IDENTIFYING PRODUCTION FACILITY CHARACTERISTICS IN SMALL AND VERY SMALL MEAT PROCESSING PLANTS WITH REFERENCE TO FSIS *SALMONELLA* TEST RESULTS

DISSERTATION

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ABSTRACT

Salmonella spp. is one of the leading microbial causes of foodborne illness in the United States with over 43,000 reported cases in 2007. This has shown an increase over the past several years, while many of the other pathogens most often linked to animal products have decreased. To address this trend, in 2006, the Food Safety and Inspection Service (FSIS) implemented a categorical system to encourage processors to make improvements to their processing conditions. This system was designed to assist plants that were in danger of failing initial *Salmonella* test sets.

Production facilities with less than 500 employees face unique challenges, such as lack of technical support, financial and physical flexibility. These processors make a wide array of products. These unique challenges necessitate identifying processing conditions and sanitation protocols that correlate with reduced *Salmonella* contamination.

Using the results from the FSIS 2005 *Salmonella* test sets, a case-control study was designed to address this need. The small and very small plants that failed test set A were selected as cases (n=32) and controls were matched to the case plants by inspection district and size, 4:1. Control plants had completed and passed the A set tests. The survey instrument was created in 3 parts: General Hazard Analysis and Critical Control Points (HACCP), Slaughter, and Raw Product Processing. The slaughter survey contained additional questions regarding livestock species-specific practices. Surveys were

completed by phone with company representatives familiar with the establishments' HACCP plans and sanitation practices. The response rates were 40% and 38% for case and control plants, respectively. Other than variables representing plant size, such as numbers of employees and volume of production, there were few significant differences between small and very small respondents. Differences between cases and controls were found in animal washing before slaughter, type of poultry evisceration and percentage of raw product from in-house slaughter. Most of the plants (71%), operate under 2 or 3 processing categories; with the majority of the plants processing 10 or more products (60%). Seventy-six percent process raw products daily. Only 34% of the respondents slaughter red meat with 57% of those slaughtering daily. Gloves are worn during processing in 88% of the plants that process raw products; however, almost a quarter of those reported no policy requiring glove use. Ninety-five percent of plants reporting woven glove use have policies to launder or dispose of gloves. About 36% of the plants had Sanitation Standard Operating Procedures or Good Manufacturing Practices in place to specifically address *Salmonella*. Almost 28% have determined *Salmonella* contamination as a hazard likely to occur in their processes. Consistent use and knowledge of sanitation protocols were lacking in many cases. Additional details from these plants could provide more useful information for *Salmonella* control in smaller processing facilities. Results from this research will help focus and expand specific Extension programs for small and very small meat processors.

Dedicated to all of my teachers, many of whom never stood in front of a classroom.

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FIELDS OF STUDY

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CHAPTER 1

INTRODUCTION

Salmonella spp. is one of the leading microbial causes of foodborne illness in the United States. In 2007, there were more than 43,000 reported cases of salmonellosis in the U.S. Due to underreporting, the Centers for Disease Control and Prevention uses a multiplication factor of 38 times the surveillance rate to estimate the actual number of cases (41) indicating over 1.5 million cases in 2007. In comparison, the 2007 estimated number of illness resulting from an infection of *Listeria monocytogenes* was less than 1,500 and illnesses from Shiga-toxin producing *Escherichia coli* (including *E. coli* O157:H7) were less than 90,000. While many of the illnesses caused by foodborne pathogens often linked to animal products have decreased over the past several years, the salmonellosis incidences have remained constant.

In 1996, the Pathogen Reduction/ Hazard Analysis Critical Control Point (PR/HACCP) regulations were implemented. *Salmonella* testing in raw meat processing establishments was an integral part of the Pathogen Reduction measures. Products tested included chickens (broilers), cattle (cows/bulls and heifers/steers), and hogs at slaughter plants and chicken, turkey and beef at grinding operations. The selection of plants was changed in 2006, and the sampling of turkey carcasses was added.

United States Department of Agriculture (USDA) Food Safety and Inspection Service (FSIS) categorizes meat processing plants in to three size categories; large (500+ employees), small (10 – 499 employees) and very small (less than 10 employees) (63). Of the more than 6,000 federally inspected establishments, over 80% fall into the small and very small categories. Most small and very small plants do not have the resources that large plants have in terms of technical support, flexibility to incorporate new technologies, and the ability to train employees. Small and very small meat processing plants are also highly variable; producing many different types of products, in many different processing categories in the same plant.

A comprehensive characterization of these smaller meat processors in the United States has not been published. The unique challenges of these smaller processors heighten the need for a detailed investigation to both describe the production facility characteristics and assess what characteristics are associated with bacterial contamination of meat products. A survey was built to carry out this investigation, covering three major areas: HACCP, Slaughter, and Raw Products Processing. A case-control study was developed, selecting federally inspected small and very small meat processors based on their 2005 *Salmonella* test set A results. Each of the selected plants were sent the questionnaires then contacted by telephone. The surveys were subsequently carried out by telephone interview.

There were three objectives for this study. The first was to evaluate the characteristics of small and very small meat processors. Second, to ascertain currently used practices for controlling *Salmonella* in those small and very small plants, and finally

to determine the efficacy or risk of the above characteristics and practices in reference to failing FSIS *Salmonella* test sets.

CHAPTER 2

REVIEW OF LITERATURE

Foodborne Illness

Foodborne pathogens are responsible for over 76 million illnesses a year in the United States. The most common etiological agents are norovirus, *Campylobacter*, *Salmonella*. Due to the severity of the illness and the most susceptible population (children and older adults), even though *Escherichia coli* O157:H7, and *Listeria monocytogenes* cause fewer illnesses, they garner much attention when either are suspected of causing an outbreak. It is estimated that foodborne pathogens are responsible for 325,000 hospitalizations and 5,000 deaths each year (41).

Salmonella Infection

Salmonella spp. is one of the leading microbial causes of foodborne illness in the United States (11, 59) with more than 43,000 reported cases of S*almonella* infections in 2007. A typical *Salmonella* infection, known as salmonellosis, presents as acute enterocolitis, headache, abdominal pain, diarrhea, nausea, and fever. Sometimes vomiting accompanies these symptoms (24). In extreme cases, the infection can spread to the skin, bloodstream (sepsis), heart, kidneys, bone marrow, or meningeal lining of the brain

leading to severe illness and possibly death (5). Though the mortality rate of salmonellosis is low (0.78%), the number of cases makes salmonellosis the most common cause of death from foodborne viruses, bacteria, or parasites (41).

Due to underreporting of salmonellosis, the Centers for Disease Control and Prevention (CDC) uses a factor of 38 times the surveillance rate to estimate the actual number of cases (41), indicating that there have been over 1.5 million cases in 2007 (approximately a rate of 14.5 per 100,000 people). It is estimated that the financial impact of salmonellosis in the United States costs over $4.0 billion each year (61). In comparison, the 2007 estimated number of illness resulting from an infection of *Listeria monocytogenes* is less than 1,500 and illnesses from Shiga-toxin producing *Escherichia coli* (including *E. coli* O157:H7) were less than 90,000, rates of 0.3 and 1.1 per 100,000 people, respectively (68).

In 2000, a coalition of federal agencies (CDC, Food and Drug Administration (FDA), Health Resources and Services Administration, National Institutes of Health (NIH), United States Department of Agriculture (USDA) Food Safety and Inspection Service (FSIS) among many others) released health related goals and objectives for the nation called "Healthy People 2010." The two goals were to increase the quality and years of healthy life and to reduce the health disparities between population segments. To achieve these goals, 28 focus areas were established as general areas for improvement of American health, including Food Safety. One of the several actions set forth in the Food Safety focus area was to reduce foodborne illnesses caused by *E. coli* O157:H7,

Campylobacter spp., *Listeria monocytogenes*, and *Salmonella* spp. to half of the 1997 baseline rates (69).

Salmonella spp.

The genus *Salmonella* contains two recognized species: *S. bongori* and *S. enterica.* There are over 2400 *Salmonella* serovars and many of the serovars include multiple serotypes. An example of the nomenclature system currently used is *Salmonella enterica* serovar Typhimurium. This may be abbreviated as *Salmonella* Typhimurium (9).

All *Salmonella* serovars are considered pathogenic. Most of them cause enterocolitis; only two of the serotypes are known to cause Typhoid fever and two others cause bacteremia (51). However, according to FoodNet, which tracks the strains of bacteria that are implicated in foodborne outbreaks, only a few serotypes have been implicated in human illness; just 5 serotypes (Typhimurium, Enteritidis, Newport, Heidelberg, and Javiana, in descending order) have caused over 60% of the human cases for the years 1987-1997, and continue to be the leading serotypes implicated in human salmonella infections (12, 51).

In general, *Salmonella* will grow between 5.3°C (41.5°F) and 45°C (113°F), in the pH range of 6.6 to 8.2 and a water activity level of 0.94 or above. However, conditions outside of these ranges do not necessarily indicate destruction of the bacteria. In dry conditions (water activity of 0.94 or less) or temperatures less than 41°F, growth is not evident but survival has been shown (27).

Salmonella in Meat

In the U.S. the most common foods identified as the source for *Salmonella* outbreaks are eggs, poultry, and beef (59). However, pork and pork products are more often contaminated with *Salmonella* than beef and beef products. The difference in outbreaks related to beef and pork may be a result of different serotypes and pathogenicity of those strains, and/or a result of cooking practices. While it is very common to consume raw or undercooked beef and egg products, most pork and pork products are fully cooked. Chicken, though not usually consumed raw, is the most common animal source associated with human salmonellosis in the U.S. According to samples taken by the United States Department of Agriculture (USDA) Food Safety and Inspection Service (FSIS) in 2005, 16.1% of the whole broiler chickens were found to be positive for *Salmonella* spp. (20), as well as 32.4% and 23.2% of ground chicken and turkey samples, respectively. For the same year, contamination rates for market hogs, cows/bulls, steers/heifers and ground beef were 3.7%, 1.3%, 0.6% and 1.1%, respectively (64).

Consumption of chicken and turkey products has dramatically increased. U.S. consumers in the early 1990s purchased twice the amount of poultry products purchased compared to the early 1970's. For the same time period, beef consumption fell while pork consumption remained level (36, 50). With the increased consumption of products with the highest rates of contamination, the population has a higher risk for exposure to the pathogen and a potential for an increase in the incidence of illness.

Contrary to the Healthy People 2010 goals, salmonellosis rates have not decreased. The baseline established in 1997 was an incidence rate of 13.6 per 100,000 people. The rate of salmonellosis seemed to peak in 2002 at 16.2, but has not declined below 14 since 1999, more than double the goal of 6.8 cases per 100,000 people (68).

Sources of *Salmonella* contamination

Salmonella are primarily intestinal bacteria and are commonly found in fecal material and widespread in the environment (71). Food animals such as cattle, hogs, and chickens can become infected through many pathways, such as water sources, feed, and other animals (same species or wildlife). Hens carrying *Salmonella* can contaminate eggs and pass the infection to the chicks. Animals may be infected with *Salmonella* and not exhibit signs of illness. It is from these animals as they enter into the processing environment that contamination into food stems from.

In the slaughter establishments, fecal material is ubiquitous, and preventing contamination of clean carcasses is a challenge. Manure covered hides, the gastrointestinal track, even manure in the holding pens and on the floor are sites for potential contamination.

A number of studies have reported a relationship between live animal/slaughter practices and contamination of carcasses. Berends et. al. (1997) determined that 5 to 15% of carcass contamination occurs during polishing, 5 to 35% during dressing and splitting, with the remainder as a result of evisceration practices. The authors speculated that approximately 15% of the salmonellosis cases in The Netherlands are a result of

eating contaminated pork (8). Using this information, Miller et. al. (2005) modeled the influence of contaminated live hogs on human health care costs (43). In studies of abattoir and lairage practices, it was found that cleaning methods were not standardized and that cleaning chemicals were only used in 30% of the abattoirs in the UK (55). The length of time in lairage and cleaning methods have a significant impact on the contamination of hog carcasses, however, cleaning of the animals themselves did not reduce contamination (26, 52). Swanenburg et. al. (2001) showed that while cleaning the lairage reduced *Salmonella* contamination further into the process, it was not sufficient to eliminate the risk (57). Morrow et. al. (2002) showed that feed withdraw from hogs does not significantly impact carcass contamination (45) while Miller et. al (1997) showed that a longer feed withdrawal time lightened the gastrointestinal tracts, reducing visceral ruptures and reducing carcass contamination (44). Live animal washing has been shown to reduce the contamination level of *Salmonella* on live animals and subsequently on carcasses, however, the reports are mixed as to the benefits of this practice as the following steps of stunning and bleeding can spread contamination (10, 42)

In further processing, it is assumed that *Salmonella* contamination is a result of slaughter procedures; however, as fecal contamination can be carried by any host, some portion of the contamination may be introduced by personnel. Adequate sanitation and appropriate handling must be practiced. Aramouni et. al. (1996) reported that the areas most contaminated during processing included plastic lugs, knives, meat grinders. Other areas of potential contamination were knit gloves, cutting tables, other equipment and walls (6).

Control Measures

Salmonella can be controlled and/or destroyed in food systems. *Salmonella* spp. are susceptible to many common methods of bacterial control, including heat, pH, water activity, and other chemicals. In the late 1970s, Goodfellow and Brown published a preeminent paper on the lethality of humidity and heat treatments on *Salmonella* (22). *Salmonella* spp. could be destroyed by temperatures as low as 125°F (51.6°C) given long enough duration. This research has become a benchmark for the meat industry and is known as a "safe haven" for processors. If the parameters in this research are adhered to, the processor needs no further justification for *Salmonella* control at the cooking step. When cooking meat products a processor is required to show that the production process is equivalent to a 7 log reduction of *Salmonella* for poultry products and 6.5 log reduction for red meat (60). Goodfellow and Brown also showed that dry conditions may allow the bacteria to survive, even when exposed to typically lethal temperatures.

The fat content and species origin of the fat in the product also affects the thermal destruction of the bacteria. As the fat level of beef increases, the d-value of *Salmonella* increase, however, when pork fat increases the same d-value increase is not found (29). Other conditions have been shown to be effective at destroying *Salmonella*, including salt, acidity, and water activity. A 9% salt solution will destroy the bacteria, as will a pH below 4. Efficacy of bactericidal treatments against *Salmonella* is compounded when

more than one condition is outside of the optimal growth range; for example, nitrite is more effective as the pH value decreases (27).

Sanitation of food processing environment

The suggested method for general sanitation includes four steps; rinse, clean (with detergent), rinse and sanitize (53). To remove protein-based and fat-based soils, such as prevalent in the meat industry, an alkaline detergent is recommended (53). Mosteller and Bishop (1993) proposed a 3 log reduction of surface contamination as an appropriate goal for effective sanitzing (47). Warm water (43.3 - 54.4°C (110 - 130°F)) in combination with 150 to 200 ppm quaternary ammonia compounds (QAC) were shown to be effective achieving that level of sanitation. Another study reports that scrubbing in combination with hot water or warm QAC significantly increases *Salmonella* removal (58).

Common sanitizers used in the food processing environments capitalize on the vulnerability *Salmonella* exhibits toward extremes in pH. In combination with high temperature (e.g., hot water), many detergents and sanitizers manipulate the pH of the environment to be cleaned. Common acids used are hydrochloric (muriatic), hydrofluoric, sulfamic, sulfuric, and phosphoric acids (38). Other sanitizers, including chlorine and ammonia based products, employ chemicals that disrupt the cell structures (34, 53). Sanitizers have varying degrees of effectiveness depending on the oxidative potential of the base compounds, synergistic effects with additional compounds, and the concentrations of both ingredients (32, 54, 73). The condition of the water, amount of

organic material present, pH and temperature of the sanitizing solution impact the efficacy of many sanitizers (53).

Meat Industry in the United States

Establishment impact and output

Meat processors in the United States provide over 90 billion pounds of meat and meat products to both domestic and international consumers (72). The 50 largest companies produce 75 percent of that product (70). For matters of inspection the industry is divided into three size categories. Table 2.1 defines the meat processing establishment size categories. While the large plants produce the majority of the meat products in the U.S., currently there are 2,860 very small, 2,371 small, and 365 large meat processing establishments under federal inspection (31).

Very Small	Less than 10 employees or less than $2.5 million annual sales
Small	10 to 499 employees
Large	500 or more employees

Table 2.1: Establishment size categories for inspection purposes (63)

In a survey of the largest 1,725 processors in the U.S. (this included all of the large establishments and some in the small category), the largest plants were found to be spending nearly twice as much on food safety technologies as were the smaller

processors questioned (21). Other research has found that the cost of implementing food safety systems such as HACCP (Hazard Analysis and Critical Control Points) programs in the smaller plants far exceeds the cost in large plants when compared by cost per pounds produced (25).

These factors heighten the need for assistance to the smaller processors. They can neither afford to implement unproven methods for food safety, nor can they easily change their operation when an intervention is not effective. Recognizing the challenges that the small and very small processor face, the inspection service has developed a small plant outreach office. After recent changes, this group is now called the Office of Outreach, Employee Education and Training. Since its conception, the small plant outreach office has funded research and training through land grant universities, and made important information regarding processing and food safety easily available to the meat industry.

There has been little research published covering a wide scope of the meat industry, especially small and very small plants. Hooker et. al. (2002) looked at economic impact and responses to HACCP implementation in meat processing plants (25). Others mentioned later in this chapter have investigated specific parts of the processing system, but not an overall characterization of meat processing establishments.

