

AN ANALYSIS OF VARIABLE COSTS IN SMALL GREAT PLAIN MEAT PROCESSORS  
WITH A FOCUS ON FOOD SAFETY COSTS

by

WILLIAM CALLIS

B.S., Colorado State University, 2012

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Economics  
College of Agriculture

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

2014

Approved by:

Major Professor  
Dr. Sean Fox

## **Abstract**

The United States has been inspecting commercial meat processing for over 100 years. Currently there is a push to increase the number of bacteria that meat processors are responsible to test for, which would lead to an increase in the costs of production. The goal of this thesis was to investigate antimicrobial practices used in small beef processing facilities across the Great Plains and the costs associated with those practices. A survey instrument was constructed and administered resulting in a total of 39 usable surveys for analysis. Preliminary analysis of the data was followed by an ordinary least squares regression to determine cost increasing or decreasing practices and attributes of the small processors. It was determined that on average small meat processors face a per ton variable cost of \$914.71 or \$0.46 per pound. Regression analysis indicated that plants can benefit from economies of scale. It was also determined there are no cost savings from being a state inspected as opposed to a federally inspected plant. Certain practices such as dry aging beef to increase quality and decrease bacterial load were found to increase the variable cost per pound. Microbial testing accounted for only 0.5% of the total variable cost of production.

# Table of Contents

List of Figures .....	v
List of Tables .....	vi
Acknowledgements.....	vii
Chapter 1 - Introduction.....	1
Sanitation Measures .....	3
Interventions .....	3
Hot and Warm Water Rinses .....	4
Organic Acids .....	5
Dry Aging .....	8
Carcass Irradiation .....	9
Testing Protocols and Procedures.....	10
Chapter 2 - Literature Review.....	13
Cost of HACCP Implementation .....	13
Consumer Willingness to Pay for Food Safety.....	16
Chapter 3 - Sample and Data Collection.....	19
Population surveyed.....	19
Kansas .....	20
Nebraska .....	21
Oklahoma.....	21
Survey instrument and delivery .....	21
Sample characteristics.....	23
Plant Cleaning and Sanitation.....	25
On Carcass Interventions .....	28
Pathogen Testing.....	30
Utility Costs .....	32
Chapter 4 - Results and Analysis .....	33
Regression Analysis.....	40
Chapter 5 - Summary and Conclusions .....	49

References.....	51
Appendix A - Survey Instrument.....	54
Appendix B - Intervention Information .....	58
Appendix C - List of Sanitation Chemicals .....	69

## List of Figures

Figure 4.1 .....	40
------------------	----

## List of Tables

Table 3.1 .....	24
Table 3.2 .....	25
Table 3.3 .....	26
Table 3.4 .....	27
Table 3.5 .....	30
Table 3.6 .....	31
Table 3.7 .....	32
Table 4.1 .....	33
Table 4.2 .....	44

## **Acknowledgements**

I would like to take this time to say acknowledge the USDA and Kansas State University for providing the funding for this project and my masters study. I would also like to acknowledge and thank Dr. Sean Fox for keeping me on schedule and ensuring that I remained on track throughout this research. Also, I would like to thank him for help with editing and formatting the entirety of this thesis. I would like to thank Drs. Tonsor and Schroeder for offering advice and guidance throughout this project. I must also send out my sincerest thanks to all my friends and family who have supported me through all of my academic career and helped me to become the successful person I am today.

## Chapter 1 - Introduction

In 1905 Upton Sinclair published his groundbreaking novel, *The Jungle*, and the world of food safety changed forever. In response to his graphic descriptions of conditions in Chicago meat packing plants Congress passed the Meat Inspection Act of 1906. In 1967, the Wholesome Meat Act allowed for State Meat Inspection for intrastate commerce as long as the standards were equal to those of federal regulations. Most recently in 1997, Congress passed the Hazard Analysis and Critical Control Point (HACCP) Final rule. The HACCP Final Rule was formed in response to several *E. Coli* O157 H7 outbreaks, most notably an outbreak that involved the Jack in the Box fast food restaurant chain that resulted in the deaths of four children. Since the HACCP final rule was implemented meat processing plants have been required to create and implement HACCP plans which require a certain set of practices including, sanitation protocols and process verification in the form of testing for bacterial populations. This thesis has two main goals with regards to better understanding the costs associated with the current food safety regulations.

- 1) Through a survey determine the variable costs of small meat processors in the mid-west, with special emphasis on food safety practices and the costs associated with these practices
- 2) Determine cost increasing or decreasing practices and attributes of the plants

HACCP was regarded as a major shift in meat inspection practices. Whereas previously meat inspection had relied almost entirely on visual inspection of carcasses, HACCP relies on system wide evaluation involving multiple steps for bacterial control along with testing for efficacy (FAO, 2001). In a HACCP plan, meat processing plants must determine the points



along the system where contamination is most likely to occur. They must then implement one or more Critical Control Points (CCP) which will lead to a sufficient reduction in bacterial load to render the meat product wholesome. Verification is required periodically to ensure that the practices implemented at the CCP are effective in reducing bacteria to an acceptable level. Each plant's individual HACCP plan is overviewed by either the U.S. Department of Agriculture (USDA) Food Safety and Inspection Service (FSIS) or the appropriate state inspection service. All HACCP plans must be periodically reviewed to ensure they are appropriate for the plant and its operations. Additionally, federal or state inspectors are on site in plants to ensure that practices are being followed as well as to take samples for testing.

CCPs can take many different forms. In a meat processing facility often times a cooking process can be used as a CCP in order to kill bacteria. However, in slaughter and fabrication facilities this is not an option. Many plants subscribe to a "Multiple Hurdle" approach, establishing several CCPs in order to kill as many bacteria as possible. But, due to the need to test and verify CCPs, many plants attempt to have as few CCPs as possible.

Good Manufacturing Practices (GMPs) are a set of guidelines and regulations set forth for the manufacturing of food and cosmetic products. They were established in 1969 by the FDA in order to assist producers in conforming to the Food, Drug, and Cosmetic Act (Keener, 07). The full GMP regulations are available in the Code of Federal Regulations (CFR) Title 21 Part 110. The FDA has regulatory authority over all food products except for meat, poultry, and eggs. GMPs require that all facilities and equipment must be cleaned and sanitized periodically among other regulations. In order to properly follow the GMPs set forth by FDA producers must establish a written set of SSOPs (9CFR416). All facilities must have a written set of SSOPs as well a log that is updated as to when the SSOPs are performed. Both the written

SSOPs and the log must be provided for state or federal inspectors upon request. SSOPs have two categories beneath them, operational and pre-operational procedures. By having a strict set of SSOPs producers are able to limit environmental contamination and therefore lower the number of CCPs which must be implemented in a given facility.

### **Sanitation Measures**

All equipment must be cleaned and sanitized periodically according to a pre written and approved system of directions listed in the SSOPs. Slaughter facilities generally have to clean and sanitize on a daily basis. Most small to medium sized facilities take care of this process with in house employees. The larger, higher capacity plants often hire a third party cleaning and sanitation company to come in and clean and sanitize the facility on a nightly basis. Prior to beginning production the following day, all equipment and machinery must be inspected for cleanliness and temperature readings must be taken in different areas to ensure that the temperature is below a certain level in order to inhibit microbial growth. Generally, cleaning and sanitation includes scrubbing surfaces with either soap or water or a commercial de-greaser product followed by a hot water rinse. Finally, all food contact surfaces must be sanitized. This is usually done using either a chlorine bleach solution or quaternary ammonia compound at concentration levels acceptable for food contact.

### **Interventions**

A number of anti-microbial interventions are approved for on carcass use including, hot and warm water sprays, organic acid rinses, and dry aging. Anti-microbial interventions are needed because carcasses become contaminated at some point between stunning of an animal and chilling. Prior to de-hiding the meat is in a sterile environment. In the process of removing the hide, viscera, and blood from the carcass, fecal contamination is reasonably likely to occur.

For this reason, in beef slaughter plants, interventions must be applied prior to fabrication of the carcasses.

### ***Hot and Warm Water Rinses***

The two most common and least controversial anti-microbial interventions are hot ( $>71^{\circ}$  C) and warm water rinses ( $>32^{\circ}$  C and  $<71^{\circ}$  C). These two interventions can be applied in a number of ways. In small to medium sized plants it is most common for hot or warm water to be applied by either a hose and nozzle sprayer or a hot water pressure washer (Buege and Ingram, 2003). Depending on water temperature and pressure the amount of time that the intervention must be applied varies. One problem with warm water, high pressure systems is that spray can sometimes end up on surrounding surfaces and the temperature of the water is not high enough to kill bacteria on contact. In larger plants spray cabinets are often used to rinse carcasses on a constantly moving chain, which allows for efficient and uniform treatment per carcass. The cabinets are custom built for the facility and vary in length depending on how many animals are being processed per hour (chain speed). The faster the chain the speed, the longer the cabinet must be in order to get the proper exposure time. Spray cabinets are impractical for plants slaughtering less than 250 head per day because of the high cost of installation and maintenance. At the right time and temperature water can be just as effective as other interventions (Algino 2007). Bosivelak showed that hot water when applied in a commercial carcass wash was able to reduce the *E. Coli* load by a significantly more than a lactic acid spray. See Appendix A for a summary of other articles on the efficacy of hot and warm water interventions.

## *Organic Acids*

The second most common on carcass intervention in the United States is the use of organic acid rinses. There are multiple chemical compounds used under the label organic acids. Lactic acid, citric acid, acetic acid, and peracetic or peroxyacetic acid are the most common. Organic acids are often used in a multiple hurdle system with a hot or warm water spray. Organic acid rinses are applied in a cool water ( $\approx 50^{\circ}\text{C}$ ) solution as at high temperatures the acid will boil off before the water and effective microbial reduction will not be achieved. Unlike hot and warm water washes organic acids can be affected by incoming water pH. If the incoming water is very basic the organic acids will not be effective and this requires monitoring of incoming water pH.

A major drawback to the use of organic acid rinses is that they are not approved in many markets including the European Union (EU) and Japan. Although the European Food Safety Authority has recommended approving the use of Lactic acid, the EU still has not approved lactic acid for use or import (EFSA Journal, 2011). Another drawback to using organic acid rinses is that over time they will lead to more wear and tear on equipment and floors (Gill, 1998). They can also cause skin irritation for workers. This is a particular problem in smaller plants because they often apply lactic acid using a hand sprayer whereas large plants are able to use spray cabinets which limit employee exposure to the chemicals.

