanitizing agents, such as organic acids, with similar success.

**Organic acid sanitizers**

There are various organic acids that can be used in place of chlorine during the processing of poultry. The use of organic acids has demonstrated effectiveness in reducing pathogens and extending shelf life. Acids that have been evaluated for use and listed in the
USDA-FSIS regulations for use an acidifier in various meat and poultry products include: acetic, lactic, citric, propionic, sulfuric, hydrochloric, phosphoric, peroxyacetic, octanoic, sorbic, hypobromous, and hypochlorous acid (USDA-FSIS, 2010c). Other organic acids that have been researched for antimicrobial effectiveness include: fumaric, succinic, tartaric, and benzoid acid (SCVPH, 1998; Davidson et al., 2005). The antimicrobial action of organic acids depends on factors like carbon chain length and pH of the environment, since the degree of acid dissociation will differ at different pH values and affect the amount of un-dissociated acid remaining in solution (SCVPH, 1998). The antimicrobial activity also can be affected by the species of bacteria, temperature, and exposure time (SCVPH, 1998). The effectiveness of organic acids to kill bacteria results from the disruption of the cell membrane and acidifying the cell contents (SCVPH, 1998). Unlike chlorine, extraneous organic materials do not affect the stability of organic acids. However, they can corrode equipment and cause various sensory changes in poultry (Keener et al., 2004). One study observed a 50% reduction in Salmonella contamination on broiler carcasses using 1% succinic acid applied at 55°C (Thomson et al., 1976). In another study, 4.25% lactic acid sprays were applied to turkey carcasses, resulting in a 4.4 log reduction in APC as well as observable reductions in Salmonella and coliforms (Bautista et al., 1995). Similarly, research on the effects of lactic acid on chicken skin revealed 2.0 log reductions of Salmonella spp. and Listeria monocytogenes using a 1% lactic acid spray (Hwang and Beuchat, 1994). Caution must be taken in utilizing organic acids in the same manner for multiple processing nodes, as the concentration, temperature, surface type, and time of exposure can alter the effectiveness of organic acids (Boulder, 1997). Combining the treatment of organic acids with modified atmosphere packaging, and pre-treatment of surfaces with NaCl or sucrose also has demonstrated to be an effective intervention and extends the shelf life of poultry products.
Due to the unfavorable sensory changes that can occur in poultry using single concentrations of organic acids, more recent applications of organic acids have utilized less caustic acids, such as peracetic acid. The combination of peracetic acid and hydrogen peroxide has demonstrated promise as an alternative sanitizing agent for poultry processing. Bauermeister et al. (2008) reported a 91% and 43.4% reduction in *Salmonella*- and *Campylobacter*-positive, post-chill carcasses in water treated with a 15% peracetic acid and 10% hydrogen peroxide mixture. Due to the increase in organic poultry production, the use of organic acids in large processing plants has increased and are widely used.

**Farmers’ markets**

**Background**

Throughout the U. S., and in the last decade, Americans are purchasing food products from farmers’ markets at a significantly increasing rate (Ragland and Tropp, 2009). Farmers’ markets are typically public areas in which farmers, processors, and local entrepreneurs sell a variety of agricultural products and crafts directly to consumers. A farmers’ market is defined by the USDA Agricultural Marketing Service (USDA-AMS) as a “retail outlet in which two or more vendors sell agricultural products directly to customers through a common marketing channel” (Ragland and Tropp, 2009). The popularity of farmers’ markets in the U. S. continues to rise, with an increase from 1,755 in 1994 to 7,175 in 2011 (Ragland and Tropp, 2009; Anonymous, 2011). The increase in farmers’ markets has been observed throughout the country and the prevalence of farmers’ markets differs widely by state. In a 2010 USDA survey, California ranked first among top states containing farmers’ markets with 729. In this same survey, Pennsylvania ranked sixth with 266 (Anonymous, 2011). With an increase of 2,790
active markets in the U.S. since 2012, the rankings and prevalence of farmers’ markets in each state has likely changed considerably (Anonymous, 2011). Consumer demand for year-round, locally-produced foods also has resulted in an increase in winter farmers’ markets. In a recent USDA survey, over 570 active winter farmers’ markets are in operation nationwide, with 42 establishments throughout Pennsylvania (Anonymous, 2011b).

Farmers’ markets are not a new phenomenon, having been active in the U. S. for over 50 years. The resurgence of farmers’ markets reflects changes in government and consumer attitudes towards locally-produced foods. Many of these attitudes have historical relevance dating back to the late 1970s. The Farmer-to-Consumer Direct Marketing Act of 1976 contributed significantly to the rebirth of the local food movement (Hardesty, 2010). This act promoted the development of direct marketing of agricultural commodities from farmers to consumers and required the USDA to support state and local agricultural departments to promote direct marketing (Hardesty, 2010). This statute also created the USDA-AMS Farmers’ Market Promotion Program (FMPP), which supports direct agricultural marketing and farmers’ markets through grants and loan support. Funding for FMPP is allocated through the annual Farm Bill, which was projected to apportion $10 million for fiscal year 2011 and 2012 (Hardesty, 2010). Other government support and promotion of farmers’ markets include USDA’s “Know Your Farmer, Know Your Food Program,” which resulted in over 25 new government grant and loan programs. Among these grant programs are “farm-to-school programs” and “Women in Crisis (WIC) Farmers’ Market Nutrition Program” (USDA, 2012).

As a result of the Farmer-to-Consumer Direct Marketing Act, the number of farmers engaged in direct-to-consumer sales peaked in 1982, at levels nearly equivalent to those seen in 2007 (Low and Vogel, 2011). From 1982-1992, farms selling local foods directly to consumers
dropped significantly to its lowest reported level (Low and Vogel, 2011). From 1992-2007, direct market sales have increased steadily by 58% (Low and Vogel, 2011). Direct-to-market sales of local foods have been fueled by small farms. In fact, a 2008 Agricultural Resource Management Survey (ARMS) reported that small, local, food farms (gross farm sales less than $50,000) represented 81% of all local food farms (Low and Vogel, 2011). Among these small food producers, two-thirds of local food sales accounted for at least 75% of their total gross farm sales (Low and Vogel, 2011). Among small farms, local food sales (on average) gross $6,737 per farm annually through direct-to-consumer channels only, compared to medium sized farms (gross farm sales between $50,000-249,999) grossing $66,247 annually (Low and Vogel, 2011). In 2008, farmers’ markets represented 34% and 25% of small and medium-sized farm marketing outlets respectively, with roadside stands mostly accounting for the remainder of direct-to-consumer outlets (Low and Vogel, 2011). Farmers’ markets vary in size and in products sold, with the quantity of vendors at one market ranging from 2-40 or more. In a 2006 USDA survey, vendors located at markets containing 10-19 vendors saw 371 customers per week and earned an average of $971 per week (Ragland and Tropp, 2009).

The products sold at farmers’ markets will vary, since the sale of many agricultural products are seasonal. Many markets also may limit their vendors to “growers only” or may have specialized craft and other non-food sales to attract a larger customer base. In a 2006 market manager survey, 92% of market managers reported the sale of fresh fruits and vegetables at their markets, with 81% selling herbs and flowers and 45% selling meat or poultry (Ragland and Tropp, 2009). Among vendors at farmers’ markets, 45% sold fresh fruits and vegetables, 15% herbs and flowers, and 3.2% sold meat and poultry (Ragland and Tropp, 2009). This information suggests that although each farmers’ market may provide a variety of agricultural
products, very few vendors sell more unique items such as meat and poultry and dairy products. It is important to note that national statistics may not reflect the same trends in each state, as many states have larger infrastructure and customer base for certain agricultural products, such as access to small, USDA-exempt meat processors.

Although government support and funding is now more widely available for farmers’ markets and direct-to-consumer marketing programs, the increase in farmers’ markets is no doubt a result of social movements to support “local” food, as well as a fear or distrust of modern industrial farming. The term “local food” has origins in the “Slow Food” movement as well as organic agriculture; however the term “local” continues to be used in new and different ways that challenge the mainstream food system (Hand and Martinez, 2010).

**Farmers’ market research**

Although the occurrence of farmers’ markets in the U.S. is not new, research focusing on farmers’ market vendors, food quality, and food safety have begun to emerge. Much of what has been studied on farmers’ markets has originated from the national USDA farmers’ market surveys. A limited number of consumer preference studies also have been published in an effort to understand the motivations of consumers who eat and purchase local, organic, and farmers’ market products. However, as social progressive movements continue to evolve in the U.S., the motivations of farmers’ market consumers have continued to change.

Interestingly, the average demographic of farmers’ market patrons has remained relatively consistent in the past 20 years. A study performed in 1998 at six Tennessee farmers’ markets found that the typical farmers’ market patron was a 45 year old, or older, female with some college education (Eastwood et al., 1998; McGarry-Wolf et al., 2005). Similarly, in a 1995 survey of farmers’ markets in Maine, among the 220 patrons surveyed, 41% were between the
ages of 35-54, 71.3% were female, and 67% had a bachelor’s or advance degree (Kezis et al., 1998). In a more recent study performed in Iowa of over 4,000 farmers’ market patrons, the most frequently reported age was between 51-65 (Varner and Otto, 2007). In 2011, similar observations were reported in a study involving 281 farmers’ market patrons in Arkansas farmers’ markets, where 64% of patrons were 46 and older, 67% were female, and 62% had college or advanced degrees (Crandall et al., 2011). Identifying the demographics of farmers’ market patrons is an important piece to understand consumer preference and attitudes towards food. Although farmers’ markets represent a minimal portion of the agricultural market, farmers’ markets have become a significant source of food products for many Americans.

In a statewide study performed on 161 farmers’ markets in Iowa, 55,000 Iowans shopped at farmers’ markets every week, accounting for total annual sales of $21 million in 2004 (Varner and Otto, 2007). The USDA reported in 2006 that the average number of customers per week at farmers’ markets less than five years old were 430, with a total average of 959 customers per week amongst all farmers’ markets in the U.S. (Ragland and Tropp, 2009). As the quantity of patronage continues to increase at farmers’ markets across the country, the risks associated with purchasing fresh products directly from the farmer or vendor must be evaluated. Crandall et al. (2011) investigated consumer awareness and concerns about food safety at three Arkansas farmers’ markets and concluded that only 2-6% of respondents were concerned about harmful bacteria in food purchased at farmers’ markets. Pesticides were the biggest safety concern of Arkansas market patrons, with 76% believing that organic foods were safer than conventional food products. Additionally, 42% of Arkansas respondents stated they purchased foods at farmers’ markets because they wanted to support local farmers (Crandall et al., 2011).

Potentially hazardous foods, such as milk, meat, and poultry, are popular items sold at
farmers’ markets and require specific processing and handling to ensure the safety of the product. Due to the nature of those products sold at open air markets, it is questionable whether consumers value food safety when purchasing potentially hazardous foods at these venues.

Gwin and Lev (2011) investigated the behaviors of consumers who purchase meat and poultry at farmers’ markets in Oregon. Amongst patrons at three farmers’ markets, 27% purchased meat only, while 21% of patrons purchased meat and poultry at farmers’ markets (Gwin and Lev, 2011). Amongst those who purchased meat and poultry, only 12% listed food safety as a concern, with cost and inconvenience being the greatest limitation to meat and poultry purchases (Gwin and Lev, 2011). As local, state, and federal regulation move to meet the requirements necessary to ensure safety of farmers’ market food products, many markets and vendors will continue to provide a range of food products in which the quality and food safety is unknown.

Farmer’s market regulations

Regulation of farmers’ markets can vary drastically between and within states. Local public health and city/county regulations may add stipulations or more strict requirements for farmers’ markets. Pennsylvania, Maryland, and Oregon are a few states that proposed or passed recent legislation in an effort to form regulations for farmers’ markets. Pennsylvania has been viewed as a frontrunner in developing regulations for farmers’ markets with the recent release of the Pennsylvania Department of Agriculture (PDA) Act 106 (Anonymous, 2010c). Major focus points in this legislation are to provide more stringent regulation of food safety and the handling and selling of potentially hazardous foods at farmers’ markets (Anonymous, 2010d). Meat and poultry items make up a large portion of potentially hazardous foods sold at farmers’ markets, but only meat products (beef, lamb, pork) are required by federal law to be processed in a USDA-inspected facility (Anonymous, 2010d). Poultry however, can be grown and processed
by individual farmers under exemption status afforded to farmers by the Poultry Products Inspection Act (PPIA). Those farmers who are exempt can grow, process, and sell their individual poultry products at farmers’ markets without daily USDA inspection.

**Poultry processor grower exemptions**

The 1957 Wholesome Poultry Products Act (Public Law 90-492), which is more commonly known as the Poultry Products Inspection Act (PPIA), was passed by Congress to ensure that adulterated and misbranded poultry does not enter interstate or foreign commerce (Anonymous, 2003). This act requires any business that slaughters or processes poultry for use as human food must do so under federal or state inspection, unless that business meets exemption criteria. A processor who is deemed “exempt” qualifies to operate without the daily or bird-by-bird federal inspection (Anonymous, 2003). Additionally, inspectors do not have to be present during slaughter or processing of the poultry (Anonymous, 2003). Exemption status does not release processors from regulatory requirements. Instead, this approach still requires processors to manufacture poultry products that are not adulterated or misbranded, as dictated in the PPIA. In simplified terms, a product would be considered adulterated if it contained a substance injurious to health or it had been held, packed, or produced under insanitary conditions (Anonymous, 2003).

Poultry processors who raise, slaughter, and process no more than 20,000 poultry in a year are eligible to process under one exemption, and may fit into certain unofficial categories commonly used when interpreting the regulations. Processors can fall under a “Personal Use Exemption,” “Custom Slaughter,” “Producer/Grower 1,000 Limit,” Producer Grower – 20,000 Limit,” “Small Enterprise Exemption,” or “Retail Exemption.” Vendors who sell poultry at farmers’ markets may fall into one of the Producer Grower (PGOP) exemptions (USDA-FSIS,
To qualify for PGOP, the producer/grower must slaughter and process no more than 20,000 poultry on his or her premises, raised by him or her, in a calendar year. The poultry products must be distributed solely by the producer/grower within the state in which it was processed and the slaughter and processing must be conducted using sanitary standards that are sound, clean, and fit for human food production (USDA-FSIS, 2006).

In some circumstances, poultry growers may not have the facilities to slaughter and process their own poultry, and may rent the facilities or equipment from an exempt processor in order to process their own poultry (USDA-FSIS, 2006). In this instance, the grower may distribute no more than 20,000 whole, dressed carcasses or cuts annually (USDA-FSIS, 2006). Under this exemption, the poultry products will be considered misbranded if they do not bear the name of the product, ingredients, quantity in terms of weight or measures, name and address of manufacturer, handling statement, safe handling instructions, date of packing, and an exemption explanatory statement (USDA-FSIS, 2006). Any exempt poultry grower or processor can only operate under one exemption and must contact USDA-FSIS or state inspectors to claim exemption status (USDA-FSIS, 2006). Although exemptions free processors and growers of daily inspection, USDA-FSIS personnel are authorized to make inspections of exempt facilities annually and/or periodically to ensure they are in accordance with the law.

Farmers’ market outbreaks

Although farmers markets are responsible for a small portion of the agricultural product market, illnesses and outbreaks have been linked to numerous vendors selling food products at farmers’ markets. In July 2010, the Iowa Department of Public Health investigated more than 10 illnesses that were related to freshly prepared fruit and vegetable products sold at farmers’ markets (Schreck, 2010). In March 2010, the Washington Department of Agriculture and the
FDA recalled two farmers’ market cheese vendors selling cheese contaminated with *Listeria monocytogenes* (Anonymous, 2010b). Similarly, in 2003, Capital Health in Edmonton, Canada investigated an outbreak of *E.coli* O157:H7 which was linked to a cheese vendor at an Alberta farmers’ market (Anonymous, 2009). In this outbreak, 13 cases were confirmed after analysis showed identical outbreak strains linked to the same cheese sold at three farmers’ markets.

Although cheese produced from raw products appears to be a consistent source of outbreaks, foods typically not contaminated by pathogens have caused illnesses. In 2008, Alaskan health officials identified vendors selling frozen peas as the source of a *Campylobacter* outbreak in the Matanuska Valley (Anonymous, 2008). Another larger outbreak occurred in Iowa in 2010 where a Mexican food retail vendor sold salsa and tamales at five farmers’ markets. In this case, 25 individuals became sick with salmonellosis from salsa or guacamole (Anonymous, 2010d). Although traceability of farmers’ market food products would appear to be simplified, when compared to that of large food processors, an *E. coli* outbreak from a strawberry farm in Portland, Oregon in 2011 demonstrated the difficulty in tracking outbreaks related to foods sold at farmers’ markets. The strawberries, produced 20 miles southwest of Portland, were identified as the source of *E. coli* O157:H7 that sickened over a dozen individuals and led to the death of an elderly woman (Lies, 2011). Shortly after the outbreak was identified, investigators revealed that the strawberries had been distributed to 23 farm stands, 10 retail outlets, and 6 farmers’ markets. As part of the investigation, it was determined that of the hundreds of roadside stands and farmers’ market vendors in Oregon, only 100 were properly licensed to allow resale of fruit (Lies, 2011). This outbreak was a clear example of how decentralized and complex an outbreak or recall associated with farm stands or farmers’ markets products can be, as well as the risks, especially when there is limited or no food safety
regulations of direct-to-consumer sales.

**Needs assessments**

**Planning and conducting needs assessments**

Needs assessments have been defined by numerous researchers in many different disciplines. McCawley (2009) described needs assessments as “a systematic approach to studying the state of knowledge, interest, or attitude of a defined audience or group involving a particular subject.” Alternatively, Witkin and Altschuld (1995) describe needs assessments as “a systematic set of procedures undertaken for the purpose of setting priorities and making decisions about program or organizational improvement and allocation of resources.” In this sense, the needs assessment is organized towards identifying priorities based on identified needs (Witkin and Altschuld, 1995). In a general sense, needs assessments are tools that help identify a starting point and direction when designing new programs, surveys, and projects for a particular audience. The ultimate goal of a needs assessment is to identify “needs” which are considered to be discrepancies or gaps between “what is” and “what should be” (Kaufman, 1988). These needs are specific to the group studied and what is considered the present and desired state of affairs (Witkin and Altschuld, 1995).