Inspection history

U.S. government regulation of the meat industry began in 1906 with the inspection of 632 red meat slaughter and processing establishments, under the Meat Inspection Act (39). The Poultry Products Inspection Act was added in 1957. In the

years since there has been a 10-fold increase in the number of inspected plants. All meat processors that sell their products across state lines in the U.S. fall under the authority of FSIS. In 1977, the Food Safety and Quality Service was created and renamed to Food Safety and Inspection Service in 1981 (66).

Revisions to the Meat Inspection Act (1967 – renamed the Wholesome Meat Act) and the Poultry Products Inspection Act (1968) gave authority to the states to form their own inspection services equal to the requirements of federal inspection (4, 3). Because the two acts are separate, states may choose to inspect only red meat or poultry. Today, there are 28 state agencies that assist in meat inspection; of those, Georgia and South Dakota opt to inspect red meat only (19). In general, the processors under state meat inspection fall into the small or very small categories. The difference between these state inspected plants and the 5,000 federally inspected plants of the same size categories is only that the federally inspected plants are allowed to have interstate commerce.

Inspection Process and the MegaReg

Under the authority of the Wholesome Meat Act and the Poultry Products Inspection Act, establishments fell under an inspection system commonly described as "command and control." The inspection personnel had discretion to evaluate the safety and quality of the products as he felt appropriate. In 1996, the Pathogen Reduction; Hazard Analysis and Critical Control Point System Final Rule was enacted (63). These regulations were commonly called the "MegaReg" because of the scale and extent of the

new requirements (14, 25). This new system of inspection gave the responsibility of proving a safe food processing system to the processors.

With the implementation of the MegaReg. all meat processing establishments became subject to *Salmonella* testing. *Salmonella* was chosen as the target organism because of its frequent link to human food borne illness, widespread prevalence in species commonly used for food, and success at control of *Salmonella* can be an indication of control for other enteric bacteria (67). The sample set size and the number of allowed positive tests (within each set) were determined according to the type of product (Table 2.2). The positive tests allowed was calculated to give the plant an 80% chance of passing, given the establishment is working at the national prevalence baseline (65). The national baseline for *Salmonella* prevalence in red meat ranges from 1% for steers and heifers to nearly 9% for hogs (1). In poultry, the baselines are much higher, with 20% for whole broiler chickens, 45% for ground chicken and almost 50% for ground turkey (2). Failing to meet the performance standards triggers another set of testing and review of the plant's HACCP plans; the failure of the second set (set B) triggers a third sample set.

In FSIS's review of the first 5 years of *Salmonella* testing, 1,584 federally inspected plants completed test sets. Of those, 658 were very small processors, 703 were small plants and 223 large establishments. Less than 20% of the plants failed the test set "A" (n=302) and 27% of those also failed their test set "B." The review also found that small plants were more likely than large and very small plants to have failed the set "A" (17)

PRODUCT	TESTS IN SET	POSITIVES ALLOWED	% POSITIVES ALLOWED
Steers/Heifers	82	1	1.2
Bulls/Cows	58	2	3.4
Hogs	55	6	10.9
Broiler Chickens	51	12	23.5
Whole Turkeys[a]	56	13	23.2
Ground Beef	53	5	9.4
Ground Poultry	53	26	49.1

[a] Whole turkey testing was implemented in 2006

Table 2.2: Quantity of tests and allowable positives in FSIS *Salmonella* test sets

Reassessment of Pathogen Reduction Strategies

Ten years later (2006) in light of the steady human salmonellosis rate, FSIS introduced a new plan for *Salmonella* testing. While the sample set size and the allowed number of positive tests remained constant, the reaction to positive tests within the set has been augmented. The addition of testing whole turkeys was also implemented (67).

Prior to 2006, establishments were selected at random to begin "A" *Salmonella* test sets or processors were targeted by product. Under the new system a processing plant's previous performance on test sets places it into one of three categories (Table 2.3). Category 1 is considered "Consistent Process Control for *Salmonella* Reduction" and is achieved when less than 50 percent of the allowed positive tests are received. When an

establishment collects more than 50 percent of the allowed positive test results, but does not fail the set, the process control is "Variable," category 2. Plants with positive tests exceeding the limit are termed "Highly Variable Process Control," category 3.

Each month, approximately 75 establishments are chosen to start test sets (set A); beginning with new establishments that have operated through their 90 day validation period, all plants that fall into Category 3, Category 2 plants and finally, if the quota has not been filled, Category 1 establishments are selected for sampling. Table 2.3 defines the target sampling categories and selection criteria.

Furthermore, establishments that fall into Categories 2 and 3 are encouraged to reassess the *Salmonella* control strategies in their processes. Following the second year of the new sampling scheme, total positive *Salmonella* tests have been reduced slightly (64).

CATEGORY	CHARACTERISTICS	SAMPLING SELECTION
New	Processing establishment has never started a *Salmonella* test and has been in operation 90 days.	All establishments in this category will be selected for sampling.
3 – "Highly Variable Process Control"	Previous *Salmonella* test set resulted in more than the limit of allowed positive samples.	All establishments will be selected for sampling
2 – "Variable Process Control"	Previous *Salmonella* test set resulted in more than 50% but less than the limit of the allowed positive samples.	Establishment will be selected for sampling based on processing type, and serotypes isolated in two previous test sets. The order of processing priority is: Broilers Young Turkeys Market Hogs Ground Poultry Ground Beef Cows/Bulls Steers/Heifers Serotype determination uses the 20 most common human serotypes as reported in the previous year by CDC.
1 – "Consistent Process Control"	Previous *Salmonella* test set resulted in less than 50% of the allowed positive samples.	Establishment will be selected to fill quota, giving priority to those that finished previous set longest ago and serotypes isolated in previous test sets. Serotype determination is same as above.

Table 2.3: FSIS 2006 *Salmonella* testing sampling program. (Adapted from FSIS Scheduling Criteria for Salmonella Sets in Raw Classes of Product (64))

Hazard Analysis and Critical Control Points (HACCP)

HACCP was introduced to the U.S. meat industry in 1996 as part of the MegaReg with the pathogen reduction regulations. HACCP is a system of food control based on prevention (46) by seeking out and addressing possible problems before the product is made. HACCP does not guarantee safety; it is a system that allows for consistency, and by applying the science correctly, a consistently safe product.

The HACCP system is comprised of the following seven basic principles (46):

1. Conduct a hazard analysis.
2. Identify the critical control points.
3. Establish critical limits.
4. Establish monitoring requirements for the critical control points.
5. Establish corrective actions.
6. Establish verification procedures for the entire plan.
7. Establish effective record-keeping procedures.

Recognizing the daunting task before the processors, FSIS allowed the small and very small plants more time to implement their HACCP programs. Large meat processors were required to have working HACCP plans in place before January 1998, January 1999 for small plants, and January 2000 for very small establishments (63).

Within the framework of HACCP, FSIS defined 10 processing categories for all meat products. These categories are helpful when determining the hazards that are likely

to occur in the processing and handling of a product. Products that are similar and fall in the same processing category can be processed under the same HACCP plan.

The categories are (63):

Red Meat Slaughter

Poultry Slaughter

Raw, Not-Ground Process

Raw, Ground Process

Fully Cooked, Not Shelf Stable Process

Heat Treated, Not Fully Cooked Process

Not Heat Treated Shelf Stable Process

Heat Treated, Shelf Stable Process

Secondary Inhibitors, Not Shelf Stable Process

Thermally Processed, Commercially Sterile Process

Epidemiology

Within the realm of epidemiology there are three types of studies; experimental, cohort or longitudinal, and case-control (7). An experimental study is one in which the subjects are chosen from the population and then assigned to a specific treatment or exposure group. This type of study is very controlled, but in many cases is impossible to carry out due to ethical violations. An investigator cannot expose a group of subjects to a known pathogen or carcinogen, or withhold an accepted standard treatment to satisfy research objectives. The cohort or longitudinal study usually investigates exposures and

outcomes over time. These studies can be retrospective (i.e. the information is gathered after both the exposure and the outcome have occurred) or prospective (i.e. the exposure may have already occurred or is likely to occur to a specific group, but the outcome (usually illness) has not). Subjects in cohort studies are selected based upon exposure. Finally, in a case-control study participants are selected based on the occurrence of the outcome and investigates the potential causes or risk factors (exposures) that led to the outcome. The population of interest and type of study performed are selected based on the objectives and purposes for the research. These research designs can be used to define studies with any subject populations of interest: humans, livestock, or meat processing establishments (7).

Surveys

When gathering information it is important that all of the subjects are treated equally, asked the same questions, in the same manner. To accomplish this, a standardized questionnaire or survey is needed. However, when collecting data in this manner, there are several problems that may arise and skew the results.

Bias

Bias is a partiality or disposition to a specific data outcome and is a challenge faced by all epidemiologic studies. Once introduced into a study there is little that can be done to correct it, therefore bias should be minimized or avoided when designing a study. There are two major types of bias: selection bias and observation or information bias (7).

Selection bias is a result of the assortment of participants. This bias could occur when a convenience sample is taken and those that are easiest to enlist are inherently different from the population. Selection bias can also be in the form of response bias. Particularly in low response rate surveys, the responders may be different from the non-responders thus making them more willing to participate in the research. The best prevention of this type of bias is random selection of participants and a high response rate. In some studies, creative control selections are appropriate; case-crossover can be useful in studies where the cases act as their own controls in another time period. (40).

The second type of bias, observation or information bias, stems from faulty information gathering. This could be on the part of the investigator knowing the status of the subjects (case or control) and thus treating the cases differently than controls or interpreting responses based on status. The subject may also be the cause of this problem if the details of the study are known to the subject. In an effort to help, or get the questions "right" a participant may answer a survey with the answers that he thinks is correct instead of answering honestly. This bias is avoided by "double-blinding" so that neither the participant nor the investigator know the status of the subject.

Another facet of information bias is flawed recall of either group (case or controls). When studying a salmonellosis outbreak, subjects that became ill are more likely to have thought about the food they have consumed in the recent past, whereas, controls in such a study may have difficulty recalling their diets for the past several days. Inversely, if the questions are about something that may be embarrassing or even criminal, a subject may not want to respond honestly fearing judgment or punishment.

Methods to minimize these biases include tools, such as a menu to help remind subjects of their meals, and assurance of anonymity. Case-other disease comparisons (using patients that are ill from something other than the disease of interest as controls) can also minimize recall bias as the other patients would also be thinking about their health and what might have prompted the illness (40).

Establishment Surveys

Surveys and studies involving establishments, rather than individuals, face unique challenges (48). The first is unit non-response. Just as with individuals companies have many reasons for non-response; a company policy may be in place to prevent employees from answering surveys, or the survey never gets to the correct person because of multiple offices or a "gatekeeper" that does not know the appropriate person. The second major hurdle in establishment response is the necessity for cooperation between personnel or departments. An extensive survey may cover questions that span the expertise of several people. A third challenge to establishment response is seasonal business activities (13). Understanding the industry in question can increase response rate.

Investigations

When investigating sporadic cases of salmonellosis, (single cases not associated with an outbreak), the case-control design is most often used. The investigation of an outbreak in a small easily defined population, such as workers in a specific building or

residents of a nursing home, can employ a cohort study of examining all of the members of the group (18).

Case-control studies select a group of "cases" or people that were diagnosed with salmonellosis within the time frame of the outbreak. From the group of people that may have been exposed but did not become ill, controls are selected. This process of selecting control subjects (controls) is the point of most variation between research studies. In the outbreak investigation, reported by the CDC that occurred in an electronics factory in Huizhou, Guangdong Province, China, (35) the cases were selected by convenience (the 92 workers that went to the local hospitals were recruited). Controls (n=100) were selected and matched to the cases by dormitory or workshop. Another outbreak investigation in Arizona, California, Georgia and Virginia, selected cases randomly and matched controls by gender, age and geographic area. Each state that contributed to this study employed different methods for identifying and recruiting control subjects and ratios of cases to controls. The Arizona study matched 18 controls to 10 cases by systematic telephone dialing as did the researchers in Virginia to identify 33 controls for the 11 cases. In California, 17 cases were matched to 32 controls that had previously been infected with *Salmonella,* and the 5 Georgia patients identified 10 friends to serve as controls (15).

Variation in the control selection is common in investigations of sporadic salmonellosis cases as well. A study investigating sporadic *Salmonella* infections in infants enrolled a ratio of just over 1:2 cases to controls by randomly selecting healthy babies matched by month of age and area of residence (28). Similar studies excluding

infants attempted to contact all of the salmonellosis patients identified in the study area and matched them to two control subjects in the same age category and telephone exchange (23, 33 , 37).

While most salmonellosis research focuses on the diets of the case and control subjects, one study looked further into the lives of the subjects. Parry et. al. (2005) investigated the microbiology of the home kitchens in their case-control study. The case-control ratio was approximately 1.4:1. The results for this study showed no significant difference between the contamination levels of the dishcloths, and refrigerators of the case and control homes (49).

Conclusion

A comprehensive characterization of the meat industry has not been published. Many studies have attempted to elucidate risk factors and causes of both sporadic case and outbreaks of salmonellosis. These studies commonly focus solely on recent foods consumed and other common sources of contamination such as handling reptiles. Even studies attempting to link poor sanitation practices to cases are minimal. In general, though the link between salmonellosis and specific foods have been well vetted, little work has been done to connect ineffective production practices to those illnesses.

Salmonella and salmonellosis is a problem that the entire meat industry must address. The governing bodies have taken steps to ensure that measures are being taken to minimize the contamination of raw meat products. However, implementing the correct strategies remain a challenge for many, meat processors, especially the small and very

small establishments. Sharing information between researchers and processors will be the key in lowering the morbidity and mortality of salmonellosis in the future.

CHAPTER 3

MATERIALS AND METHODS

Introduction

There were three objectives for this study.

- Evaluate the characteristics of small and very small meat processors
- Ascertain currently used practices for controlling *Salmonella* in those small and very small plants
- Determine the efficacy or risk of the above characteristics and practices in reference to failing FSIS *Salmonella* test sets

These objectives were accomplished through the design and administration of a case-control study. A three part questionnaire was developed, selected case and control processors were contacted and an assessment of the responses was performed.

Survey Construction

A questionnaire was designed to systematically assess all areas of meat processing from farm to raw products processing to attempt to determine risk factors and preventive measures for failure of *Salmonella* test sets. The topics encompassed included: physical features, sanitation practices, good manufacturing practices (GMPs),

microbial sampling program and methods, Hazard Analysis and Critical Control Points (HACCP) plans, measurement practices, and range of processing and methods. Cooking, thermal processing, Ready-to-Eat (RTE) products and RTE handling was not covered in this survey as FSIS *Salmonella* testing was only performed on carcasses and raw ground products. For each section of the survey instrument, a flow chart of a typical operation was followed and questions were generated to collect processing details for each step. There was some repetition between the sections, as the same questions address different areas of the processing plants.

The first section of the questionnaire was a general examination that applied to all meat processors (Appendix A). This section began with questions to identify the HACCP processing categories and the number of products in each category. The survey then addressed the HACCP plans, critical control points and critical limits for each of the categories under which the plant operates. Questions about the plants' sanitation standard operating procedures (SSOPs) and good manufacturing practices (GMPs), and hazard analysis were directed toward how the plants specifically control *Salmonella.* Finally, the general questions for all processors addressed microbial sampling programs. The survey requested information about the type of samples taken, microbiological testing, how the sampling plan was developed and how the results were evaluated.

The second section of the questionnaire systematically addressed the slaughter process (Appendix B). The building and construction of the slaughter area was the first area addressed. Then the frequency, scale and variety of species slaughtered were examined. The survey then addressed the slaughter employees, specifically their formal

HACCP training and other responsibilities in the plant. Animal handling questions, such as policies regarding animal conditions prior to lairage and management of the live animals, were included. Questions were included about the plants' *E. coli* test results. Finally, questions about sanitation practices, both routine and periodic, were asked.

Separate sets of questions were compiled for specific slaughter practices for each of the species: cattle, hogs, sheep and goats, and poultry (Appendix B pg 98, 99, 100, and 101 respectively). The species specific segments included questions to collect information regarding the nature and implementation of *Salmonella* intervention procedures. Excluding poultry slaughter, questions about chilling rates for the carcass surfaces were included. The sets for ruminants (cattle, sheep and goat), asked about *E. coli* intervention procedures, noting that these are required for cattle but only suggested for the other ruminants. Hog-specific questions asked about skinning and scalding practices. The poultry slaughter section addressed scalding, picking, evisceration, chilling and reprocessing.

The raw products instrument followed much the same format as the slaughter questionnaire (Appendix C). The building and construction of the processing area was addressed. Then the regularity, scale and variety of species processed were evaluated. The origin and condition of the raw material was then questioned, and just as in each of the species-specific slaughter sections, the survey included questions about specific *Salmonella* intervention procedures. The survey then addressed the processing employees' practices and their HACCP training. General questions about the processing

operation were then asked such as room temperatures, packaging and retail sales. Finally, sanitation of the processing area was addressed.

Beta Test

The survey instrument was tested with a group of eight small and very small processors, all members of the Ohio Association of Meat Processors. The plants were either inspected by FSIS or the Ohio Department of Agriculture Division of Meat Inspection (ODAMI); and operate under at least one HACCP plan. These processors that have previously worked with Ohio State University Meat Extension, answered the survey questions and critiqued the instrument. Based on feedback from these participants, the instrument was modified. The processing categories changed from common terms to FSIS official terms (e.g., Commercially Sterile was changed to Thermally Processed - Commercially Sterile). Sections were relabeled with common usage terms, "harvest" was replaced with "slaughter." Job training questions were modified to differentiate between "teaching" (understood as in-plant education) as opposed to "training" (understood as formal off-site HACCP certification). Sanitation questions were grouped together to streamline the survey. The building composition questions were changed from open-ended to multiple choice questions.