Lactic acid is currently the most commonly applied organic acid rinse (Beuge and Ingram, 2003). It can be applied at levels below 4% concentration. However, it is not effective as an antimicrobial at levels below 2% and therefore most applications occur between 2% and 4%. Lactic acid works by lowering the pH on the surface of the carcass to a point which pathogenic bacteria can no longer survive. Lactic acid is used in all sizes of beef plants from small locker plants that process less than one head per day to plants that process hundreds of

head per hour. Often times chemical companies will supply proprietary blends of organic acids and lactic acid is often used in conjunction with citric acid in these blends. Lactic acid is preferred by many plants because of the organic acids, it is the most gentle on equipment and skin. It also has one of the less offensive odors of the organic acids.

Lactic acid has been found to be effective as an intervention on beef sides, trim, and sub-primals. It has also been found effective on post chilled beef sides. King et al, Dorsa et al, and Hardin et al, all found that between 2% and 4% lactic acid sprays on pre chilled beef carcass sides had a significant reduction in *E. Coli* O157 H7. It has also been found effective on trim and beef sub-primals. (Gill et al, 2004, Castillo et al, 2001).

Peracetic or Peroxyacetic acid is another common organic acid used in the beef industry, although in other sectors it is the most commonly used organic acid. Peracetic acid is very popular in the medical field as it has a faster disinfecting time than chlorine. It is also popular in the bottled beverage industry where it is used to create aseptic packaging. Legally it can be applied to food surfaces at levels lower than 200 parts per million (ppm) (21CFR173.370). It can be applied to non-food surfaces at much higher concentrations. Peracetic acid is a combination of acetic acid (vinegar) and hydrogen peroxide. Peracetic is valued because it is an environmentally friendly chemical, which quickly breaks down into carbon, oxygen and hydrogen molecules. It is also the least expensive of all of the organic acids (Birko Corp, 2013).

Although it is popular in other industries, in the beef industry peracetic acid has not been proven to be an effective intervention. At the approved usage levels and even up to levels three times the regulated limit, peracetic acid has not been found to be an effective antimicrobial when sprayed directly onto a carcass (King et al, 2005). Ellerbracth et al, Gill et al, and Ransom et al, all found less than significant reductions in overall bacterial load.

Additionally, it is highly irritating to human skin, eyes, mucous membranes, and respiratory tract (New Jersey Department of Health, 2004). It is currently listed on the EPA's Extremely Hazardous Substance list (40CFR355.50). Peracetic acid becomes extremely dangerous when heated to high temps such as in a fire as it emits carbon monoxide and carbon dioxide, which can lead to asphyxiation and death. There is also an acrid smoke released which can lead to permanent damage to the respiratory tract. One final negative associated with the product is that it must be stored at refrigerated temperatures as opposed to other chemicals which can be stored at room temperature.

An alternative to peracetic acid is acetic acid. Acetic acid is the active component in vinegar. Because it can be purchased at a local store, acetic acid is a popular chemical amongst small beef processing plants because of ease of procurement. Acetic acid is allowed to be applied at concentrations below 5%. As an added benefit, acetic acid does not need to be kept at refrigerated temperatures and unlike peracetic acid is not considered a hazardous material. However, studies have shown that acetic acid is no more effective at killing bacteria than any other intervention (Algino et al, 2007). Also it has been shown that although it reduces the aerobic plate count at the same level as other interventions, it reduces *E. Coli* O157 H7 loads proportionally less (Anderson et al, 1989).

Citric acid is the fourth organic acid commonly used in beef processing plants. It is as effective an antimicrobial as lactic acid and, when used in conjunction with lactic acid, has been found to have greater antimicrobial effectiveness than when the two are used independently. Citric acid currently has no limitations on concentration other than those set in the GMPs (21CFR184.103). Laury et al. has shown that both citric and lactic based antimicrobial solutions

when applied via spray cabinet have a significant reduction in both aerobic plate count and *E. Coli* O157 H7.

### ***Dry Aging***

A commonly used intervention in small meat plants is the process of dry aging. Dry aging is the practice of hanging a beef side, primal, or sub-primal at refrigerated temperatures for extended periods of time, anywhere between 6 and 28 days. Traditionally this has been done to increase tenderness and flavor of the beef through enzymatic break down of proteins, but has been approved as an acceptable antimicrobial intervention for a HACCP plan (Buege and Ingram, 2003). Currently the FSIS recognizes dry aging as a critical control point if the beef is aged a minimum of six days at temperatures below 5° C and above -2° C with a humidity level below 90%. The sides of beef must also have enough space so no two sides are touching (Algino, Ingham, and Zhu, 2007). Dry aging works as an antimicrobial in two ways. Initially low temperatures force bacteria to exert more energy and in turn consume more food. On top of this, as the beef sits in the cooler the surface of the meat dries out to a point that the bacteria can no longer survive. Proper spacing must be ensured, because if two or more carcasses are touching, the surface can retain moisture and a proper microbial reduction will not be achieved.

One drawback to dry aging as an intervention are that it requires enough cooler space to store one week's worth of beef before the specific level of microbial reduction has occurred. The other drawback is that the dried surface of the meat must be trimmed off before sale which leads to a large amount of product loss in a small margin industry. Water weight is also lost in the cooler leading to lighter sale weights. Small meat plants have embraced this method of intervention because dry aging is still a common business practice. Larger plants generally do

not use dry aging because they have limited cooler space and need to move large volumes of beef to remain profitable.

### ***Carcass Irradiation***

Irradiation is another form of antimicrobial intervention that has been approved for use on red meat by the USDA. However, this process is only approved for use on individual red meat cuts and ground beef. There are several reasons irradiation has not been approved for full carcass application. First, the USDA says there is not clear whether the non-uniform surface of a full carcass would allow equal penetration of radiation for a fully effective treatment. This could also lead to the issue of certain areas receiving greater than the maximum allowable dosage (USDA FSIS, 2011). Second, the American Meat Institute petitioned to get it approved as a “processing aid” which would require the carcasses to be labeled as irradiated but would not require individual cuts of meat or ground beef originating from that carcass to be labeled as irradiated. The USDA denied petition on the grounds that further processors would not be informed if they had received irradiated cuts or sub-primals and subsequent irradiation could exceed maximum allowable doses (USDA FSIS, 2011).

Unlike other interventions any product that has received radiation treatment of any sort must be labeled by law. Irradiated products will have a green radura (see appendix) symbol with the words “Treated with Radiation” or “Treated by Irradiation” on them. Irradiation has been shown to eliminate 99.9% of all bacteria on food products. The major downfalls of irradiation technology are cost and consumer preference. Currently it is estimated that E-beam radiation would cost between \$0.10 and \$0.20 per pound. Also although it has been proven safe and consumers have indicated a desire for irradiated foods many producers don’t believe that it would command the premium needed in order to make the technology practical (University of



Minnesota, 2012). Currently irradiation is not utilized in any commercial beef facilities in the United States. The primary use of this technology has been in the spice industry where it has been adopted by nearly all spice processors. However, foods that use irradiated foods as an ingredient are not required to label the entire food as irradiated as long as the entire product was not irradiated. Restaurants are also not required to label foods as irradiated (21CFR179.26)

### **Testing Protocols and Procedures**

In order to comply with HACCP regulations, each individual plant must verify the different processes they use to limit microbial contamination of finished product. To achieve proper verification plants must take samples of product and test them for microbial loads (CFR 9 304). Tests are often performed for generic *E. Coli* which are non-pathogenic *E. Coli* strains but are indicators of fecal contamination on a product. Tests are also conducted for specific *E. Coli* strains. Currently plants must only test for *E. Coli* O157 H7 and generic *E. Coli* if they are a slaughter and fresh meat processing facility (USDA FSIS, 1997). If they also prepare ready to eat products they are required to test for *Listeria Monocytogenes*. The state and federal inspectors also will pull samples from products and run independent tests to see if contaminants are present. As of June 2012 the FSIS requires that tests must also be performed for six additional *E. Coli* strains that produced shiga toxin. They are *E. Coli* O145, O111, O103, O26, O121, and O45. Collectively these serotypes of *E. Coli* are known as shiga toxin producing *E. Coli* strains (STECs). Shiga toxin is known to lead to two serious and sometimes fatal diseases Hemolytic Uremic Syndrome and Hemorrhagic Colitis.

The FSIS requires that small processors (see list of small processor qualifications in appendix) must test once a week for generic *E. Coli*, for thirteen weeks beginning on June 1<sup>st</sup> of every year. The sampling is done using a sponging method where a sponge is wiped on three

different points on the chilled post intervention carcass and submitted for testing. The plant must sample the primary species they slaughter, be it beef, bison, pork, or poultry. The process begins on June 1<sup>st</sup> and continues throughout the summer because *E. Coli* has been shown to be more prevalent in the bovine gut during the hot summer months (Sofos et al. 1999). Plants must continue to submit samples until they have thirteen consecutive negative test results. Low capacity plants are then no longer required by the federal government to test carcasses for generic *E. Coli* again until the following year (USDA FSIS, 1997). However, the majority of small plants also produces ground beef products and therefore must test trim and fresh ground beef for *E. Coli* O157 H7. Plants producing less than 1,000 pounds of ground beef product per day must sample incoming trim and fresh ground beef once every three months for *E. Coli* O157 H7(USDA FSIS, 1997). All test results must be recorded and provided to the state or federal inspectors upon request.

Small plants will often perform further processing on meat products and sell ready to eat (RTE) products. These can take the form of dried sausages, hot dogs, snack sticks, and beef jerky. Because *Listeria Monocytogenes* has been identified as a risk that is reasonably likely to occur in ready to eat products, plants that sell ready to eat products must test food contact surfaces monthly to verify that sanitation processes are effectively eliminating *Listeria* from the environment. *Listeria Monocytogenes* is a bacterium that thrives at refrigerated temperatures and if it causes an infection has the highest fatality rate of food borne pathogens. It is especially dangerous for pregnant women as the disease Lysteriosis often results in late term abortions.

Large plants often follow much more comprehensive testing programs than small plants. These plants will often perform thousands of tests a month in order to verify that the interventions in place are being effective. Tests are done on chilled post intervention carcasses,

on trim after additional interventions have been applied, and on fresh ground beef. Tests are also done at different times to determine the log reduction in bacteria that is being achieved through the interventions being applied. Beyond the testing practices required set by the FSIS, large plants typically have an extensive Quality Assurance program which involves testing to ensure that processes are functioning correctly (Conover, 2013). Large plants primarily focus on producing fresh boxed beef and ship trim off site for further processing. They must test this trim for *E. Coli* O157 H7 but often do not grind the beef themselves. They also do not run cooked or RTE production lines so they are not legally required to test for *Listeria Monocytogenes*.