In many cases, the same populations or groups have been repeatedly studied, so, it is questionable as to why needs assessments are necessary. One reason offered by Kaufman and Altschuld (1995) is that populations with little demographic differences, often seem similar, but in reality, perceive their needs as being very different from each other. Needs assessments are an important piece of social science research allowing the target audience to verify its own level of knowledge and skill, its interests and opinions, or its learning habits and preferences (McCawley, 2009). Needs assessments used for food safety education should focus on collecting data to
identify the “gaps” in order to move forward with developing and designing programs to address those needs.

Several methodologies exist for conducting needs assessments, and the steps taken can vary slightly depending on the process chosen. Such approaches include: writing objectives, selecting the audience, collecting data, selecting audience sample, picking an instrument, and analyzing data (McCawley, 2009). Needs assessments also can be organized or subdivided into phases, as described by Altschuld and Kaufman, (1995), where pre-assessment (exploration), assessment (data gathering), and post-assessment (utilization) phases allow for systematic movement from one step to another. Utilizing a phase system may be better suited for a research-based needs assessment, where data must be collected in a specific manner over a set period of time. Other needs assessment methodologies utilize four phases: beginning with planning and organizing, data collection, summarizing and disseminating the results, and sharing the results through public forums to facilitate action planning (Sharma et al., 2000). This methodology incorporates the “self-help” and inclusive participant interaction adopted from the Community Concerns Report Method developed by Schriner and Fawcett (1988). Due to the unique variables that may exist in examining the needs of different groups, it is at the discretion of the researcher to determine which needs assessment methods are most suitable.

Designing needs assessments begins with formulating objectives. One way of ensuring that objectives are measurable is to utilize the SMART method of writing objectives. In this acronym, objectives must be specific, measurable and meaningful, assigned, realistic, and timed or timely (Doran, 1981). In the case of needs assessments, it is also important to understand which needs will be explored. It is crucial to identify whether the needs will be felt (is known within the group), unfelt, (is not known to the group), or ascribed, (an artificial need that the
group may not have known existed) (Rothman and Grant, 1987). Once the group or audience and type of data have been identified, researchers must choose the method or instrument of data collection. Research in this realm typically utilizes one or a combination of four data collection instruments including: surveys, interviews, focus groups, and working groups (McCawley, 2009). Data sources used for needs assessments can be archival in nature, communicative, interactive, or analytic (Witkin and Altschuld, 1995). Records, logs, demographic data, and census data are all archival data sources that can be useful in understanding the target group before communicative or interactive forms of data collection are used (Witkin and Altschuld, 1995). Communicative data sources are typically in the form of surveys, questionnaires, and interviews, while interactive sources can be public forums, hearings, and focus groups (McCawley, 2009).

No matter which data collection tool is used, the planning process is crucial to minimize and eliminate error. Researchers must consider the effect of sampling and sample size, external and internal validity, as well as the reliability of the sampling methods and data collection. In many cases, such research does not lend itself to large sample sizes, which must be considered. Low participant responses are common for surveys which can make interpreting data difficult and inconclusive. Internal validity threats also can affect the quality of the data, since poorly worded or ambiguous questions can negatively affect the outcome of the data collection. Reliability of the data collection instrument is also important, as low reliability may cause large variations in responses from the same participants at different time points, possibly skewing the results.

One method used to test and identify problem areas are the utilization of pilot tests (McCawley, 2009) in which a random subset or hand-picked test group that may perform or use
the selected data collection tool to help identify unforeseen errors and issues. Pilot tests can help identify whether the tools are effective and if the data collected is useful; ultimately refining the data collection. As with any experimental design, the method of data analysis is crucial to draw valid conclusions. Needs assessment analysis should be incorporated into the planning phases. As McCawley (2009) states, “the effort needed to analyze your data is inversely proportional to the effort invested to plan and conduct the needs assessment.” Analysis can involve the determination of estimates or using actual results. Answers to questions can be weighted and open-ended questions can be analyzed by looking for key words or phrases. The use of surveys and questionnaires also may require intricate data entry systems to organize responses and track the progress of the assessment. Proper planning and utilization of applicable needs assessments methodologies and tools may provide researchers with valid and precise results to make good decisions based on identified needs.

**Human subject survey methodology**

Surveys are the best way to gather data from a population sample and allow for the organized collection of attitudes and opinions, knowledge, demographics, behavior, or relationships between chosen variables (Burges, 1976). Goals of conducting surveys can be to explain why a particular phenomenon is true, describe a population, compare selected variables and groups, or test relationships (Burges, 1976). Modern survey techniques have evolved in the last decade as the internet and technology have changed the way society communicates. Traditionally, three methods are used to conduct surveys: mailings, face-to-face, or telephone (McCawley, 2009). Web-based surveys also are another method that has become much more common place, with similarities to traditional mailings.
Although each survey method has advantages and disadvantages, mailings or web-based surveys are least appropriate, especially when discussion is used to stimulate involvement and the rate of return is low, depending on the target population and sample size (Burges, 1976). Mailings can provide a relatively inexpensive method to randomly sample large populations and eliminate the potential of interviewer bias or influence. Telephone interviews are an inexpensive method of surveying, yielding a greater rate of return, as many participants may feel more comfortable when interviewed “at a distance” (Burges, 1976). The use of random, digitized calling may ensure random sampling, and provide easy access to populations geographically separated or difficult to reach, while allowing the participant and interviewer to perform the survey from home (Burges, 1976). Face-to-face surveys or interviews can typically offer researchers a broad perspective on the target population as participants can be asked open-ended questions, allowing one to probe for further understanding (McCawley, 2009). Face-to-face surveys also allow the interviewer to clarify questions, view nonverbal cues of participants, and receive immediate feedback (McCawley, 2009). Face-to-face surveys, however, are much more complex to analyze and significant preparation must be taken to ensure that collected data can be analyzed in the desired manner.

**Statement of the problem**

Although poultry products from farmers’ markets have not been identified specifically as a source of foodborne outbreaks, many factors related to the processing and sale of these items make them a high-risk food product. It is unclear as to how exempt processors and growers are slaughtering, processing, transporting, and ultimately handling poultry products sold at farmers’ markets. It is suspected that exempt processors use minimal or no interventions in their poultry processing, which raises significantly the risk of contamination with *Salmonella* and
Campylobacter, potentially leading to infection in consumers.

Although the PDA has released stricter regulations for farmers’ market vendors, it is unknown what effect these regulations may have on poultry vendors, and how those policies will be enforced. There is growing concern that with the significant increase in farmers’ markets throughout Pennsylvania and the country, and the increase trend in purchasing locally grown foods, outbreaks originating from farmers’ markets will continue to increase. Research is needed to assess the microbiological quality and potential hazards of foods, such as poultry products sold at farmers’ markets. Likewise, the practices, knowledge, and attitudes of vendors must also be assessed. Research in these areas can be used to generate a comprehensive assessment of vendors selling meat and poultry, which could subsequently be used for Extension-based food safety educational programs in the near future.

Statement of objectives

This study will determine the prevalence of Campylobacter spp. and Salmonella spp. present in raw, whole chicken products obtained from farmers’ markets and supermarkets throughout the state of Pennsylvania, for a period of one year, including winter and summer farmers’ market seasons. Populations of generic E. coli, coliforms, and APC counts also will be determined for all poultry surveyed.

Data obtained from the first part of this study will be used to develop a needs assessment for farmers’ market vendors to assess vendor poultry processing practices, knowledge, and attitudes of towards food safety, poultry processing, and regulatory requirements. The needs assessment survey will be distributed on site to farmers’ market poultry vendors throughout the state of Pennsylvania. Surveys will be completed during market hours at each vendor’s respective farmers’ market. If vendors require additional time to consider participating in the
survey, they will be provided a survey and pre-addressed and stamped envelope to mail completed surveys back to the Food Science Department at Penn State. The data obtained from both the microbiological and vendor surveys will aid in the development of future farmers’ market research, as well as to help generate recommendations, guidelines, fact sheets, and outreach material on food safety issues for vendors selling meat and poultry products at farmers’ markets.
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Figures

Figure 1: Conventional poultry processing flow diagram adapted from Mead (2004)
Chapter 2
A microbiological comparison of poultry products obtained from farmers’ markets and supermarkets in Pennsylvania
Abstract

The popularity of farmers’ markets in the United States (U.S.) continues to rise, with an increase from 1,755 in 1994 to 7,175 in 2011. Potentially hazardous foods, such as raw poultry products sold at farmers’ markets, are of particular concern due to the U.S. Department of Agriculture (USDA) inspection exemption status afforded to many poultry vendors. Currently, little to no data have demonstrated the microbiological profile of poultry (chicken or turkey) sold at farmers’ markets and/or compared the findings to conventionally-processed, organic and non-organic poultry sold in supermarkets. The purpose of this study was to determine the presence/absence of foodborne pathogens, as well as hygiene indicators, in fresh or frozen chicken purchased at farmers’ market and conventionally-processed, organic and non-organic chicken sold in supermarkets. Whole chicken carcasses from farmers’ markets and supermarkets throughout Pennsylvania were obtained and transported to the Penn State Muscle Foods Laboratory at 4°C until further analysis. Each chicken carcass was rinsed and levels of aerobic plate counts (APC), generic *Escherichia coli* and total coliforms were measured. Resulting rinses also were evaluated for presence/absence of *Campylobacter* spp. and *Salmonella* spp. following standard culture and confirmation methods. Results demonstrated that 28% (28/100) and 90% (90/100) of chicken from farmers’ markets, 20% (10/50) and 28% (14/50) of conventionally-processed organic, and 8.0% (4/50) and 52% (26/50) of non-organic chicken, were positive for *Salmonella* spp. and *Campylobacter* spp. respectively. Additionally, among the 90% of *Campylobacter* spp. positive farmers’ market poultry, 67% of rinses were enumerable, with a mean count of 1.6 log_{10} CFU/ml. These data suggest that poultry purchased from farmers’ markets in Pennsylvania were more likely to be contaminated with *Salmonella* spp. and *Campylobacter* spp., as compared to conventionally-processed poultry sold at supermarkets.
Introduction

Throughout the U. S., and in the last decade, Americans are purchasing food products from farmers’ markets at a significantly increasing rate (Ragland and Tropp, 2009). Farmers’ markets are typically public areas where farmers, processors, and local entrepreneurs sell a variety of agricultural products and crafts directly to consumers. The popularity of farmers’ markets in the U. S. continues to rise, with an increase from 1,755 in 1994 to 7,175 in 2011 (Anonymous, 2011c). Farmers’ markets are not a new phenomenon, having been active in the U. S. for over 50 years. The resurgence of farmers’ markets reflects changes in government and consumer attitudes towards locally-produced foods. As such, research focusing on farmers’ market vendors, food quality, and food safety, have begun to emerge. Although farmers’ markets represent a minimal portion of the agricultural market, farmers’ markets have become a significant source of food products for many Americans. The USDA reported in 2006 that the average number of customers per week at farmers’ markets, operating less than 5 years, was 430, with an average of 959 customers per week amongst all farmers’ markets in the U. S. (Ragland and Tropp, 2009). As patronage continues to increase at farmers’ markets across the country, the risks associated with purchasing fresh products directly from the farmer or vendor must be evaluated. Potentially hazardous foods, such as raw milk, produce, as well as fresh meat and poultry, are popular items sold at farmers’ markets and require specific processing and handling measures to ensure the safety of the product. Due to the nature of those products sold at these venues, it is questionable whether consumers and vendors value food safety when purchasing these products. Poultry are one such hazardous food item, posing an even greater risk due to the exemption status afforded to many poultry processors and growers. Under the Poultry Product Inspection Act (PPIA), poultry processors who raise, slaughter, and process no more than 20,000
poultry in a year, are eligible to process without daily and bird-by-bird USDA inspection.

Foodborne pathogens continue to be a major cause of human disease in the U. S., with over 9.4 million illnesses, 55,961 hospitalizations, and 1,351 deaths reported in 2010 (Scallan et al., 2011). Among the 3.6 million illnesses caused by bacteria, non-typhoidal *Salmonella* and *Campylobacter* continue to be the leading cause of bacterial foodborne illnesses in the U.S. Both of these pathogens are commonly associated with poultry and pose a significant risk to consumers who do not properly handle and prepare raw poultry products. Industry efforts to control pathogens in poultry include numerous antimicrobial intervention processes, such as chlorinated- and organic acid-poultry washes, precise control of chilling and storage temperatures, and numerous pre-harvest measures to reduce the total pathogen load in live poultry prior to slaughter. It is unknown whether poultry vendors at farmers’ markets are utilizing preventative measures to reduce pathogens, and whether they are taking necessary measures to reduce food safety hazards in their products. Additionally, it is unclear as to how exempt processors and growers are slaughtering, processing, transporting, and ultimately, handling poultry products sold at farmers’ markets. It is presumed that exempt processors use minimal or no interventions during poultry processing, which raises significantly the risk of contamination with *Salmonella* and *Campylobacter*, potentially leading to infection in consumers. Although the Pennsylvania Department of Agriculture (PDA) has released stricter regulations for farmers’ market vendors, it is unknown what effect these regulations may have on poultry vendors or how those policies will be enforced. There is growing concern that with the significant increase in farmers’ markets throughout Pennsylvania and the country, and the increasing trend to purchase locally grown foods, outbreaks originating from farmers’ markets will rise. Therefore, research is needed to assess the microbiological quality and potential
hazards of foods, such as poultry products sold at farmers’ markets. This study will determine the prevalence of *Campylobacter* spp. and *Salmonella* spp. present in raw, whole chicken products obtained from farmers’ markets and supermarkets throughout the state of Pennsylvania, for a period of one year, including winter and summer farmers’ market seasons. Populations of generic *E. coli*, coliforms, and aerobic plate counts (APC) will also be determined for all poultry surveyed.

**Methods**

**Identification of farmers’ market poultry vendors in Pennsylvania**

Although efforts to produce national and state farmers’ market directories are compiled by the USDA Agriculture Marketing Service (USDA-AMS, 2012), much of the advertising and production of farmers’ market directories have been performed by non-profit and private organizations. Due to the grassroots and local nature of many farmers’ markets, detailed descriptions of farmers’ markets and their associated market managers, vendors, hours of operation, location, and products offered are not always available or updated via the internet. Therefore, this study utilized multiple sources to identify farmers’ markets throughout Pennsylvania.

Farmers’ markets in Pennsylvania were identified using multiple web sites containing farmers’ market directories and information, as well as word of mouth, brochures, and advertisements posted in local media sources. The three primary internet sources used to locate farmers’ markets were *Buy Fresh, Buy Local* (http://www.buylocalpa.org/), *Local Harvest* (www.localharvest.com), and the USDA-AMS Farmers’ Market Search (http://search.ams.usda.gov/farmersmarkets/). All of these web sites are dedicated to compiling and listing information on farmers’ markets within Pennsylvania and throughout the country. *Buy Fresh, Buy Local* is
managed by the Food Routes Network, which is described on their web site as, “a national nonprofit organization that provides communications tools, technical support, networking and information resources to organizations nationwide that are working to rebuild local, community-based food systems” (Anonymous, 2011). Local Harvest is headquartered in Santa Cruz, California, founded by Guillermo Payet, a software engineer and activist, and the web site is self-described as, “a definitive and reliable ‘living’ public nationwide directory of small farms, farmers’ markets, and other local food sources” (Anonymous, 2011b). The USDA-AMS farmers’ market search engine continues to be updated and provides a comprehensive farmers’ market directory and market information collected from national USDA farmers’ market surveys (USDA-AMS, 2012).

Due to the turnover of market managers, change in vendors, variability in products sold by vendors, and changes in hours of operations and locations, it is difficult for farmers’ market directories to provide complete up-to-date information. Therefore, this study identified the existence of farmers’ markets using those previously identified web sites, verified information by contacting market managers, searching for individual market web sites, utilizing word of mouth, and visiting identified markets. Those farmers’ markets with poultry vendors also were identified in the same manner, although in many cases, poultry vendors did not advertise the sale of poultry or their vendor information was not updated on the selected web sites. Therefore, visitation of farmers’ markets with poultry vendors was the primary method for verification.

In this study, 25 farmers’ markets in Pennsylvania accommodated approximately 44 poultry vendors. This sampling does not reflect the total prevalence of farmers’ markets and poultry vendors in Pennsylvania, since more poultry vendors may be identified as online farmers’ market directories are updated. Due to time and budget constraints, the first 21 vendors
verified to sell poultry at farmers’ markets were chosen for microbiological sampling, representing 17 cities across Pennsylvania.

Poultry vendors selected for microbiological sampling were defined as those vendors who sold poultry that were either raised or processed by the vendor or other non-commercial poultry farmer. For the purposes of this study, only those vendors who sold whole-bird chicken carcasses were utilized for microbiological sampling. Label claims made by vendors such as “Organic Chicken” were recorded, however due to the unregulated nature of those claims, all farmers’ market poultry were sampled as one group. Among the 21 selected vendors, all vendors provided a sign, brochure, or advertisement at their stand describing their poultry products. To verify those advertised claims, vendors were asked whether their poultry products were produced or raised in a non-commercial manner, before the time of sale. Poultry vendors selling commercially processed or wholesale poultry products were excluded from the microbiological sampling.