Study Design and Subject Selection

The population of interest is all small and very small processors inspected by FSIS. A non-concurrent prospective (also known as a retrospective cohort) study was

proposed. However, the definition of the cohort became either the definition of the population or the definition of the exposure; processed or slaughtered meat under inspection during the year examined or completed *Salmonella* test set A during the year examined, respectively. Ignoring the definition problems, randomly selecting subjects from the cohort also faced a rare occurrence problem. To reach a 60% confidence level, over 50,000 subjects were needed to detect a difference between those plants that passed their *Salmonella* test set A and those plants that failed; there are 6,200 meat processors of all size categories in the U.S.

In order to match study design to the rare occurrence structure of failed Salmonella "test set A" a case-control study was designed. The architecture of this type of study fit the population and the desired analysis. The population of interest did not change; meat processing plants that had completed a *Salmonella* test set A in 2005. A case was defined as a small or very small federally inspected plant that failed the *Salmonella* test set A in 2005. Inversely, a control was defined as a small or very small federally inspected plant that passed the *Salmonella* test set A in 2005. A 4:1 ratio (control:case) was used, as it was determined to be the most appropriate for the population and is considered the limit for meaningful increases of power. Controls were matched to the cases by plant size classification and FSIS inspection district (Figure 3.1).

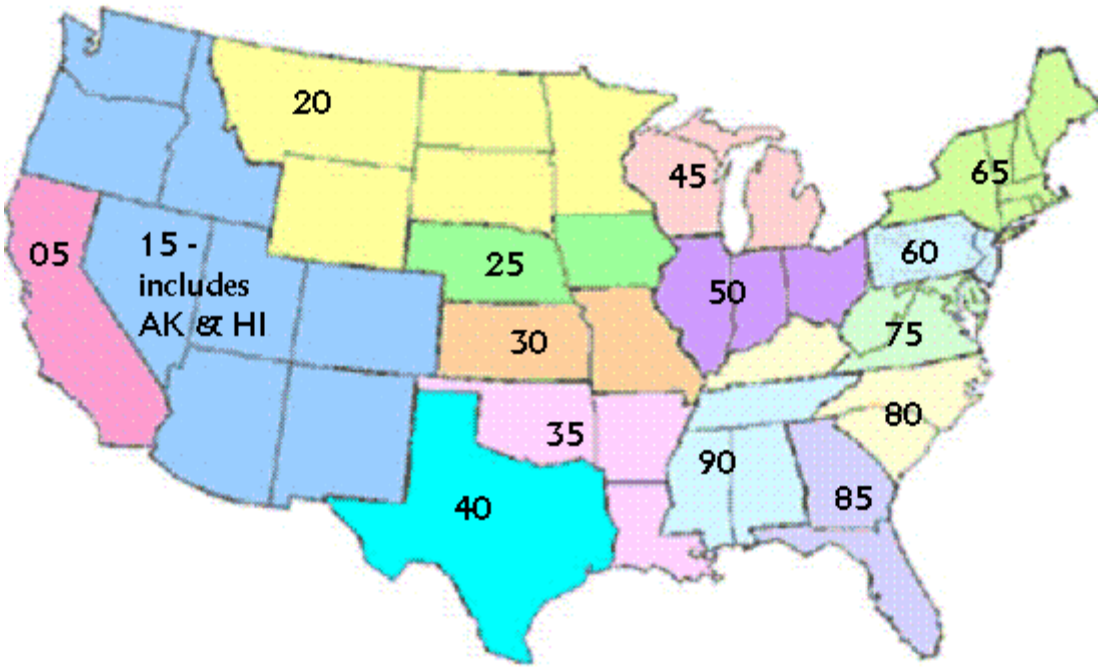


Figure 3.1: FSIS inspection districts. Numbers are assigned by FSIS as a label for the districts. (adapted from FSIS (62)

Subjects (meat processing facilities) and case/control status were determined from information obtained from FSIS through the Freedom of Information Act (FOIA). Information from FSIS included a list of the plants that had completed *Salmonella* test sets in 2005 (identified by establishment number), their inspection district, state, size classification, sample set identification, laboratory in which the sample was processed, and set results. The spreadsheet also included the number of tests included in the set and the number of positive tests both allowed and obtained. A second spreadsheet delineated

information about the product samples were taken from and results for each test, including serogroups and serotypes for each positive sample.

All of the 32 plants that failed their *Salmonella* test set A in 2005 were identified as cases. From the same information, all of the plants that passed *Salmonella* set A were eligible to be designated as controls. The information was sorted according to inspection district and plant size. In each district, all of the control-eligible establishments were assigned a random number. For each of the case establishments in the district, the four plants of the same size classification with the lowest random number assignment were chosen as controls. There were more cases than matching controls in District 25, however Districts 30 and 35 had no cases. The plants from those three districts were combined to obtain the 4:1 control:case ratio.

The selection process was completed using the establishment number as the only identifier. A contact list of plant name, address, and phone numbers was compiled from those establishment numbers so that the case/control status remained unlinked to the plant information. A total of 160 plants, 32 cases and 128 controls were selected.

Contact with Subjects

A human subjects Institutional Review Board exemption was obtained before contact with the subjects began (project number 2006E0664). The board granted a category 2 exemption in that information was gathered through a survey, individual subjects (individual processing establishments) could not be identified once the

information was gathered, and disclosure of the information would not place the subjects at risk for liability or damage to reputation.

The initial contact was made with the selected subjectes in three groups of 50 (the last wave contained 60 subjects). The subjects were contacted by mail to introduce the plant to the study. The coverletter (Appendix D) clearly explained that participation was voluntary and would remain confidential. The information collected from all plants would not be reported individually and would not be linked with the individual plants. A $50 gift certificate to a supplier was offered as incentive and compensation for the time spent with the survey. The full survey was included with this letter so that the plant personnel would be familiar with the questions and be able to make an informed decision as to participation.

The first 50 letters were sent on September 5, 2007, the second group of 50 was sent on October 11, 2007, and the remaining 60 were mailed on January 15, 2008 along with six that were sent to plants that had previously responded that they would have more time to respond in January. Telephone calls were made to each of the plants starting September 12, October 22, 2007, and January 25, 2008 for each of the groups, respectively. For most subjects, contact names were unavailable. During the initial telephone contact, a representative of the company that was familiar with the HACCP plans and sanitation practices of the plant was requested. Once connected with the appropriate person and consent for the survey was given, an appointment was made to complete the survey by telephone.

A group of cases and controls were later targeted to increase the response rate, especially of the case establishments. The procedures for selecting this targeted contact, are discussed in the next section. Contact was made with this sub-set in the same manner as the original subjects. The letters and surveys were sent on May 27, 2008 and initial phone contact was attempted starting on June 2, 2008.

The time to complete the survey ranged from 10 minutes to more than one hour. In general, contact time was approximately 30 minutes. Processors were asked to answer only the sections that applied to their inspected operations. The first section described in the survey construction section was applicable to all plants and was used to determine which of the following sections were to be answered. Follow-up contact was made after survey completion regarding the incentive; all responding processors received the higher incentive reward.

Contact with all subjects was double-blind in that the investigator did not know the case/control status of the plant and the plant did not know it had been selected on the basis of *Salmonella* test results. This blinding was maintained through the targeted second contact as the processors were selected by another investigator that had no direct contact with the plant. To maintain consistency, the same investigator conducted all of the telephone contact with the processors.

Targeted Contact

After evaluation of the response case: control ratio and the size and district representation it was deemed necessary to target contact with specific processors. These

plants were chosen from the non-responders of the original set of 160 plants. All of the non-responding case plants and an equal number of selected control processors were included in the targeted inquiry. The control plants were selected to match both the nonresponsive case plants as well as cases plants that had responded and were lacking matching control plant responses.

Again, surveys and cover letters were disseminated to the selected plants with the same information as the initial cover letter except that the incentive was increased to $100. Because of previous contact with the plants, a contact name was available for most of the targeted processors; the survey packet was addressed to the contact name. Further contact and survey completion was carried out in the same manner as the initial contact.

Data Analysis

The questionnaire was coded, and numerical values were assigned to each of the possible categorical responses; open-ended responses were left as string variables. Responses were recorded into a spreadsheet along with case/control status and size category. Where appropriate, variables were created to combine information from several responses, such as the total number of products made, and the number of CCPs in an operation. The data were first screened for differences between small and very small establishments using univariate methods. The same types of analyses were performed to distinguish between case and control establishments. For any variables that were significantly different between size categories, the case/control analysis was performed on each category separately. The associations of production facility factors with failed

Salmonella test sets then used to build a forward, step-wise logistic regression model, however as the subjects were separated out the power of the model failed and is therefore not reported. All analyses were performed using Intercooled Stata 8.2 for Windows (StataCorp LP, College Station, TX).

CHAPTER 4

RESULTS

Response Rate

Of the 160 meat and poultry processing plants that were selected 62 completed the survey for a response rate of 39%. Of the non-responders, 38% declined to participate (23% overall). The remaining 62% of the non-responders did not return telephone messages after multiple attempts at contact. One plant was removed from the data analysis because it was a large plant that had been misclassified as a small plant. Table 4.1 lists the size composition in regard to case and control status of the responding establishments. Comparisons were first made using Student's t-test for continuous variables and χ^2 analyses for categorical variables to determine differences between the size categories. These differences are reported in red lettering throughout this chapter. The differences between case and control respondents were then evaluated in the same manner and are reported in blue lettering. When a significant difference was found for size, the case status was evaluated for small and very small establishments separately. No variables were significantly different ($\alpha = 0.05$) for both size categories and case statuses. The entirety of these results and statistics are reported in Appendix E. Selected results are reported in this chapter. All significant findings are reported; variables listed

that do not have differences noted were not significant at the $\alpha = 0.05$ level for either size categories or case status.

		Small Establishments	Very Small Establishments
	% of respondents	66% (n=40)	34% (n=21)
Case Establishments	21% (n=13)	69% (n=9)	31% (n=4)
Control Establishments	79% (n=48)	65% (n=31)	35% (n=17)

Table 4.1: Proportion and number of respondents by size category and case/control status.

All of the respondents completed the HACCP section of the questionnaire. The other sections were completed only as applied to the specific plant. Table 4.2 reports the number of plants that responded to each of the survey sections.

Operations

Table 4.3 shows the extent of processing of the respondents regarding the variety of processing categories and products produced. These characteristics were not significantly different ($\alpha = 0.05$), between small and very small processors, nor between case and control establishments.

	Total	Small Establishments	Very Small Establishments	Cases Establishments	Controls Establishments
Slaughter	28	15	13	9	19
Cattle	15	5	10	3	12
Hogs	16	4	12	14	2
Sheep/goats	9	1	8	1	8
Poultry	7	6	1	5	2
Raw Products Processing	58	37	21	13	45

Table 4.2: Total number, number of small and very small establishment and case/control establishment respondents reported by questionnaire section

Overall, the majority of the responding plants slaughter and/or process daily and in only one shift (Table 4.4). However, this is not the case for very small slaughter operations. Significantly more ($\chi^2(3) = 9.24$, p-value = 0.026) of the very small slaughter plants responded that slaughter processing was less frequent (Table 4.5) than for small plants. The very small slaughter plants also responded that the hours of slaughter operation was less than for small plants. Many of the responding very small slaughter operations reported that the number of animals slaughtered and the hours involved were only what were necessary. The average operation hours for all slaughter operations was reported as 7.7 hours between sanitation, ranging from 1.5 hours to 19 hours. The raw processing operations reported 8.8 hours sanitation to sanitation, ranging from 2 hours to 20 hours. The differences between the average hours of operation of small and very

small establishments are reported in Table 4.6. The small respondents indicated that slaughter and processing was on-going and for many, simultaneously.

	Mean (Range)
Processing Categories	3 (1 to 7)
Products made	49 (1 to 525)
Number of CCPs	5 (1 to 13)
Maximum number of HACCP plans operating in one production day	3 (1 to 7)

Table 4.3: Mean and range of general characteristics regarding the extent of processing.

Slaughter daily	57%[a]
Process raw products daily	76%
Slaughter only in one shift	96%
Process only in one shift	86%

[a] Significant difference between small and very small respondents ($\alpha = 0.05$)

Table 4.4: Percentage of respondents that operate daily and during only one shift.

	Small Establishments % daily	**Very Small Establishments % daily**	**p-value**
Slaughter	80% n=15	30.8% n=13	0.004
Processing	84% n=38	62% n=21	0.07

Table 4.5: Daily operation of slaughter and processing operations by size category.

	Small Establishments Mean in hours	**Very Small Establishments** Mean in hours	**p-value**
Slaughter	8.8 (n=15)	6.4 (n=13)	0.02
Processing	9.36 (n=38)	7.86 (n=21)	0.06

Table 4.6: Hours of slaughter and processing by size category determined by the time from one sanitation event to the next.

Table 4.7 lists the average and range of the number of animals slaughtered and pounds of raw products processed each year at the responding slaughter establishments and raw processors, respectively. As expected from the information above, the number of animals and the pounds of raw product processed are significantly related to the size category of the establishment. Table 4.8 reports the volume measured by size category.

	Mean (Range)
Number of animals slaughtered per year	3.57×10^{6} [a] (125 to 4.25×10^{7})
Pounds of raw product processed per year	1.46×10^{7} [a] (1000 to 1.31×10^{8})

[a] Significant difference between small and very small respondents ($\alpha = 0.05$)

Table 4.7: Mean and range of the annual numbers of animals slaughtered and pounds of raw products processed

	Small Establishments Mean	**Very Small Establishments** Mean	**p-value**
Animals slaughtered per year	6.64×10^{6}	9.99×10^{3}	0.032
Pounds processed per year	2.26×10^{7}	5.15×10^{5}	0.006

Table 4.8: Volume of production per year by size category

Percentages of the respondents that either slaughter or process more than one species in a day are listed in Table 4.9. Also shown are the proportions that practice either partial or full sanitation between species. There were no differences ($\alpha = 0.05$) between small and very small respondents for these characteristics. There was also no difference between case and control establishments (p-value = 0.36).

	Slaughter Establishments	Raw Processing Establishments
More than one species per day	46%	64%
Sanitation between species	62%	32%

Table 4.9: Percentages for slaughter and raw products processing respondents that slaughter or process more than one species in a production day.

Employees

As explained in chapter 2 (Table 2.1), the size categories were based upon the number of employees, thus the number of employees was significantly different for the size categories (Table 4.10). Despite the inherent differences in the number of employees, there were no differences ($\alpha = 0.05$) between size categories or case statuses for the number of employees that are HACCP trained, or that work on sanitation (Table 4.11). This indicates that the very small plants have a higher percentage of their employees HACCP trained. Furthermore, very small case and control respondents do not differ, but small case and controls do. These percentages are listed in Table 4.12. The response from slaughter establishments indicated that there was at least one employee that has received HACCP training working in 82% of the slaughter areas and 88% of the processing areas.

For all responding producers, 57% have specific training for employees concerning the monitoring of critical limits. In 61% of the slaughter plants there are employees that worked in other areas of processing and 76% of those plants reported that those employees worked in other areas on the same day as slaughter. Neither of those characteristics was significantly different between size categories or case status. (Table E.4)

	Small Establishments Mean	**Very Small Establishments** Mean	**p-value**
Employees on the slaughter floor	40.4 (n=15)	3.5 (n=13)	<0.01
Employees in processing area	53.82 (n=38)	5.67 (n=21)	<0.01

Table 4.10: Number of employees for slaughter and processing respondents by size category.

	Slaughter Establishments Mean (range)	**Raw Processing Establishments** Mean (range)
Employees that are HACCP trained	5.43 (0 to 100)	10.46 (0 to 200)
Sanitation employees	5.38 (1 to 40)	6.07 (1 to 60)

Table 4.11: Mean and range of the number of employees that are HACCP trained and involved in sanitation.

	Small/Very Small Establishments (p-value)	**Case/Control Establishments** (p-value)
Slaughter	23% / 49% (0.04)	49% / 50% (0.98)
Processing	39% / 34% (0.33)	9% / 37% (0.64)

Table 4.12: Percentage of HACCP trained employees reported to be working in slaughter and processing areas.

Facilities

The oldest of the responding establishments were built in 1900. There were no significant differences between slaughter and processing; small and very small; or case and control. The median age of the slaughter renovations was 7 years and 4 years for the processing renovations. Table 4.13 shows the mean and the ranges of the ages and years since the most recent updates.

The majority of the respondents' floors were made of concrete (Table 4.14). The other 7% of slaughter plants and 19% of the processing plants reported floors made of tile or brick (Tables E.4 and E.9). Small slaughter respondents were more likely to have coated or sealed floors than the very small slaughter plants; however, this difference was not seen in the processing establishments (Table 4.15).

	Slaughter Establishments Mean (Range)	**Raw Processing Establishments** Mean (Range)
Age of the building	42 (12-108)	40 (3-108)
Age of the most recent updates	9 (0-33)	8 (0-58)

Table 4.13: Age in years of the buildings and most recent updates for slaughter and raw processing respondents.