## Chapter 2 - Literature Review

### Cost of HACCP Implementation

Costs associated with pathogen control in beef processing plants have been investigated in a number of studies that focused on the cost of complying with the 1997 HACCP regulations. In one pre-implementation study, USDA FSIS estimated that the per pound cost of HACCP implementation would be \$0.0024 per pound (USDA, 2006). Crutchfield *et al.* 1997 authored an Economic Research Service (ERS) report which estimated the cost of the new HACCP regulation at \$0.0062 per pound at very small beef slaughter plants, \$0.0002 per pound for small beef slaughter plants, and \$0.00006 per pound for large beef slaughter plants. Thus, based on Crutchfield *et al.*, per pound costs at very small plants were estimated to be 100 times greater than those facing large plants.

Antle (2000) estimated HACCP implementation costs using data from the Census of Manufacturers to create a cost function which included loss of production. This method found that for a base of 50% safe product, a 20% reduction in contamination would cost small plants an additional \$0.165 per pound and large plants an additional \$0.170 per pound. With a base safety of 70%, a 20% reduction in contamination would cost \$0.055 per pound for small plants and \$0.057 per pound for large plants. Finally, with a base safety of 90%, a 20% reduction in microbial contamination would cost \$0.018 per pound for a small plant and \$0.019 for a large plant. These estimated costs are much higher than the estimates from USDA. Antle's work accounts for loss of productivity in the costs associated with HACCP, whereas USDA assumed that the new regulations would have a zero impact on productivity.

Boland *et al.* (2001) surveyed meat slaughter and processing plants in North Dakota, South Dakota, Nebraska, Kansas Missouri, and Oklahoma to ascertain the cost of HACCP

implementation. Fifty plants were asked to participate in the survey which was administered through on-site visits or over the phone. Phone and face to face interviews were preferred over written surveys in order to be able to clarify question intent if there were any problems. The survey contained 47 questions and completion took on average 2.5 hours. Data was gathered from 18 different plants. Total costs associated with HACCP ranged from \$5,700 to \$218,974 with a median cost of \$53,394. Total implementation costs per pound were estimated to be \$0.009 per pound of product. This is roughly four times more than the FSIS estimates (\$0.009/lb. vs. \$0.0024/lb.), and eighteen times larger than the Crutchfield *et al.* estimate (\$0.009/lb. vs. \$0.0005/lb.). Similar to those studies, Boland *et al.* do not account for productivity losses and the resulting estimates are lower than those from Antle's study.

Ollinger, Moore, and Chandran (2004) performed a national survey of meat and poultry slaughter and processing plants. Working with the USDA Economic Research Service, a survey was mailed to 1,725 meat or poultry slaughter or processing facilities, to which 996 facilities responded. Surveys were sent by 2-day priority mail and included a \$5 incentive in addition to letters from five different industry groups as well as the USDA encouraging participation in the survey. The sample included 108 beef slaughter facilities and 185 beef and swine slaughter facilities of which 55 beef and 121 beef and swine facilities responded. The study found that small cattle slaughter facilities faced increased variable costs of \$0.036 per pound and fixed costs of \$0.039 per pound. Large cattle slaughter facilities had an increased variable cost of \$0.020 per pound and an increased fixed cost of \$0.025 per pound. These results are much higher than the initial USDA estimates, but are not outside of the range of estimates from Antle.

The authors also created a food safety technology index for five categories: equipment, testing, de-hiding, sanitation, and operations. The index is monotonic - thus, plants with more

intensive cleaning programs or more pieces of technology receive higher index scores – and it allows for comparison across plants. The indexes were constructed by giving the most stringent answer to a question a value of 1 and the least stringent a value of 0. All possible answers in between were given decimal values. For questions regarding ownership of a certain piece of equipment the possible values were 1 and 0. After all the scores for each question were totaled per plant, the score was divided by the number of questions in that respective category resulting in an index score between 0 and 1. Therefore plants with a score closer to 1 had a stronger food safety technology system in the given category. Generally speaking, plants in the upper quintile of production received higher scores on the food safety technology index than plants in the lowest quintile with a nearly linear relationship for the other quintiles in between.

Ward (1984) reported on a survey of Oklahoma's meat processing industry. The survey was mailed to 225 processors with 60 usable surveys completed for a response rate of 24%. One quarter of respondents stated that they planned on downsizing or closing their business. Even though the survey was conducted long before HACCP rules were introduced, respondents listed difficulties complying with government regulations as their seventh most concerning issue. Problems with state and federal inspection were ranked lower at fifteenth. The highest ranked concerns were: labor; energy, water, and sewage; insurance; and repairs and maintenance. Most respondents indicated they priced their meat in order to cover costs with a small margin. Two thirds of respondents reported that they charged between \$0.15 and \$0.26 per pound for processing of meat. On average, prices for cattle processing were higher than prices for pork processing. At the time, it was also indicated that the highest cost of doing business was labor. Finally, only 50% of processors calculated costs on a per pound basis for meat processed.

According to Ward, this indicated a need for more accurate and detailed cost accounting and analysis.

### **Consumer Willingness to Pay for Food Safety**

There has been conflicting research on consumers' willingness to pay for additional food safety. Theory would suggest that there should be a premium applied to food with higher food safety levels, but others argue that many consumers would not be willing to pay a premium for safe food and would actually only purchase certain products at a discount if they had been treated with certain processes.

Shin *et al.*, 1992 was the first attempt at valuing consumer willingness to pay for an increase in food safety using an experimental auction. In a 20 round Vickery auction, participants were asked to bid on both a standard food item which had a typical probability of being contaminated with either *Salmonella* or *Trichinella spiralis*, and a carefully screened item that was indicated to have a 1 in 100 million chance of being infected. Prior to the first round, all participants were given \$15 and told that only one bidding round would be binding. The first 10 rounds consisted of "naïve" bids, i.e., subjects were asked to bid based on their current knowledge of the probability of being infected as well as their current perceptions of the severity of symptoms. Rounds 10-20 were "informed bids" before which the participants were informed as to the actual risk of contracting trichinosis and salmonellosis. After the experiment was completed the participants had to eat the sandwich which they had won in the selected round or not receive compensation. The first round of bidding indicated a WTP of \$0.61 to avoid *Salmonella* and \$0.48 to avoid *Trichinella spiralis*. The average willingness to pay under naïve information was \$0.44 to avoid *Salmonella* and \$0.69 to avoid *Trichinella spiralis*. After

receiving the information about risk average bids increased to \$0.55 to avoid *Salmonella* and \$0.81 to avoid *Trichinella spiralis*.

Hayes *et al.*, 1995 expanded on Shin *et al.*'s work by introducing more pathogens into a similar Vickery second price auction as well as adjusting the information given to the participants during the informed round. The pathogens included in this experiment were *Campylobacter*, *Salmonella*, *Staphylococcus aureus*, *Trichinella spiralis*, and *Clostridium perfringens*. Prior to bidding the participants were asked what they believed the risk associated with each pathogen was. They then went through ten rounds of "naïve" bidding. After the tenth round each participant was given information on one type of bacteria, including both the actual risk of infection and the symptoms. For the participants given information on *Salmonella* the probability of infection was varied in order to see if participants would vary bidding levels based upon higher or lower levels of risk. The informed bidding price averages ranged between \$0.42 and \$0.86 per meal to achieve a higher level of safety. It was also found that, in general, the participants were originally underestimating the initial risk associated with the given pathogens. Marginal willingness to pay was found to decrease as risk increased in the *Salmonella* treatments. Also, it appeared that subjects used an individual bacterium as a surrogate for overall food safety.

Rozan *et al.* (2003) looked at consumer willingness-to-pay (WTP) for new information about food safety. In an experimental setting, 120 French adults were asked to bid on bread, apples, and potatoes in either a second price auction or a Becker-deGroot-Marschak procedure. They were initially asked to bid on the products with no additional information. In a following round they were informed of others bids and allowed to adjust accordingly. After five rounds they were offered one product that was certified as being within legal limits for heavy metal



concentration and another product that was not certified. The prices bid for the new certified product were not statistically different from the initial prices bid for the non-certified products. However, after being offered a certified product many participants either abstained from bidding on the non-certified product or offered a lower bid.

Haninger and Hammitt (2011) used a stated preference survey to investigate WTP to reduce foodborne illness. They were investigating whether WTP increased with a corresponding increase in potential quality of life gains. Data from a survey of 2,858 individuals found that the relationship between WTP and an increase in quality of life expectancy was not linear. Respondents were willing to pay a premium to avoid a mild level of illness, but were not willing to pay double the initial amount to avoid an illness regarded as twice as severe. The authors noted that previous research had shown a non-linear willingness to pay with respect to length-of-illness, but a possible increasing willingness to pay with respect to severity. However, their results indicated decreasing willingness to pay associated with both length and severity of illness. Currently, government agencies investigating new regulations must supply both a benefit cost analysis and a cost effectiveness analysis. A benefit cost analysis simply subtracts total cost from total benefits, whereas cost effectiveness divides cost by units of effectiveness. When it comes to health policy cost effectiveness analysis assumes a constant linear relationship between willingness to pay and quality adjusted life years. Because of this assumption, there is currently no deviation between the two cost frameworks, however if the assumption were loosened it would lead to possibly conflicting results between benefit cost analysis and cost effectiveness analysis. At this point, it would be unclear as to which result was more accurate and therefore make instituting regulations even more complex.

## **Chapter 3 - Sample and Data Collection**

### **Population surveyed**

Plants in Kansas, Nebraska, and Oklahoma were surveyed and asked about their scale of operations, food safety practices, and costs associated with these practices. Nebraska and Kansas along with Texas are the top three states in terms of total beef production accounting for approximately 31% of the total beef slaughter capacity of the United States (USDA NASS, 2013).

Beef plants in the U.S. are classified into three categories: federally inspected, state inspected, and custom exempt. Large federally inspected facilities will have several federal inspectors on site during all working hours. Medium sized federally inspected plants will have a single inspector on site during working hours, and small federally inspected plants will have an inspector on site during all slaughtering activities. The inspector will visit daily, but may visit two or three plants in a day. Under federal inspection, some plants are classified as Talmadge Aiken (T/A) plants. T/A facilities are staffed by state employees but are still under FSIS jurisdiction which allows them to engage in interstate commerce, be listed on the federal register, and have an FSIS establishment number.