Identification of supermarkets containing conventionally processed organic and non-organic poultry in Pennsylvania

A total of five supermarkets selling conventionally-processed or organically-processed chicken were selected for microbiological sampling. Among the five supermarkets selected, two sold only conventionally-processed or organically-processed chicken, while one supermarket sold both types. These supermarkets were selected based on the following criteria: met the USDA-ERS definition of a supermarket (USDA-ERS, 2009), the availability of whole chickens, locations in multiple states, and their proximity to The Pennsylvania State University.

Among the whole chickens selected, five separate, conventionally-processed brands were sampled from three supermarkets, and three separate, organically-processed brands were
sampled from three supermarkets. The use of multiple supermarkets and multiple brands was selected to ensure one brand and supermarket did not account for the majority of variance within each whole chicken sampled. Although multiple organic whole chicken brands were sampled in this study, all of the organic whole chicken brands were labeled as being processed under air chilled conditions on the immediate packaging. Alternatively, none of the conventionally processed whole chicken brands contained labels specifying chilling conditions during processing.

Sample collection-chicken

Fresh and frozen chickens purchased from farmers’ markets and supermarkets throughout Pennsylvania, were placed into rolling transportable coolers containing crushed ice, and transported to the Penn State Muscle Foods Microbiology Laboratory. Whole chickens were additionally wrapped in a secondary plastic bag to avoid contact with cooler ice. Upon arrival at the laboratory, whole chickens were transferred from coolers, and kept refrigerated (4°C) or frozen (-20°C), until analyzed. Fresh chickens were analyzed within 24 hours of purchase, while frozen chickens were kept frozen until analysis (< 7 days). Frozen chickens were thawed for approximately 72 hours at 4°C prior to analyses. Chickens were stored in the original packaging and secondary shopping bag or packaging that was provided by the vendor or retailer at the time of sale.

Poultry rinse

Chickens were removed from their packaging using aseptic technique and placed into sterile, chicken-rinse bags (Nasco, Fort Alkinson, WI). Approximately 400 ml of sterile buffered peptone water (BPW; Becton Dickinson and Company, Sparks, MD) were poured into and around the surface of the chicken and the chicken rinsed for approximately 1 min in an arcing
motion, thereby assuring that all surfaces of the chicken were rinsed (USDA-FSIS, 2012). The chicken was removed from the bag using aseptic technique, the chicken rinse was transferred to a sterile container, and stored at approximately 4°C until further analysis.

**APC, generic *E. coli*, and coliform enumeration**

APC, generic *E. coli*, and coliform counts were determined using 3M APC and *E. coli*/Coliform Petrifilm (3M Microbiology Products, Minneapolis, MN). Chicken rinses were serially diluted in sterile BPW and plated in duplicate onto APC and *E. coli*/Coliform Petrifilm in accordance with the manufacturer’s instructions and incubated for 48 hours at 35°C. Colony counts were calculated automatically using the 3M Petrifilm Plate reader (3M Microbiology Products, Minneapolis, MN)

**Salmonella spp. enumeration, isolation, and confirmation**

Isolation of *Salmonella* spp. was performed by combining 30 ml of individual chicken rinses with 30 ml of sterile Lactose Broth (LB; BD) and incubated at 37°C for 24 hours. One ml of LB and chicken rinse solution was transferred to 10 ml of Tetrathionate Broth (TT; BD) and 10 ml of Selenite Cystine Broth (SC; BD), in duplicate, with each set of tubes incubated at 37°C or 42°C for 24 hours, to select for non-thermophilic and thermophilic *Salmonella* spp. respectively. Following incubation, a loopfull of inoculated TT and SC broths were streaked, in duplicate, onto Xylose Lysine Deoxcholate Agar (XLD; BD) and incubated at 37°C for 24 hours. Presumptive colonies were picked and re-streaked onto Tryptic Soy Agar (TSA; BD), and incubated at 37°C for 24 hours. Presumptive *Salmonella* spp. colonies were confirmed using the Oxoid Salmonella Latex Agglutination Test kit (Oxoid Ltd., Basingstoke, Hampshire, England). Confirmed colonies were re-streaked onto TSA slants, incubated at 37°C for 24 hours, and held under refrigeration (4°C) until species identification. *Salmonella* enumeration was performed by
spread plating 100 µL of chicken rinse directly onto XLD, in duplicate and incubating at 37°C for 24 hours. *Salmonella* colonies were counted manually and confirmed using the Oxoid Salmonella Latex Agglutination Test kit.

**Campylobacter spp. enumeration, isolation, and confirmation**

Isolation of *Campylobacter* spp. was performed by combining 30 ml of individual chicken rinses with 30 ml of sterile, double strength Bolton Broth (Remel, Lenexa, KS) and incubating at 42°C for 48 hours under microaerophilic conditions (5.0% O₂, 10% CO₂, 85% N₂) using a CO₂ incubator (VWR International, West Chester, PA) supplied with a constant infusion of bone dry CO₂ gas. Following incubation, a loopful of the inoculated Bolton Broth and chicken rinse were streak-plated, in duplicate, onto modified Charcoal Cefoperazone Deoxycholate agar (mCCDA; Remel), and incubated at 42°C for 24-72 hours under microaerophilic conditions. Streaked mCCDA plates showing no growth after 24 hours were incubated further for 48-72 hours, as necessary. No growth after 72 hours was considered a negative result. Gray-colored colonies were selected and streaked onto Brucella Agar (BA; BD) and incubated at 42°C for 24-72 hours under microaerophilic conditions. Presumptive colonies were picked from BA and confirmed using the Microgen Campylobacter Agglutination Test Kit (Microgen Bioproducts Limited, Surrey, UK). Colonies confirmed by the agglutination test kit were further confirmed by Gram-staining for corkscrew morphology. *Campylobacter* spp. enumeration was performed by spread plating 100 µL of each chicken rinse, in duplicate onto mCCDA and incubated at 42°C for 24-72 hours under microaerophilic conditions. *Campylobacter* colonies were confirmed using agglutination. Colonies confirmed by agglutination and Gram-staining were frozen for species confirmation by transferring individual colonies to 10 ml of Brucella Broth (BB; BD) and incubating at 42°C for 48 hours. BB was
inoculated with 1.2 ml of the suspended culture, transferred to a 2.0 ml freezer vial and combined with 400 µL of sterile defibrinated sheep blood (PML Microbiologicals, Wilsonville, OR) and 200 µL of 10% glycerol (VWR). The solution was mixed gently and stored at -80°C for future use.

**Salmonella spp. serotyping**

Isolated colonies confirmed to be *Salmonella* spp. by latex agglutination were streaked onto TSA slants, incubated at 37 ºC for 24 h, refrigerated at 4ºC and shipped to the University of Pennsylvania, School of Veterinary Medicine (New Bolton, PA) for serotyping.

**DNA extraction**

Frozen isolated cultures of confirmed *Campylobacter* spp. were regrown by transferring a small amount of frozen culture stock into 10 ml of sterile BB and incubating at 42ºC for 48 hours under microaerophilic conditions (5.0% O₂, 10% CO₂, 85% N₂). Template DNA was prepared by transferring 1 ml of inoculated BB to a sterile microcentrifuge tube and centrifuging at 13,000 x g for five minutes. The bacterial pellet was re-suspended in 500 µL of sterile distilled water and heated at 100°C for 20 minutes. The suspension was centrifuged at 13,000 x g for five minutes and the supernatant containing the DNA was used for PCR assays as described below.

**Campylobacter spp. PCR assays**

Primers were selected for *C. jejuni*, and *C. coli* utilizing previously developed and tested primer sequences. Primer sequences for *C. jejuni* were derived from the *mapA* gene, a 24-kDa membrane-associated protein A that is species-specific and used successfully in the serological discrimination between *C. jejuni* and *C. coli* (Stucki et al., 1995). Amplification of the *mapA* gene produces a 589 bp fragment. Primer sequences utilized for *C. coli* amplified a 462 bp fragment originating from the *ceuE* gene, encoding a 34.5-36.2 kDa lipoprotein component of a
transport system specific for the siderophore enterochelin (Gonzales et al., 1997). Amplification of the *mapA* and *ceuE* genes utilized individual PCR assays. Reaction contents (11-µ total reaction volume) consisted of 3.0 µL of template DNA, extracted as described above: 0.5 µM of primers (Penn State University Nucleic Acid Facility, University Park, PA), 0.18 mM concentration of each of the four dNTPs, 2 or 3mM of MgCl₂, 0.4 U of *Taq* DNA polymerase (Epicentre Biotechnologies, Madison, WI), and 50 mM Tris buffer (Epicentre Biotechnologies). The PCR was performed using the Eppendorf Mastercycler Pro Thermocycler (Westbury, NY), consisting of 30 cycles of template denaturation at 94°C for 40s, primer annealing for *C. jejuni* at 58°C for 30s and extension at 74°C for 35s. *C. coli* primer annealing was performed at 46°C for 30s and primer extension at 72°C for 30s. Each assay was analyzed using gel electrophoresis in a 1% agarose gel at 200v for 30 min. Gels were stained with 0.1 µg/ml ethidium bromide and visualized under UV light. Samples identified as positive were those with the presence of bands at the expected bp sizes.

**Statistical analysis**

All bacterial populations were converted to log<sub>10</sub> CFU/ml for analysis and transformations of data were performed as necessary to meet the assumptions of the statistical test. Analysis of statistical tests were performed using SAS (SAS software, Version 9.3

Copyright © 2012, SAS Institute Inc., Cary, NC, USA). Comparisons of hygiene indicators between conventional, organic, and farmers’ market chicken were determined using ANOVA with Tukey’s HSD at α = 0.05. To determine if differences existed between percent positive *Salmonella* and *Campylobacter*, a test for difference between proportions was performed with α = 0.05. In cases where there was a zero count on duplicate plates, a count of 1.0 CFU/ml was assigned to allow for count conversion to log<sub>10</sub> CFU/ml.
Results

APC, generic *E. coli*, and total coliforms

In this study, a total of 200 whole chickens and subsequent rinses were obtained after purchase from farmers’ markets and supermarkets across Pennsylvania. A mean APC count of 4.1±1.1 log_{10} CFU/ml was obtained from farmers’ market whole chicken rinses, which were found to be significantly higher than conventionally processed whole chicken rinses with a mean APC count of 2.9±0.4 log_{10} CFU/ml (Table 1). Mean APC counts obtained from organically processed whole chicken rinses were 2.8±0.7 log_{10} CFU/ml, and were not found to be statistically different from farmers’ market chicken. Mean generic *E. coli* counts between all groups were shown to be statistically different, with organic chicken rinses exhibiting the highest mean count of 1.3±0.7 log_{10} CFU/ml. Mean total coliform counts from both farmers’ market, 1.5±0.9 log_{10} CFU/ml, and organically processed chicken rinses, 1.5±0.7 log_{10} CFU/ml, were found to be statistically higher than mean total coliform counts of 0.9±0.6 log_{10} CFU/ml, from conventional chicken rinses.

*Salmonella* spp. and *Campylobacter* spp. prevalence

Twenty-eight percent (28%) of chicken obtained from farmers’ markets were positive for *Salmonella* spp., which was not significantly different than the prevalence of 20% found in organically-processed chicken. *Salmonella* spp. prevalence in both farmers’ market and organic chicken however, were found to be significantly higher than that of conventional chicken, exhibiting a prevalence of 8.0%. Among the three groups evaluated in this study, only farmers’ market chicken rinses exhibited enumerable concentrations of *Salmonella* spp., which were found to contain a mean concentration of 1.1±0.2 log_{10} CFU/ml (Table 3).
Among the three groups of chickens sampled, farmers’ market chicken carcasses were found to have the highest prevalence of *Campylobacter* spp. (Table 2). Conventionally-processed chicken exhibited the second highest prevalence rate with 52% of rinses positive for *Campylobacter* spp., which was significantly higher than the 28% prevalence of *Campylobacter* spp. in organically-processed chicken. Within the 90 *Campylobacter* spp.-positive farmers’ market whole chicken rinses, 60 were found to harbor enumerable *Campylobacter* spp. with concentrations higher than 1.0 log$_{10}$ CFU/ml (Table 3). Among the 60 enumerable farmers’ market rinses, a mean of 1.6±0.5 log$_{10}$ CFU/ml of *Campylobacter* spp. was determined. Twenty-two percent (22%) of *Campylobacter* spp.-positive, organic chicken contained enumerable *Campylobacter* spp. concentrations, with a mean of 1.2±0.3 log$_{10}$ CFU/ml. Conventionally processed chicken rinses were positive for *Campylobacter* spp., yet did not yield concentrations higher than 1.0 log$_{10}$ CFU/ml, and only 1 out of the 50 samples were enumerable. See Appendix D for *Salmonella* serotype identification of isolates and Appendix E for a breakdown of pathogen prevalence amongst whole chicken obtained from specific farmers’ market vendors in Pennsylvania.

**Pathogen prevalence in fresh versus frozen chicken**

Within the farmers’ market obtained chicken rinses, 60 were purchased as fresh products, while 40 were frozen. Variability in the prevalence of non-enumerable and enumerable positive *Campylobacter* spp. and *Salmonella* spp. chicken rinses were observed between fresh and frozen rinses (Table 4). Both fresh and frozen rinses exhibited a high prevalence rate of *Campylobacter* spp., with 93% of fresh rinses and 85% of frozen rinses positive for *Campylobacter* spp., however these prevalence rates were not statistically different. Seventy-five percent (75%) of fresh chickens exhibited enumerable *Campylobacter* spp. which was significantly higher when
compared to frozen rinses (38%). Prevalence of \textit{Salmonella} spp.-positive chicken rinses were not found to be statistically different, with fresh and frozen chicken rinses exhibiting non-enumerable \textit{Salmonella} spp. positive prevalence of 32% and 23% respectively.

\textbf{Discussion}

\textbf{Hygiene Indicators}

APC, generic \textit{E. coli}, and total coliforms counts were utilized as hygiene indicators to evaluate and gauge the microbiological profile of raw, fresh and frozen, whole chickens. Hygiene indicators such as generic \textit{E. coli}, or commonly referred to as \textit{E. coli} Biotype 1 in USDA-FSIS regulations, are typically measured to assess the effectiveness of sanitation practices and potential fecal contamination on meat and poultry products (Anonymous, 1995). In this study, APC, generic \textit{E. coli}, and total coliform counts were found to be statistically higher in farmers’ market chicken rinses, when compared to conventionally-processed chicken rinses (Table 1). Total coliform counts in farmers’ market chicken rinses were not statistically higher than organically-processed chicken rinses; however organically-processed chicken rinses were found to contain significantly higher counts of generic \textit{E. coli} and total coliforms compared to conventionally-processed chicken rinses. These results may suggest that differences in processing conditions such as air chilling versus water chilling or organic acid versus chlorine-based antimicrobial treatments, could significantly alter the levels of generic \textit{E. coli} and coliforms on whole chicken carcasses. A study by Northcutt et al. (2006) found APC and \textit{E. coli} counts of post-chill chicken carcass rinses of 3.2 log_{10} CFU/ml and 1.7 log_{10} CFU/ml respectively. These counts were lower than those found in farmers’ market chicken rinses, yet are slightly higher than those found in conventional and organic chicken sampled in this study. In another study, Blank and Powell (1995) reported standard plate counts of 3.7 log_{10} CFU/ml
from post-chill chicken carcasses, which also were lower than APC counts from farmers’ market chicken rinses evaluated in this study. Norberg (1981), reported 45% of frozen retail chicken had APC above $10^5$ bacteria per ml, as well as 62% of the chickens having coliform counts above $10^2$ bacteria per ml, suggesting that high APC and coliform counts can occur in conventionally-processed retail chicken.

The higher counts of APC, generic E. coli, and total coliform found in farmers’ market chicken rinses may suggest a lack of antimicrobial interventions during processing, leading to higher and variable levels of background microflora. Difference in counts between farmers’ market, conventional, and organic chicken rinses also may reflect the variability observed between fresh and frozen chickens. The data also may reflect the variability in processing methods employed for chickens sold at farmers’ markets, versus methods employed for conventional or organic chicken processing.

**Salmonella spp. and Campylobacter spp. prevalence**

In the current study, chicken obtained from farmers’ markets had significantly higher counts of *Salmonella* spp. and *Campylobacter* spp., when compared to conventional or organic chicken purchased at supermarkets (Table 2). Twenty-eight percent (28%) of farmers’ market chicken rinses were *Salmonella* spp.-positive, which was significantly higher when compared to conventional chicken containing 8.0% positive. *Salmonella* spp. prevalence in organic chicken was not significantly different from farmers’ market chicken (Table 2). *Salmonella* spp. prevalence in farmers’ market chicken rinses also were higher than reported in several previous studies on raw retail chicken. Meldrum et al. (2005) reported a 5.0% *Salmonella* prevalence from raw, retail chicken products sampled in the U.K, which was similar to that found in conventional chicken rinses in the current study, but lower than those reported in organic
chicken. The figures reported by Meldrum et al. (2005) are also in agreement with Zhao et al. (2001) who reported a 4.0% *Salmonella* prevalence in raw retail chicken products obtained in the greater Washington D.C. area. Most recently, the NARMS (2010) report identified a 13% *Salmonella* prevalence in retail chicken breast obtained from multiple states. *Salmonella* spp. prevalence in conventional chicken sampled in the current study are in general agreement with previously reported figures; however differences between previously reported *Salmonella* prevalence in raw retail chicken products may be due to the varied sampling methodologies and the variability among chicken brands sampled. Nevertheless, it appears that the *Salmonella* spp. prevalence in farmers’ market chicken products were consistently higher than conventional chicken found in this study and are in agreement with prevalence rates previously reported from raw retail chicken sampled in other published studies.