Though less homogenous, there is no significant difference between categories of respondents regarding the wall composition. The table (4.14) reports the percentage of responding establishments using fiberglass boards for walls. The other wall materials include tile, brick, glazed block, and stainless steel.

Slaughter floors are made of concrete	93%
Processing floors are made of concrete	81%
Slaughter floors are coated or sealed	50%[a]
Processing floors are coated or sealed	41%
Slaughter walls are made of fiberglass board	50%
Processing walls are made of fiberglass board	66%

[a] Significant difference between small and very small respondents ($\alpha = 0.05$)

Table 4.14: Composition of floors and walls for slaughter and raw processing respondents.

	Small Establishments	Very Small Establishments	p-value
Slaughter floor coated or sealed	73% (n=15)	23% (n=13)	<0.01
Processing floor coated or sealed	47% (n=38)	29% (n=21)	0.082

Table 4.15: Coated or sealed floor for slaughter and raw processing respondents by size category.

Slaughter

Establishments that slaughter made up 46% of the respondents to the questionnaire. Of those plants, 55% slaughtered cattle, 55% slaughtered hogs, 31% slaughtered sheep, and 24% slaughtered poultry (refer to Table 4.2 for n values).

Animal Handling

The time that animals were housed on-site prior to slaughter ranged from less than one hour to 7 days. Almost 90% of the establishments responded that animals are housed 12 hours or less (Table E.4). In that time, animals are required to have water and few plants reported a feed withdraw policy (Table 4.16). Even less of the respondents reported animal washing practices prior to slaughter. This practice, though, is significantly different ($\alpha = 0.05$) between case and control establishments (Table 4.16).

Of the respondents that reported live animal washing, 83% reported using water, the other 17% use chlorine to wash the animals.

Policy regarding feed withdrawal	36%
Animals are washed before slaughter	21%[a]
Case	0%[b]
Control	32%[b]

[a] Significant difference between case and control respondents ($\alpha = 0.05$)
[b] p-value = 0.03

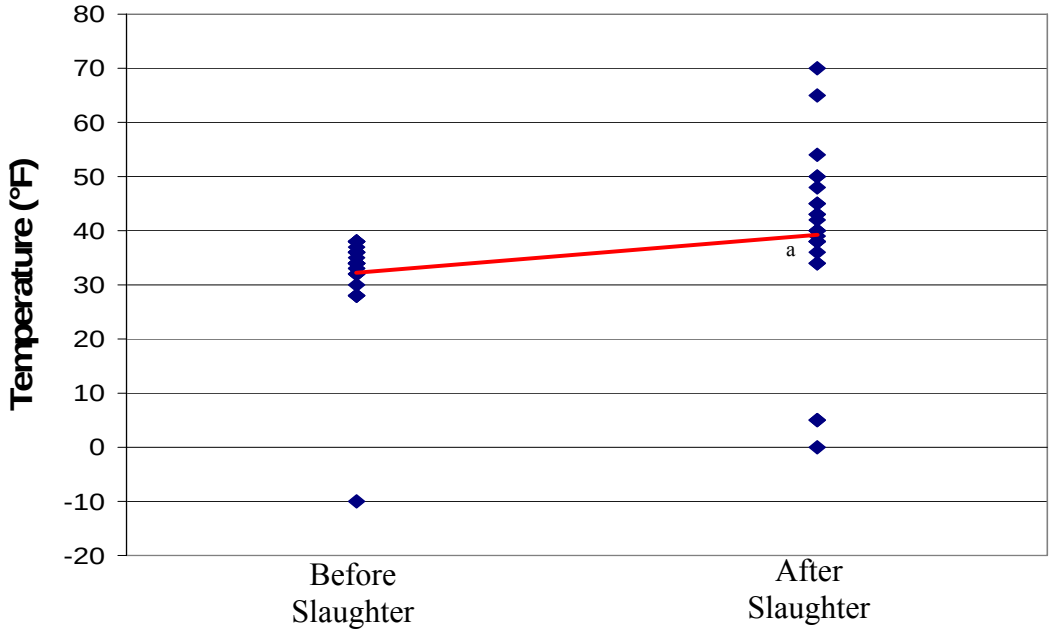
Table 4.16: Percentage of slaughter respondents regarding live animal policies with live animal washing reported by case/control status.

Of the plants that have holding pens, 57% reported cleaning them daily; however, when separated by size, 87% of the small and only 23% of the very small slaughter respondents clean the pens daily (p-value < 0.01) (Table E.4). While cleaning the pens, 18% of the respondents used sanitizing chemicals with no differences ($\alpha = 0.05$), between size categories or case status.

Carcass Chilling

There was a significant increase in the average temperature of the carcass chill cooler (p-value < 0.0001) after being filled with hot carcasses. The average temperature of the carcass chill cooler, prior to the first carcass entering, was reported as 32°F. The average temperature of the coolers was 39°F after all the carcasses from the slaughter shift were entered. Figure 4.1 illustrates the variation of the cooler temperatures prior to and following slaughter. The trend line illustrates the increase in average temperature.

Data was collected regarding the time it took each carcass species to reach 40°F once it had entered the chill cooler. However, the results were a product of the processing schedule and not a reflection of the actual chill time. Hogs and sheep carcasses were reported to have reached 40°F at the surface in 12 hours or less by 50% of the respondents. Beef carcasses were reported to reach 40°F in 16 hours or less by 50% of the respondents. Most of the responses were not an exact number but an approximation: less than 24 hours, less than 12 hours, etc.



[a] Line indicates average temperatures (p-value < 0.01)

Figure 4.1: Carcass chill cooler temperatures before and after slaughter. Line indicates average temperatures which are significantly different (P-value <0.01)

The following sections report the findings from each of the species-specific slaughter questionnaires. These characteristics were not found to be significantly different between the size categories or the case statuses.

Cattle

Use of captive bolt stunning was reported by 94% of the plants that slaughter cattle. A lactic acid spray was used by 69% for the required *E. coli* intervention. Hot water and acidified NaCl composed the remaining 31% of the responses.

Sheep

Captive bolt stunning was reported by 90% of the plants that slaughter sheep. An *E. coli* intervention was reported by 56% of the respondents and 60% of those said that a lactic acid spray was used, the other 40% used hot (160-180°F) water.

Hogs

Captive bolt and electric stunning both were reported to be used by 44% of the respondents that slaughter hogs. Of those establishments, 69% skin the carcasses, and 50% scald the carcasses (some responded that they skin or scald depending on the customer). The scald water, at an average temperature of 146°F (range: 138°F to 155°F), was reported to be stationary for 88% of those plants. Scald water additives were used by 50% of the hog scalding establishments and reported either the use of a specific amount or a target pH.

Poultry

The responding plants that slaughter poultry reported an average scald water temperature of 135°F (range: 111°F to 145°F); 43% use an additive in the scald water. The pH of the scald water was unknown for 29% and ranged from acidic (4.4) to slightly basic (7.6) for the remaining 71%. The scald water flowed counter-current to the carcasses for 71% of the respondents. The poultry slaughter plants that reported additives in the after picking rinse (86%) all indicated chlorine or sodium hypochlorite use. A significant difference was found between cases and controls regarding the type of

evisceration practiced, none of the control respondents reported hand evisceration. Chill water additives were used by 57% of the poultry slaughter respondents and include peracetic acid, chlorine and sodium acid sulfate. The plants reported an average chill water temperature of 35°F (range: 32°F to 38°F) and counter-current to the carcass flow for 43%. Table 4.17 lists percentages of other poultry slaughter practices for the respondents.

Mechanical picking	100%
Mechanical evisceration	43%[a]
Off-line reprocessing	86%
Post-chill antimicrobial treatment	14%

[a] Significant difference between case and control respondents (p-value = 0.05)

Table 4.17: Percentages of poultry slaughter respondents that mechanically pick, mechanically eviscerate, take carcasses off-line for reprocessing and employ a post-chill antimicrobial treatment.

Processing

Of the respondents to the survey, 97% processed raw products. Of those processors, 47% also slaughter (all of the slaughter respondents also process raw products). Table 4.18 reports characteristics regarding the origin and handling of raw products. The generation of rework is significantly different ($\alpha = 0.05$) between case and

control facilities. Contrary to expectations, however, it is much more prevalent among the control respondents (39% generate rework) than the case respondents (8% generate rework) (p-value = 0.02). Rinsing of dropped product with water is significantly more common with very small processors (81% rinse with water, whereas 55% of small processors rinse with water (p-value = 0.02)). Discarding dropped product and rinsing dropped product with sanitizers (54% and 14%, respectively) are found in both size categories and case statuses without difference (Size: $\chi^2(2) = 4.89$, p-value = 0.09; Case/control: $\chi^2(2) = 1.35$, p-value = 0.51) (Table E.9).

Percentage of raw products obtained from own slaughter process	83%
Use frozen products to process	63%
Generate rework during processing	32%[a]
Discard dropped product	54%
Rinse dropped product with water	64%[b]

[a] Significant difference between case and control respondents ($\alpha = 0.05$)
[b] Significant difference between small and very small respondents ($\alpha = 0.05$)

Table 4.18: Percentages of raw products from own slaughter, the use of frozen products, generation of rework, and dispatch of dropped product.

The average temperature in the respondents' processing areas was 45°F and 63% of the plants reported less than 5°F in temperature fluctuation in a typical production day. However, very small processors reported a significantly higher average room temperature than small processors, and experience significantly more variation in the room temperature (Table 4.19).

	Small Establishments	**Very Small Establishments**	**p-value**
Temperature of the processing area (Mean °F)	42	50	>0.01
Temperature of processing area varies less than 5° F (% yes)	82%	29%	>0.01

Table 4.19: Reported temperature and fluctuation of slaughter and processing areas by size category

Table 4.20 reports the proportion of the respondents that directly sold products through a retail outlet and characteristics thereof. The respondents that operate a retail outlet are more likely very small (Table 4.21). Considering only the plants that have retail outlets, those that are directly attached to the production facility and those that employee separate retail personnel do not differ significantly ($\alpha = 0.05$) by size or case status.

Retail sales	47%[a]
Retail connected to production area	57%
Separate retail employees	43%

[a] Significant difference between small and very small respondents (α = 0.05)

Table 4.20: Percentage of raw products processors that have retail sales, sales attached to production areas, and separate employees for retail sales.

Percent yes	**Small Establishments**	**Very Small Establishments**	**p-value**
Retail Sales	39% (n=38)	62% (n=21)	0.05

Table 4.21: Retail sales by size category

The respondents indicated that vacuum bags were the most common type of packaging used (80%). Second were waxed cardboard or poly bags in cardboard boxes (68%). Butcher paper was reportedly used by 20% of the establishments, and only 8% said that overwrap and trays were used. There is no significant difference between the size categories or case statuses for the type of packaging products used, despite the above

information that retail sales are more common among the very small respondents (Table E.9).

Sanitation

Table 4.22 reports sanitation practices regarding equipment maintenance. There was a significant difference found between raw products case respondents and control respondent regarding cleaning and/or sanitizing tools used for maintenance, however it was the cases that responded more likely to clean or sanitize maintenance tools. This difference was not seen for slaughter respondents but the inverted proportions were still evident (Table 4.23).

	Slaughter Establishments	**Raw Processing Establishments**
Tools for maintenance are cleaned and/or sanitized	46%	61%[a]
Equipment is cleaned and/or sanitized after maintenance	96%	98%

[a] Significant difference between case and control respondents ($\alpha = 0.05$)

Table 4.22: Percentage of slaughter and raw products processing respondents that practice sanitation on tools and equipment after maintenance.

Tools for maintenance are cleaned and/or sanitized	Case Establishments	Control Establishments	p-value
Slaughter	56% (n=9)	42% (n=19)	0.26
Raw Processing	85% (n=13)	54% (n=43)	0.02

Table 4.23: Slaughter and raw products processing maintenance tool sanitation by case/control status

During slaughter, 68% of the plants reported at least some employees wore non-woven gloves, while 88% of the processing plants responded the same (Table 4.24). However, size category was a significant factor in employees wearing non-woven gloves (e.g. latex, vinyl, rubber) during both slaughter and raw products processing. The proportions are separated by size category in Table 4.25. The responses also indicate that the majority of the plants that are using fabric gloves have a policy to either launder or discard the gloves after each use (Table 4.24).

The average number of knife sterilizers on the respondents' slaughter floors was 12 (range: 0 to 150). The number of knife sterilizers were significantly different between the size categories (small = 21, very small = 2, p-value = 0.05). All of the plants indicated that the sterilizers were kept at or above the required 180°F.

	Slaughter Establishments	Raw Processing Establishments
Some or all employees wear non-woven gloves	68%[a]	88%[a]
Have a policy to launder or discard woven gloves after use	100% (n=3)	87% (n=47)

[a] Significant difference between small and very small respondents (α = 0.05)

Table 4.24: Percentage of slaughter and raw products processing respondents that wear non-woven gloves and the percentage of those that use woven gloves with sanitation policy implemented.

	Small Establishments	Very Small Establishments	p-value
Slaughter employees wear non-woven gloves	100% n=15	31% n=13	0.000
Processing employees wear non-woven gloves	97% n=38	71% n=21	0.003

Table 4.25: Non-woven glove use by slaughter and processing employees by size category

Slaughter sanitation was reported to be contracted to an outside company by 29% of the respondents, while 34% of the processing respondents report contracting sanitation

to another company. Though not statistically significant in the slaughter plants (p-value = 0.08), 81% of the very small processing plants kept sanitation in-house as opposed to 58% of the small respondent plants (p-value = 0.04).

For the respondents that performed their own sanitation, the most common cleaning and sanitizing agents used, along with the percentage of respondents that rotate those agents is found in Table 4.26. The alternative cleaning and sanitizing agent responses were extremely varied, and no significant differences were detected between the size categories or case statuses (Table E.4 and E.9).

	Slaughter Establishments (n=20)	**Raw Processing Establishments** (n=39)
Use a hypochlorite based cleaning agent	45%	36%
Rotate cleaning agents	19%	22%
Use a hypochlorite based sanitizing agent	33%	31%
Use a quaternary ammonia based sanitizing agent	24%	27%
Rotate sanitizing agent	19%	31%

Table 4.26: Slaughter and raw products processing sanitation respondents that use a hypochlorite based cleaning agent, rotate cleaning agents, use hypochlorite sanitizing agent, use quaternary ammonia based sanitizing agent, and rotate sanitizing agents.

The percentages of those plants that perform sanitation on the walls, ceilings and floor drains on a daily basis are found in Table 4.27. Responses regarding sanitation of the walls and floor drains for slaughter establishments indicated a significant difference between the size categories, and cleaning the processing establishment walls approached significance. The percentage of daily sanitation practices for the walls and floor drains are reported in table 4.28.

	Slaughter Establishments (n=20)	**Raw Processing Establishments** (n=39)
Walls are cleaned daily	71%[a]	76%
Ceiling is cleaned daily	14%	22%
Floor drains are cleaned daily	81%[a]	78%

[a] Significant difference between small and very small respondents ($\alpha = 0.05$)

Table 4.27: Wall, ceiling and floor drain sanitation practices for slaughter and raw products processing respondents.

	Small Establishments	Very Small Establishments	p-value
Slaughter walls	100% (n=9)	50% (n=12)	<0.01
Processing walls	85% (n=26)	63% (n=19)	0.05
Slaughter floor drains	100% (n=9)	66.7% (n=12)	0.03
Processing floor drains	85% (n=26)	68% (n=19)	0.22

Table 4.28: Sanitation reported daily of wall and floor drain by size for slaughter and raw products processing respondents.

Microbial Interventions

The questionnaire asked about identification of specific hazards, procedures, and interventions related to both *Salmonella* and generic *E. coli*. Reported in Table 4.29 are those inquiries which apply to all of the respondents. Significantly more small plants (45% to 19% of very small (p-value = 0.02)) responded that SSOPs or GMPs were implemented to specifically address *Salmonella* hazards. Case establishment were more likely to respond that *Salmonella* was identified as a "food safety hazard likely to occur" in their hazard analysis (case = 62%, control = 19% (p-value < 0.01)) (Table E.3).

SSOPs or GMPs that specifically address *Salmonella*?	36%[a]
Salmonella is a food safety hazard likely to occur	28%[b]
Microbial sampling program	92%

[a] Significant difference between small and very small respondents ($\alpha = 0.05$)
[b] Significant difference between case and control respondents ($\alpha = 0.05$)

Table 4.29: Percentage of all respondents that have *Salmonella* hazard identification and prevention as sanitation standard operating procedures or good manufacturing practices and microbial sampling programs.

Each of the slaughter establishments must submit to generic *E. coli* testing by FSIS. The majority of the slaughter respondents passed all of those tests in 2005 (Table 4.30). None of the respondents failed all of the tests. Each of the species-specific questionnaires and the raw product processing questionnaire inquired as to interventions specific to *Salmonella* (Table 4.30). None of these responses were significant by size of company or case status.

Slaughter respondents	Passed all 2005 generic *E. coli* tests	75%
	Policy about animal conditions regarding *Salmonella or E. coli*	0%
	Specific *Salmonella* intervention during cattle slaughter	6%
	Specific *Salmonella* intervention during hog slaughter	6%
	Specific *Salmonella* intervention during sheep slaughter	0%
Raw Products Processing respondents	Specific *Salmonella* intervention during processing	5%

Table 4.30: Implementation of *Salmonella* and *E. coli* interventions and policies by slaughter and raw products processing respondents.