The operation of a state inspection service is optional for the states. Currently 27 states are operating state meat inspection services (NASDA, 2013). State inspection services must have standards at least equal to the federal inspection standards. State inspected facilities are not legally allowed to sell or ship products across state lines for retail sale. All plants under state inspection will have an inspector on site during slaughter activities. Most plants will have an inspector on site every day, although not always for the entire day. Typically, one inspector will serve several plants in an area. Some meat plants are classified as slaughter inspected with a

retail exemption. These plants will only have an inspector on site for slaughter. They are allowed to sell retail product but only if total retail sales fall below \$69,600 and are less than 25% of total plant sales. These plants can legally sell to end consumers and to food service outlets, but cannot sell product that will be resold by other entities such as grocery stores. Plants with more than \$69,600 retail sales or with retail comprising more than 25% of total sales must go under full inspection (CFR 9, 303.1).

Plants classified under the custom exempt title are inspected annually by the state or federal meat inspection service to ensure cleanliness and sanitation. They are not required to do many things that inspected plants must do, such as process verification. Custom exempt plants only sell a butchering service, and all meat is returned to the original owner of the animal. All products that leave a custom exempt plant must be marked “Custom. Not for Sale.” (CFR 9, 303.1).

### ***Kansas***

In 2012, Kansas ranked third in total head of beef processed at 6,227,300 head of cattle over 500 pounds (USDA NASS, 2013). Kansas is home to multiple large scale beef processing facilities which can process upwards of 1,000,000 head a year. It is currently home to 26 federally inspected (FI) slaughter facilities and 27 FI processing facilities (USDA FSIS, 2013). The Kansas Meat and Poultry Inspection act was passed in 1969 and sets out the guidelines for a meat and poultry inspection service in the state of Kansas. Kansas has 40 state inspected (SI) slaughter and processing facilities and 13 SI processing only facilities. It also is home to 26 custom exempt meat processing facilities (Kansas Department of Agriculture, 2013). Kansas has no T/A plants.

### ***Nebraska***

In 2012 Nebraska was the nation's leader in beef processing with 6,731,800 cattle over 500 pounds (USDA NASS, 2013). Nebraska, like Kansas, is also home to several large scale beef processing facilities. In January 2013, the Nebraska state legislature passed a bill paving the way for a state inspection service but at the time of writing, a state inspection service has not been introduced. Therefore all plants in Nebraska are either federally inspected or custom exempt. Nebraska is currently home to 33 FI slaughter facilities and 52 FI processing facilities (USDA FSIS, 2013).

### ***Oklahoma***

In 2012, Oklahoma, which does not have any major processing facilities, slaughtered 24,100 head of cattle over 500 pounds (USDA NASS, 2013). Oklahoma has five FI slaughter facilities and 33 FI processing facilities. It is also home to three T/A slaughter facilities and 15 T/A processing only facilities (USDA FSIS, 2013). Oklahoma operates a state inspection program servicing 20 SI slaughter and processing facilities and 10 SI processing only plants. It also has 48 custom exempt slaughter or processing facilities (Oklahoma Department of Agriculture Food and Forestry, 2013).

## **Survey instrument and delivery**

An initial draft of the survey instrument was developed based on the objectives of the study and following a review of the literature on plant sanitation practices and anti-microbial interventions. Prior to mailing the survey, a series of interviews were conducted using the draft instrument at eight small to medium sized meat plants. These interviews allowed for a better

understanding of the sanitation and anti-microbial interventions used in small and medium sized plants, and resulted in some adjustments in the survey instrument.

A copy of the final survey instrument and cover letter are contained in the appendix. The instrument begins with questions about the plant, including number of head of different species processed in 2012, number of full-time and part-time employees, type of food safety training used, and inspection status. The following section asked about the plant's daily sanitation procedures and the monthly or annual cost of any chemicals used for sanitation. Section three asked about on-carcass interventions used in the plant, and the monthly expenditure on antimicrobial chemicals. The next set of questions asked about frequency and cost of testing for *E. coli* and *Listeria*, and the final questions asked about the monthly costs of utilities.

Following the in-plant interviews, 103 surveys were sent by standard mail to beef slaughter and processing plants in Kansas, Nebraska and Oklahoma. On a state by state basis 54 surveys were sent to plants in Kansas, 25 to Oklahoma, and 24 to Nebraska. Two days after the surveys were mailed, all plants were called in order to inform them that they would be receiving the survey and requesting that they participate.

Twenty surveys were returned within the first two weeks after mailing. After the initial two week period, phone calls were made to all plants that had not yet responded, and an additional eighteen surveys were re-mailed to plants which either had not received the initial mailing due to an incorrectly listed address or had lost or discarded the initial survey. Following the re-mailing and the second round of phone calls, thirteen more surveys were returned. A third round of phone calls was made four weeks after the initial mailing. No additional surveys were sent out, and no additional surveys were received.

A total of 33 surveys were completed from the initial mailing of 103, giving a response rate of 32%. Combined with information gathered from six of the eight on-site interviews, the survey generated a total of 39 usable responses. Two interviews were excluded from the analysis as the plants did not fit the profile of the sample – one was the Kansas State University meat lab, and the other was a larger plant which did not provide complete data. Twenty-three responses were obtained from the 57 state inspected facilities that were surveyed, a response rate of 40.3%. Only ten of 48 federally inspected facilities responded for a response rate of 20.8%. The majority of returned surveys came from the state of Kansas where we had 18 responses, for a response rate of 34.6%. Oklahoma returned 8 surveys for a response rate of 30.7%, and Nebraska had the lowest rate of return at 30.4%. With the interviews which include three federally and 3 state inspected plants the total number of responses sums to 39.

### **Sample characteristics**

Descriptive characteristics for our sample are summarized in Table 1.1. On average the 39 plants in our sample killed 576.2 head of cattle per year with a range from 120 head up to 1,300 head. All plants indicated they processed pigs with a sample mean being 480 head per year, and a range from 10 up to 2,600. Twenty-six plants processed deer carcasses with an average of 302 head per facility, and a range from 27 to 700 among plants that did process deer. Seventeen plants killed sheep and goats with an average of 44 per year. The top three plants in this category accounted for 55.3% of the sheep and goats slaughtered by plants in this sample. Seven plants processed buffalo and 16 plants processed elk. Only one plant indicated that they processed any poultry.

**Table 3.1**

Number of head processed in 2012. (N=39 plants)

	# responding	Mean	Olympic Average	Minimum	Maximum
Cattle	39	576	569	120	1,300
Pigs	39	480	436	10	2600
Deer	26	302	297	27	700
Elk	16	13	10	2	67
Sheep and Goats	17	44	38	8	169
Buffalo	7	29	15	1	124

Twenty-five of the 39 respondents indicated that they have either a federal or state inspector on site every day of operation, with the remaining plants indicating a range from one to four days per week. Thirty-six plants responded to a question that asked about the number of hours per day the inspector was on-site, with a mean response of 5 hours per visit, and a range from 1 to 8 hours. Ten of the 39 plants responded that they have an inspector on site for the entirety of production every day. Thirty-five plants responded that they perform custom slaughter services. The average price per pound for beef processing was \$0.57 with a range from \$0.40 up to \$0.75. The average price for processing pork was \$0.58 with a range from \$0.20 up to \$0.85

Thirty-seven plants answered how many days a week they slaughter cattle, with the average being 1.9 and a range from 1 to 5 days a week. All plants surveyed indicated they work one shift per day. The average number of full time employees was 7.48, with a range from 1 to 38, and a median of 6. Thirty-one plants have part time employees with the mean number being

2.4. All but one plant use on the job training for employee training in food safety, twelve also use an employee handbook, four use an instructional video, and three plants use an outside contractor.

**Table 3.2**

Plant Inspection Status (N=39 plants)

	# responding	Mean	Olympic Average	Minimum	Maximum
Days Inspector is Present	39	4.02	4.02	1	6
Number of Hours Inspector is on Site	36	5.02	5.02	1	8
Days Cattle are Slaughtered	37	1.9	1.9	1	5
Number of Full Time Employees	39	7.5	6.83	1	38
Number of Part Time Employees	31	1.97	1.86	1	8

### **Plant Cleaning and Sanitation**

In section two of the survey, plants were asked which cleaning/sanitizing processes they used. A list of six different process was provided that included: a) warm (>90F) water, b) hot (>160F) water, c) soap and water, d) commercial de-greaser, e) chlorine bleach, and f) quaternary ammonia. Respondents were asked to indicate all processes they regularly used, and space was provided to write in any other techniques they used which were not listed. All plants used a combination of at least two of the above techniques with the most frequently used being chlorine bleach (by 33 plants) and soap and water (by 32 plants). All plants used either warm (N=27) or hot (N=27) water with 15 plants indicating they used both warm and hot water in



sanitation. Twenty four plants used a commercial de-greaser, and 17 used a quaternary ammonia compound. No plant indicated they used another sanitation practice that was not listed as an alternative in the question.

**Table 3.3**

Plant Sanitation Practices

	Warm Water	Hot Water	Soap and Water	Degreaser	Bleach	Quaternary Ammonia
# Responding	27	27	32	24	33	17

The next questions asked about water temperature and pressure used for cleaning.

Thirty-one plants responded to the question about water temperature indicating an average of 145 degrees F and a range from 90 to 190. Among plants reporting use of warm water, the average temperature reported was 141F with a range from 90F to 180F. Among plants reporting use of hot water, the average temperature reported was 155F with a range from 95F to 190F. For the 15 plants reporting use of both warm and hot water the reported temperatures reported (by 13 of the 15 plants) ranged from 100F up to 180F, with 8 being at or above 160F. For subsequent analysis, where plants will be designated as using either warm or hot water but not both, plants reporting 160F or above will be designated as using hot water sanitation, while those reporting a water temperature below 160 or not reporting will be designated as using warm water sanitation.

Fourteen plants responded to the question about water pressure, reporting a mean of 225 pounds per square inch and a range from 30 psi to 1300 psi. Two of the fourteen plants reported using high water pressure levels at 1200 and 1300 psi, with the next highest reported level being 125. Both plants using high pressure also indicated they used hot water with reported

temperatures of 180F and 190F. Excluding the two high pressure data points, the average for the remaining 12 is 54 psi.