The 90% prevalence rate of *Campylobacter* spp. in farmers’ market rinses also were found to be higher than previously reported in conventional, retail, raw chicken products. Zhao et al. (2001) reported a 71% prevalence rate of *Campylobacter*-positive chicken obtained from retail stores in the greater Washington, D.C area. In a three-year surveillance study performed in the United Kingdom, Meldrum et al. (2005) reported a *Campylobacter* prevalence of 69% in 2004, from fresh and frozen, raw whole chicken purchased at retail. The data reported by Meldrum et al. (2005) is in agreement with Zhao et al. (2001), and the lower prevalence of *Campylobacter* spp. in conventional and organic chicken reported in this study, may be due to differences in sampling and sample size. These studies also report prevalence rates closer to those found in conventional and organic chicken rinses in the current study, but may highlight the variability of *Campylobacter* prevalence in retail chicken. Alternatively, in a recent National Antimicrobial Resistance Monitoring System (NARMS) report (FDA, 2010), *Campylobacter*
prevalence in chicken breasts sampled from 12 states was found to be 38%, a lower prevalence than that reported from farmers’ market chicken purchased for this study. Cui et al. (2005) examined the prevalence of *Campylobacter* in organic and conventional retail chicken and reported little differences between the two groups, with a *Campylobacter* prevalence of 76% in organic and 74% in conventional chicken. Differences between previously reported *Campylobacter* prevalence in raw retail chicken products and conventional and organic chicken reported in the current study may reflect the variability in sampling methods and analysis, as well as differences in processing between chicken brands. The lower *Campylobacter* spp. prevalence rates in conventional chicken found in this study, as well as the recent NARMS report, also may represent the recent success in controlling *Campylobacter*.

**Pathogen prevalence in fresh versus frozen farmers’ market chicken**

In this study, farmers’ market obtained whole chicken carcasses were either purchased as fresh or frozen. Chicken obtained from supermarkets were purchased as fresh. However, only a small portion of those whole chicken products were labeled as “fresh never frozen.” Therefore, it is unknown whether the conventional and organic chicken were frozen at one point. Therefore, fresh versus frozen comparisons were only performed on farmers’ market chicken in which the storage temperatures were verified. *Campylobacter* spp. and *Salmonella* spp. prevalence between farmers’ market, fresh and frozen chicken were not significantly different from one another, suggesting that freezing may not reduce either pathogen to non-detectable levels. Significant differences were found between the number of chicken rinses containing enumerable *Campylobacter* spp. concentrations above 1.0 log_{10} CFU/ml in frozen versus fresh chicken obtained from farmers’ markets. Seventy-five percent (75%) of fresh farmers’ market chicken were found to contain *Campylobacter* spp. at levels higher than 1.0 log_{10} CFU/ml, which was
significantly higher than frozen rinses, which exhibited a 38% positive rate for *Campylobacter* spp. This observation may suggest that freezing raw chicken may not reduce *Campylobacter* spp. to undetectable levels, yet the lower storage temperatures may reduce higher populations of *Campylobacter* spp. present on the raw chicken. These conclusions are in agreement with Ritz et al. (2007), who observed a 0.6-3.2 log reduction in *Campylobacter* on chicken meat stored at -20°C.

**Conclusions**

This study demonstrated that significant differences in *Campylobacter* spp. and *Salmonella* spp. prevalence exist between chicken purchased at farmers’ market and conventional and organic chicken purchased in retail supermarkets throughout Pennsylvania. The data also suggest that the microbiological profile of organic chicken obtained from supermarkets is similar to non-organic, conventional chicken. This study demonstrated that the majority of chicken sampled from farmers’ markets were contaminated with *Campylobacter*, while a portion of chicken also were contaminated with *Salmonella*. The data obtained from this study suggest that vendors selling chicken at farmers’ markets may not be processing chicken in a hygienic manner or processors may not be using any antimicrobial interventions to reduce pathogens in their products. This study demonstrates the rationale for further research into potentially hazardous foods sold at farmers’ markets and the need for farmers’ market vendor food safety training. The information gathered in this study may be of interest to regulatory officials who are responsible for local, state, or federal regulations directed at farmers’ markets and possible food safety training programs for vendors.
References


Ragland, E. and D. Tropp. 2009. USDA national farmers market manager survey, USDA-ARS.


### Tables

Table 1: Log$_{10}$ CFU/ml of Aerobic Plate Count (APC), generic *E. coli*, and coliform counts from chicken carcass rinses obtained from farmers’ markets and supermarkets in Pennsylvania.

<table>
<thead>
<tr>
<th>Number of Vendors/Brands</th>
<th>Farmers’ Market</th>
<th>Conventional</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Vendors/Brands</td>
<td>21 Vendors (n=100)</td>
<td>5 Brands (n=50)</td>
<td>2 Brands (n=50)</td>
</tr>
<tr>
<td>APC</td>
<td>4.1±1.1$^A$</td>
<td>2.9±0.4$^B$</td>
<td>2.8±0.7$^B$</td>
</tr>
<tr>
<td>Generic <em>E. coli</em></td>
<td>0.9±0.8$^B$</td>
<td>0.5±0.5$^C$</td>
<td>1.3±0.7$^A$</td>
</tr>
<tr>
<td>Total coliforms</td>
<td>1.5±0.9$^A$</td>
<td>0.9±0.6$^B$</td>
<td>1.5±0.7$^A$</td>
</tr>
</tbody>
</table>

$^A,^B,^C$ Different capital letters within a row represent significant difference at $\alpha = 0.05$
Table 2: Prevalence and percentage of *Campylobacter* spp.- and *Salmonella* spp.- positive, chicken carcass rinses obtained from farmers’ markets and supermarkets in Pennsylvania using conventional culture methods.

<table>
<thead>
<tr>
<th></th>
<th>Farmers’ Market</th>
<th>Conventional</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Vendors/Brands</td>
<td>21 Vendors (n=100)</td>
<td>5 Brands (n=50)</td>
<td>2 Brands (n=50)</td>
</tr>
<tr>
<td>Confirmed <em>Salmonella</em> spp.</td>
<td>28/100 (28%)(^A)</td>
<td>4/50 (8.0%)(^B)</td>
<td>10/50 (20%)(^{AB})</td>
</tr>
<tr>
<td>Confirmed <em>Campylobacter</em> spp.</td>
<td>90/100 (90%)(^A)</td>
<td>26/50 (52%)(^B)</td>
<td>14/50 (28%)(^{C})</td>
</tr>
</tbody>
</table>

\(^{A,B,C}\) Different capital letters within a row represent significant difference at \(\alpha = 0.05\)
Table 3: Prevalence and mean bacterial concentrations of enumerable *Campylobacter* spp.-and *Salmonella* spp.-positive, chicken carcass rinses obtained from farmers’ markets and supermarkets in Pennsylvania using conventional culture methods.

<table>
<thead>
<tr>
<th></th>
<th>Farmers’ Market*</th>
<th>Conventional*</th>
<th>Organic*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of Vendors/Brands</strong></td>
<td>21 Vendors (n=100)</td>
<td>5 Brands (n=50)</td>
<td>2 Brands (n=50)</td>
</tr>
<tr>
<td><strong>Confirmed</strong>&lt;br&gt;<em>Salmonella</em> spp.</td>
<td>6/100 (6.0%)&lt;br&gt;(1.1±0.2 log(_{10}) CFU/ml**)</td>
<td>0/50 (0%)</td>
<td>0/50 (0%)</td>
</tr>
<tr>
<td><strong>Confirmed</strong>&lt;br&gt;<em>Campylobacter</em> spp.</td>
<td>60/100 (60%)&lt;br&gt;(1.6±0.5 log(_{10}) CFU/ml **)</td>
<td>1/50 (2.0%)</td>
<td>11/50 (22%)&lt;br&gt;(1.2±0.3 log(_{10}) CFU/ml)</td>
</tr>
</tbody>
</table>

*The detection limit for enumerable colonies was 10^log\(_{10}\) CFU/ml following direct plating from poultry carcass rinses.*

**Colonies were picked following direct plating and confirmed using methods described previously.*
Table 4: Prevalence, percentage, and mean bacterial concentrations of *Campylobacter* spp.- and *Salmonella* spp.- positive fresh and frozen chicken carcass rinses obtained from farmers’ markets in Pennsylvania.

<table>
<thead>
<tr>
<th></th>
<th>Confirmed <em>Salmonella</em> spp. (28/100)</th>
<th>Confirmed <em>Campylobacter</em> spp. (90/100)</th>
<th>Enumerable <em>Salmonella</em> spp. (6/100)*</th>
<th>Enumerable <em>Campylobacter</em> spp. (60/100)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh (n=60)</td>
<td>19/60 (32%)*A</td>
<td>56/60 (93%)*A</td>
<td>5/60 (8.0%)*A (1.2±0.2 log\textsubscript{10} CFU/ml)</td>
<td>45/60 (75%)*A (1.7±0.5 log\textsubscript{10} CFU/ml)</td>
</tr>
<tr>
<td>Frozen (n=40)</td>
<td>9/40 (23%)*A</td>
<td>34/40 (85%)*A</td>
<td>1/40 (3.0%)*A (1.0 log\textsubscript{10} CFU/ml)</td>
<td>15/40 (38%)*B (1.5±0.5 log\textsubscript{10} CFU/ml)</td>
</tr>
</tbody>
</table>

* The detection limit for enumerable colonies was 1 log\textsubscript{10} CFU/ml.

A,B,C Different capital letters within a column represent significant difference at \( \alpha = 0.05 \).
Chapter 3
Food safety knowledge, behavior and attitudes of vendors of poultry products sold at Pennsylvania farmers’ markets
Abstract

Throughout the United States (U.S.), and in the last decade, Americans are purchasing food products from farmers’ markets at a significantly increasing rate (Ragland and Tropp, 2009). The popularity of farmers’ markets in the U. S. continues to rise, with an increase from 1,755 in 1994 to 7,175 in 2011 (Anonymous, 2011). Although farmers’ markets represent a minimal portion of the agricultural market, farmers’ markets have become a significant source of food products for many Americans. Potentially hazardous foods, such as milk, meat, and poultry, are popular items sold at farmers’ markets and require specific processing and handling to ensure the safety of the product. Meat and poultry items make up a large portion of potentially hazardous foods sold at farmers’ markets, but only meat products (beef, lamb, pork) are required by federal law to be processed in a USDA-inspected facility. Poultry however, can be grown and processed by individual farmers under exemption status afforded to farmers by the Poultry Products Inspection Act (PPIA) (USDA-FSIS, 2006).

In this study, a needs assessment survey was developed to assess the processing methods, knowledge, and attitudes of poultry vendors at farmers’ markets in Pennsylvania, in the areas of poultry processing, food safety, and regulation. Vendors were administered a 32-question, paper-based questionnaire at their respective farmers’ markets during market hours. The results highlighted that 52% (11/21) of vendors slaughtered and processed their own poultry, while 48% (10/21) had their poultry processed at a separate farm or facility. Among those vendors who knew of their processing conditions, 33% (7/21) processed their poultry outdoors, 38% (8/21) processed their poultry inside a fixed or dedicated processing area, while the remainder either used a combination of both or did not know. The majority of vendors appeared to have a good understanding of correct temperature control of poultry during processing, however more than
50% (11/21) incorrectly answered questions related to pathogens and cross-contamination during processing. Additionally, the attitudinal section revealed that 100% of vendors agreed that their poultry was safe and 95% (20/21) of vendors believed their poultry products to be safer than poultry sold in retail supermarkets. Seventy percent (70%; 14/20) of vendors recognized that antimicrobial sprays and washes can reduce pathogens on poultry however only 25% (5/20) agreed that additional food safety interventions were needed, and only 33% (7/21) utilized an antimicrobial spray or wash on their poultry before packaging.

The results revealed specific vendor practices and identified important vendor knowledge gaps and attitudes on food safety and poultry processing, while also highlighting the need for training and educational materials for poultry vendors. The data obtained from the vendor needs assessment surveys will aid in the development of future farmers’ market research, as well as generating recommendations, guidelines, fact sheets, and outreach material on food safety issues for vendors selling meat and poultry products at farmers’ markets.

**Introduction**

Farmers’ markets are not a new phenomenon, having been active in the U. S. for over 50 years. The resurgence of farmers’ markets reflects changes in government and consumer attitudes towards locally-produced foods. Many of these attitudes have historical relevance dating back to the late 1970s. The Farmer-to-Consumer Direct Marketing Act of 1976 contributed significantly to the rebirth of the local food movement (Hardesty, 2010). This act promoted the development of direct marketing of agricultural commodities from farmers to consumers and required the USDA to support state and local agricultural departments to promote direct marketing (Hardesty, 2010). Although government support and funding is now more widely available for farmers’ markets and direct-to-consumer farming programs, the increase in
farmers’ markets is no doubt a result of social movements to support “local” food, as well as a fear or distrust of modern industrial farming.

A farmers’ market is defined by the USDA Agricultural Marketing Service (USDA-AMS) as a “retail outlet in which two or more vendors sell agricultural products directly to customers through a common marketing channel” (Ragland and Tropp, 2009). The popularity of farmers’ markets in the U.S. continues to rise, with an increase from 1,755 in 1994 to 7,175 in 2011 (Anonymous, 2011). The products sold at farmers’ markets varies, and in a 2006 market manager survey, 92% of market managers reported the sale of fresh fruits and vegetables at their markets, with 81% selling herbs and flowers and 45% selling meat or poultry (Ragland and Tropp, 2009). Among vendors at farmers’ markets, 45% sold fresh fruits and vegetables, 15% herbs and flowers, and 3.2% sold meat and poultry (Ragland and Tropp, 2009). Although the occurrence of farmers’ markets in the U.S. is not new, research focusing on farmers’ market vendors, food quality, and food safety have begun to emerge. Much of what has been studied on farmers’ markets has originated from the national USDA farmers’ market surveys. A limited number of consumer preference studies also have been published in an effort to understand the motivations of consumers who eat and purchase local, organic, and farmers’ market products. However, as social progressive movements continue to evolve in the U.S., the demographics and motivations of farmers’ market consumers have continued to change. A study performed in 1998 at six Tennessee farmers’ markets found that the typical farmers’ market patron was a 45 year old, or older, female with some college education (Eastwood et al., 1998; Wolf et al., 2005). Similarly, in a 1995 survey of farmers’ markets in Maine, among the 220 patrons surveyed, 41% were between the ages of 35-54, 71.3% were female, and 67% had a bachelor’s or advance degree (Kezis et al., 1998). Although farmers’ markets represent a minimal portion of the
agricultural market, farmers’ markets have become a significant source of food products for many Americans. In a statewide study performed on 161 farmers’ markets in Iowa, 55,000 Iowans shopped at farmers’ markets every week, accounting for total annual sales of $21 million in 2004 (Varner and Otto, 2007).

Potentially hazardous foods, such as milk, meat, and poultry, are popular items sold at farmers’ markets and require specific processing and handling to ensure the safety of the product. Due to the nature of those products sold at open air markets, it is questionable whether consumers value food safety when purchasing potentially hazardous foods at these venues. Gwin and Lev (2011) investigated the behaviors of consumers who purchase meat and poultry at farmers’ markets in Oregon. Amongst patrons at three farmers’ markets, 27% purchased meat only, while 21% of patrons purchased meat and poultry at farmers’ markets (Gwin and Lev, 2011). Amongst those who purchased meat and poultry, only 12% listed food safety as a concern, with cost and inconvenience being the greatest limitation to meat and poultry purchases (Gwin and Lev, 2011). Meat and poultry items make up a large portion of potentially hazardous foods sold at farmers’ markets, but only meat products (beef, lamb, pork) are required by federal law to be processed in a USDA-inspected facility. Poultry however, can be grown and processed by individual farmers under exemption status afforded to farmers by the Poultry Products Inspection Act (PPIA) (USDA-FSIS, 2006). Those farmers who are exempt can grow, process, and sell their individual poultry products at farmers’ markets without daily USDA inspection, and as local, state, and federal regulation move to meet the requirements necessary to ensure safety of farmers’ market food products, vendors will continue to provide a range of food products in which the quality and food safety is unknown.
In this study, a needs assessment survey was developed to assess the processing methods, knowledge, and attitudes of poultry vendors at farmers’ markets in Pennsylvania, in the areas of poultry processing, food safety, and regulation. The data obtained from this study will aid in the development of future farmers’ market research as well as to help generate recommendations, guidelines, fact sheets, and outreach material on food safety issues for vendors selling meat and poultry products at farmers’ markets, and to ultimately aid and support the growth of farmers’ markets and vendors into the future.

Methods

Obtaining Institutional Review Board approval for human subject social science research

This study involved the use of human subjects and their participation in a confidential paper based survey. Due to the use of human subjects and the sensitivity of participant answers to questions, approval from the Pennsylvania State Universities’ Institutional Review Board (IRB) was necessary to perform human subject survey research. An on-line application for IRB approval to use human subjects was submitted to the IRB through the Office for Research Protections at The Pennsylvania State University. All survey materials including a consent form (Appendix B), verbal script (Appendix C), and a 32-question paper based survey were submitted with the application (Appendix A). It was determined that this study was exempt from IRB initial and ongoing review on 01 September 2011, IRB # 37851. Additional recommendations and requests by IRB officials included that market managers be contacted prior to approaching vendors, and that confidentiality of vendor responses to questions be retained throughout the study.
Development of farmers’ market poultry vendor needs assessment survey

The development of the needs assessment survey utilized the methodology described by Witkin and Altschuld (1995) in which a needs assessment consists of three phases; a Pre-assessment Phase, Assessment Phase, and Post-assessment Phase. Phase 1, the Pre-assessment Phase, consisted of defining the purpose and goals of the needs assessment and obtaining observations at farmers’ markets, specifically looking for observable vendor knowledge and attitudinal gaps in food safety and regulation. The Pre-assessment Phase also was performed alongside the microbiological sampling portion of this study. Phase 2, the Assessment Phase, consisted of utilizing gathered observational data to develop a paper based survey for those vendors who had poultry products sampled. Questions were developed to first explore the general practices performed by poultry vendors during the growing and processing of poultry. Second, questions were designed to test the knowledge of vendors on poultry processing, HACCP based interventions used in processing, food safety, and regulation. Lastly, a series of attitudinal statements were developed to explore the level of agreement that vendors may have on topics related to poultry processing, food safety, and regulation. General demographic questions also were developed as well as questions querying the vendor’s willingness to participate in extension based educational programs in the future. The third and last phase of the needs assessment, the Post-assessment Phase, consisted of analyzing the data collected from the completed surveys, evaluating the major gaps identified, and formulating ideas for vendor educational materials or programs.