CHAPTER 5

DISCUSSION

Changes from β-test

After the initial test group there were several changes made. The first was that "public" words such as "harvest" were not used by processors, and while the words were understood, they had negative connotations with those involved with "slaughter". Other semantic changes were made as well. The test subjects noted that there was confusion between what was implied by "training." To the processors "training" is formal, out-of-plant classroom time. To illicit information about in-plant training the word "teaching" was used. The processors responded that the processing categories were only used when communicating with their inspectors, thus the official FSIS terminology was most familiar.

The initial survey allowed open-ended responses for the composition of the walls and floors. The entire test group responded with the same materials for the floors and walls, with one exception. From this information, those four questions were changed into a multiple choice format.

The test group showed that despite being actively involved with all aspects of their operation including sanitation, the majority of the respondents did not know

specifics about the chemicals used. This will be discussed later in reference to the entire test set.

Response and Power

According to Curtain et. al. (2005), the response rates for telephone surveys have been steadily declining in the last 25 years (16). Extrapolating their results to 2008, an expected response rate is 40.5%. This survey resulted in an overall response rate of 39%. Despite achieving the expected response rate, the small numbers of the population and subcategories made some analysis impossible. Identification of risk factors for failure of *Salmonella* test set A was the original goal of this project. The small subpopulations and the homogeneity of the responses made logistic regression faulty. This could be a result of the time between the event (the failure of the test set) and the survey (up to 3 years). For some specific *Salmonella* related practices, the timings of implementation were questioned; however, the plants were not questioned about reactions to the test failure and subsequent changes to the practices. The homogeneity of the results could be a result of these plants making appropriate changes as a reaction to the failed test sets. Although risk factors or preventive measure for failure of *Salmonella* test set failure could not be ascertained, the results of this study provide a valuable view into the small and very small meat processing establishments.

General production and employees

It was hypothesized that small and very small processors are producing many types of products under various processing categories. Furthermore, it was thought that

this characteristic may over-extend these smaller processors regarding personnel and scientific resources so that the risk of *Salmonella* positive tests increased. The results from the first questionnaire section showed that the processors are producing an average of 49 products with an average of 5 CCPs in their HACCP plans. Unexpectedly, none of these levels were significant when the case and control status plants were compared. Similarly, there was no difference between cases and controls when comparing the number of animals slaughtered or pounds of product produced each year. This again could have been an indicator of too high throughput and over-extension of resources.

The conventional trends indicate that the smallest plants are moving away from slaughtering. Though not an indication over time, the results indicate significantly less very small processors slaughtering on a daily basis. The combination of slaughtering and raw products processing was thought to be a risk factor for *Salmonella* positives, but again, no difference was found between case respondents and control respondents. Also not a risk factor, were employees that work in both the slaughter area and other areas of production on the same day. It is known that the live animals are hosts for *Salmonella*, therefore it could be easily transferred from the slaughter area to other areas of production by employees. This, however, was not demonstrated with these respondents.

As discussed in chapter 2, the size categories are determined by the number of employees. So it was expected that the number of employees would be significantly different between the size categories. Not expected was that the number of HACCP trained employees remained constant between both the size categories and the case statuses, therefore the proportion of HACCP trained employees is significantly higher for

very small processors. This did not affect the case or control status. Additionally, the vast majority of the respondents have at least one slaughter or processing employee that has been HACCP trained.

Facilities

The buildings were thought to have a major impact on the *Salmonella* test set results. With older materials, wear from use and age, and lack of newer wisdom of materials and design, older building are more difficult to clean (56), though this proved not a significant risk factor to these respondents. These responses do tell us that over 50% of the plants are operating in buildings that were built in the mid to late 1960s. Interestingly, the median age of the most recent renovations (7 years for slaughter respondents and 4 years for raw processing respondents) infers that there is a divide between the plants that are making changes and keeping an updated plant and those that do not. As plants continue to age, this disparity may become more evident through test results and other factors.

As evidenced by the initial test group, the composition of the floors and walls are surprisingly homogeneous throughout the meat industry. Coating or sealing the concrete floors was found to be significantly different between the small and very small respondents. This extra protection was much more common for small plants than very small plants, especially on the slaughter area floor. This may be related back to the fact that a much smaller percentage of the very small operations are slaughtering daily. With

less use of the area, the necessity of extra protection on the floor may be perceived to be less.

Slaughter

It was suggested by Miller et. al. (44) that an increased feed withdrawal time could decrease microbial contamination on carcasses. However, the responses to this survey indicate that this is not a widespread practice and therefore no differences were seen between the groups of respondents. Animal washing practices were found to be significant, but further statistical analysis was not possible because none of the case respondents washed animals.

The differences in daily cleaning of the animal holding pens between small and very small respondents may be a related to the difference in the proportion that are slaughtering daily. Therefore it is not surprising that there is a size difference, but no case status difference for frequency. The result of 18% using chemicals for cleaning is lower than the finding of Small et al (55) that indicated there were no standard procedures for lairage cleaning and only 30% of the processors in the study used chemicals for such cleaning.

It was hypothesized that the time to chill the surface of carcasses to below 40°F would have an impact on the case status; however, the lack of exact knowledge interfered with this analysis. For most of the respondents, a chilling time was only noted if there was a problem.

Just as mentioned earlier, even though the respondents are actively involved in the operation of the plants many did not know specifics about the type and concentration of chemicals used. However, hog scalding water was the exception to that generalization. All of the operators that responded they scald hogs, knew the additives used and either a specific amount or a target pH. Following the rule, if a target pH was not used the pH was not known. Kampelmacher et. al. (30) noted that *Salmonella* was not found in hog scald water at 140°F or higher, which 75% of the respondents met or exceeded. Unawareness of details was common among the respondents for poultry scalding additives, concentrations, and pH. Notably, only 14% of the poultry slaughter respondents used an antimicrobial treatment post-chill. It is of interest that the type of evisceration is significantly related to case status. Despite small numbers (empty cells that would not allow for regression), hand evisceration of poultry is a risk factor for failure of the *Salmonella* test sets. This is an area that should be more closely investigated.

Processing

It is interesting to note the percentage of the raw products that were obtained from adjoined slaughter processes. When plants that do not slaughter were averaged into this figure with a 0%, there was a significant difference between the cases and controls (not reported) with case respondents using a higher percentage of raw products from their own slaughter operations. This could be a result of requiring microbial standards and certificates of analysis before receiving, or purchasing meat from larger slaughter

operations that have more microbial interventions. Again, because of homogeneity of responses, once the non-slaughtering plants were removed from the analysis, there was no difference between cases and controls; 15% of the plants that both slaughter and process raw products obtain less than 25% of the meat processed from their own slaughter.

The practice of rinsing dropped product with water is more common in very small establishments than in small, but this did not translate into a difference between cases and controls. The more "safety oriented" responses of rinsing with sanitizer or discarding dropped products did not indicate control status either.

It is not surprising that very small processors reported having warmer processing rooms and more temperature fluctuation during a processing day, but again this did not translate into a difference between cases and controls. According to USDA's Pathogen modeling program, at 50°F it takes at least 30 hours for *Salmonella* to increase one log, and over 12 hours for a generation time. Given that the average very small processor reported a processing day of less than 8 hours, *Salmonella* growth due to temperature is minimal.

Very small plants were more likely to have retail sales. Still, only 62% reported having a retail outlet. Conversely, 61% of the small plants reported not having a retail outlet. This is rationale for the high percentage of all raw processing respondents that use cardboard boxes for primary packaging. The responses indicate that vacuum bags are the packaging of choice for the establishments.

Sanitation

There was a much higher percentage of raw processing case respondents that reported cleaning or sanitation of the tools for maintenance than control respondents. The implementation of this practice may have been a result of those plants failing a *Salmonella* test set. There were fewer slaughter plants that performed tool sanitation, and the case status difference was not significant.

Cotton knit gloves were noted as one of the primary sources of contamination during the processing day by Aramouni et. al. (6). The responses from this survey indicate that the processors have an understanding of contamination and microbial growth; nearly all of the responders (both slaughter and raw products processing) reported having policies in place to either launder or discard woven gloves after each use. Non-woven glove use, however, was not as prevalent; very small plants were more likely that none of the employees wear non-woven gloves.

Some of the processing respondents reported that outside cleaning contracts were required by customers. With reference back to retail sales, small plants are more likely to have wholesale customers that would request such a practice. Those respondents that did perform their own sanitation were fairly similar in responses. Just as discussed earlier, even though the representative that responded to the survey was actively involved with sanitation in many instances, the details of concentrations used were not known. Rotating cleaning and sanitizing agents was not a common practice for the respondents, and the most common cleaning and sanitizing agents have a chlorine bleach or quaternary ammonia base.

Interestingly, only cleaning the slaughter floor walls daily was significant between small and very small respondents. Daily cleaning of the processing walls neared significance at the α=0.05 level. This difference is most likely a result discussed earlier in that the very small establishments are not as likely to slaughter and process daily.

Microbial Hazards

As anticipated, more of the case respondents had identified *Salmonella* as a food safety hazard likely to occur. Whether this is a result of the test set failure, or if the hazard was identified prior to the failure could not be determined. Despite the acknowledgement of the hazard, very few plants have implemented any type of specific *Salmonella* interventions during slaughter or processing. Small plant respondents were more likely to have SSOPs or GMPs that address *Salmonella,* but that does not translate into a difference between case statuses. Indicating adequate sanitation concerning generic coliforms, a majority of the responding slaughter establishments reported passing all of the generic *E. coli* tests performed in 2005.

Summary

Many of the result indicated that these small and very small processors have implemented positive food safety practices. These results also indicate there are areas that these plants could improve their food safety awareness. Tables 5.1 and 5.2 list these respectively.

Positive Food Safety Awareness Implemented Practices
• At least one HACCP trained employee in the slaughter or processing area
• Average hog scalding temperature is above threshold for *Salmonella* survival and an awareness of additives to the scald water was high
• Birds are taken off-line for reprocessing in poultry slaughter operations
• Employees are working in slaughter as well as processing, but no link between the practice and case status suggests sanitation awareness
• Inverse association with the generation and use of rework indicates hazard awareness and prevention measures
• Processing room temperatures below *Salmonella* growth optimums
• Non-woven gloves are worn by processing employees
• Policies to either launder or dispose of woven gloves after each use
• Equipment is cleaned and/or sanitized after maintenance
• Daily sanitation of wall and floor drains

Table 5.1: Indicators of positive food safety awareness

Areas for Food Safety Improvement
• Number of employees that are HACCP trained or involved in sanitation is not proportional to number of employees • Employees are working in both slaughter and processing areas on the same day
• Buildings are aging and most recent updates are >5 years old
• Very small processing establishments have more that 5°F fluctuation in room temperature • Rotation of cleaning and sanitizing agents is minimal
• Specific knowledge of sanitation details such as chemicals and concentrations used are minimal • SSOPs or GMP to address *Salmonella* are not implemented
• *Salmonella* has not been identified as a food safety hazard likely to occur
• Few plants have any specific *Salmonella* intervention procedures during processing or slaughter.

Table 5.2: Areas for food safety improvement

CHAPTER 6

CONCLUSIONS

There were three objectives for this study. The first was to evaluate the characteristics of small and very small meat processors. Second, to ascertain currently used practices for controlling *Salmonella* in those small and very small plants, and finally to determine the efficacy or risk of the above characteristics and practices in reference to failing FSIS *Salmonella* test sets. To reach these goals a case-control study was designed using data from the 2005 FSIS *Salmonella* test sets. This study focused on the plants that had failed the first set of *Salmonella* tests (test set A). The plants that were sampled in 2005 were not specifically targeted because of previous performance as it was prior to the implementation of the new sampling scheme.

A characterization of the small and very small meat processing facilities surveyed was accomplished using the instrument designed. Practices were identified that indicate food safety awareness as were areas that need improvement. However, because of the study design the results cannot be extrapolated to all small and very meat processors. In relation to failed *Salmonella* test sets, few of the variables were significantly different between those plants that passed or failed their test sets. Future studies targeted at sanitation details such as chemicals, concentrations and specific application practices may elucidate more differences between these two populations.

The information presented in this dissertation indicates that these small and very small meat processors are very much the same in many aspects. Most of the physical structures are composed of the same materials; there are only a few chemicals that are used for sanitation; few have implemented specific interventions to challenge *Salmonella* and many do not consider it a food safety hazard likely to occur. The latter indicate an opportunity for education and improvement for food safety.

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APPENDIX A

HACCP SURVEY INSTRUMENT

1. In which categories do you have HACCP plans? Check all that apply.

- ☐ Slaughter
- ☐ Poultry Slaughter
- ☐ Raw Product - Not Ground
- ☐ Raw Product - Ground
- ☐ Fully Cooked, Not Shelf Stable
- ☐ Heat Treated, Shelf Stable
- ☐ Heat Treated Not Fully Cooked, Not Shelf Stable
- ☐ Not Heat Treated, Shelf Stable
- ☐ Secondary Inhibitors, Not Shelf Stable
- ☐ Thermally Processed-Commercially Sterile

2. How many products do you have in each process category?

- ___ Slaughter
- ___ Poultry Slaughter
- ___ Raw Product - Not Ground
- ___ Raw Product - Ground
- ___ Fully Cooked Not Shelf Stable
- ___ Heat Treated Shelf Stable
- ___ Heat Treated Not Fully Cooked, Not Shelf Stable
- ___ Not Heat Treated Shelf Stable
- ___ Secondary Inhibitors, Not Shelf Stable
- ___ Thermally Processed-Commercially Sterile

3.
HACCP Category:

What are your CCPs for each plan?	What are your critical limits?
CCP1 -	
CCP2 -	
CCP3 -	

HACCP Category:

What are your CCPs for each plan?	What are your critical limits?
CCP1 -	
CCP2 -	
CCP3 -	

HACCP Category:

What are your CCPs for each plan?	What are your critical limits?
CCP1 -	
CCP2 -	
CCP3 -	

4. Do you have a policy regarding teaching employees how to monitor CCPs?

☐ yes ☐ no

5. What is the maximum number of HACCP plans you operate in a production day? ____

6. Do you have prerequisite programs (SSOPs or GMPs) that specifically address *Salmonella* in your operation? ☐ yes ☐ no

7a. In any of your HACCP plans, have you determined that *Salmonella* is a food safety hazard likely to occur? ☐ yes ☐ no

7b. If yes, in which step is Salmonella a hazard likely to occur? _____

7c. Which CCP controls this hazard? _____

8. Do you have a microbial sampling program? ☐ yes ☐ no **If no, please go to appropriate process category specific questions.**

9. What do you sample?

☐ Product ☐ Environmental ☐ Product contact surfaces

☐ Other _____

10. What do you test for?

☐ TPC/APC ☐ Listeria species ☐ *Listeria monocytogenes*

☐ *Salmonella* ☐ Generic *E. coli* ☐ *E. coli* O157:H7

☐ Other _____

11. Did you employ a statistician or statistical program to develop your sampling program?

☐ yes ☐ no

12. How do you evaluate your microbial test results? (Check all that apply)

☐ Test by test, individually ☐ Tracking and trending

☐ Weekly ☐ Monthly ☐ Yearly ☐ Other _____

☐ Sliding window of tests according to FSIS determination

(How many tests in a set? _____)

Please continue to the next appropriate section.

APPENDIX B

SLAUGHTER SURVEY INSTRUMENT

Slaughter

1a. In what year was the slaughter area of your plant built? _____

1b. What year was the most recent updates made to the slaughter area? _____

2. What is the composition of the floor in the slaughter area?

☐ Concrete ☐ tile ☐ brick ☐ coated/sealed

☐ Other _____

3. What is the composition of the walls in the slaughter area?

☐ Concrete ☐ tile ☐ brick ☐ glazed block ☐ Fiberglass tile

☐ Other _____

4. How often do you slaughter?

☐ Daily ☐ 3 or more days a week ☐ 1 or 2 days a week ☐ less than once a week

5. On a typical slaughter day, how many shifts do you slaughter?

☐ 1 ☐ 2 ☐ 3

6. What is your slaughter volume? Hogs_____ head/ year

Cattle _____ head/ year

Sheep _____ head/ year

Goats _____ head/ year

Chicken _____ head/year

Turkey _____ head/year

Other _____ head/year

7. In a typical slaughter shift, how long is the time from the beginning to the end of slaughter? _____

8. Do you slaughter more than one species in one day? ☐ yes ☐ no

If no, please skip to question 11

9. Please indicate in what order you slaughter by placing a number by each species applicable. (1 beside the first that you slaughter in a day, 2 beside the second and so on)

☐ no specific order followed, go to next question

_____ Hogs

_____ Cattle

_____ Sheep

_____ Goats

_____ Chicken

_____ Turkey

_____ Other

10. Do you have clean-up between species?

☐ No clean-up between species

☐ Partial clean-up

☐ Full Sanitation

11. Typically, how many employees work on the slaughter floor? _____

12. How many employees on your slaughter floor are HACCP trained? _____

13a. Do slaughter floor employees also work in other processing areas (fresh meat or fully cooked) when not working on the slaughter floor? ☐ yes ☐ no

13b. If yes, do they working in multiple areas on the same day? ☐ yes ☐ no

13c. If yes, which areas are they working in addition to the slaughter floor (e.g. fresh meat, fully cooked)? _____

14. Please list any policies you may have to address the condition of the animals prior to entering your facility (i.e. agreements with suppliers about *Salmonella* or *E. coli* control).

_____

_____

☐ no policies regarding animal conditions

15a. Do you have a policy on how long feed needs to be withdrawn from animals before slaughter?