Respondents were then asked to indicate the brand name of any sanitation chemicals used. That question was answered by 31 plants and resulted in a list of 29 different brand name chemicals. This list can be viewed in the appendix.

**Table 3.4**

Cleaning and Sanitation Practices (N=39 plants)

	# responding	Mean	Olympic Average	Minimum	Maximum
Days Inspector is Present	39	4.02	4.02	1	6
Number of Hours Inspector is on Site	36	5.02	5.02	1	8
Days Cattle are Slaughtered	37	1.9	1.9	1	5
Number of Full Time Employees	39	7.5	6.83	1	38
Number of Part Time Employees	31	1.97	1.86	1	8

Two questions then elicited information about the costs associated with daily cleaning and sanitation. One asked about the cost of sanitation chemicals and the respondent was asked to provide either a monthly or an annual cost. They were then asked to report the number of labor hours used per day for sanitation. Eighteen plants provided a response for the monthly cost of sanitation chemicals, reporting an average cost of \$93/month with a range from \$10/month up to \$284.50/month. Interestingly, the plants at both the upper and lower end of that range reported using the same combination of sanitation techniques – i.e., warm water in combination with soap, commercial de-greaser, and chlorine bleach. An additional seventeen plants reported an

annual cost for their sanitation chemicals, with an average of \$1,889/year ranging from \$127.60 up to \$7,000. Converting those numbers to a monthly basis gives an average of \$157/month and a range from \$11 up to \$583. The plant reporting the highest annual cost was one that reported using all of the listed sanitation options – i.e., both warm and hot water, in addition to soap, de-greaser, bleach and quaternary ammonia – and was also one of the larger plants in the sample slaughtering 1200 head of cattle. The plant reporting an annual cost of \$127.50 indicated they used hot water, soap and de-greaser, and slaughtered 634 head of cattle. The overall average monthly cost for chemicals (from 35 plants reporting on either a monthly or annual basis) was \$124 with a range from \$10 up to \$583. On average, plants reported taking 4.4 labor hours per day for sanitation, with a range from 1 to 20 hours, and a median of 3 hours.

### **On Carcass Interventions**

In the third section of the survey, respondents were asked about on-carcass antimicrobial interventions. A list of seven commonly-used interventions was provided and the respondent was asked to indicate all those used in the plant. The listed interventions were: a) warm (>90F) water spray, b) hot (>160F) water spray, c) organic acid, d) steam cabinet, e) hot water cabinet, f) carcass trimming, and e) dry aging. Space was provided to describe other interventions not included on the list. The most frequently reported intervention, by 32 of the 39 plants, was some type of organic acid. Plants indicating that they used an organic acid were further asked to indicate what type they used – acetic, citric, peracetic, or lactic. Lactic was the most commonly reported (by 20 plants), followed by acetic (8 plants), and citric (4 plants). No plant reported use of peracetic acid. Eleven of the 20 plants using lactic acid responded to a question asking about the monthly expenditure on antimicrobial chemicals. Those plants reported an average cost of lactic acid per month of \$24.41 with a range from \$5 to \$45. Only one of the plants using acetic

acid responded to the question on expenditure, reporting a monthly cost of \$10. All four plants using citric acid reported expenditure, with a mean of \$49.00 per month and a range from \$17 to \$102.

The second most commonly reported intervention was the use of carcass trimming by 31 of the 39 plants. This is not surprising as there is a zero tolerance policy for visible contaminants and trimming is the most effective, yet also most costly, way of removing visible contamination. The third most frequent on-carcass intervention was dry aging, used by 24 plants. In a follow up question plants were asked the number of days carcasses were dry aged. The minimum number of days was 6 and the maximum was 21, with a mean of 11.6 days. It is unclear whether minimum number of 6 was chosen because it is the minimum number of days needed for bacterial control or whether it is the threshold for noticeable quality improvement due to dry aging.

Twenty-two plants indicated that they used a warm water rinse as an anti-microbial intervention, while 13 reported use of a hot water rinse. Five plants reported using both a warm and a hot water rinse, and all 5 were among the 15 plants that indicated using both warm and hot water for sanitation. Among the 22 plants reporting use of warm water as an anti-microbial intervention, 19 also used an organic acid (5 acetic, 3 citric, 11 lactic), 20 used trimming, and 15 used dry-aging. Sixteen of the 22 reported water temperature, with an average of 129F and a range from 80F to 180F, while 7 reported water pressure with an average of 51.7 psi and a range from 35 to 90. Among the 13 plants reporting use of hot water as an anti-microbial intervention, 10 also used an organic acid (all of which were lactic acid), 12 used trimming, and 9 used dry-aging. Eleven of the 13 reported water temperature, with an average of 173F and a range from 160F to 190F, while 5 reported water pressure. Average reported pressure was 299 psi and

include one plant reporting 1200 psi, with the others ranging from 50 to 125psi. Four of the five plants that reported using both warm and hot water as an antimicrobial intervention also reported their water temperature, and all four reported a temperature at or above 160F. For subsequent analysis, those five plants will be considered as using a hot water intervention.

No plants in the sample indicated they used a steam cabinet or hot water cabinet, and none indicated they used a steam vacuum. These results were expected as larger plants are usually the ones who invest more heavily in labor saving, high fixed cost capital.

**Table 3.5**

On Carcass Sanitation Practices (N=39 plants)

	Organic Acid	Trimming	Dry Aging	Hot Water	Warm Water
# Responding	32	31	24	13	22

### Pathogen Testing

The fourth section of the survey asked plants about their pathogen testing regimen and costs associated with it. All but one respondent indicated they test for generic *E. coli*. That one plant indicated they were state inspected until summer 2013 when they became a solely custom plant and no longer had to test for pathogens. Thirty-three plants reported that they tested for generic *E. coli* 13 times annually as mandated by the FSIS protocol. The remaining 5 plants reported between 14 and 17 tests, except for one plant that reported testing weekly (i.e., 52 tests per year).

Thirty five plants responded that they test for *E. coli* O157 H7. The average number of tests annually is 6.97 with a range from 1 to 60. However, all but the one plant reporting 60 tests (the same plant testing weekly for generic *E.coli*) indicated a number at or below 10 per annum.

The average reported cost for an *E. coli* test (including shipping) was \$37.34 with a range from \$15.00 to \$73.00. The final question on pathogen testing dealt with testing for *Listeria monocytogenes*, indicating the plant produces ready to eat products. Nineteen plants responded they tested for *Listeria monocytogenes* with an average of 8.73 tests per year. The most common response was 12 tests annually indicating plants process RTE products all year round. On average a test for *Listeria monocytogenes* costs \$32.57 with a range from \$25 to \$42.

**Table 3.6**

Costs and Frequency of Pathogen Testing (N=39 plants)

	# responding	Mean	Olympic Average	Minimum	Maximum
Generic <i>E. coli</i> Testing Frequency	38	14.3	13.3	13	52
<i>E. coli</i> O157 H7 Testing Frequency	35	6.97	5.5	1	60
<i>E. coli</i> Testing Cost	38	37.33	36.96	15	73
<i>Listeria monocytogenes</i> Testing Frequency	19	4.4	4.2	0	16
<i>Listeria monocytogenes</i> Testing Cost	20	32.57	32.46	25	42

## Utility Costs

The final section of the survey asked plants about monthly utility costs. Thirty three plants provided a monthly cost for water, two plants only gave a combined utility cost and three indicated they have a well system. For those 33 respondents, the average monthly water bill was \$276.48 with a range from \$39 to \$1200. Monthly expenditure on gas was reported by 36 plants, indicating an average monthly cost of \$298.72 with a range from \$36 to \$900. All 39 respondents provided monthly expenditure on electricity with a mean of \$2,209.49 with a standard deviation of \$1,129.59.

**Table 3.7**

Utility Costs per Month (USD) (N=39 plants)

	# responding	Mean	Olympic Average	Minimum	Maximum
Electricity Costs	39	2209.48	2176.21	650	5000
Gas Costs	36	298.72	287.61	75	900
Water Costs	33	276.48	254.35	39	1200
Total Utility Costs	39	2719.18	2655.35	950	6850

## Chapter 4 - Results and Analysis

The analysis focuses on the variable costs incurred by various sized beef processing plants with a focus placed upon sanitation, anti-microbial interventions, and testing. Hereafter, we will refer to these costs in aggregate as variable costs of production. Survey responses were used to calculate cost for each plant in the sample as described in the following paragraphs and

Table 4.1

**Table 4.1**

Costs per Ton (USD) (N=39 plants)

	Mean	Olympic Average	Minimum	Maximum	Percent of Total
Total Variable Costs	914.71	875.63	213.84	3,061.49	100%
Processing Labor Costs	724.36	696.48	129.92	2,350.06	77%
Sanitation Labor Costs	52.18	51.03	0.23	146.87	6.2%
Electricity Costs	102.70	98.70	32.39	320.79	12.6%
Gas Costs	14.28	12.25	2.43	95.05	1.6%
Water Costs	14.75	11.05	1.62	142.57	1.6%
Sanitation Chemical Cost	5.63	5.35	0.42	19.8	0.7%
Carcass Chemicals Cost	1.07	1.01	0.34	2.77	0.1%
Testing Costs	4.39	3.49	0.83	40.82	0.5%

Sanitation costs included costs associated with labor and chemicals. Labor cost was estimated using the reported number of man hours used in daily sanitation multiplied by \$12.50,



the average wage in meat processing as reported by the Bureau of Labor Statistics. The sanitation labor cost per day was then multiplied by 250, the assumed number of days a plant would be in operation resulting in the total labor cost of sanitation per year. The cost of sanitation chemicals for each plant was reported in the survey on either a monthly or annual basis. The reported monthly costs were multiplied by twelve to provide an annual cost. The reported monthly cost for chemicals for anti-microbial carcass interventions was treated in similar fashion to provide an annual cost. Costs associated with testing was calculated using the survey reported cost per test multiplied by the number of tests conducted. To account for the cost of labor associated with testing, one half hours wage was added to the cost of every test conducted.

Another component of the variable costs of production was the costs of meat processing. This would be the hourly wages associated with the employees who kill, cut, and package the meat on a service basis. The processing labor was calculated by taking the number of full time employees multiplied by eight plus the number of part time employees multiplied by four. This value was then multiplied by the assumed wage of \$12.50 dollars and the assumed number of days of production 250. Finally, the cost of sanitation was subtracted to give a value for processing costs.