A paper based survey of 32 questions was developed consisting of 15 exploratory, 8 knowledge, 6 attitudinal, and 2 demographic questions, as well as 1 question assessing the vendor’s willingness to participate in future extension education programs (Appendix A).
Exploratory and knowledge based questions were formatted as true and false and multiple-choice, with certain questions allowing for the selection of multiple answers. Attitudinal questions were formatted using a five point Likert Scale. The paper-based survey was printed on standard 8.5 x 11 inch paper using a font size of 12, and questions were printed on both the front and back of the paper. The survey also consisted of an introductory cover sheet explaining the study, its purpose, and the confidentiality of the study (Appendix A). Before implementation of the survey, draft surveys and survey questions were critiqued by professors in the Department of Food Science at Penn State, graduate students, and multiple lay persons outside of the food science field in order to assess the readability of questions, length of time of completion, whether questions were understandable, and to identify grammatical errors. The final 32-question survey was estimated to take vendors 15 minutes to complete. Due to time constraints and the preliminary nature of the study, a pilot study was not performed prior to survey implementation; however surveyed vendors did not show difficulty in reading or taking the survey.

Identification of farmers’ market poultry vendors in Pennsylvania

During the Pre-assessment Phase of the needs assessment, farmers’ markets and poultry vendors were identified using the techniques described in Chapter 2 of this report. Additional poultry vendors were identified after discussions with vendors and market managers, as well as from new postings on Buy Fresh, Buy Local (http://www.buylocalpa.org/), Local Harvest (www.localharvest.com), the USDA-AMS Farmers’ Market Search (http://search.ams.usda.gov/farmersmarkets/), and the discovery of previously unidentified individual farmers’ market websites.
Acquiring approval to conduct needs assessment survey from farmers’ market managers

Based on the request of IRB officials, regardless of the established exempt status of this study, it was requested that market managers of each respective vendor were contacted prior to visitation and contact with each market and vendor for the purposes of performing the survey. Market manager contact information was gathered generally from individual farmers’ market websites, and in some cases was provided by other market managers from separate farmers’ markets. Market managers were sent an e-mail explaining the study, requesting their approval for visitation to the market and specific poultry vendor. If market managers did not respond through e-mail, they were contacted by phone. The majority of market managers contacted their individual vendors prior to approving survey visits, and in most cases, specific meeting times were scheduled to conduct the survey at the leisure of the vendor.

Conducting the needs assessment survey

Among the 44 poultry vendors initially identified during the pre-assessment phase, 30 were chosen to be targeted for the survey. Due to time and budget constraints, 28 vendors were approached for participation in the survey, however only 21 agreed to take the survey. Contacting market managers and receiving approval to approach vendors at particular farmers’ markets typically took between one-two weeks’ time, which greatly increased this portion of the study’s time frame. After gaining approval from market managers, researchers would travel to each individual farmers’ market, and vendors would be approached at their respective booths during market hours. Vendors were asked to participate in the survey using a pre-formatted and memorized verbal script (Appendix C) which was used when first approaching each vendor. An incentive of $10 cash was also used to promote participation in the survey, and was only awarded to vendors upon completion of the survey. Once vendors agreed to participate, vendors
were read the informed consent form, and only once vendors verbally agreed and signed the consent form were they allowed to participate in the survey. Vendors were informed that their answers to questions were completely confidential and never associated with their contact information. Vendors were also informed that they could stop the survey at any time and could skip questions. Paper surveys were physically handed to each vendor and the researcher would leave the area. Typically, vendors spent between 15-30 minutes to complete each survey. Once completed, the researcher would answer any questions, and upon receiving the completed survey, vendors were awarded $10 cash. In some instances, vendors agreed to participate in the survey, but requested to take the survey home for further review. In these instances, vendors were given a pre-addressed and stamped envelope with all survey materials. Vendors were given instructions and asked to sign the informed consent form prior to completing the survey. Once vendors had completed the survey, they would seal the envelope containing the informed consent form, as well as the survey which was addressed to return to the Department of Food Science at Penn State. Among vendors who had agreed to participate and complete the survey, 14% (3/21) requested to take the survey home, and all of those surveys were received by mail within three weeks of distribution. Once completed survey materials were received, $10 cash incentives were given to vendors either in person during market hours or by mail, if they provided the researcher with a mailing address. Vendors also were instructed never to put their names or any identifying information on the surveys and completed surveys were stored in a secure, locked filing cabinet at the PSU Food Science Department under the supervision of Dr. Catherine Cutter. Responses to questions were transferred to a password-protected computer database and no identifying vendor information was ever associated with survey responses. Confidentiality of vendor
responses was required by IRB officials, and thus all efforts were performed to ensure vendor contact information was never associated with their individual responses to survey questions.

**Statistical analysis**

Responses to survey questions were compiled and analyzed by converting response rates to percentages. Measures of central tendency were also calculated for certain questions.

**Results**

**Vendor poultry processing practices**

The first section of the needs assessment survey consisted of 15 exploratory questions, which were further subdivided into five groups which explored the practices of poultry vendors during poultry production and processing. These groups included: pre-harvest, slaughter/processing, packaging/storage/transportation, regulation, and market retail practices. The majority of exploratory questions were formatted as multiple choice, with the option of selecting multiple answers, as well as one true/false formatted question. Four out of the 15 questions were skipped by at least one vendor, Q:6,10,13,14 (Appendix A), which included two pre-harvest, one packaging, and one processing question. Further review revealed that the majority of vendors who did not process poultry, skipped those particular questions, suggesting they may have no knowledge of those topics since they likely use a private processor to slaughter, process, and package their poultry products sold at farmers’ markets.

Results from pre-harvest questions (Table 1) revealed that 10% (2/20) of poultry vendors utilize conventional poultry housing units, while the remaining 90% (18/20) of poultry vendors either utilize one or combination of pasture-based poultry housing systems or do not have knowledge of the raising of their poultry, 5% (1/20). Among those vendors who utilized a pasture-based production system, 44% (7/16) kept 1-50 birds in each pen, 38% (6/16) kept 51-
100, and 19% (3/16) kept 101-200 birds per pen, while none of the vendors reported using systems containing over 200 birds. Although it is unknown whether these pasture-based systems are custom-produced by the vendor, the results suggest they are not typically built to hold more than 200 birds, or the vendors cannot produce flocks of more than 200 birds.

Among the vendors surveyed in this study, 48% (10/21) do not process the poultry they sell at farmers’ markets, while the remaining 52% (11/21) of vendors do process their own poultry (Table 2). Among those vendors who do not process poultry, 50% (5/10) utilize a local processor and 20% (2/10) purchase poultry at wholesale to be sold at farmers’ markets. Additionally, among those vendors who process their own poultry, 36% (4/11) may also use a separate processor in combination with their own processing. Vendors who had knowledge of their poultry processing reported that 33% (7/21) performed processing outside, 5% (1/21) in a barn, and 38% (8/21) processed poultry inside a fixed building, while the majority of vendors 57% (12/21) reported separating their poultry slaughter and de-feathering areas from their final packaging areas by more than 20 feet. The reported equipment used during poultry processing varied, with the majority of vendors reporting the use of scalding water baths, picker machines, kill cones, chilled water baths, refrigerators, hoses, and dedicated cutting tables; however few vendors utilized a poultry hanging device, 22% (4/18), and electric stunners, 0% (0/21). Less than half of vendors, 33% (7/21), reported the use of chlorinated or peroxyacetic acid sprays, washes, or dips on poultry before packaging. Fourteen percent (14%; 3/21) of vendors reported that they do not use any spray, wash, or dips in their processing, and 29% (6/21) do not use any sanitizing agents in their processing areas at all.

Packaging, storage, and transportation questions revealed that vendors utilize a wide range of cold storage devices, with many using multiple devices (Table 3). The majority of
vendors reported utilizing an electrically-powered freezer or refrigerator, while a small number of vendors utilized a pre-chilled ice box, 5% (1/21), or cooler with ice, 29% (6/21). Fourteen percent (14%; 3/21) of vendors did not know the temperature of their cold storage unit, which consisted of those respondents who do not process poultry. Poultry sold at farmers’ markets were reported to either be pre-packaged, 95% (19/20), or sold fresh or frozen and placed into a food grade plastic bag at the time of sale, 30% (6/20). Forty-five percent (45%; 9/20) of vendors reported the use of vacuum-sealed pre-packaging of their poultry. Transportation of poultry to the market also was reported to vary, as 57% (12/21) of vendors transported poultry in a cooler with ice, 14% (3/21) used a cooler with no ice, while the remaining vendors utilized an electrically powered cooling truck or cooler, 29% (6/21), or pre-chilled frozen ice chest, 24% (5/21).

Although vendors surveyed were targeted due to their reported sale of poultry, all surveyed vendors sold other items at farmers’ markets that included fruit and vegetables, dairy products, and other meat and poultry items, besides chicken (Table 4). Additionally, market practice questions revealed that 29% (6/21) of vendors who did not sell fresh poultry on a market day would re-sell poultry items fresh on a following market day, while 48% (10/21) of vendors froze their unsold fresh poultry to be sold frozen on the next market day. Although 10% (2/21) of vendors also selected “other” as their response to Q:12 (Table 4), it is unknown what other methods vendors may be using to re-sell unsold fresh poultry.

Two regulatory questions, one in the exploratory section and one in the knowledge section of the survey, were used to assess the vendor’s familiarity with poultry and farmers’ market regulatory requirements (Table 5). Vendors reported that 48% (10/21) had read the recently passed “Pennsylvania Department of Agriculture’s Act 106 on Food Safety and
Farmers’ Markets,” while the remaining vendors reported having not read, 29% (6/21), or did not know of its existence, 24% (5/21). Similarly, 65% (13/20) of vendors correctly answered Q:16 (Appendix 1), pertaining to the U.S. Poultry Products Inspection Act (PPIA), while 15% (3/20) answered incorrectly, and 20% (4/20) did not know the basic PPIA rules for exempt poultry processors.

Vendor knowledge of poultry processing, food safety, and regulations

As part of the needs assessment survey, poultry vendors were asked eight questions which evaluated the knowledge of vendors in the areas of poultry processing, food safety, and regulations (Table 6). Five out of the eight questions, Q:16 (Table 5), Q:17,21,22, 23 (Table 6) were skipped by at least one vendor, which consisted of those vendors who processed their own poultry. Among the eight knowledge questions, more than 50% of vendors incorrectly answered Q:17 and Q:22. Q:17 asked vendors to select among multiple responses, which pathogenic bacteria could be found in raw poultry. Those poultry vendors who did not select two responses; *Campylobacter* and *Salmonella*, or also selected probiotics or methicillin resistant *Staphylococcus aureus*, were considered incorrect. Sixty-three percent (63%; 12/19) of vendors incorrectly answered Q:17, while Q:22 also had a high incorrect response rate of 50% (10/20), in which the correct answer was “all of the above.” However if vendors individually selected all of the correct responses, they were counted as a correct. The remaining knowledge questions, Q:18,19,20,23, had correct response rates above 80%, in which three of these questions, Q:18,19,22, all explored the knowledge of vendors on proper chilling and storage temperature control of poultry during processing. Q:20 and Q:21 were found to have the lowest incorrect response rates, in which questions explored the knowledge of processing and slaughter separation and use of antimicrobial sprays, dips, or washes. In addition, Q:21 had the highest
rate of “I do not know” responses, 25% (5/20), amongst all knowledge questions in the survey. The results also revealed that questions formatted in a true and false form had the lowest incorrect response rates, while those multiple choice questions with multiple answers had the highest incorrect response rates. Q:17, having been a multiple choice formatted question, was also the most skipped question in the knowledge section.

**Vendor attitudes on food safety and regulations**

In this study, vendors also were asked to respond to six questions which explored their attitudes on the safety of their poultry products, food safety, and government regulations (Table 7). The attitudinal questions were formatted using a five point Likert scale, in which a response of 5 reflected a strong agreement, three with neutral, and a response of 1 reflected strong disagreement with a statement. Mean scores were also calculated for each attitudinal statement. The results demonstrated that all vendors surveyed agreed or strongly agreed that their poultry products were safe, and the majority, 95% (20/21), agreed or strongly agreed that poultry products sold at farmers’ markets were safer than conventional poultry sold at supermarkets. Over 50% of vendors surveyed were concerned about pathogens in their poultry, while 33% (7/21) responded as having a neutral attitude or disagreement with Q:26. Vendors responded variably to Q:27, in which 35% (7/20) agreed or strongly agreed that they do not need any additional food safety interventions in their poultry processing, while a larger portion of vendors responded as neutral, 40% (8/20). Alternatively, the majority of vendors agreed or strongly agreed, 71% (15/21) that food safety is important and they would like to learn more about keeping their poultry products safe; however few vendors, 30% (6/20) responded in agreement to supporting government regulations of poultry sold at farmers’ markets as stated in Q:29.
Vendor demographics

Surveyed vendors were asked two demographic questions in order to better understand the educational background of poultry vendors at farmers’ markets in Pennsylvania (Table 8). The results revealed that the educational background of surveyed vendors varied dramatically. In addition, at least three vendors skipped each question, suggesting that vendors may not want to reveal their age or educational background to outside sources. The results revealed that 12% (2/17) of vendors did not complete any formal education, while 35% (6/17) had been formally educated to the High School level or below. Alternatively 18% (3/17), of vendors reported having completed at least some college, while 29% (5/17) held Bachelor’s degrees with one vendor, 6% (1/17), holding a Master’s degree. The age of responding vendors also varied, with the majority of vendors, 89% (16/18), reported being above the age of 35 but below 65 years of age. The last question of the needs assessment survey queried whether vendors would be apt to attend food safety and poultry processing training if hosted by Penn State Cooperative Extension. The results demonstrated that 65% (11/17) of responding vendors would attend training; however only 24% (4/17) would pay for it. The remaining vendors responded as not wanting to participate in any training; however 24% (4/17) would still like information on food safety pertaining to poultry processing.

Discussion

Vendor poultry processing practices

No study to date has examined the specific food processing practices of farmers’ market poultry vendors using a paper-based survey methodology. In this study, a needs assessment survey was performed on vendors selling poultry products at farmers’ markets in an effort to identify specific poultry processing practices, as well as potential gaps in the knowledge and
attitudes of vendors on food safety, poultry processing, and regulations. Responses from 21 vendors on 15 exploratory questions revealed important trends and gaps in the practices of vendors during poultry processing.

The results revealed that among those vendors surveyed, pasture-based systems, whether moveable, day-range, or free-range, appear to be the common method of live poultry production among those vendors surveyed, with the majority of vendors raising less than 100 birds per pen. The preference towards pasture-based poultry production, in contrast to employing conventional poultry raising methods, may reflect current vendor and consumer attitudes towards agriculture and livestock production. Organic poultry production in the U.S. has increased substantially in the last decade. Organic broiler production tripled from 2002-2008, with total U.S. certified organic farmland increasing 123% from 2002-2007 (USDA-ERS, 2010). It is likely that farmers’ market vendors are attempting to appeal to those consumers who value organic food and those agriculture practices encompassed in organic food production. Although vendors do not typically advertise or claim their products are organic, confusion exists among consumers as to what organic standards and practices are. Consumers tend to associate organic with other label claims like “cage-free,” “natural” and possibly “pasture-raised” (Hughner et al., 2007; Chryssochoidis, 2000; Hutchins and Greenhalgh, 1995; Fotopoulos et al., 2003; Aarset et al., 2004).

This study revealed that among surveyed vendors, approximately half raised, slaughtered, or processed their own poultry at their own farm or facility. Among those vendors who do not process their own poultry, the majority seek out local poultry processors or other farmers who likely have access to necessary processing equipment, as well as experience in poultry processing. The results demonstrate that vendors who sell poultry at farmers’ markets in
Pennsylvania can vary dramatically in their experience in poultry processing, since many vendors rely on private processors for the processing of their poultry products, while others perform slaughter and processing on their farms. Future training and research in these areas must be designed to address these dynamics in order to cater to the range of experience that vendors may have in poultry processing.

Responses to questions on slaughter and processing of poultry also revealed that approximately half of the vendors surveyed are performing all or some of their poultry processing outside, which significantly increases the risk of cross contamination from the environment, thereby increasing the difficulty of maintaining sanitary conditions for poultry processing. This observation also suggests that those vendors who process poultry do not have access to dedicated indoor facilities and may have taken up poultry processing as a supplemental source of income. This conclusion also was evident from vendor responses to types of equipment found in their processing areas. None of the vendors reported the use of a stunning device and only 22% used a poultry hanging device in their processing areas, suggesting that vendors may be slaughtering poultry using a traditional knife-based method that may be performed close to the ground or on a separate table.

Surprisingly, 33% of vendors reported using an organic acid or chlorinated spray, wash, or dip on their poultry during processing. However, over half of vendors were using no chemical interventions at any point in their poultry processing. Although 24% of vendors responded as using a chemical sanitizer for their processing areas, the type of sanitizer was not determined in this study. Furthermore, it is unknown whether sanitizers used by vendors are suitable for poultry processing. Although a large portion of vendors were found to use no chemical antimicrobial interventions in their poultry processing, the 33% of those vendors who do
suggests that vendors may still be willing to include an intervention step in their processing, possibly after further education and training in food safety and poultry processing.