☐ yes ☐ no

15b. If so, how long is your feed withdrawal time? _____

☐ Varies by species

16. How long are animals housed at your plant before slaughter (overnight, <4 hrs.)?_____

17a. Are animals washed before slaughter? ☐ yes ☐ no

17b. If yes, what is used? _____

17c. If applicable, what concentration? _____

18. What do you use for your final carcass rinse (e.g. warm water, hot water, organic acid, other)? _____

19. What temperature is used? _____°F

20. If an organic acid rinse is used, what concentration? _____

21. How many knife sterilizers are available for use on your slaughter floor?

_____

22. What temperature is your knife sterilizer(s) kept at during slaughter?

_____

23a. Are gloves used by the slaughter employees? ☐ yes ☐ no

23b. If so, what is your policy on wearing gloves? (check all that apply)

☐ All employees are required to wear gloves (not fabric) during slaughter

☐ No policy, some employees wear gloves during slaughter

☐ Some or all employees wear fabric gloves during slaughter

23c. What is your policy regarding sanitation of fabric or cutting gloves?

☐ All used gloves are laundered after each shift

☐ No specific policy

☐ Other _____

24. What is the air temperature of the chill cooler before the first hot carcasses enter?

_____

25. What is the air temperature of the cooler when all hot carcasses have been pushed in for the production period? _____°F ☐ not applicable

(Why?_____)

26a. During 2005, what results did you receive for generic E. coli testing?

☐ passed tests ☐ failed tests ☐ both passed and failed tests

26b. If at least some tests were failed, were actions taken to make control more consistent? ☐ yes ☐ no

26c. What actions were taken? _____

27a. Are the tools used for maintenance cleaned? ☐ yes ☐ no

27b. If so, what is used? _____

27c. What concentration is used? _____

28a. Are the tools used for maintenance sanitized? ☐ yes ☐ no

28b. If so, what is used? _____

28c. What concentration is used? _____

29a. Is equipment cleaned after maintenance? ☐ yes ☐ no

29b. If so, what is used? _____

29c. What concentration is used? _____

30a. Is equipment sanitized after maintenance? ☐ yes ☐ no

30b. If so, what is used? _____

30c. What concentration is used? _____

31. How often is/are the holding pen(s) cleaned? _____

32a. Is a disinfectant or sanitizer used when cleaning the holding pens? ☐ yes ☐ no

32b. If so, what is used? _____

32c. What concentration is used? _____

33. Do you contract cleaning and sanitation to another company? ☐ yes ☐ no

If yes, please skip to the appropriate species specific questions on the next page.

34. How many people work on sanitation of the slaughter floor? _____

35. Please indicate the order of the steps of your cleaning and sanitizing operation. (1 indicates the first step, if you repeat a step, place a second number beside that step. If you do not do a particular step, place a 0 on that line.)

_____ Remove pieces of meat/fat from equipment

_____ Remove pieces of meat/fat from floor

_____ Disassemble equipment

_____ Move equipment

_____ Water rinse

_____ Apply soap

_____ Use brushes

_____ Use abrasive pads

_____ Clean floor

_____Apply sanitizer

_____ Steam (☐ Room ☐ Equipment)

_____ Other step _____

36. For each water rinse step indicated above, what temperature water is used?

1st rinse _____ 2nd rinse _____ 3rd rinse _____ More _____

37a. What cleaning agent(s) do you use?_____

37b. What concentration?_____

37c. How is it applied? (check all that apply)

☐ Brush or abrasive pads ☐ Flooding ☐ Foam ☐ Spray

38a. What kind of sanitizer do you use?_____

38b. What concentration? _____

38c. How is it applied? (check all that apply)

☐ Flooding ☐ Foam ☐ Spray ☐ Dip

39a. Do you rotate types of cleaning agents? ☐ yes ☐ no

39b. How often? _____

40a. What is the alternative cleaning agent? _____

40b. What concentration? _____

41a. Do you rotate types of sanitizer? ☐ yes ☐ no

41b. How often? _____

42a. What is the alternative sanitizer? _____

42b. What concentration? _____

43. How often do you clean the walls of your slaughter area? _____

44. How often do you clean the ceiling of your slaughter area? _____

45. How often do you clean your floor drains in the slaughter area? _____

Cattle slaughter facilities:

1. What type of stunning do you use on cattle? _____

2a. What is your *E. coli* intervention? _____

2b. If applicable, what concentration?_____

2c. What temperature? _____

2d. How is it applied?

☐ Rinse ☐ Pressure Sprayer ☐ Other _____

3a. Do you have a specific *Salmonella* intervention procedure? ☐ yes ☐ no

3b. What is it? _____

3c. If applicable, what concentration?_____

3d. When was this implemented? _____

4. Once in the chill cooler, how long does it take for the surface of your carcasses to reach 40°F? _____

Hog slaughter facilities:

1. What type of stunning do you use on hogs? _____

2. Do you: ☐ skin or ☐ scald your carcasses?

If you scald:
3a. What is the temperature of your scalding water? _____
3b. Do you add any additives into your scalding water?

☐ yes ☐ no

3c. What do you use? _____

3d. What concentration? _____

3e. What is the pH of the scald water? _____

4. The scald water:

☐ is stationary. ☐ flows with the carcasses. ☐ flows counter-current to carcasses.

5a. Do you have a specific *Salmonella* intervention procedure? ☐ yes ☐ no

5b. What is it? _____

5c. If applicable, what concentration?_____

5d. When was this implemented? _____

6. Once in the chill cooler, how long does it take for the surface of your carcasses to reach 40°F? _____

Sheep and goat slaughter facilities:

1. What type of stunning do you use on sheep and goats?

_____

2a. Do you have an *E. coli* intervention? ☐ yes ☐ no

2b. What is it? _____

2c. If applicable, what concentration?_____

2d. What temperature? _____

2e. How is it applied?

☐ Rinse ☐ Pressure Sprayer ☐ Other _____

3a. Do you have a specific *Salmonella* intervention procedure? ☐ yes ☐ no

3b. What is it? _____

3c. If applicable, what concentration?_____

3d. When was this implemented? _____

4. Once in the chill cooler, how long does it take for the surface of your carcasses to reach 40°F? _____ sheep _____ goats

Poultry slaughter facilities:

1a. Do you use any additives in the scald water?

☐ no ☐ yes ☐ Do not use scald water (**Skip to question 5)**

1b. What do you use? _____

1c. What concentration? _____

2. What temperature is the scald water? _____°F

3. What is the pH of the scald water? _____

4. The scald water:

☐ is stationary. ☐ flows with the carcasses. ☐ flows counter-current to carcasses.

5. How do you remove feathers?

☐ hand pluck ☐ mechanical pickers ☐ other method

_____

6a. Do you use any additives in the rinse water after picking?

☐ no ☐ yes ☐ Do not rinse after picking

6b. What do you use? _____

6c. What concentration? _____

7. How are the birds eviscerated?

☐ hand evisceration ☐ mechanical evisceration

8a. Do you use any additives in the chill water?

☐ no ☐ yes ☐ Do not use chill water (**Skip to question 11)**

8b. What do you use? _____

8c. What concentration? _____

9. The chill water:

☐ is stationary. ☐ flows with the carcasses.☐ flows counter-current to carcasses.

10. What temperature is the chill water? _____°F

If chill water is not used, what temperature is the cooler when carcasses are placed in the room? _____°F

11a. Do you have a post-chill anti-microbial treatment? ☐ yes ☐ no

11b. What is it? _____

11c. If applicable, what concentration?_____

12. Do you take birds off-line for reprocessing? ☐ yes ☐ no

APPENDIX C

RAW PRODUCT PROCESSING SURVEY INSTRUMENT

Raw Products

1a. In what year was the raw processing area of your plant built? _____

1b. What year was the most recent updates made to the processing area? _____

2. What is the composition of the floor in the processing area?

☐ Concrete ☐ tile ☐ brick ☐ coated/sealed

☐ Other _____

3. What is the composition of the walls in the processing area?

☐ Concrete ☐ tile ☐ brick ☐ glazed block ☐ Fiberglass tile

☐ Other _____

4. How often do you process raw meat products?

☐ Daily ☐ 3 or more days a week ☐ 1 or 2 days a week ☐ less than once a week

5. How many shifts do you process raw meat products?

☐ 1 ☐ 2 ☐ 3

6. What is your volume of production?

Pork_____ pounds/ year

Beef _____ pounds/ year

Lamb/Mutton _____ pounds/ year

Chevon (Goat) _____ pounds/ year

Chicken _____ pounds/ year

Turkey _____ pounds/ year

Mixed species _____ pounds/ year

Other _____ pounds/ year

7. What percent of the raw product that you process do you obtain from your own slaughter facility? _____

8a. Do you use frozen materials to produce raw products? ☐ yes ☐ no

8b. If yes, how is the frozen product thawed before use?

☐ Water (Temperature: _____) ☐ Air (Temperature: _____) ☐ Not thawed

9a. Is rework generated during raw product processing? ☐ yes ☐ no

(If no, go to question 10)

9b. How long is rework held? _____

9c. How is rework used? (check all that apply)

☐ Added to specific lots
☐ Same shift/daily ☐ Next day ☐ Weekly ☐ Monthly

☐ Added to matching product

☐ Added to next batch of product

10. How is product that has been dropped on the floor handled? (Check all that apply)

☐ All discarded ☐ Rinsed in water (Temperature: _____)

☐ Rinsed with sanitizer (What?_____; What concentration? _____;

Temperature _____)

☐ Trim surface that touched the floor ☐ Trim all outer surfaces

11. How long is the time from the beginning to the end of processing (full sanitation to full sanitation)? _____

12. Do you process more than one species in one day? ☐ yes ☐ no

If no, skip to question 15

13. Please indicate in what order you process by placing a number by each species applicable.

(1 beside the first that you process in a day, 2 beside the second and so on)

☐ no specific order followed/process multiple species simultaneously, **go to question 14**

_____ Pork

_____ Beef

_____ Lamb/Mutton

_____ Chevon (Goat)

_____ Chicken

_____ Turkey

_____ Other

14. Do you have clean-up between species?

☐ No clean-up between species

☐ Partial clean-up

☐ Full Sanitation

15a. Do you have a specific *Salmonella* intervention procedure? ☐ yes ☐ no

15b. What is it? _____

15c. If applicable, what concentration?_____

15d. When was this implemented? _____

16. On a typical production day, how many employees work in the processing area?

_____

17. How many employees in your processing area are HACCP trained? _____

18a. What is the average room temperature of the processing area? _____ °F

18b. How much does it vary in a production day?

☐ 0° to 5°F ☐ 5°F to 10°F ☐ 10°F to 15°F ☐ 15°F or more

19. What is the primary packaging used? (check all that are used regularly)

☐ Butcher paper ☐ Overwrap on Styrofoam tray ☐ Vacuum bags

☐ Poly bag in a box ☐ Other

20a. Are products packaged in a separate room or time from production? ☐ yes ☐ no

20b. If yes, what is the temperature of the room during packaging? _____

21. Do you have retail sales? ☐ yes ☐ no **If no, skip to question 24**

22. Is there a retail sales area attached to or in your production area? ☐ yes ☐ no

23. Are there separate employees for retail sales? ☐ yes ☐ no

24a. Are gloves used by the processing employees? ☐ yes ☐ no

24b. If so, what is your policy on wearing gloves? (check all that apply)

☐ All employees are required to wear gloves (not fabric) while in the processing area

☐ No policy, some employees wear gloves while in the processing area

☐ Some or all employees wear fabric gloves in cold processing rooms

24c. What is your policy regarding sanitation of fabric or cutting gloves?

☐ All used gloves are laundered after each shift

☐ No specific policy

☐ Other _____

25a. Are the tools used for maintenance cleaned? ☐ yes ☐ no

25b. What kind of cleaning agent(s) do you use? _____

25c. What concentration? _____

26a. Are the tools used for maintenance sanitized? ☐ yes ☐ no

26b. What kind of sanitizer do you use? _____

26c. What concentration? _____

27. Is equipment cleaned after maintenance? ☐ yes ☐ no

27b. What kind of cleaning agent(s) do you use? _____

27c. What concentration? _____

28a. Is equipment sanitized after maintenance? ☐ yes ☐ no

28b. What kind of sanitizer do you use? _____

28c. What concentration? _____

29. Do you contract cleaning and sanitation to another company? ☐ yes ☐ no

If yes, you have completed the questionnaire, Thank you.

30. How many people work on sanitation of the processing area? _____

31. Please indicate the order of the steps of your cleaning and sanitizing operation. (1 indicates the first step, if you repeat a step, place a second number beside that step. If you do not do a particular step, place a 0 on that line.)

_____ Remove pieces of meat/fat from equipment

_____ Remove pieces of meat/fat from floor

_____ Disassemble equipment

_____ Move equipment

_____ Water rinse

_____ Apply soap

_____ Use brushes

_____ Use abrasive pads

_____ Clean floor

_____Apply sanitizer

_____ Steam (☐ Room ☐ Equipment)

_____ Other step _____

32. For each water rinse step indicated above, what temperature water is used?

1st rinse _____ 2nd rinse _____ 3rd rinse _____ More _____

33a. What cleaning agent(s) do you use?_____

33b. What concentration?_____

33c. How is it applied? (check all that apply)

☐ Brush or abrasive pads ☐ Flooding ☐ Foam ☐ Spray

34a. What kind of sanitizer do you use?_____

34b. What concentration? _____

34c. How is it applied? (check all that apply)

☐ Flooding ☐ Foam ☐ Spray ☐ Dip

35a. Do you rotate types of cleaning agents? ☐ yes ☐ no

35b. How often? _____

36a. What is the alternative cleaning agent? _____

36b. What concentration? _____

37a. Do you rotate types of sanitizer? ☐ yes ☐ no

37b. How often? _____

38a. What is the alternative sanitizer? _____

38b. What concentration? _____

39. How often do you clean the walls of your processing area? _____

40. How often do you clean the ceiling of your processing area? _____

41. How often do you clean your floor drains in the processing area? _____

APPENDIX D

SURVEY COVERLETTER

The Department of Food Science and Technology

College of Food, Agricultural, and Environmental Sciences
Parker Food Science Building 2015 Fyffe Road
Columbus, Ohio 43210-1007

Phone 614 292-6281
FAX 614 292-0218
http://fst.osu.edu

January 10, 2008

The Ohio State University, funded by the Cooperative State Research, Education and Extension Service branch of the United States Department of Agriculture (USDA), is gathering information about small and very small federally inspected meat processing plants. This information will be used to better serve smaller processing establishments, indicate what information is needed, and better understand what technology is being employed by this size establishment.

We ask that your company participate in this research. It is voluntarily that you do. No records will be kept indicating if you choose not to. We are offering a $50 gift certificate for a supplier to companies that complete the survey. Your establishment has been chosen from the list of inspected plants published by the Food Safety and Inspection Service (FSIS). The selection process was made based on size of your plant (small or very small) and your inspection district.

I will be contacting you by telephone within the next two weeks to schedule a time that is convenient for you to work through the questions with me. I have enclosed the questionnaire with this letter so that you will be able to see the information about which I will be inquiring. It should take us about 30 minutes to complete the questions.

Once I have collected information from all of the plants that have been selected I will remove all identification from your responses. Information from all of the plants will be reported as a group; no individual plant information will be disclosed.

If you have any questions or concerns about this study, please feel free to contact me at (614) 247-7135, or by email at folk.13@osu.edu.

Thank you for your assistance!

Sincerely,

Mary Kay Folk
Graduate Research Assistant
The Ohio State University
Department of Food Science and Technology

Lynn Knipe, Ph.D
Associate Professor
The Ohio State University
Department of Food Science and Technology

APPENDIX E

RESULTS

	Very Small/ Small	statistic	Control / Case	statistic
Slaughter	23% / 57%	<0.01	VS: 65% / 25%	0.16
			S: 19% / 33%	0.39
Poultry Slaughter	5% / 15%	0.24	4% / 38%	<0.01
Raw Product – Not Ground	100% / 88%	0.09	94% / 85%	0.29
Raw Product – Ground	100% / 78%	0.02	100% / 100%	
			81% / 67%	0.39
Fully Cooked, Not Shelf Stable	24% / 40%	0.21	38% / 23%	0.34
Heat Treated, Shelf Stable	10% / 15%	0.53	11% / 23%	0.25
Heat Treated Not Fully Cooked Not Shelf Stable	14% / 10%	0.62	10% / 15%	0.63
Not Heat Treated, Shelf Stable	5% / 3%	0.64	4% / 0%	0.46
Secondary Inhibitors	5% / 5%	0.97	6% / 0%	0.36
Thermally Processed, Commercially Sterile	0% / 3%	0.47	2% / 0%	0.61
Average of Total Processing Categories	3 / 3	0.27	3 / 3	0.99

Table E.1: Results for "In which categories do you have HACCP plans?" by size category and case/control status.

	Very Small/ Small	statistic	Control / Case	statistic
Slaughter	3 / 1	<0.01	VS: 3 / 3	-
			S: 2 / 1	0.35
Poultry Slaughter	2 / 2	-	3 / 1	0.20
Raw Product – Not Ground	15 / 23	0.50	21 / 16	0.70
Raw Product – Ground	3 / 26	0.13	18 / 11	0.75
Fully Cooked, Not Shelf Stable	6 / 42	0.33	24 / 92	0.12
Heat Treated, Shelf Stable	2 / 24	0.46	9 / 34	0.36
Heat Treated Not Fully Cooked Not Shelf Stable	3 / 9	0.03	VS: 3 / 1	-
			S: 10 / 5	-
Not Heat Treated, Shelf Stable	1 / 1	-	No cases	-
Secondary Inhibitors	2 / 2	-	No cases	-
Thermally Processed, Commercially Sterile	No VS	-	No cases	-
Average of Total Processing Categories	22 / 62	0.14	47 / 53	0.87

Table E.2: Results for "How many products do you have in each process category?" by size category and case/control status.