The final component used to calculate variable cost of production was the annualized cost of utilities - gas, water, and electricity. Although some of the cost of utilities can be attributed to non-HACCP uses such as lighting and the heating of offices, a major part of the cost of utilities is due to sanitation and temperature control. Most of the water used in a plant is used in cleaning and sanitizing carcasses and equipment. Gas is used to heat the water used for sanitation and carcass washing, and electricity is used to keep the plant and coolers within the plant at the

proper refrigerated or frozen temperature to inhibit microbial growth. This is especially true in plants using dry aging as a carcass intervention which must maintain proper temperatures in order to meet the standards laid out in their HACCP plans.

Adding all of the costs elements described above for sanitation, carcass intervention, testing, processing labor, and utilities generates a total variable cost of production for each plant. Total meat production was then calculated for each plant in order to estimate variable cost of production per ton of meat production. Meat production was estimated using reported numbers for the various species processed and assumptions about carcass weight. For cattle, it was assumed that the average live weight was 1250 pounds, which, using an assumed dressing percentage of 64% results in an 800 pound dressed carcass. For hogs, live weight was assumed to be 270 pounds and with a 74% dressing percentage resulting in a 200 pound dressed pork carcass. The average lamb carcass was assumed to be 80 pounds which would be the result of a 150 pound lamb dressing at 53%. An average bison weighs 1160 pounds and dresses at 57% resulting in a 650 pound dressed weight. The average dress weights for deer and elk vary more widely and have been assumed to be 140 and 330 pounds respectively. Chickens are assumed to have a 3.5 pound captured weight. Captured weight is the weight of a carcass after a chill bath due to water uptake. To create total pounds of production these weights were multiplied by the respective number of animals processed and then summed to give the total pounds of product produced annually. A final value for cost in dollars per short ton was considered more easily interpretable, so the total number of pounds was divided by 2000. Finally, the total variable cost in dollars was divided by the number of tons to provide a value in terms of dollars per ton (\$/T). Average meat production in the sample was 296 tons with a range from 68 tons up to 640 tons.

The estimated average variable cost was \$914 per ton with a range from \$213.83 per ton to \$3,061.48 per ton. The maximum is possibly an outlier as the next highest cost is \$2635.28 per ton. The Olympic average was \$875.63. Olympic averages exclude the maximum and minimum values when calculating the mean.

The initial analysis of the cost data evaluated individual factors in terms of their contribution to the total variable cost. Costs associated with microbial testing averaged \$4.40 per ton, with a range from \$0.83 up to \$40.82. This maximum is an extreme outlier as the next highest per ton cost of testing is \$6.96. The outlying high cost was associated with the smallest capacity plant in the sample which also tested the most frequently for generic *E. coli* (52 per year vs average of 14.3) and for *E-coli O157* (60 per year vs sample average of 7). On average, testing accounted for 0.5% of the estimated variable cost per ton of product. However, when comparing plants that prepare ready to eat products with plants that only prepare fresh products we see that plants who perform *Listeria* testing report testing costs to be 0.48% of food safety costs per ton whereas plants who do not report *Listeria* testing, saw testing costs come to 0.52% of food safety costs per ton. This is not the expected relationship, however it may be that because these plants must take more sanitation precautions, testing becomes a smaller percentage of the total cost of sanitation. However, the correlation between the testing percentage and the number of sanitation procedures is 0.01 indicating this may not be the case.

As stated previously, it is believed that plants using different types of interventions and sanitation practices will see different components account for different proportions of total food safety costs. For example plants that use dry aging as an intervention must have enough refrigerated capacity to store carcasses at the appropriate temperatures. The survey data indicated that the largest individual cost element of those we examined was for electricity with

an average cost of \$102/ton and a range from \$32/ton up to \$320/ton. On average, electricity accounted for 12.6% of the estimated variable cost per ton. Plants that used dry aging reported electricity as accounting for 13.13% of estimated variable costs while in plants that did not dry age electricity accounted for 11.9% of variable cost. This observation goes along with the hypothesis that plants that use dry aging would face electricity as a higher percentage of total variable costs.

Similarly, in plants that use hot water we should expect to gas account for a higher proportion of variable cost than in plants using warm or cold water. These same plants may see a lower proportion of costs from water, because use of hot water may lead to a decrease in the total number of gallons used. Plants reported that on average gas cost \$14.28 per ton with a range from \$2.43 up to \$95.05. Once again the high end of this range is an outlier with the next highest value being \$35.74 per ton. The Olympic average for this category is \$12.25 per ton.

On the survey plants were asked to report the water temperature ranges they used for two different practices - plant sanitation and on-carcass rinses. Many plants indicated they used both hot and warm water in sanitation and hot or warm water for an on-carcass wash. For plants reporting they used both ranges of rinses, they were designated as using a specific practice of either hot or warm water by using the reported temperatures. For example, if a plant reported they used both hot and warm water in sanitation and then reported the temperature was 140 degrees F, they were placed in the warm water category. Plants were classified into one of three categories: a) those using hot water for both sanitation and on-carcass intervention (*Hot-Hot*), b) those using hot water for one practice and warm for the other (*Hot-Warm*), and c) plants using warm water for both sanitation and on- carcass intervention (*Warm-Warm*). For plants using hot water in both practices, gas costs accounted for 1.73% of variable cost. Plants using a mixture of

temperatures, see gas cost as 1.12% of variable cost, while those using only warm water see gas accounting for 1.65% of their cost.

Water use in a plant can be attributed primarily to sanitation. Although some water use is associated with quality control, most practices that include quality preservation also have an antimicrobial effect, such as scalding of hog carcasses to loosen and remove hair from the skin in order to make it edible. On average plants reported a water cost for food safety of \$14.75 per ton with a range from \$1.62 per ton up to \$142.57 per ton. As with the other cost elements, this range has one major outlier with the next highest value being \$35.74 per ton. The outlier is created by the third smallest plant which also faces the largest monthly water bill. On average water accounts for 1.6% of variable costs. As discussed earlier plants that use hot water in both sanitation and on carcass rinses are expected to use less water than plants that use a warm water rinse exclusively or that use a mix of hot and warm water. On average plants that use only hot water see water accounting for 1.45% of costs, plants that use a mix of hot and warm water see water accounting for 1.75% of costs, and those using only warm water see water account for 1.61% of variable costs.

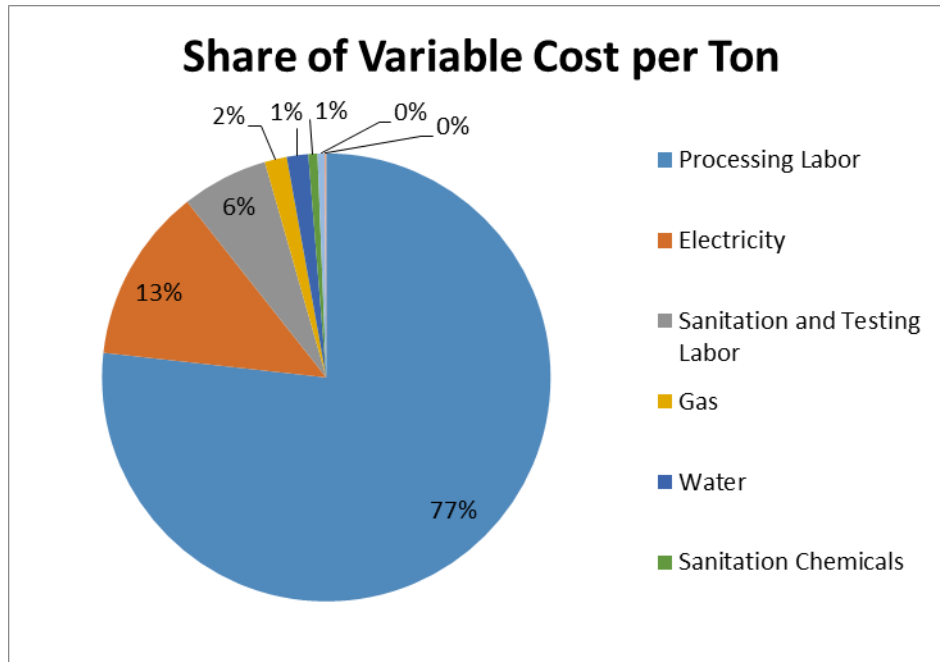
Labor is also a major cost faced by the plants. Labor costs were incorporated in two areas as discussed previously, daily sanitation and testing protocols, and processing labor. On average plants faced a sanitation and testing labor cost of \$52.19 per ton ranging from \$0.23 per ton up to \$146.87 per ton. The minimum on this range is an outlier as the next lowest labor cost per ton is \$10.73. The very low value is a result of the producer not reporting the number of hours used for daily cleaning, so this labor value only represents the cost of labor associated with testing. On average sanitation and testing labor accounted for 6.2% of the cost of food safety per ton. The high percentage of food safety costs accounted for by labor are to be expected in

small plants. This also helps to explain why large plants have invested in high capital cost systems (such as carcass washing cabinets, automated production lines, and steam vacuums) that reduce the total amount of labor needed to meet food safety standards.

Processing labor accounts for the largest percentage of variable cost for small beef meat processors. On average processing labor accounted for \$724.35 per ton with a range from \$129.92 up to \$2350.06 per ton. On average processing labor accounted for 77.1% of the variable cost for small meat processors. There were zero plants in the sample where processing labor accounted for less than 50% of the variable cost of production.

The remaining element of cost is that associated with chemicals – for either plant sanitation or on-carcass intervention. Plant sanitation chemicals accounted for an average of \$5.62 per ton with a range from \$0.42 up to \$19.80. On average sanitation chemicals account for 0.65% of variable cost per ton. On-carcass chemicals cost an average of \$1.07 per ton (0.13% of total cost) ranging from \$0.34 up to \$2.77. This range includes the 17 plants which reported a cost for on carcass chemicals which excludes the 15 plants that use organic acid but did not report a cost. Figure 4.1 illustrates the percentages of variable costs associated with the various elements.