Vendors reported the use of multiple types of cold storage devices; over half of the vendors reported the use of an electrically-powered freezer or refrigerator. However, a small portion of poultry vendors were storing processed poultry in non-electrically powered cold storage devices or in coolers with ice, and it is questionable whether those storage units can maintain proper freezing or refrigeration temperatures over longer periods of time. Additionally, 14% of vendors reported storing their frozen poultry in an unknown manner, while 5% stored their processed poultry at another farm or property. Refrigerated or frozen storage of processed poultry may not only reduce spoilage of the product, but also can reduce viability and growth of potential pathogenic organisms present on processed poultry. Previous research has shown that pathogens such as *Campylobacter jejuni* can be reduced on chicken skin up to $3.39 \log_{10} \text{CFU/g}$ when carcasses are pre-refrigerated and frozen at $-20^\circ\text{C}$ (Bhaduri and Cottrell, 2004). Proper cold storage is a critical step in preventing the growth and survival of potential pathogens present on raw poultry. The identified variability and use of questionable cold storage devices by poultry vendors is an important finding in this study; but one which could be easily mitigated through basic food safety training.

The variability among cold storage devices also was observed among those cold storage methods used for transport of poultry to farmers’ markets. Approximately 57% of vendors utilize a cooler with ice for transport of poultry to farmers’ markets, while 29% of vendors utilize an electrically-powered cooler or refrigerated/freezer truck. Of concern however, were those vendors who reported the use of coolers with no ice (14%) and those using some form of a pre-chilled ice chest (24%). Since vendor behavior at the market was not examined in this study, it is
unclear whether vendors are utilizing thermometers and verifying the temperatures of their cold storage. Based on the results, it is clear that the storage of poultry, either at the processing location, during transport, or at the market, are critical food safety nodes in the production and sale of poultry at farmers’ markets. More importantly, none appear to be procedures recognized by vendors in this survey.

Few questions were targeted at the retail market practices of vendors, since the focus of the needs assessment survey concentrated on the processing of poultry. Results from the market level practices revealed that poultry vendors engaged in the sale of a variety of other products at their respective farmers’ markets. These products included: chicken, vegetables, turkey, beef, “other poultry,” and cheese. In fact, 48% of vendors who sold poultry also sold vegetables, which has been reflected in previous USDA farmers’ market surveys. In these surveys, fruits and vegetables were found to make up 42.4% of all U.S. farmers’ market sales (Ragland and Tropp, 2009). The 2008 Agriculture Resource Management Survey (ARMS) also reported that vegetable, fruit, and nut farms accounted for 65% of sales of locally grown food (Low and Vogel, 2011). The results from the current study appear to be in agreement with previous farmers’ market surveys, suggesting that poultry production may not be the main focus of poultry vendors, with produce production and sales as more important to those vendors.

The current survey also investigated the practices of vendors on the resale of unsold fresh poultry products. The results revealed that 48% of vendors freeze unsold fresh poultry for resale, with 29% reported reselling fresh poultry on the next market day. These results demonstrate that vendors may resell poultry that has been transported to farmers’ markets, yet it is unknown how vendors are restoring and freezing the unsold poultry products. This issue may also have regulatory implications as food items produced for retail at farmers’ markets and stored on-farm
or at processing facilities are required to be licensed as a certified warehouse according to USDA and PDA regulations (Anonymous, 2010). Also, it is unknown whether vendors who resell unsold fresh poultry are storing their poultry properly and how long the unsold poultry remain stored in a fresh versus frozen condition. It is of concern that fresh poultry products could be stored repeatedly under unsafe temperature conditions, allowing for the propagation of pathogens on those products.

Vendors surveyed in this study also were asked two questions regarding regulatory requirements considered essential for poultry vendors in Pennsylvania. It was clear, based on the results, that the majority of vendors (50%) were not familiar with PDA Act 106 on Food Safety and Farmers’ Markets. This finding is critical as it highlights the apparent poor dissemination and knowledge of the regulatory requirements for farmers’ market vendors. A slightly higher percentage of vendors (65%), were familiar with the PPIA, which has been around for longer and may have more direct implications for poultry producers. The apparent lack of knowledge and familiarity with two basic regulations that directly impact poultry vendors at farmers’ markets highlights a critical gap amongst vendors surveyed. These results underscore the importance of future training and education for farmers’ market vendors, as a lack of understanding of regulatory requirements could severely impact vendors and those markets in which they operate.

**Vendor knowledge of poultry processing, food safety, and regulations**

In this study, eight questions were developed to evaluate the knowledge of vendors on basic poultry processing and food safety topics related to poultry. Among the eight knowledge questions included in this survey, two questions resulted in an incorrect response rate greater or equal to 50%. The top question answered incorrectly was Q:17 (Table 6), which asked vendors to select which pathogenic organisms could be found in raw poultry. Only 37% of vendors
correctly selected \textit{Campylobacter} and \textit{Salmonella}. Ninety-five (95\%) of vendors selected \textit{Salmonella} as at least one of their answers, while 37\% of vendors selected \textit{Campylobacter}. The data suggests that few vendors may have knowledge of \textit{Campylobacter} as an important pathogen in poultry, but that vendors do appear to be familiar with \textit{Salmonella}. Similarly, the high response rate of “I do not know” seen in Q:21, may also suggest a lack of familiarity or understanding of basic microbiological concepts such as antimicrobial sprays washes or dips. Due to the higher difficulty of Q:17 however, it is also possible that questions involving multiple answers may confuse vendors, and that these style of questions may be too difficult for some vendors.

This same formatting was also used in the second highest missed knowledge question in the needs assessment survey. Q:22 (Table 6) was formatted in the same manner as Q:17 and also asked vendors to select multiple responses, in which the correct answer was “all of the above.” Among those incorrect responses, only 5\% of vendors had included blood and 15\% had included internal organs as a source of cross-contamination during poultry processing. Although the data may demonstrate the apparent difficulty of the question format, the results from Q:17 and Q:22 appear to suggest that there are apparent knowledge gaps on pathogens and cross-contamination among poultry vendors.

In contrast, the results from the remaining knowledge questions from the needs assessment survey revealed that vendors appear to have a good understanding of temperature control, since over 80\% correctly answered Q:18,19, 23 (Table 6), which examined the knowledge of poultry chilling and storage temperatures. This finding is promising, as it suggests that although vendors may not be utilizing optimal chilling and storage processes, they do have an understanding that those processes require strict temperature controls. This level of
understanding of temperature control is encouraging and will be helpful in educating vendors on the importance of food safety and proper poultry processing.

**Vendor attitudes of food safety and regulations**

The last major section of the needs assessment survey examined the attitudes of vendors on six statements related to poultry processing, food safety, and government regulations. As expected, 100% of vendors agreed or strongly agreed that their poultry products were safe, while 95% agreed or strongly agreed that their products were safer than conventional poultry sold at supermarkets. The responses to these statements suggest that vendors believe their products are safe using their current practices, which may be considered unsanitary or unsafe. Vendors also may lack knowledge on proper sanitation and food safety standards and practices used in modern poultry processing, meaning they may be unaware that their processes do not address pathogen control. While half of the vendors were concerned with pathogenic bacteria on their raw poultry, only 35% felt they do not need additional food safety interventions in their processing. The results from Q:26 and Q:27 (Table 7) appear to be conflicting, but may demonstrate that vendors are satisfied with their current practices, even if they have concerns about food safety. It should also be noted that 40% of the vendors took a neutral stance to Q:27, which may suggest that vendors may not have an understanding of what food safety interventions are or how they might benefit their products.

Responses to Q:28 also were promising, since 71% of vendors agreed or strongly agreed that food safety is important and would like to learn more. This general attitude towards food safety will be important to the success of future vendor training, since change in the behavior of vendors will be more successful if vendor attitudes are in sync with the focus of the training. Although future training and education will be critical in ensuring the continued success of
farmers’ markets and poultry vendors, due to the growing size and scope of farmers’ markets, additional regulatory requirements may be imminent. Attitudes of vendors towards regulations will be important for their future success. However, the results from Q:29 demonstrate that few vendors (30%) support regulation of poultry products sold at farmers’ markets, while the remainder are neutral or are in disagreement. This needs assessment survey represents a snapshot of the attitudes of poultry vendors at farmers’ markets in Pennsylvania. Results also demonstrate that although vendors may agree that food safety is important, vendors believe their products are safe or safer than conventional products. The attitudes identified in this study demonstrate the potential difficulty in designing food safety training for vendors. As such, future food safety training must include the development of attitudinal changes as well as knowledge and behaviors of vendors.

Vendor demographics

A short demographic section was also included in the needs assessment survey to further understand the background of poultry vendors. It was evident from the results that there was not a typical age or educational background that was common among vendors surveyed. The most common ages of vendors were 35-44 or 55-64 years of age, with the majority being 45-54 years of age. These results also suggest future vendor training must address the educational styles and needs of older adult learners. Additionally, the educational background of vendors was even more varied, with 35% of vendors possessing a Bachelor’s degree or above, 18% with some college experience, and the remainder having a high school education or below. The final question of the needs assessment also revealed 65% of vendors would attend food safety training hosted by Penn State. These results collectively highlight the challenge of educating farmers’ market vendors, but also suggest that vendors may be eager to improve upon their understanding
and experience in food safety and poultry processing. It is clear that future training and education for vendors must take into account the specific needs and educational levels of vendors, as determined in this survey.

**Triangulation of microbiological analysis and needs assessment data**

The data collected from the microbiological survey portion of this study revealed significant higher levels of contamination of *Salmonella* spp. and *Campylobacter* spp. in whole chicken obtained from farmers’ markets, as compared to conventionally-processed, whole chicken obtained from supermarkets in Pennsylvania. These results were utilized to guide the development and implementation of the vendor needs assessment survey and to formulate questions to identify vendor knowledge and attitudinal gaps in poultry processing, food safety, and government regulations. Responses to specific questions in the needs assessment survey revealed specific high risk activities that are known to increase the likelihood of bacterial contamination during processing. Approximately half of the vendors surveyed (48%; 10/21), indicated that they performed all or part of their poultry processing either outdoors or in a barn. Among those vendors who either processed or had knowledge of their poultry processing, only 24% (5/21) utilized a chemical sanitizer in their processing areas. The higher prevalence of *Salmonella* spp. and *Campylobacter* spp. found on poultry purchased from farmers’ markets may be an indication that proper sanitation procedures are not being implemented or are ineffective. Additionally, it is not known whether processing areas located outdoors or in a barn could be properly sanitized or if measures are in place to prevent environmental contaminants from entering the processing environment. Although a small portion (33%; 7/21), of vendors applied an antimicrobial spray, wash, or dip to processed chicken carcasses, the majority did not use an antimicrobial intervention in their processing. In some cases, whole chicken from farmers’
markets exhibited *Campylobacter* spp. as high as $2.0 \log_{10}$ CFU/ml (Table 3), which may be reflective of the lack of antimicrobial interventions used by farmers’ market poultry vendors.

Results from the knowledge section of the needs assessment survey also revealed specific knowledge gaps that can be attributed to cross contamination during poultry processing, as well as a lack of basic knowledge of pathogens commonly found on poultry. Due to IRB requirements, no direct link could be established between those vendors whose poultry contained a high prevalence of pathogens and those vendors who incorrectly answered specific knowledge questions. However, the results from Q:17 and Q:22 suggest that a lack of knowledge in cross contamination and pathogens may contribute to the prevalence of *Salmonella* spp. and *Campylobacter* spp. found in farmers’ market chicken. Additionally, results from the attitudinal section revealed that 100% (21/21) of vendors believe their products are safe and only 25% (5/20) believe they need additional food safety interventions in their processing. These attitudes toward food safety may lead vendors to continue processing under high risk conditions, making vendors less willing to seek improvements to the sanitation and safety of their products.

**Conclusions**

The needs assessment survey performed in this study identified critical gaps in the knowledge, attitudes, and general practices of farmers’ market poultry vendors in Pennsylvania in food safety, poultry processing, and regulations. The results from this study are a first step to evaluate and understand the retail practices of vendors at farmers’ markets, while also exploring how vendors are growing, processing, transporting, and storing those foods sold direct to consumers. As farmers’ markets continue to spread across the country and increase in popularity, it is crucial that the food products sold to consumers be evaluated for safety, and that vendors be knowledgeable in proper food production and food safety.
In this study, approximately half of the vendors surveyed performed the slaughter and processing of poultry sold at their farmers’ markets. Several unhygienic practices were identified, including slaughter and processing of poultry outside, a lack of chemical sanitation of processing areas and poultry products, storage of poultry at improper temperatures, and questionable cold storage practices. Approximately half of the vendors surveyed also displayed inadequate knowledge of applicable regulatory requirements. Vendors also lacked an understanding of pathogens and practices leading to cross contamination during slaughter and processing. In contrast, vendors appeared to have sufficient knowledge of temperature control during poultry processing, since many vendors utilized good packaging and storage practices, such as vacuum packaging and electrically powered coolers. Vendor attitudes toward the safety of their poultry products were found to be consistent, with the majority of vendors agreeing that their products were safe or safer than conventional poultry sold at supermarkets. Inconsistencies were identified among vendor attitudes, with over half of the vendors agreeing that they are concerned about pathogens in their products, but do not agree that they need additional food safety interventions in their food processing. It was also evident that vendors vary greatly in their attitudes towards government regulation of poultry at farmers’ markets, with a large portion of vendors taking a neutral stance on the topic.

Clear and specific gaps in poultry processing, food safety, and regulations have been identified in this study. These findings will be used to develop new research and training approaches for farmers’ market vendors. Specifically, high risk slaughter and processing gaps were recognized, thereby allowing for future research to target those specific nodes in the processing of poultry and other similar products. These approaches have the potential to sustain
and ensure the continued success of farmers’ markets and the safety of those foods sold direct to consumers.
References


Ragland, E. and D. Tropp. 2009. USDA national farmers market manager survey, USDA-ARS.

USDA-FSIS. 2006. Guidance for determining whether a poultry slaughter or processing operation is exempt from inspection requirements of the poultry products inspection act. Food Safety and Inspection Service, USDA, Washington, D.C.


Tables

Table 1: Responses of farmers’ market poultry vendors in Pennsylvania to exploratory based questions on pre-harvest poultry production.

<table>
<thead>
<tr>
<th>Number of Responses (%) (n=20)</th>
<th>Conventional (fixed, enclosed houses)</th>
<th>Pasture-based with moveable pens</th>
<th>Pasture-based, day range</th>
<th>Pasture-based free range</th>
<th>I do not know</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 (10%)</td>
<td>12 (60%)</td>
<td>1 (5%)</td>
<td>6 (30%)</td>
<td>1 (5%)</td>
</tr>
</tbody>
</table>

*Q-13: How would you best describe your type of poultry production system?*

<table>
<thead>
<tr>
<th>Q-14: If you have a pasture-based production system and use moveable pens, how many birds are kept in each pen? (n=16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-50</td>
</tr>
<tr>
<td>7 (44%)</td>
</tr>
</tbody>
</table>

Questions were answered with multiple responses.

Note: Sum of rows may be greater than 100% due to rounding and multiple responses.
Table 2: Responses of farmers’ market poultry vendors in Pennsylvania to exploratory based questions on the slaughter and processing of poultry.

*Q-2: Where do you process your poultry that you sell at farmers’ markets?*

<table>
<thead>
<tr>
<th>Number of Responses (%) (n=21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I do not process poultry; it is processed by a local processor.</td>
</tr>
<tr>
<td>5 (24%)</td>
</tr>
</tbody>
</table>

**Q-3: What is the condition of the facility where your poultry is processed? (n =21)**

<table>
<thead>
<tr>
<th>The poultry is processed outside.</th>
<th>The poultry is processed inside a barn.</th>
<th>The poultry is processed in a dedicated processing area inside a fixed building.</th>
<th>Combination of outside under a fixed roof and inside a fixed building.</th>
<th>I do not know.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 (33%)</td>
<td>1 (5%)</td>
<td>8 (38%)</td>
<td>2 (10%)</td>
<td>3 (14%)</td>
</tr>
</tbody>
</table>

**Q-4: How far is the poultry slaughter and de-feathering area from your final packaging area (approximately)? (n=21)**

<table>
<thead>
<tr>
<th>I do not process poultry.</th>
<th>6 to 10 feet</th>
<th>11 to 15 feet</th>
<th>More than 20 feet apart</th>
<th>I do not know.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 (14%)</td>
<td>3 (14%)</td>
<td>12 (57%)</td>
<td>12 (57%)</td>
<td>2 (10%)</td>
</tr>
</tbody>
</table>

**Q-5: At what temperature is the poultry chilled after processing, but before packaging? (n=21)**

<table>
<thead>
<tr>
<th>I do not process poultry.</th>
<th>20 to 40°F</th>
<th>40 to 60°F</th>
<th>I do not chill my poultry before packaging.</th>
<th>I do not know.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 (14%)</td>
<td>13 (62%)</td>
<td>2 (10%)</td>
<td>0</td>
<td>3 (14%)</td>
</tr>
</tbody>
</table>

*Q-6: During processing and packaging of the poultry, which of the following equipment are used? (n=18)*

<table>
<thead>
<tr>
<th>Scalding water bath</th>
<th>Defeatherpicker machine</th>
<th>Kill cone</th>
<th>Electric stunner</th>
<th>Chilled water bath</th>
<th>Refrigerator</th>
<th>Freezer</th>
<th>Vacuum packager</th>
<th>Hose</th>
<th>Poultry hanging device</th>
<th>Dedicated cutting table</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 (89%)</td>
<td>16 (89%)</td>
<td>15 (83%)</td>
<td>0</td>
<td>14 (78%)</td>
<td>13 (72%)</td>
<td>8 (44%)</td>
<td>6 (33%)</td>
<td>12 (67%)</td>
<td>4 (22%)</td>
<td>13 (72%)</td>
</tr>
</tbody>
</table>

**Q-7: During the processing of the poultry, which of the following products are used? (n=21)**

<table>
<thead>
<tr>
<th>Chemical sanitizer (used for processing areas).</th>
<th>Chlorinated spray, wash, or dip (used on the poultry before packaging).</th>
<th>Peroxyacetic acid spray, dip, rinse, or wash (used on the poultry before packaging).</th>
<th>I do not use any spray, wash, or dips in my poultry processing.</th>
<th>I do not use any of the above products.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 (24%)</td>
<td>2 (10%)</td>
<td>5 (24%)</td>
<td>3 (14%)</td>
<td>6 (29%)</td>
</tr>
</tbody>
</table>

* Questions were answered with multiple responses.