	Very Small/ Small	statistic	Control / Case	statistic
Average total number of CCPs	5 / 5	0.94	5 / 5	0.87
Policy to teach how to monitor CCPs	38% / 68%	0.01	VS: 41% / 25%	0.57
			S: 65% / 77%	0.47
Maximum HACCP plans operate in a day	3 / 3	0.57	3 / 3	0.38
SSOPs or GMPs to address *Salmonella*	20% / 45%	0.02	VS: 18% / 25%	0.75
			S: 35% / 78%	0.02
Salmonella is a hazard likely to occur	38% / 23%	0.20	19% / 62%	<0.01
Microbial sampling plan	86% / 95%	0.22	VS: 90% / 100%	0.23
Product	81% / 90%	0.33	S: 83% / 100%	0.12
Environmental	14% / 48%	<0.01	VS: 18% / 0%	0.39
			S: 52% / 33%	0.35
Product contact surfaces	19% / 58%	<0.01	VS: 24% / 0%	0.30
			S: 58% / 56%	0.90
TPC/APC	5% / 43%	<0.01	VS: 6% / 0%	0.64
			S: 48% / 22%	0.17
Listeria spp.	19% / 38%	0.14	33% / 23%	0.49
Listeria monocytogenes	5% / 18%	0.17	13% / 15%	0.79
Salmonella	24% / 45%	0.11	31% / 62%	0.02
Generic *E. coli*	57% / 48%	0.48	48% / 62%	0.39
E. coli O157:H7	48% / 45%	0.85	50% / 32%	0.22
Employed a statistician or statistical program	5% / 35%	<0.01	VS: 6% / 0%	0.64
			S: 32% / 44%	0.51
Evaluate test results Test by test	81% / 83%	0.88	85% / 16%	0.18
Tracking and trending	5% / 25%	0.03	VS: 0% / 25%	0.02
			S: 22% / 33%	0.52
Weekly	0% / 15%	0.03	No VS	-
			10% / 33%	0.04
Monthly	0% / 13%	0.05	No VS	-
			6% / 33%	0.02
Yearly	5% / 5%	0.97	0% / 23%	<0.01

Table E.3: Results for HACCP survey section by size category and case/control status.

	Very Small/ Small	statistic	Control / Case	statistic
Age of plant (years)	38 / 46	0.37	37 / 53	0.11
Age of most recent renovations of area (years)	11 / 7	0.21	9 / 9	0.90
Composition of floor				
Concrete	100% / 87%	0.18	89% / 100%	0.33
Tile	0% / 13%	0.18	5% / 11%	0.59
Brick	0% / 7%	0.36	0% / 11%	0.15
Coated/sealed	23% / 73%	<0.01	VS:18% / 50% S: 88% / 57%	0.37 0.21
Composition of walls				
Concrete	8% / 20%	0.37	16% / 11%	0.75
Tile	0% / 47%	<0.01	No VS S: 50% / 43%	- 0.80
Brick	8% / 0%	0.29	5% / 0%	0.50
Glazed block	23% / 0%	0.03	VS: 18% / 50% No S	0.37 -
Fiberglass tile/panel	69% / 33%	0.03	VS: 73% / 50% S: 25% / 43%	0.76 0.50
Stainless Steel	15% / 47%	0.04	VS: 18% / 0% S: 50% / 43%	0.55 0.80
How often is slaughter?			VS:	VS:
Daily	31% / 80%	$\chi^2(3) = 9.24$ Pr = 0.03	28% / 50%	$\chi^2(3) = 3.40$ Pr = 0.33
3 or more days/wk	15% / 13%		18% / 0%	
1 or 2 days/wk	38% / 0%		45% / 0%	
< than once/wk	15% / 7%		9% / 50%	
			S:	S: $\chi^2(2) = 3.28$ Pr = 0.19
			88% / 71%	
			0% / 29%	
			0% / 0%	
			13% / 0%	
Shifts of slaughter		$\chi^2(1) = 0.90$ Pr = 0.34		$\chi^2(1) = 0.49$ Pr = 0.48
1	100% / 0%		95% / 100%	
2	93% / 7%		5% / 0%	

Table E.4: Results for Slaughter survey section by size category and case/control status.

Table E.4 continued

	Very Small/ Small	statistic	Control / Case	statistic
Slaughter volume (head annually)				
Hogs	4,380 / 213,521	0.03	VS: 3,596 / 13,000	-
			S: 238,776 / 112500	-
Cattle	3,919 / 83,825	0.03	VS: 909 / 31,000	-
			118,042 / 32,500	0.55
Sheep	85 / 15	-	86 / 10	-
Goats	0 / 23	-	23 / 0	-
Chickens	35,000 / 13,500,000	-	29,300,000 / 4,527,000	0.03
Turkeys	2,000 / 10,000	-	0 / 6,000	-
Other[a]	93 / 8,547000	0.06	18,891 / 8,500,005	0.06
Length of slaughter (hours)	6.4 / 8.8	0.02	VS: 6.7 / 4.8	0.30
			S: 9.5 / 8.0	0.40
Slaughter more than one species per day	77% / 13%	<0.01	VS: 82% / 50%	0.37
			S: 13% / 14%	0.93
No order to slaughter	10% / 50%	0.20	10% / 50%	0.20
100% response that hogs are slaughtered after cattle and/or sheep				
Sanitation between species			VS:	
Unknown	8% / 13%	$\chi^2(3) = 7.68$ Pr = 0.05	0% / 50%	$\chi^2(3) = 6.60$ Pr = 0.09
No	38% / 80%		45% / 0%	
Partial	46% / 7%		45% / 50%	
Full	8% / 0%		9% / 0%	
			S:	
			13% / 14%	$\chi^2(2) = 1.27$ Pr = 0.53
			88% / 71%	
			0% / 14%	
			0% / 0%	

[a] Includes Bison, Deer, Ducks, Elk, Moose, and Veal calves

Table E.4 continued

	Very Small/ Small	statistic	Control / Case	statistic
Slaughter employees	4 / 40	<0.01	VS: 4 / 3	0.70
			S: 46 / 35	0.58
Slaughter employees HACCP trained	2 / 9	0.31	7 / 2	0.53
Proportion of slaughter employees HACCP trained	49% / 24%	0.04	VS: 49% / 50%	0.98
			S: 37% / 9%	0.13
Slaughter employees work in other areas	70% / 53%	0.41	63% / 56%	0.71
On the same day[b]	56% / 100%	0.02	VS: 56% / 0%	-
			S: 100% / 100%	-
There were no reported policies regarding microbial condition / control of animals				
Feed withdrawal policy	23% / 47%	0.21	26% / 56%	0.14
Hours of w/d time	3.7 / 4.0	0.90	3.4 / 4.8	0.60
Hours animals house prior to slaughter	11 / 16	0.68	19 / 3.4	0.22
Animals washed prior to slaughter[c]	23% / 20%	0.85	32% / 0%	0.03
Final carcass rinse responses include lactic acid, water, chlorine, and acidified NaCl[d]				
Temperature of final carcass rinse (°F)	106 / 76.5	0.04	114 / 65.0	0.09
			79.0 / 73.7	0.80
Knife sterilizers[e]	2 / 21	0.05	2 / 1	0.18
			34 / 6	0.19

[b] Responses include: raw processing, packaging, and smoked meats

[c] Responses include water and hypochlorite

[d] In descending order of prevalence

[e] All knife sterilizers were reported to be kept at 180°F or higher

Table E.4 continued

	Very Small/ Small	statistic	Control / Case	statistic
Gloves are worn by employees	31% / 93%	<0.01	VS: 27% / 50%	0.56
			S: 88% / 100%	0.37
Glove use:				
Some wear	25% / 36%	$\chi^2(2)$ = 0.321 Pr = 0.85	30% / 38%	$\chi^2(2)$ = 1.13 Pr = 0.57
All wear	50% / 50%		60% / 25%	
Wear woven[f]	25% / 14%		10% / 38%	
Air temperature of chill cooler (°F)				
Before hot carcasses	29.6 / 30.4	0.89	33.2 / 22.9	0.04
After all carcasses	43.3 / 36.3	0.34	43.0 / 33.4	0.21
2005 generic *E. coli* test results				
Passed all	100% / 53%	$\chi^2(2)$ = 8.09 Pr < 0.01	100% / 100%	-
Failed and passed	0% / 47%		0% / 0%	
			63% / 43%	$\chi^2(1)$ = 0.58 Pr = 0.45
			38% / 57%	
Actions taken if failed tests	No VS / 57%	-	67% / 50%	0.72
Tools for maintenance:				
Cleaned	31% / 60%	0.66	42% / 56%	0.52
Unknown	20% / 0%	$\chi^2(4)$ = 2.89 Pr = 0.58	11% / 0%	$\chi^2(4)$ = 3.33 Pr = 0.50
No chemicals	20% / 33%		33% / 20%	
Hypochlorite	20% / 44%		22% / 60%	
Hydroxides	20% / 11%		11% / 20%	
Other	20% / 11%		22% / 0%	
Sanitized	31% / 47%	0.41	37% / 44%	0.71
Unknown	25% / 0%	$\chi^2(3)$ = 2.36 Pr = 0.50	14% / 0%	$\chi^2(3)$ = 4.52 Pr = 0.21
No chemicals	25% / 43%		14% / 75%	
Hypochlorite	25% / 14%		29% / 0%	
Quat. Ammonia	25% / 43%		43% / 25%	

[f] All respondents that wear woven gloves launder after each use

Table E.4 continued

	Very Small/ Small	statistic	Control / Case	statistic
Equipment after maintenance:				
Cleaned	92% / 100%	0.29	95% / 100%	0.50
Unknown	25% / 7%	$\chi^2(7) = 8.03$ Pr = 0.33	17% / 11%	$\chi^2(7) = 6.00$ Pr = 0.54
No chemicals	17% / 13%		17% / 11%	
Hypochlorite	17% / 53%		28% / 56%	
Ammonia	8% / 0%		6% / 0%	
Hydroxides	8% / 13%		11% / 11%	
Sulfonates	8% / 0%		6% / 0%	
Acids	0% / 7%		0% / 11%	
Other	17% / 7%		17% / 0%	
Sanitized	77% / 100%	0.03	VS: 73% / 100% S: 100% / 100%	0.44 -
Unknown	20% / 7%	$\chi^2(5) = 4.46$ Pr = 0.49	7% / 22%	$\chi^2(5) = 3.20$ Pr = 0.67
No chemicals	10% / 21%		13% / 22%	
Hypochlorite	40% / 29%		33% / 33%	
Quat. Ammonia	10% / 36%		27% / 22%	
Alcohol	10% / 0%		7% / 0%	
Acids	10% / 7%		13% / 0%	
Holding pens are cleaned:				
Never	8% / 13%	$\chi^2(3) = 15.5$ Pr < 0.01	0% / 50%	$\chi^2(3) = 6.28$ Pr = 0.09
Annually	62% / 0%		64% / 50%	
2x weekly	8% / 0%		9% / 0%	
Daily	23% / 87%		27% / 0%	
			13% / 14%	$\chi^2(1) = 0.010$ Pr = 0.92
			0% / 0%	
			0% / 0%	
			88% / 86%	
Disinfectant or sanitizer is used to clean holding pens[g]	8% / 27%	0.21	5% / 44%	<0.01
Sanitation is outsourced	15% / 40%	0.16	26% / 33%	0.71
Employees for sanitation	3 / 9	0.05	VS: 3 / 5	0.21
			S: 4 / 15	0.22

[g] Respondents reported use of hypochlorite, quaternary ammonia, water and unknown in descending order and concentration is unknown for all respondents

Table E.4 continued

	Very Small/ Small	statistic	Control / Case	statistic
Temperature of 1st water rinse (°F)	141 / 139	0.89	140 / 142	0.92
Temperature of 2nd water rinse (°F)	154 / 170	0.43	127 / 150	-
Cleaning agents:				
Unknown	25% / 13%		21% / 17%	
No chemicals	8% / 0%		7% / 0%	
Hypochlorite	42% / 50%	$\chi^2(6) = 3.45$ Pr = 0.75	43% / 50%	$\chi^2(6) = 4.52$ Pr = 0.61
Hydroxides	8% / 13%		7% / 17%	
Sulfonates	8% / 0%		7% / 0%	
Acids	0% / 13%		0% / 17%	
Other	8% / 13%		14% / 0%	
Cleaning agent is applied:				
Brush or pad	45% / 33%	$\chi^2(2) = 2.73$ Pr = 0.26	36% / 50%	$\chi^2(2) = 1.07$ Pr = 0.59
Foam	36% / 67%		50% / 50%	
Spray	18% / 0%		14% / 0%	
Sanitizing agents:				
Unknown	8% / 11%		0% / 33%	
No chemicals	25% / 22%	$\chi^2(5) = 4.96$ Pr = 0.42	27% / 17%	$\chi^2(5) = 6.16$ Pr = 0.29
Hypochlorite	42% / 22%		33% / 33%	
Quat. Ammonia	8% / 44%		27% / 17%	
Alcohol	8% / 0%		7% / 0%	
Acids	8% / 0%		7% / 0%	
Sanitizing agent is applied:				
Foam	9% / 25%	$\chi^2(1) = 0.88$ Pr = 0.35	0% / 50%	$\chi^2(1) = 7.72$ Pr < 0.01
Spray	91% / 75%		100% / 50%	

[h] Alternative cleaning agents base reported are unknown, quaternary ammonia, and acid

Table E.4 continued

	Very Small/ Small	statistic	Control / Case	statistic
Cleaning agent is rotated:[h]	17% / 22%	0.76	20% / 17%	0.87
Never	83% / 78%		80% / 83%	
2x annually	8% / 0%	$\chi^2(3) = 4.19$	7% / 0%	$\chi^2(3) = 1.26$
Weekly	0% / 22%	Pr = 0.24	7% / 17%	Pr = 0.74
Daily	8% / 0%		7% / 0%	
Sanitizing agent is rotated:[i]	17% / 22%	0.76	27% / 0%	0.09
Never	83% / 78%	$\chi^2(2) = 0.10$	73% / 100%	$\chi^2(2) = 1.98$
Weekly	8% / 11%	Pr = 0.95	13% / 0%	Pr = 0.37
Daily	8% / 11%		13% / 0%	
Walls are cleaned:				
6 months	8% / 0%	$\chi^2(4) = 6.30$	7% / 0%	$\chi^2(4) = 3.36$
Monthly	8% / 0%	Pr = 0.18	7% / 0%	Pr = 0.50
Weekly	25% / 0%		20% / 0%	
2x weekly	8% / 0%		7% / 0%	
Daily	50% / 100%		60% / 100%	
Ceiling is cleaned:				
Never	8% / 11%		7% / 17%	
Annually	0% / 11%		7% / 0%	
6 Months	25% / 0%	$\chi^2(7) = 6.03$	13% / 17%	$\chi^2(7) = 1.81$
4 months	8% / 0%	Pr = 0.54	7% / 0%	Pr = 0.97
Monthly	17% / 22%		20% / 17%	
Weekly	25% / 33%		27% / 33%	
2x weekly	8% / 0%		7% / 0%	
Daily	8% / 22%		14% / 17%	
Floor Drains are cleaned:				
Never	8% / 0%	$\chi^2(2) = 3.71$	7% / 0%	$\chi^2(2) = 1.98$
Weekly	25% / 0%	Pr = 0.16	20% / 0%	Pr = 0.37
Daily	67% / 100%		73% / 100%	

[i] Alternative sanitizing agents base reported are hypochlorite and quaternary ammonia

	Very Small/ Small	statistic	Control / Case	statistic
Type of stunning				
Captive bolt	90% / 100%	$\chi^2(1) = 0.64$ Pr = 0.42	92% / 100%	$\chi^2(1) = 0.25$ Pr = 0.62
Electric	10% / 0%		8% / 0%	
E. coli intervention[a]				
Water	30% / 17%	$\chi^2(3) = 2.56$ Pr = 0.47	31% / 0%	$\chi^2(3) = 2.22$ Pr = 0.53
Lactic acid	60% / 67%		54% / 100%	
Acidified NaCl	10% / 0%		8% / 0%	
Combination[b]	0% / 17%		8% / 0%	
Applied:				
Rinse	40% / 0%	$\chi^2(1) = 3.20$ Pr = 0.08	31% / 0%	$\chi^2(1) = 1.23$ Pr = 0.27
Pressure sprayer	60% / 100%		69% / 100%	
Lactic acid was reported as a Salmonella intervention				
Time for carcass surface to reach 40°F ranged from 1 to 24 hours				

[a] All respondents reported specific concentrations and temperatures of their intervention

[b] Combination treatment included lactic acid and acidified NaCl

Table E.5: Results from Cattle Slaughter survey section by size category and case/control status.