Figure 4.1



### Regression Analysis

Ordinary least squares regression was used to explain the variation in variable cost per ton in the sample as a function of various plant characteristics. The dependent variable was the previously described variable cost per ton of product produced. The explanatory variables hypothesized to influence variable cost included plant capacity, whether the plant was state or federally inspected, whether the plant produced ready-to-eat products, and the sanitation practices used (organic acid, hot water, dry-aging, etc.). The estimated model is as follows:

#### Equation 4.1

$$\begin{aligned} \text{CostTon} = & \beta_0 + \beta_1 \text{Tons} + \beta_2 \text{Tons}^2 + \beta_3 \text{State} + \beta_4 \text{DryAging} + \\ & \beta_5 \text{OrganicCarcass} + \beta_6 \text{CountSan} + \beta_7 \text{HotHot} + \beta_8 \text{WarmHot} + \\ & \beta_9 \text{ListeriaTest} + e \end{aligned}$$

*Tons* is a measure of plant capacity measured as tons of finished product on an annual basis. Economies of scale, if present, would result in lower per ton variable costs in higher capacity plants. Some cost elements clearly can benefit from economies of scale. For example, testing requirements for *E.coli* require 13 weekly tests during the summer regardless of plant size and the associated cost per ton will therefore be lower for larger capacity plants. On the assumption that economies of scale are present the expected sign for this coefficient is negative. *Tons2* was included in the model to account for the fact that economies of scale will eventually be limited by fixed variables such as plant capacity and at some point the marginal savings for the next unit of production should go to zero. The expected sign of *Tons2* is positive.

The *State* variable is a dummy variable for inspection status that takes a value of 1 if the plant is under state inspection and 0 if it is under federal inspection. State inspection programs are required to have standards that are at least as strict as federal standards. If that is the case, we would expect a coefficient that is not significantly different from zero. However, it may be the case that some smaller plants choose to remain under state inspection because, for whatever reason, it enables them to operate with lower cost. If plants under state inspection actually have lower costs that should be reflected in a negative coefficient value in the estimated model.

The variable *OrganicCarcass* is a dummy variable indicating whether or not plants use an organic acid on-carcass rinse. The variable takes a value of 1 if the plant uses any type of organic acid, and a value of zero otherwise. The expected sign for this variable is indeterminate. Use of organic acid clearly adds an element of costs since the plants must purchase and pay for those chemicals. However, use of an organic acid rinse may allow for reduced water usage, or



reduced water temperatures and thus overall cost may be lower. Thus, the sign of the estimated coefficient may indicate whether there are cost advantages or disadvantages associated with organic acid rinses. Similarly, the variable *DryAging* is a dummy variable taking a value of one if the plants dry aged carcasses and zero otherwise. Use of dry-aging is assumed to lead to higher electric costs since plants using this intervention will need a larger amount of cooler space. On the other hand, use of dry-aging may lead to lower costs for water and gas.

The variable *CountSan* is a number ranging between 1 and 5 which represents the number of sanitation practices used daily. It is assumed that plants that use more practices in sanitation will use more resources such as: water, gas, chemicals, and labor. Because of this it is expected that the coefficient will be positive.

The variable *ListeriaTest* was included to identify plants that test for *Listeria monocytogenes* – i.e., those that produce products which are ready to eat. In addition to the added costs for testing, such plants must ensure there is no cross contamination of RTE product within the plant. It is expected that such plants will have higher overall costs for food safety and thus the expected coefficient sign is positive. As discussed previously plants were sorted into three groups according to the water temperatures used: hot for both sanitation and on-carcass intervention (Hot-Hot), a mixture of hot and warm (Hot-Warm), and warm only (Warm-Warm). The dummy variables *HotHot* and *HotWarm* identify plants in the first two categories, the estimated coefficients on which will measure cost differences between those plants and plants using only warm water. Other things equal, plants using hot water should have higher costs than those using only warm water leading to an expectation of a positive coefficient for both variables. However, as in the case of other interventions, use of higher water temperatures may allow for use of a lower volume of water or cost savings in other interventions. Again, the estimated

coefficients will indicate the presence of cost advantages/disadvantages for plants using either strategy. The value  $e$  is a random error term.

As discussed previously, plants were sorted into three groups according to the water temperatures used: hot for both sanitation and on-carcass intervention (Hot-Hot), a mixture of hot and warm (Hot-Warm), and warm only (Warm-Warm). The dummy variables *HotHot* and *HotWarm* identify plants in the first two categories, the estimated coefficients on which will measure cost differences between those plants and plants using only warm water. Other things equal, plants using hot water should have higher costs than those using only warm water leading to an expectation of a positive coefficient for both variables. However, as in the case of other interventions, use of higher water temperatures may allow for use of a lower volume of water or cost savings in other interventions. Again, the estimated coefficients will indicate the presence of cost advantages/disadvantages for plants using either strategy. The value  $e$  is a random error term.

**Table 4.2**

OLS Regression Results

Variable	Coefficient	t-Statistic	P-Value
Tons	-8.11	-3.04	0.005
Tons2	0.010	2.75	0.010
State	-274.02	-1.32	0.197
DryAging	363.75	1.74	0.092
OrganicCarcass	-111.6	-0.43	0.669
CountSan	4.11	0.04	0.967
HotHot	-523.06	-2.42	0.022
HotWarm	-273.76	-0.98	0.335
ListeriaTest	-285.76	-1.42	0.165

N=39

R<sup>2</sup>=0.4197Adj R<sup>2</sup>=0.2396

Table 4.2 presents the results of the OLS regression. As expected the coefficient associated with *Tons* is negative and significant, indicating that even within the relatively narrow range of capacities represented in our sample, meat processing facilities can benefit from economies of scale. Previous work has estimated that larger plants would face lower costs per pound than smaller plants. Crutchfield *et al.* estimated that very small plants would face costs per pound ten times larger than large plants. Ollinger, Moore, and Chandran found that smaller plants faced costs roughly 50% more per pound than large beef facilities. This is even more dramatic in this sample as the largest facility faces a variable cost of \$536.30/ton and the smallest faces a cost of \$2635.27. The quadratic term *Tons2* corresponds with theory and has a

positive and significant. Economies of scale seem to be maximized at 405.5 tons. Median plant size in our sample is 282.9 tons per annum, with a standard deviation of 150 tons. Eight plants exceed the estimated optimal level of production, however this survey did not account for square feet of capacity and therefore, it would be difficult to say these plants are operating beyond phase II of the production function. However, as 79% of the plants in the sample operate below the economically optimal level it would indicate that these plants could decrease the variable cost per ton by increasing production.

The estimated coefficient on *State* (indicating whether a plant is state inspected as opposed to federally inspected) is negative but statistically insignificant. This corresponds with the hypothesis that whether a plant is federally or state inspected should have no impact on cost per ton. This theory was based on the fact that states are required to have standards that are at least as stringent as the federal government. Therefore the only economic incentive for plants to choose between state and federal inspection is the decision to sell products across state lines or solely within the state.

The estimated coefficient on *DryAging* is positive, and, with a p-value of 0.092, significant at the 10% level. As earlier mentioned, the expected sign is indeterminate given the possibility that use of dry-aging can lead to cost savings in other areas, and thus a 2-tailed test of statistical significance is appropriate. The estimated coefficient indicates that plants using dry-aging face costs that are approximately \$364/ton higher than those that do not dry-age. It is possible that much of this cost can be captured back via a price premium as dry aged beef is often sold at a higher price compared to wet aged beef. Our estimated coefficient suggests that a 18c/lb price premium would be required to offset the cost associated with dry-aging in a representative plant in our sample. This would be a premium assigned to a custom cut fee per

pound. If the premium were to be applied to retail cuts it would have to be much higher as the only cuts that could recoup the cost would be high value middle meats such as the loin and rib. According to the National Cattleman's Beef Association the loin and rib combined average about 25% of the carcass weight (NCBA, 2013). If dry aging of a 750 pound carcass costs an estimated 136.5 more to process than a wet aged carcass, then the loin and rib would need a premium of \$0.73 per pound to offset the cost of dry aging.

The estimated coefficient on *OrganicCarcass* is positive but not statistically significant. This suggests that plants using organic acid washes do not see an increase in variable cost compared to those not using organic acids, suggesting that use of organic acid allows for costs savings in other areas such as water volume or temperature.

The number of sanitation procedures used by plants captured in the variable *CountSan* was also expected to increase variable cost. Plants that use a greater variety of sanitation practices will likely spend more time and more money on sanitation. The estimated coefficient is positive with a value of 4.11 and highly insignificant, indicating plants with more sanitation practices do not face any increased costs compared to plants with less practices. This could be explained by plants spending less on each sanitation practice when they use several as opposed to spending more per practice if they use less practices.

The two variables associated with water temperatures returned coefficients with negative signs. The coefficient for *HotHot* is -523.06 and is statistically significant with a 2-sided p-value of 0.022 while the coefficient for *HotWarm* is -273.76 but is statistically insignificant. Although one might expect plants using hot water to have higher costs due to more gas being used, it appears this is not the case. There are two possible explanations why plants using hot water would face lower costs than plants using only warm water. The first hypothesis is that plants that

use hot water rinses on carcasses and when cleaning would use less total water. By using less water plants are decreasing not only the water bill but, if the plant is on the city sewer system, they would see a lower bill for sewer as well. This hypothesis has support from the analysis above, which showed that plants using hot water in both practices saw the water and sewer bill account for a lower percentage of per ton costs. The other hypothesis is that plants that use only hot water are able to use less labor when cleaning and able to increase efficiency of a plant. Hot water may lower the total number of hours needed to clean on a daily basis. Furthermore, if hot water is used as an on-carcass intervention, the carcasses do not need to be rinsed for as long as they would if the plants were using warm water, which allows for reduced water and electric use.

Finally, the variable *ListeriaTest* returned a sign opposite to what was expected. It was expected that plants producing ready to eat products would face higher food safety costs per ton, yet the results returned a negative coefficient of -285.76. However, the estimated coefficient is not statistically significant with a p-value of 0.165 so it may be that plants that test for *Listeria* do not actually face a lower cost per ton.

When comparing the overall results of this survey to the literature, there are many interesting comparisons. To get a more accurate comparison, the cost of processing labor was removed so that the cost more accurately reflects costs associated with food safety practices. In order to compare average costs, the dollar per ton numbers were converted to a value of cents per pound, as this is the generally the format reported in previous work. With that conversion we find that plants in this survey faced a food safety cost of \$0.095 per pound with a range from \$0.030 up to \$0.35 per pound. This is much greater than the initial USDA estimates by Crutchfield *et al.* which estimated that very small plants would face an increased cost of \$0.0062 per pound and small plants would see an increase of \$0.002 per pound. Our estimates are within

the range reported by Antle (2000). Antle estimated that depending on the initial level of food safety small plants could face an increased cost of between \$0.018 per pound up to \$0.165 per pound. The report by Ollinger, Moore, and Chandran was most similar to this study in that it was a mailed survey which asked plants about the costs of HACCP. The major differences were that Ollinger *et al.* made the survey nationwide, but did not include state inspected plants in the sample. They broke food safety costs into variable and fixed costs and found that variable costs would increase \$0.036 per pound and fixed would increase by \$0.039 per pound. As this study has a combination of fixed and variable costs it would be more representative to compare the total cost which would be variable cost plus fixed cost, from Ollinger which is \$0.075 per pound. When comparing this to the results of this survey of \$0.095 we see that the results are fairly similar especially considering the nine year difference in results. When adjusted for inflation the cost calculates to \$0.0925 in 2013 dollars which is a very nearly identical result. This would seem to indicate that the USDA vastly under estimated the costs associated with HACCP when making the initial cost benefit analysis which is the argument that Antle was making in 2000. One of shortcoming of this analysis is that it does not account for the cost of HACCP plan development. Because it is unknown how much time small producers spend annually updating and revising their individual HACCP plans, this cost is almost assuredly lower than the actual cost faced by producers. Future research should be able to take into account the cost of HACCP plan creation and alteration.