Note: Sum of rows may be greater than 100% due to rounding and multiple responses.
Table 3: Responses of farmers’ market poultry vendors in Pennsylvania to exploratory based questions on the packaging, storage, and transportation of poultry.

**Q-8: How is the poultry stored after processing and packaging? (n=21)**

<table>
<thead>
<tr>
<th>Response</th>
<th>Number of Responses (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry is stored in an electrically powered freezer.</td>
<td>11 (52%)</td>
</tr>
<tr>
<td>Poultry is stored in a pre-chilled or frozen ice box (non-electric/non-battery powered).</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Poultry is stored fresh in an electrically-powered refrigerator.</td>
<td>9 (43%)</td>
</tr>
<tr>
<td>Poultry is stored fresh in a cooler with ice.</td>
<td>6 (29%)</td>
</tr>
<tr>
<td>Poultry is stored frozen somewhere else, but stored on my farm or property.</td>
<td>3 (14%)</td>
</tr>
<tr>
<td>Poultry is stored fresh or frozen at another farm or property.</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>I do not know.</td>
<td>2 (10%)</td>
</tr>
</tbody>
</table>

**Q-9: What is the temperature of the refrigerator, cooler, or freezer where the poultry is stored? (n=21)**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Number of Responses (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20 to 0°F</td>
<td>4 (19%)</td>
</tr>
<tr>
<td>0 to 10°F</td>
<td>3 (14%)</td>
</tr>
<tr>
<td>10 to 20°F</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>20 to 40°F</td>
<td>14 (67%)</td>
</tr>
<tr>
<td>I do not know.</td>
<td>3 (14%)</td>
</tr>
</tbody>
</table>

**Q-10: How is poultry packaged for sale at farmers’ markets? (n=20)**

<table>
<thead>
<tr>
<th>Packaging Method</th>
<th>Number of Responses (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-packaged in a food grade plastic bag and tied off</td>
<td>10 (50%)</td>
</tr>
<tr>
<td>Pre-packaged in a food grade plastic bag that is vacuum sealed</td>
<td>9 (45%)</td>
</tr>
<tr>
<td>Sold fresh or frozen on ice and placed into a food grade plastic bag at the time of sale</td>
<td>6 (30%)</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
</tr>
</tbody>
</table>

**Q-11: How is poultry transported to farmers’ markets? (n=21)**

<table>
<thead>
<tr>
<th>Transportation Method</th>
<th>Number of Responses (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In a cooler with ice.</td>
<td>12 (57%)</td>
</tr>
<tr>
<td>In an electrically powered cooler (run by electric generator/car battery, etc.)</td>
<td>2 (10%)</td>
</tr>
<tr>
<td>In a pre-chilled or frozen ice chest.</td>
<td>5 (24%)</td>
</tr>
<tr>
<td>In a cooler with no ice.</td>
<td>3 (14%)</td>
</tr>
<tr>
<td>In a commercial refrigerated or freezer truck.</td>
<td>4 (19%)</td>
</tr>
</tbody>
</table>

*Questions were answered with multiple responses.

Note: Sum of rows may be greater than 100% due to rounding and multiple responses.
Table 4: Responses of farmers’ market poultry vendors in Pennsylvania to exploratory based questions on farmers’ market retail practices.

*Q-1:  What items do you sell at farmers’ markets? (Circle all that apply).

<table>
<thead>
<tr>
<th>Item</th>
<th>Number of Responses (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits</td>
<td>6 (29%)</td>
</tr>
<tr>
<td>Vegetables</td>
<td>10 (48%)</td>
</tr>
<tr>
<td>Milk</td>
<td>4 (19%)</td>
</tr>
<tr>
<td>Cheese</td>
<td>7 (33%)</td>
</tr>
<tr>
<td>Turkey</td>
<td>12 (57%)</td>
</tr>
<tr>
<td>Chicken</td>
<td>19 (90%)</td>
</tr>
<tr>
<td>Other Poultry</td>
<td>6 (29%)</td>
</tr>
<tr>
<td>Beef</td>
<td>7 (33%)</td>
</tr>
<tr>
<td>Sheep</td>
<td>5 (24%)</td>
</tr>
<tr>
<td>Goat</td>
<td>3 (14%)</td>
</tr>
<tr>
<td>Other</td>
<td>5 (24%)</td>
</tr>
</tbody>
</table>

**Q-12: What is done with unsold poultry at the end of a market day? (n=21)**

<table>
<thead>
<tr>
<th>Option</th>
<th>Number of Responses (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsold fresh poultry is stored fresh for sale on the next market day.</td>
<td>6 (29%)</td>
</tr>
<tr>
<td>Unsold fresh poultry is frozen and then sold frozen on the next market day.</td>
<td>10 (48%)</td>
</tr>
<tr>
<td>I do not resell fresh poultry.</td>
<td>3 (14%)</td>
</tr>
<tr>
<td>Other</td>
<td>2 (10%)</td>
</tr>
</tbody>
</table>

*Questions were answered with multiple responses.

Note: Sum of rows may be greater than 100% due to rounding and multiple responses.
Table 5: Responses of farmers’ market poultry vendors in Pennsylvania to exploratory and knowledge based questions on government regulations affecting poultry vendors at farmers’ markets.

Q-15: I have read and follow the Pennsylvania Department of Agriculture’s Act 106 on Food Safety and farmers’ markets.

Q-16: Under the U.S. Poultry Product Inspection Act, a producer/grower who, in a calendar year slaughters, processes, and distributes between no more than 20,000 poultry, that they raised, are exempt from bird-by-bird inspection and the presence of inspectors during the slaughter of poultry and processing of poultry products.

<table>
<thead>
<tr>
<th>Number of Responses (%)</th>
<th>Q-15 (n=21)</th>
<th>Q-16 (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>10 (48%)</td>
<td>13 (65%)</td>
</tr>
<tr>
<td>No</td>
<td>6 (29%)</td>
<td>3 (15%)</td>
</tr>
<tr>
<td>I do not know</td>
<td>5 (24%)</td>
<td>4 (20%)</td>
</tr>
</tbody>
</table>

Note: Sum of rows may be greater than 100% due to rounding.
Table 6: Responses of farmers’ market poultry vendors in Pennsylvania to knowledge based questions on poultry processing, and food safety during poultry processing.

<table>
<thead>
<tr>
<th>Question</th>
<th>Description</th>
<th>Correct Responses (%)</th>
<th>Incorrect Responses (%)</th>
<th>I do not know (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q-17:</td>
<td>Raw poultry can contain the following pathogenic (harmful) bacteria. (Check all that apply)</td>
<td>7 (37%)</td>
<td>12 (63%)</td>
<td>-</td>
</tr>
<tr>
<td>Q-18:</td>
<td>Chilling or cooling poultry is required during processing to reduce the internal temperature of the birds to less than 40°F. (True/False)</td>
<td>18 (86%)</td>
<td>2 (10%)</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Q-19:</td>
<td>Poultry that is not chilled to an internal temperature of less than 40°F can have the following risks. (Check all that apply)</td>
<td>17 (81%)</td>
<td>2 (10%)</td>
<td>2 (10%)</td>
</tr>
<tr>
<td>Q-20:</td>
<td>Cross-contamination of harmful bacteria can occur if the poultry slaughter and de-feathering areas are too close to the cutting and packaging areas. (True/False)</td>
<td>18 (86%)</td>
<td>1 (5%)</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Q-21:</td>
<td>The use of antimicrobial sprays, dips, or washes can reduce the amount of harmful bacteria on raw poultry before packaging. (True/False)</td>
<td>14 (70%)</td>
<td>1 (5%)</td>
<td>5 (25%)</td>
</tr>
<tr>
<td>Q-22:</td>
<td>During poultry processing, which of the following can contaminate the raw poultry carcass with pathogenic (harmful) bacteria before packaging. (Check all that apply)</td>
<td>9 (45%)</td>
<td>10 (50%)</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Q-23:</td>
<td>Fresh poultry products should be stored at what temperature. (Select one answer)</td>
<td>16 (80%)</td>
<td>3 (15%)</td>
<td>1 (5%)</td>
</tr>
</tbody>
</table>

Questions were answered with multiple responses.
Note: Sum of rows may be greater than 100% due to rounding and multiple responses.
Table 7: Responses of farmers’ market poultry vendors in Pennsylvania to attitudinal based questions on food safety, poultry processing, and regulations.

<table>
<thead>
<tr>
<th>Q-24: Poultry products I sell at the farmers’ markets are safe.</th>
<th>Q-25: Poultry produced and sold locally at farmers’ markets are safer than conventional poultry sold at commercial supermarkets.</th>
<th>Q-26: I am concerned about pathogenic (harmful) bacteria being present on my raw poultry.</th>
<th>Q-27: I do not need any additional food safety interventions in my poultry processing.</th>
<th>Q-28: Food safety is important and I would like to learn more about keeping my poultry products safe.</th>
<th>Q-29: I support government regulation of poultry products sold at farmers’ markets.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of Responses (%)</strong></td>
<td>Q-24 (n=21)</td>
<td>Q-25 (n=21)</td>
<td>Q-26 (n=21)</td>
<td>Q-27 (n=20)</td>
<td>Q-28 (n=21)</td>
</tr>
<tr>
<td>Strongly Agree (5)</td>
<td>16 (76%)</td>
<td>13 (62%)</td>
<td>8 (38%)</td>
<td>5 (25%)</td>
<td>12 (57%)</td>
</tr>
<tr>
<td>Agree (4)</td>
<td>5 (24%)</td>
<td>7 (33%)</td>
<td>6 (29%)</td>
<td>2 (10%)</td>
<td>3 (14%)</td>
</tr>
<tr>
<td>Neutral (3)</td>
<td>-</td>
<td>-</td>
<td>4 (19%)</td>
<td>8 (40%)</td>
<td>6 (29%)</td>
</tr>
<tr>
<td>Disagree (2)</td>
<td>-</td>
<td>1 (5%)</td>
<td>2 (10%)</td>
<td>1 (5%)</td>
<td>-</td>
</tr>
<tr>
<td>Strongly Disagree (1)</td>
<td>-</td>
<td>-</td>
<td>1 (5%)</td>
<td>4 (20%)</td>
<td>-</td>
</tr>
<tr>
<td>Mean Score</td>
<td>4.8</td>
<td>4.5</td>
<td>3.9</td>
<td>3.2</td>
<td>4.3</td>
</tr>
</tbody>
</table>

Note: Sum of rows may be greater than 100% due to rounding and multiple responses.
Table 8: Responses of farmers’ market poultry vendors in Pennsylvania to exploratory based questions on demographics and willingness to participate in future training.

| Q-30: What is the highest degree or level of school you have completed? If currently enrolled, mark the previous grade or highest degree received. |
| Number of Responses (%) (n=17) |
|------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| No schooling completed       | Middle School (6-8th grade) | High school graduate (or completed GED) | Some college credit, but less than 1 year | 1 or more years of college, no degree | Bachelor's degree | Master's degree |
| 2 (12%)                      | 4 (24%)          | 2 (12%)         | 1 (6%)           | 2 (12%)          | 5 (29%)         | 1 (6%)          |

| Q-31: What is your age? (n=18) |
|-------------------------------|-----------------|-----------------|-----------------|-----------------|
| 18-21                         | 22 to 34        | 35 to 44        | 45 to 54        | 55 to 64        | 65 and over     |
| 0                             | 2 (11%)         | 6 (33%)         | 4 (22%)         | 6 (33%)         | 0               |

| Q-32: I would attend a food safety training/workshop on food safety and poultry processing hosted by the Penn State Cooperative Extension. (n=17) |
|---------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Yes, but only if it is free.               | Yes, and I would be willing to pay $25 to $50. | Yes, and I would be willing to pay $50 to $100. | No, but I would like information on food safety pertaining to poultry processing. | No, and I do not want any additional assistance or information from Penn State. |
| 7 (41%)                                     | 3 (18%)         | 1 (6%)          | 4 (24%)         | 2 (12%)         |

Note: Sum of rows may be greater than 100% due to rounding and multiple responses.
Chapter 4
Conclusions and future research
Conclusions and future research

This project determined the prevalence of *Campylobacter* spp., *Salmonella* spp., aerobic plate counts (APC), generic *E. coli*, and coliforms in whole chicken obtained from farmers’ markets and supermarkets throughout Pennsylvania. This study demonstrated that the prevalence of *Campylobacter* spp. and *Salmonella* spp. on whole chicken obtained at farmers’ markets was significantly higher, when compared to conventionally-processed, whole chicken purchased at supermarkets. Whole chicken obtained from farmers’ markets was determined to be contaminated with *Campylobacter* spp., and *Salmonella* spp., since 90% and 28% of whole chickens sampled from farmers’ markets were positive for the pathogens, respectively, after enrichment. The data obtained from this study suggest that organically-processed, whole chicken obtained from supermarkets in Pennsylvania may have a similar microbiological profile to whole chickens purchased at farmers’ markets. This study also demonstrated that levels of generic *E. coli*, coliforms, and prevalence of *Salmonella* spp. were not significantly different between farmers’ market and organic whole chicken. However, APC and *Campylobacter* spp. prevalence were significantly higher in farmers’ market, as compared to organic, whole chicken.

Additionally, this study investigated potential differences in the prevalence of *Campylobacter* spp. and *Salmonella* spp. on whole fresh or frozen chickens obtained at farmers’ markets. While no significant differences in the overall prevalence of *Campylobacter* spp. and *Salmonella* spp. were observed on fresh and frozen whole chicken, *Campylobacter* spp. – positive, fresh whole chicken did exhibit a significantly higher percentage of enumerable samples, when compared to *Campylobacter* spp. – positive frozen samples. This observation suggests that frozen storage may reduce the level of *Campylobacter* spp. present on contaminated chicken.
Microbiological data obtained from this study also suggest that vendors selling chicken at farmers’ markets may be able to improve the bacteriological quality and safety of their product by adopting control measures, such as antimicrobial interventions. Identification of species and serotyping of *Campylobacter* and *Salmonella* isolates, respectively, may provide insight into the reservoirs and phylogenetic relationships of these organisms.

After the microbiological data were collected, a needs assessment of poultry vendors at farmers’ markets was developed and implemented to identify potential gaps in food safety knowledge, attitudes, and general practices of poultry processing and regulatory requirements, as well as explore how vendors are growing, processing, transporting, and storing those foods sold direct to consumers. Among the 30 poultry vendors identified at farmers’ markets throughout Pennsylvania, 21 agreed to participate in a 32-question, paper-based needs assessment. The results revealed that approximately half of the vendors surveyed indicated that they performed the slaughter and processing of their poultry sold at their respective farmers’ markets. Specific unhygienic poultry processing practices also were identified: 33% of vendors slaughter and process poultry outdoors; 43% lacked chemical sanitation of processing areas and poultry products; and 48% of vendors are utilizing questionable cold storage containers in which the temperatures are unknown. Approximately half the vendors also lacked knowledge of applicable regulatory requirements and the majority of vendors did not appear to understand the concept of pathogens and their role in cross contamination during slaughter and processing. In contrast, vendors appeared to have sufficient knowledge of temperature control during poultry processing, 45% of vendors utilized vacuum packaging, and over 50% utilized electrically-powered coolers for cold storage. All vendors surveyed also believed their products were safe or safer than conventional poultry sold at supermarkets. Inconsistencies were identified among
vendor attitudes, with over half of vendors agreeing that they are concerned about pathogens in their products, but do not agree that they need additional food safety interventions during poultry processing. It was also evident that vendors vary greatly in their attitudes towards government regulation of poultry at farmers’ markets, with a large portion of vendors having taken a neutral stance on the topic.

The results from this project will aid in the development of a multi-state project seeking to explore the microbiological profile of multiple farmers’ market products across the Northeast U.S., as well the development of large scale vendor needs assessments and training. The results also revealed specific high risk slaughter and processing gaps in which future research also can begin to target those specific nodes in the processing of poultry and other similar products. The information gathered in this study may be of interest to regulatory officials who are responsible for local, state, or federal regulations directed at farmers’ markets and for educators who are interested in implementation of food safety training programs. Educating this underserved audience has the potential to sustain and ensure the continued success of farmers’ markets and the safety of those foods sold direct to consumers.
Appendix A
Needs Assessment Survey of Farmers’ Market Poultry Vendors in Pennsylvania
APPENDIX A. Needs Assessment Survey of Farmers’ Market Poultry Vendors in Pennsylvania

To Whom it May Concern;

Farmers’ markets have recently become a significant source of food for many Pennsylvania residents, as well as an important outlet for farmers and small businesses to sell their agricultural products directly to customers. With more and more farmers’ markets opening each year, and the thousands of people visiting farmers’ markets every week, the Department of Food Science at Penn State University would like to understand more about what foods are being sold and how we can help vendors ensure their products are safe for the consuming public.

Currently, our research focus is on poultry sold at farmers’ markets. We would like to learn more about your poultry products and processing steps in order to develop important food safety training that addresses your needs and the needs of vendors like you. Attached, you will find a questionnaire that asks about the types of poultry products you may sell at farmers’ markets, your knowledge of safe food handling practices, regulations, and steps in poultry processing as well as attitudes and beliefs about food safety and government regulation.

The questionnaire will take no longer than 15 minutes of your time. The information you provide will be kept strictly confidential. We will not connect your name with your responses and we will not share this information with anyone not involved in this study. We will only track responses, so no answers will be tracked to you as an individual or vendor. Do NOT put your name on the questionnaire and please be honest.