	Very Small/ Small	statistic	Control / Case	statistic
Type of stunning Captive bolt Electric Bullet	 58% / 0% 25% / 100% 17% / 0%	$\chi^2(2) = 6.86$ Pr = 0.03	VS: 55% / 100% 27% / 0% 18% / 0% S: 100% use Electric	$\chi^2(2) = 0.33$ Pr = 0.85
Skin	83% / 25%	0.01	VS: 81% / 100%	-
			S: 31% / 0%	-
Scald	42% / 75%	0.28	43% / 100%	0.07
Temperature of scald water (°F)	150 / 139	<0.01	VS: 149 / 155	-
			139 / 138	-
Scald water additives[a]	40% / 67%	0.53	50% / 50%	1.0
Scald water: Is stationary Flows counter-current to carcass	 80% / 100% 20% / 0%	$\chi^2(1) = 0.69$ Pr = 0.41	 100% / 50% 0% / 50%	$\chi^2(1) = 3.43$ Pr = 0.06
Lactic acid was reported as a Salmonella intervention				
Time for carcass surface to reach 40°F ranged from 1 to 24 hours				

[a] Each respondent reported different additives but all used a specific concentration or target pH

Table E.6: Results from Hog Slaughter survey section by size category and case/control status.

	Very Small/ Small	statistic	Control / Case	statistic
Type of stunning Captive bolt Electric	88% / 100% 13% / 0%	$\chi^2(1) = 0.14$ Pr = 0.71	88% / 100% 13% / 0%	$\chi^2(1) = 0.14$ Pr = 0.71
E. coli intervention[a] Water Lactic acid	50% / 100% 50% / 0% 50% / 100%	- $\chi^2(1) = 0.83$ Pr = 0.36	63% / 0% 40% / 0% 60% / 0%	- -
Applied: Rinse Pressure sprayer	50% / 0% 50% / 100%	$\chi^2(1) = 0.83$ Pr = 0.36	40% / 0% 60% / 0%	$\chi^2(1) = 1.23$ Pr = 0.27
No *Salmonella* intervention were reported				
Time for carcass surface to reach 40°F ranged from 1 to 24 hours for both sheep and goats				

Table E.7: Results from Sheep/Goat Slaughter survey section by size category and case/control status.

	Very Small/ Small	statistic	Control / Case	statistic
Additives in scald water[a]	100% / 33%	-	0% / 60%	0.20
Temperature of scald water (°F)	144 / 134	-	124 / 139	0.07
Scald water:				
Is stationary	100% / 0%	$\chi^2(2) = 7.00$ Pr = 0.03	All VS are case and are stationary	-
Flows with carcass	0% / 17			
Flows counter-current to carcass	0% / 83%		S: 0% / 0% 0% / 25% 100% / 75%	$\chi^2(1) = 0.60$ Pr = 0.44
All respondents mechanically pick				
All respondents that use an additive in the after picking rinse use chlorine				
Evisceration:		$\chi^2(1) = 0.88$ Pr = 0.35		$\chi^2(1) = 3.73$ Pr = 0.05
Hand	100% / 50%		0% / 80%	
Mechanically	0% / 50%		100% / 20%	
No VS respondents use chill water, 33% use additives 67% do not[b]				
Chill water:				
Is stationary	33%		0% / 50%	
Flows counter-current to carcass	67%		100% / 50%	
Acidified Sodium Chloride was reported as a post-chill antimicrobial treatment				
86% report taking birds off line for reprocessing				

[a] Additives reported were citric acid, chlorine and sodium acid sulfate (SAS), the known pH levels ranged from 4 to 7.6

[b] Additives reported were peracetic acid, chlorine and SAS, the average temperature of the chill water was 34.8°F

Table E.8: Results from Poultry Slaughter survey section by size category and case/control status.

	Very Small/ Small	statistic	Control / Case	statistic
Age of plant (years)	38 / 41	0.63	40 / 41	0.91
Age of most recent renovations of area (years)	8 / 8	0.91	8 / 7	0.66
Composition of floor				
Concrete	90% / 73%	0.19	78% / 92%	0.26
Tile	0% / 8%	0.19	4% / 8%	0.63
Brick	10% / 11%	0.91	13% / 0%	0.17
Coated/sealed	29% / 47%	0.16	39% / 46%	0.66
Other	10% / 0%	0.03	VS:6% / 25% No S	0.26
Composition of walls				
Concrete	19% / 16%	0.75	20% / 8%	0.32
Tile	5% / 11%	0.46	7% / 15%	0.32
Brick	5% / 3%	0.67	4% / 0%	0.45
Glazed block	5% / 13%	0.32	11% / 8%	0.74
Fiberglass tile/panel	86% / 55%	<0.01	VS: 88% / 75% S: 55% / 56%	0.52 0.98
Stainless Steel	10% / 34%	0.02	VS: 6% / 25% S: 34% / 33%	0.26 0.95
How often is processing				
Daily	62% / 84%		76% / 77%	
3 or more days/wk	19% / 5%	$\chi^2(3) =$	11% / 8%	$\chi^2(3) =$
1 or 2 days/wk	14% / 8%	4.13 Pr =	11% / 8%	1.11 Pr =
< than once/wk	5% / 3%	0.25	2% / 8%	0.77
Shifts of processing		$\chi^2(1) =$		$\chi^2(1) =$
1	95/ 82%	2.15	85% / 92%	0.49
2	5% / 18%	Pr = 0.14	15% / 8%	Pr = 0.48

Table E.9 Results for Processing survey section by size category and case/control status.

Table E.9 continued

	Very Small/ Small	statistic	Control / Case	statistic
Processing volume (pounds annually)				
Pork	70,080 / 3,717,546	0.44	3,035,109 / 187,769	0.60
Beef	317,771 / 10,600,000	0.05	VS: 323,012 / 295,500	0.91
			S: 7,832,814 / 19,300,000	0.29
Lamb/Mutton	31,000 / 117,100	0.58	110,749 / no cases	0.53
Chevon	38,143 / no S	0.19	17,800 / no case	0.59
Chicken	12,586 / 6,874,757	0.20	3,302,244 / 8,156,100	0.44
Turkey	95 / 234,286	0.40	181,818 / 16,833	0.62
Mixed species	3,333 / 306,944	0.41	24,711 / no case	0.57
Other[a]	41,548 / 780,583	0.43	587,189 / 212,500	0.74
Percent from own slaughter	78% / 86%	0.52	82% / 84%	0.84
Use frozen material	57% / 66%	0.52	63% / 62%	0.92
Not thawed	29% / 11%	$\chi^2(2) = 3.56$ Pr = 0.18	17% / 15%	$\chi^2(3) = 0.36$ Pr = 0.83
Thawed in air	38% / 40%		37% / 46%	
Thawed in water	33% / 50%		46% / 39%	
Rework produced	24% / 37%	0.31	39% / 8%	0.02
Dropped product:				
Discarded	48% / 58%	0.46	57% / 46%	0.52
Rinsed with water	81% / 55%	0.02	VS: 82% / 75%	0.75
			S: 57% / 44%	0.47
Rinsed with sanitizer	57% / 46%	0.07	11% / 23%	0.26
Trimmed	57% / 39%	0.20	43% / 54%	0.52

[a] Includes Bison, Deer, Ducks, Elk, Moose, and Veal calves

Table E.9 continued

Length of processing (hours)	7.9 / 9.4	0.06	9.2 / 7.5	0.07
Process more than one species per day	71% / 61%	0.41	72% / 38%	0.01
No order to processing	10% / 21%	0.32	20% / 8%	0.37
100% response that pork is processed after beef and/or lamb/mutton or goat				
Sanitation between species No Partial Full	 86% / 76% 14% / 18% 0% / 5%	$\chi^2(2) = 1.39$ Pr = 0.50	 76% / 92% 20% / 8% 4% / 0%	$\chi^2(2) = 1.74$ Pr = 0.42
Specific *Salmonella* interventions include cleaning and garment change				
Processing employees	6 / 54	<0.01	VS: 6 / 5	0.83
			S: 58 / 39	0.42
Processing employees HACCP trained	2 / 15	0.05	VS: 2 / 3	0.44
			S: 17 / 10	0.64
Proportion of processing employees HACCP trained	38% / 34%	0.65	36% / 35%	0.94
Average room temperature (°F)	49.7 / 42.3	<0.01	VS: 48.6 / 54.3	0.31
			S: 41.2 / 46.1	0.07
Daily fluctuation: 0°-5° 5° - 10° 10° - 15° 15°+	 29% / 82% 62% / 13% 5% / 3% 5% / 3%	$\chi^2(3) = 16.96$ Pr = <0.01	VS: 29% / 25% 59% / 75% 6% / 0% 6% / 0% S: 83% / 78% 14% / 11% 0% / 11% 3% / 0%	$\chi^2(3) = 0.63$ Pr = 0.89 $\chi^2(3) = 3.59$ Pr = 0.31

Table E.9 continued

	Very Small/ Small	statistic	Control / Case	statistic
Primary packaging				
Butcher paper	38% / 11%	<0.01	VS: 41% / 25%	0.25
Overwrap/Styrofoam	14% / 5%	0.24	S:18% / 0%	0.91
Vacuum bags	90% / 74%	0.06	9% / 8%	0.62
Poly bags in box	57% / 74%	0.09	78% / 85%	0.43
Other	19% / 16%	0.75	65% / 77%	0.51
			15% / 21%	
Packaged in a separate room	25% / 34%	0.48	29% / 38%	0.52
Retail sales	62% / 39%	0.05	VS: 59% / 75%	0.57
			S: 34% / 56%	0.27
Retail sales attached to processing area	54% / 60%	0.75	55% / 63%	0.73
Separate retail employees	46% / 40%	0.75	45% / 38%	0.73
Gloves are worn by employees	31% / 93%	<0.01	VS: 27% / 50%	0.56
			S: 88% / 100%	0.37
Glove use:		$\chi^2(2) = 15.69$ Pr < 0.01		
Some wear	19% / 26%		41% / 25%	$\chi^2(2) = 3.08$ Pr = 0.22
			12% / 50%	
All wear	38% / 71%		72% / 67%	$\chi^2(2) = 0.56$ Pr = 0.76
			24% / 33%	
Wear woven gloves	57% / 95%	<0.01	VS: 59% / 50%	0.43
			S: 93% / 100%	0.43
Launder after use	75% / 61%	$\chi^2(2) = 0.764$ Pr = 0.683	62% / 73%	$\chi^2(2) = 0.419$ Pr < 0.81
Discard after use	17% / 25%		24% / 18%	
Other	8% / 14%		14% / 9%	

Table E.9 continued

	Very Small/ Small	statistic	Control / Case	statistic
Tools for maintenance:				
Cleaned	48% / 63%	0.26	52% / 77%	0.06
Unknown	5% / 16%	$\chi^2(6)$ =	11% / 15%	$\chi^2(6)$ =
No chemicals	57% / 50%	3.55	59% / 31%	5.91
Hypochlorite	9% / 16%	Pr =	11% / 23%	Pr =
Hydroxides	14% / 8%	0.74	9% / 15%	0.43
Sulfonate	9% / 5%		2% / 0%	
Alcohol	0% / 2%		4% / 0%	
Other	5% / 2%		4% / 15%	
Sanitized	43% / 55%	0.37	43% / 77%	0.71
Unknown	5% / 8%	$\chi^2(3)$ =	9% / 0%	$\chi^2(3)$ =
No chemicals	62% / 59%	1.27	63% / 50%	2.98
Hypochlorite	19% / 11%	Pr =	11% / 25%	Pr =
Quat. Ammonia	14% / 22%	0.74	17% / 25%	0.39
Equipment after maintenance:				
Cleaned	100% / 97%	0.46	98% / 100%	0.60
Unknown	19% / 22%	$\chi^2(8)$ =	22% / 17%	$\chi^2(8)$ =
No chemicals	9% / 11%	10.32	11% / 8%	4.42
Hypochlorite	19% / 36%	Pr =	24% / 50%	Pr =
Ammonia	0% / 6%	2.43	4% / 0%	0.82
Hydroxides	14% / 14%		13% / 17%	
Sulfonates	5% / 3%		4% / 0%	
Acids	0% / 3		2% / 0%	
Alcohol	9% / 0%		4% / 0%	
Other	24% / 6%		13% /8%	
Sanitized	95% / 97%	0.67	96% / 100%	0.45
Unknown	19% / 16%	$\chi^2(7)$ =	17% / 17%	-
No chemicals	10% / 22%	10.36	15% / 25%	
Hypochlorite	43% / 19%	Pr =	28% / 25%	
Quat. Ammonia	14% / 32%	0.17	24% / 33%	$\chi^2(7)$ =
Hydroxides	0% / 5%		4% / 0%	2.72
Alcohol	5% / 0%		2% / 0%	Pr =
Acids	5% / 5%		7% / 0%	0.91
Other	5% / 0%		2% / 0%	

Table E.9 continued

	Very Small/ Small	statistic	Control / Case	statistic
Sanitation is outsourced	19% / 42%	0.04	VS: 24% / 0%	0.30
			S: 41% / 44%	0.88
Employees for sanitation	3 / 9	0.01	VS: 3 / 2	0.41
			S: 6 / 19	0.02
Temperature of 1st water rinse (°F)	148 / 146	0.84	146 / 151	0.72
Temperature of 2nd water rinse (°F)	122 / 115	0.77	111 / 144	0.25
Cleaning agents:				
Unknown	26% / 27%		28% / 22%	
No chemicals	0% / 4%		3% / 0%	
Hypochlorite	37% / 35%		33% / 44%	
Quat. Ammonia	0% / 8%	$\chi^2(8) = 6.18$ Pr = 0.63	6% / 0%	$\chi^2(8) = 6.15$ Pr = 0.63
Hydroxides	10% / 12%		11% / 11%	
Sulfonates	5% / 8%		8% / 0%	
Alcohol	5% / 0%		3% / 0%	
Acids	0% / 4%		0% / 11%	
Other	16% / 4%		8% / 11%	
Cleaning agent is applied:				
Brush or pad	53% / 23%	$\chi^2(3) = 5.14$ Pr = 0.16	31% / 56%	$\chi^2(3) = 2.32$ Pr = 0.51
Flood	0% / 8%		6% / 0%	
Foam	37% / 58%		53% / 33%	
Spray	11% / 12%		11% / 11%	
Cleaning agent is rotated:[b]	16% / 27%	0.37	25% / 11%	0.38
Never	84% / 73%		75% / 89%	
2x annually	5% / 0%		3% / 0%	
Quarterly	5% / 4%	$\chi^2(5) = 5.30$ Pr = 0.38	6% / 0%	$\chi^2(5) = 1.74$ Pr = 0.88
Monthly	0% / 4%		3% / 0%	
Weekly	0% / 15%		8% / 11%	
Daily	5% / 4%		6% / 0%	

[b] Alternative cleaning agents base reported are unknown, hypochlorite, and quaternary ammonia.

Table E.9 continued

	Very Small/ Small	statistic	Control / Case	statistic
Sanitizing agents:				
Unknown	11% / 19%		14% / 22%	
No chemicals	11% / 19%		17% / 11%	
Hypochlorite	47% / 19%	$\chi^2(7) = 8.84$ Pr = 0.26	31% / 33%	$\chi^2(7) = 1.92$ Pr = 0.96
Quat. Ammonia	16% / 35%		25% / 33%	
Hydroxides	0% / 4%		3% / 0%	
Alcohol	5% / 0%		3% / 0%	
Acids	8% / 4%		6% / 0%	
Other	5% / 0%		3% / 0%	
Sanitizing agent is applied:				
Flood	5% / 0%	$\chi^2(3) = 2.98$ Pr = 0.39	3% / 0%	$\chi^2(3) = 9.76$ Pr = 0.02
Foam	16% / 12%		6% / 44%	
Spray	79% / 81%		86% / 56%	
Sanitizing agent is rotated:[c]	26% / 35%	0.56	33% / 22%	0.53
Never	74% / 65%	$\chi^2(5) = 5.30$ Pr = 0.38	67% / 78%	$\chi^2(5) = 5.77$ Pr = 0.33
Quarterly	5% / 4%		6% / 0%	
Monthly	0% / 8%		6% / 0%	
Weekly	16% / 15%		17% / 11%	
Daily	5% / 4%		6% / 0%	

[c] Alternative sanitizing agents base reported are hypochlorite and quaternary ammonia

Table E.9 continued

	Very Small/ Small	statistic	Control / Case	statistic
Walls are cleaned:				
Never	5% / 4%		6% / 0%	
6 months	5% / 0%		3% / 0%	
Monthly	5% / 0%	$\chi^2(6) = 6.20$ Pr = 0.40	3% / 0%	$\chi^2(6) = 1.76$ Pr = 0.94
3x monthly	5% / 0%		3% / 0%	
Weekly	11% / 12%		11% / 11%	
2x weekly	5% / 0%		3% / 0%	
Daily	63% / 85%		72% / 89%	
Ceiling is cleaned:				
Never	16% / 12%		14% / 11%	
6 months	16% / 0%		6% / 11%	
4 months	5% / 0%	$\chi^2(7) = 9.96$ Pr = 0.19	3% / 0%	$\chi^2(7) = 1.70$ Pr = 0.98
Quarterly	0% / 8%		6% / 0%	
Monthly	21% / 12%		14% / 22%	
Weekly	21% / 42%		33% / 33%	
2x weekly	0% / 4%		3% / 0%	
Daily	21% / 23%		22% / 22%	
Floor Drains are cleaned:				
Never	5% / 4%		6% / 0%	
6 months	5% / 0%		3% / 0%	
Quarterly	0% / 4%	$\chi^2(6) = 5.15$ Pr = 0.53	3% / 0%	$\chi^2(6) = 2.81$ Pr = 0.83
Monthly	0% / 4%		3% / 0%	
Weekly	11% / 4%		8% / 0%	
2x weekly	5% / 0%		3% / 0%	
Daily	74% / 85%		75% / 100%	