This study is being conducted for research purposes. If you have any questions, please contact the questionnaire administrator (Joshua Scheinberg) or the principal investigator (Dr. Catherine Cutter). Mr. Scheinberg and Amanda Svoboda will be present to administer the questionnaire to help ensure confidentiality and anonymity. All of their contact information is listed below.

Responses to this questionnaire will help Penn State University develop new food safety educational programs to help meet your needs as a farmers’ market vendor.

Thank you for your time!

Dr. Catherine Cutter
Associate Professor
433 Food Science Building
University Park, PA 16802
cnc3@psu.edu

Joshua Scheinberg
Graduate Research Assistant
431 Food Science Building
University Park, PA 16802
jas6387@psu.edu

Amanda Svoboda
Graduate Research Assistant
431 Food Science Building
University Park, PA 16802
als5929@psu.edu
Section I: Farmers’ Markets and Poultry Processing:

1. **What items do you sell at farmers’ markets?** (Circle all that apply)

   - Fruits
   - Vegetables
   - Milk
   - Cheese
   - Turkey
   - Chicken
   - Other poultry
   - Beef
   - Sheep
   - Goat

   Other (please list) __________________________________________________________

2. **Where do you process your poultry that you sell at farmers’ markets?**

   - □ I do not process poultry; it is processed by a local processor
     (please list processor) ___________________________________________________
   - □ I do not process poultry; it is processed by someone else at another location
   - □ I do not process poultry; I purchase my poultry from a wholesale supplier
   - □ I process poultry on my farm or property

3. **What is the condition of the facility where your poultry is processed?**

   - □ The poultry is processed outside, with no cover
   - □ The poultry is processed outside, under a fixed roof or covering
   - □ The poultry is processed inside a barn
   - □ The poultry is processed inside a house
   - □ The poultry is processed in a dedicated processing area inside a fixed building
   - □ I do not know

4. **How far is the poultry slaughter and de-feathering area from your final packaging area (approximately)?**

   - □ I do not process poultry
   - □ 1 to 2 feet
   - □ 3 to 5 feet
   - □ 6 to 8 feet
   - □ 9 to 10 feet
   - □ 11 to 15 feet
   - □ 15 to 20 feet
   - □ More than 20 feet apart
   - □ I do not know
5. **At what temperature is the poultry chilled after processing but before packaging?**

- [ ] I do not process poultry
- [ ] 0 to 20°F
- [ ] 20 to 40°F
- [ ] 40 to 60°F
- [ ] I chill my poultry, but I do not know the temperature
- [ ] I do not chill my poultry before packaging
- [ ] I do not know

6. **During processing and packaging of the poultry, which of the following equipment are used: (Check all that apply)**

- [ ] Scalding water bath
- [ ] Defeathering/picker machine
- [ ] Kill cone
- [ ] Electric stunner
- [ ] Chilled water bath
- [ ] Refrigerator
- [ ] Freezer
- [ ] Vacuum packager
- [ ] Hose
- [ ] Raised poultry hanging device
- [ ] Dedicated cutting table

Other (please list)_____________________________________________________________________________________

7. **During the processing of the poultry, which of the following products are used: (Check all that apply)**

- [ ] Chemical sanitizer (used for processing areas)
- [ ] Chlorinated spray, wash, or dip (used on the poultry before packaging)
- [ ] Peroxyacetic acid spray, dip, rinse, or wash (used on the poultry before packaging)
- [ ] I do not use any spray, wash, or dips in my poultry processing
- [ ] Other spray, wash, or dip (used on the poultry before packaging)
  (If other, please list)_______________________________________________________________________________
- [ ] I do not use any of the above products
- [ ] I do not know
8. How is the poultry stored after processing and packaging? (Check all that apply)

☐ Poultry is stored in an electrically powered freezer
☐ Poultry is stored in a pre-chilled or frozen ice box (non-electric/non-battery powered)
☐ Poultry is stored fresh in an electrically-powered refrigerator
☐ Poultry is stored fresh in a cooler with ice
☐ Poultry is stored frozen somewhere else, but stored on my farm or property
☐ Poultry is stored fresh or frozen at another farm or property
☐ I do not know

9. What is the temperature of the refrigerator, cooler, or freezer where the poultry is stored? (Check all that apply)

☐ -20 to 0°F
☐ 0 to 10°F
☐ 10 to 20°F
☐ 20 to 40°F
☐ I do not know
☐ There is no refrigerator, cooler, or freezer at the farm or on the property

10. How is the poultry packaged for sale at farmers’ markets?

☐ Pre-packaged in a food grade plastic bag and tied off
☐ Pre-packaged in a food grade plastic bag that is vacuum sealed
☐ Sold fresh or frozen on ice and placed into a food grade plastic bag at the time of sale
☐ Other:______________________________________

11. How is poultry transported to farmers’ markets? (Check all that apply)

☐ In a cooler with ice
☐ In an electrically powered cooler (run by electric generator/car battery, etc.)
☐ In a pre-chilled or frozen ice chest
☐ In a cooler with no ice
☐ In a commercial refrigerated or freezer truck
☐ I do not transport poultry, it is delivered to my vending area
☐ I do not know

12. What is done with unsold poultry at the end of a market day?

☐ Unsold fresh poultry is stored fresh for sale on the next market day
☐ Unsold fresh poultry is frozen and then sold frozen on the next market day
☐ I do not re-sell fresh poultry
☐ Other
   (If other, please explain)_________________________________________
13. **How would you best describe your type of poultry production system?**

- □ Conventional (fixed, enclosed houses)
- □ Pasture-based with moveable pens
- □ Pasture-based, day range
- □ Pasture-based free range
- □ I do not know

14. **If you have a pasture-based production system and use moveable pens, how many birds are kept in each pen?**

- □ 1-50
- □ 51-100
- □ 101-200
- □ Over 200
- □ I do not have a pasture-based production system

15. **I have read and follow the Pennsylvania Department of Agriculture’s Act 106 on Food Safety and farmers’ markets.**

- □ Yes
- □ No
- □ I do not know
Section II: Knowledge Questions:

16. Under the U.S. Poultry Product Inspection Act, a producer/grower who, in a calendar year slaughters, processes, and distributes between no more than 20,000 poultry, that they raised, are exempt from bird-by-bird inspection and the presence of inspectors during the slaughter of poultry and processing of poultry products.

- True
- False
- I do not know

17. Raw poultry can contain the following pathogenic (harmful) bacteria: (Check all that apply)

- Campylobacter
- Salmonella
- Probiotics
- Pathogenic E. coli
- Methicillin resistant Staphylococcus aureus
- I do not know

18. Chilling or cooling poultry is required during processing to reduce the internal temperature of the birds to less than 40°F?

- True
- False
- I do not know

19. Poultry that is not chilled to an internal temperature of less than 40°F can have the following risks: (Check all that apply)

- Growth of pathogenic (harmful) bacteria
- Growth of spoilage microorganisms
- There are no risks, it is not important to chill poultry after slaughter
- I do not know

20. Cross-contamination of harmful bacteria can occur if the poultry slaughter and defeathering areas are too close to the cutting and packaging areas.

- True
- False
- I do not know
21. The use of antimicrobial sprays, dips, or washes can reduce the amount of harmful bacteria on raw poultry before packaging.

- True
- False
- I do not know

22. During poultry processing, which of the following can contaminate the raw poultry carcass with pathogenic (harmful) bacteria before packaging? (Check all that apply)

- Feathers
- Feces
- Internal organs
- Blood
- All of the above
- I do not know

23. Fresh poultry products should be stored at what temperature?

- Less than 51°F
- Less than 41°F
- Less than 31°F
- I do not know
Section III: Attitude Questions:

To what extent do you agree or disagree with each of the following statements

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

(Circle your choice under each question)

Poultry products I sell at the farmers’ markets are safe.

1  2  3  4  5

Poultry produced and sold locally at farmers’ markets are safer than conventional poultry sold at commercial supermarkets.

1  2  3  4  5

I am concerned about pathogenic (harmful) bacteria being present on my raw poultry.

1  2  3  4  5

I do not need any additional food safety interventions in my poultry processing.

1  2  3  4  5

Food safety is important and I would like to learn more about keeping my poultry products safe.

1  2  3  4  5

I support government regulation of poultry products sold at farmers’ markets.

1  2  3  4  5
What is the highest degree or level of school you have completed? If currently enrolled, mark the previous grade or highest degree received.

- □ No schooling completed
- □ Elementary school (1st to 6th grade)
- □ Middle School (6th to 8th grade)
- □ Attended high school, but did not graduate
- □ High school graduate (or completed GED)
- □ Some college credit, but less than 1 year
- □ 1 or more years of college, no degree
- □ Associate degree
- □ Bachelor’s degree
- □ Master’s degree
- □ Professional degree
- □ Doctorate degree

What is your age?

- □ 18-21
- □ 22 to 34
- □ 35 to 44
- □ 45 to 54
- □ 55 to 64
- □ 65 and over
- □ I do not wish to answer

I would attend a food safety training/workshop on food safety and poultry processing hosted by the Penn State Cooperative Extension.

- □ Yes, but only if it is free
- □ Yes, and I would be willing to pay $25 to $50
- □ Yes, and I would be willing to pay $50 to $100
- □ No, but I would like information on food safety pertaining to poultry processing
- □ No, and I do not want any additional assistance or information from Penn State

Thank you for taking time to complete this questionnaire!
Appendix B
Informed Consent Form
APPENDIX B: Needs Assessment Survey Informed Consent Form

Informed Consent Form for Social Science Research
The Pennsylvania State University

Title of Project: Farmers’ Market Poultry Vendors, an Exploratory Needs Assessment

Principal Investigator: Dr. Catherine Cutter, 433 Food Science Building, University Park, Pa 16802 (XXX)- XXX-XXXX
  cnc3@psu.edu

Other Investigator(s): Joshua Scheinberg, 431 Food Science Building, University Park, Pa 16802 (XXX)- XXX-XXXX, jas6387@psu.edu

Amanda Svoboda, 435 Food Science Building, University Park, Pa 16802 (XXX)-XXX-XXXX, als5929@psu.edu

1. **Purpose of the Study:** The purpose of this research is to explore the food safety knowledge and attitudes (in the areas of poultry processing, food safety, and government regulations) of vendors selling fresh or frozen poultry products at farmers’ markets in Pennsylvania.

2. **Procedures to be followed:** This needs assessment questionnaire will require one visit to a farmers’ market for approximately fifteen minutes before or after the working hours of the farmers’ market. During this time, you will be asked to complete a short questionnaire consisting of approximately 30 questions.

3. **Discomforts and Risks:** There are no risks in participating in this research, beyond those experienced in everyday life.

4. **Benefits:** The benefits to you include future invitations to training and future access to informational materials in the areas of food safety and poultry processing customized for vendors who raise and sell poultry. The benefits to society include an overall safer food supply.

5. **Duration/Time:** The questionnaire will only be needed to be taken once and will take approximately fifteen minutes to complete.

6. **Statement of Confidentiality:** Your participation in this research is confidential. The data will be aggregated stored and secured at Penn State University in a locked or password-protected file. Only Dr. Catherine Cutter and Joshua Scheinberg will have access to the information for the duration of the materials being kept, which is a period of not less than three years, but within five years. In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared. “The Pennsylvania State University’s Office for Research Protections and Institutional Review Board, and the Office for Human Research Protections in the Department of Health and Human Services may review records related to this project.”
7. **Right to Ask Questions:** Please contact Dr. Catherine Cutter at (814) 865-8862 or via email at cnc3@psu.edu with questions, complaints or concerns about this research. You can also call this number if you feel this study has harmed you. If you have any questions, concerns, problems about your rights as a research participant or would like to offer input, please contact The Pennsylvania State University’s Office for Research Protections (ORP) at (814) 865-1775. The ORP cannot answer questions about research procedures. Questions about research procedures can be answered by the research team.

8. **Voluntary Participation:** Your decision to be in this research is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive otherwise.

9. **Payment for Participation:** You will be compensated with $10 in cash for your participation in the needs assessment.

You must be 18 years of age or older to consent to take part in this research study. If you agree to take part in this research study given the information outlined above, please sign your name and indicate the date below.

You will be given a copy of this consent form for your records.

__________________________________________________________________________  
Participant Signature  
_________  
_________  
Date

__________________________________________________________________________  
Person Obtaining Consent  
_________  
_________  
Date
APPENDIX C: Needs Assessment Verbal Script

Good Morning/Afternoon,

My Name is (state your name), this is (state second researcher’s name, if present)

(I/We) are from the Department of Food Science at Penn State and we are conducting a survey in order to learn more about farmers’ market vendors, and specifically those who sell poultry products. This survey is being conducted for research purposes only, and the information you provide will help us understand more about farmers’ markets, and how we can develop future educational tools and programs to assist farmers’ market vendors like you, in providing safe and quality food products.

This questionnaire should take only 15 minutes to complete, and upon completion, you will be awarded $10 in cash. All information you provide will be kept confidential. The responses you provide on the survey will never be associated with your name or business name, and we will not share this information with anyone not involved in this study.

Would you like to participate in the survey?

If No:

Thank the vendor for their time, and leave the premise.

If yes:

Proceed with providing the vendor with the consent form and needs assessment survey.
Appendix D
Identification of *Salmonella* serotypes from *Salmonella* isolates obtained from whole chicken at farmers’ markets and supermarkets in Pennsylvania
APPENDIX D. Identification of *Salmonella* serotypes from *Salmonella* isolates obtained from whole chicken at farmers’ markets and supermarkets in Pennsylvania

Table 1: Identification of *Salmonella* serotypes from *Salmonella* isolates obtained from whole chicken at farmers’ markets and supermarkets in Pennsylvania

<table>
<thead>
<tr>
<th></th>
<th>S. Enteritidis</th>
<th>S. Typhimurium</th>
<th>S. Kentucky</th>
<th>S. Thompson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional (n=3)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3/3 (100%)</td>
</tr>
<tr>
<td>Organic (n=10)</td>
<td>5/10 (50%)</td>
<td>-</td>
<td>4/10 (40%)</td>
<td>-</td>
</tr>
<tr>
<td>Farmers’ Market (n=30)**</td>
<td>6/30 (20%)</td>
<td>8/30 (27%)</td>
<td>16/30 (53%)</td>
<td>-</td>
</tr>
<tr>
<td>4 Vendors*</td>
<td>3 Vendors</td>
<td>7 Vendors*</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*Among the 13 vendors containing *Salmonella*-positive whole chicken, one vendor contained whole chicken with two different serotypes; *S. Kentucky* and *S. Enteritidis.*

**Thirty isolates included two obtained from enumeration procedures, which were not different from those isolates obtained from the same sample through enrichment.
Appendix E

Prevalence and percentage of *Campylobacter* spp.- and *Salmonella* spp.-positive, chicken carcass rinses obtained from individual farmers’ market vendors in Pennsylvania using conventional culture methods
**APPENDIX E. Prevalence and percentage of *Campylobacter* spp.- and *Salmonella* spp.-positive, chicken carcass rinses obtained from individual farmers’ market vendors in Pennsylvania using conventional culture methods**

Table 1: Prevalence and percentage of *Campylobacter* spp.- and *Salmonella* spp.- positive, chicken carcass rinses obtained from individual farmers’ market vendors in Pennsylvania using conventional culture methods.

<table>
<thead>
<tr>
<th>Vendor*</th>
<th>Fresh Samples**</th>
<th>Frozen Samples**</th>
<th>Total Samples</th>
<th>Confirmed <em>Salmonella</em> spp.</th>
<th>Confirmed <em>Campylobacter</em> spp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>8</td>
<td>0</td>
<td>8</td>
<td>4/8 (50%)</td>
<td>8/8 (100%)</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>9</td>
<td>9</td>
<td>1/9 (11%)</td>
<td>9/9 (100%)</td>
</tr>
<tr>
<td>C</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>0/8</td>
<td>6/9 (67%)</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>0/5</td>
<td>3/5 (60%)</td>
</tr>
<tr>
<td>E</td>
<td>8</td>
<td>4</td>
<td>12</td>
<td>4/12 (33%)</td>
<td>12/12 (100%)</td>
</tr>
<tr>
<td>F</td>
<td>8</td>
<td>0</td>
<td>8</td>
<td>4/8 (50%)</td>
<td>8/8 (100%)</td>
</tr>
<tr>
<td>G</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>0/8</td>
<td>8/8 (100%)</td>
</tr>
<tr>
<td>H</td>
<td>0</td>
<td>7</td>
<td>7</td>
<td>6/7 (86%)</td>
<td>7/7 (100%)</td>
</tr>
<tr>
<td>I</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1/2 (50%)</td>
<td>2/2 (100%)</td>
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<tr>
<td>J</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1/2 (50%)</td>
<td>2/2 (100%)</td>
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<td>K</td>
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<td>0/2</td>
<td>1/2 (50%)</td>
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<td>L</td>
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<td>0</td>
<td>4</td>
<td>4/4 (100%)</td>
<td>4/4 (100%)</td>
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<tr>
<td>M</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>1/3 (33%)</td>
<td>3/3 (100%)</td>
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<tr>
<td>N</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>0/4</td>
<td>4/4 (100%)</td>
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<td>O</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1/2 (50%)</td>
<td>2/2 (100%)</td>
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<td>P</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0/2</td>
<td>2/2 (100%)</td>
</tr>
<tr>
<td>Q</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>1/3 (33%)</td>
<td>3/3 (100%)</td>
</tr>
<tr>
<td>R</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>0/5</td>
<td>5/5 (100%)</td>
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<tr>
<td>S</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0/2</td>
<td>2/2 (100%)</td>
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<td>0</td>
<td>2</td>
<td>2</td>
<td>0/2</td>
<td>0/2</td>
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<td>U</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1/2 (50%)</td>
<td>0/2</td>
</tr>
</tbody>
</table>

* Vendors were given random alphabetic designators to ensure confidentiality.

** Certain vendors only sold fresh or frozen whole chicken.