## Chapter 5 - Summary and Conclusions

Food safety standards have been under constant review and revision for the last 105 years. Since 1997 plants have had to adhere to Hazard Analysis and Critical Control Points. With the rise of awareness associated with Non O157 STECS, the public and government officials are calling for more testing. Before testing is implemented it is imperative we understand the impact increased testing would have on small scale beef producers. A producer survey regarding costs of food safety practices was constructed and mailed to state and federally inspected small beef processors in Kansas, Nebraska, and Oklahoma.

Costs were compiled and it was found that the majority of variable costs for small producers were labor costs associated with meat processing, accounting for nearly 77% of the average producers cost per pound. The next largest cost was labor for sanitation and testing, accounting for 6.2% of the variable costs per pound. Thus, labor accounts for approximately 83.6% of the variable costs for small sized meat processors. Testing accounted for roughly 0.5% of the average producers cost per pound, indicating that the increased testing would increase cost but would not have a large impact on the operation. For comparison, if the average testing cost was increased tenfold to \$44/ton from \$4.40/ton, the average variable cost per ton would go from 914.7/ton up to \$954.20/ton, this would represent a total increase of cost of roughly 4.3% per pound

An ordinary least squares regression was constructed to determine which attributes are associated with low cost producers. As was expected plants benefited from economies of scale, by being able to decrease cost per pound by increasing the number of pounds processed. All else equal plants operating under state inspection had no significant difference in cost from plants under federal inspection. Plants that use dry aging face higher costs per pound than similar



plants that do not engage in dry aging. Counter to the expectations plant that use hot water for plant sanitation and as an on carcass intervention operate at a lower cost than plants that use warm water washes. The remaining variables were far from being significant but plants that use organic acid rinses and more sanitation practices may face higher costs per pound. Plants that produced ready to eat products or use a mix of hot and warm water may face lower costs per pound.

When compared to previous studies the survey results reinforce the argument that the USDA severely underestimated the cost per pound of HACCP in 1997. The survey results for average food safety cost per pound fit within the range presented by Antle in 2000, which took into account a loss in productivity associated with food safety standards which the initial estimates did not. Ollinger *et al.* conducted a similar larger scale survey but excluded state inspected plants. The results gathered from this project were similar to the results from Ollinger when time is taken into account. Overall, the results from this survey were consistent with the literature.

Although the results from this survey are consistent with the higher estimates of food safety cost per pound in Antle and Ollinger, they still do not outweigh the estimated benefits associated with food safety or the consumer's willingness to pay for food safety. All the associated literature for willingness to pay for food safety indicates consumers are willing to pay much more for food safety than the current cost of food safety.

## References

- Algino, R.J., Ingham, S.C., and Zhu, J. 2007. "Survey of Antimicrobial Effects of Beef Carcass Intervention Treatments in Very Small State-Inspected Slaughter Plants." *Journal of Food Safety* 72(5): 173-179.
- Anderson, M.E., Marshall, R.T. 1989. "Interaction of Concentration and temperature of acetic acid solution on reduction of various species of microorganisms on beef surfaces." *Journal of Food Protection* 52(5): 312-315.
- Antle, J.M.. 2000. "No Such Thing as a Free Safe Lunch: The Cost of Food Safety Regulation in the Meat Industry." *American Journal of Agricultural Economics* 82(2):310-322.
- Boland, M., Fox, J.A. 2012. "Food Irradiation and Public Health." University of Minnesota Food Policy Research Center, November.
- Boland, M., Hoffman, D.P., Fox, J.A. 2001. "Post Implementation Costs of HACCP and SSOP's in Great Plains Meat Plants." *Journal of Food Safety* 21(3): 195-204.
- Buege, D., Ingham, S., 2003. "Small Plant Intervention Treatments to Reduce Bacteria on Beef Carcasses at Slaughter." Department of Animal Science, University of Wisconsin-Madison, June.
- Birko Corp. 2013. *Beef Products: Cleaning, Sanitation and Intervention*.  
[www.birkocorp.com/beef/beefxide](http://www.birkocorp.com/beef/beefxide).
- Castillo, A., Lucia, L.M., Goodson, K.J., Savell, J.W., and Acuff, G.R. 1998. "Comparison of water wash, trimming, and combined hot water and lactic acid treatments for reducing bacteria of fecal origin on beef carcasses." *Journal of Food Protection*. 61:823-828.
- Conover, T. 2013. "The Way of All Flesh: Undercover in an Industrial Slaughterhouse." Harper's Magazine, May, pp. 31-40.
- Crutchfield, S.R., Buzby, J.C., Roberts, T., Ollinger, M. Lin, C.J., 1997. *Economic Assessment of Food Safety Regulations: The New Approach to Meat and Poultry Inspection*. Washington D.C.: U.S. Department of Agriculture: Economic Research Service.

- Dorsa, W.J., Cutter, C.N., Siragusa, G.R., Koohmaraie, M. 1996. "Microbial decontamination of beef and sheep carcasses by steam, hot water spray washes, and steam-vacuum sanitizer. *Journal of Food Protection* 59: 127-135.
- Engeljohn, D.L., 2011. *Response to Citizens Petition to Recognize the Use of E-Beam on Carcasses as a Processing Aid*. Washington D.C.: U.S. Department of Agriculture: FSIS, June.
- Gill, C.O. 1998. Microbiological contamination of meat during slaughter and butcher of cattle, sheep and pigs. In *The Microbiology of Meat and Poultry*, A. Davies and R Board, Eds. Blackie Academic and Professional, London.
- Hardin, M.D., Acuff, G.R., Lucia, L.M., Oman, J.S., Savell, J.W. 1995. "Comparison of methods for decontamination from beef carcass surfaces. *Journal of Food Protection*. 58:368-374. Kansas Department of Agriculture. 2013. *Inspected Slaughter and Processing Plants*. Records Center. Topeka, Kansas, March.
- Keener, K. 2007. "Safe food guidelines for small meat and poultry processors: SSOP and GMP Practices and Programs." Purdue University Extension (FS-21-W), September.
- King, D.A. , Lucia, L.M., Castillo, A., Acuff, G.R., Harris, K.B., Savell, J.W. 2005. "Evaluation of peroxyacetic acid as a post-chilling intervention for control of *Escherichia coli* O157:H7 and *Salmonella* Typhimurium on beef carcass surfaces." *Meat Science* 69(3):401-407.
- National Association of State Departments of Agriculture. "Interstate Meat Inspection." Food Regulations.
- National Cattlemen's Beef Association. 2013. "Beef Cuts: Primal and Subprimal Weights and Yields." Centennial, CO
- New Jersey Department of Health and Senior Services. 2004. *Hazardous Substance Fact Sheet: Peroxyacetic Acid*. Trenton, NJ.
- Official Journal of the European Union. 2013. *Concerning the use of lactic acid to reduce microbiological surface contamination on bovine carcasses*. Luxembourg, April.
- Oklahoma Department of Agriculture. 2012. *State Inspected Plants*. Oklahoma City, Oklahoma, May.
- Ollinger, M., Moore, D., Chandran, R., 2004. *Meat and Poultry Plants' Food Safety Investments: Survey Findings*. Washington D.C.: U.S. Department of Agriculture: Economic Research Service, May.

- Ransom, J.R., Belk, K.E., Stopforth, J.D., Sofos, J.N., Scanga, J.A., Smith, G.C. 2001. "Comparison of new intervention additives/chemicals with interventions presently in use for reducing incidence of *Escherichia coli* on beef cuts and trimmings." Submitted to National Cattlemen's Beef Association by Colorado State University.
- Rozan, A., Stenger, A., Willinger, M. 2004. "Willingness-to-pay for food safety: an experimental investigation of quality certification on bidding behavior." *European Review of Agricultural Economics* 31(4): 409-425.,
- Sofos, J.N., Belk, K.E., Smith, B.C., 1999. "Processes to Reduce contamination with pathogenic microorganisms in meat." Presented at 45<sup>th</sup> Intl. Congress of Meat Sci. and Tech., Yokohama, Japan, August 1-6.
- U.S. Department of Agriculture. 2013. *FSIS Meat, Poultry and Egg Product Inspection Directory Legend for Establishment Numbers and Directory Search Guidance*. Food Safety and Inspection Service. Washington, D.C.
- U.S. Department of Agriculture. 2013. *Red Meat, Slaughter, Commercial, Production by state*. Food Safety and Inspection Service. Washington D.C.
- U.S. Department of Agriculture. 1998. *SSOP's and Generic E. coli Testing*. Food Safety and Inspection Service, Washington D.C.
- United Nations, Food and Agriculture Organization. 1997. *Hazard Analysis and Critical Control Point (HACCP) System and Guidelines for its Application*. Rome.

## Appendix A - Survey Instrument

# Microbial Intervention Practices in Beef Slaughter Facilities

### **Introduction:**

A research team at Kansas State University is collecting information on beef slaughter facility processes and costs of operation. This information will help inform policymakers about the costs associated with anti-microbial interventions and testing. Any information provided by you will be treated as confidential. We estimate that completing this survey will take between fifteen and thirty minutes.

*Thank you for your help.*

## General Information

---

Establishment name: \_\_\_\_\_

Establishment number: \_\_\_\_\_

Your name and title: \_\_\_\_\_

## Plant Capacity

---

Approximate number of head processed in 2012:

Beef: \_\_\_\_\_

Pork: \_\_\_\_\_

Deer: \_\_\_\_\_

Elk: \_\_\_\_\_

Other (please give detail): \_\_\_\_\_

How many days per week do you typically slaughter cattle? \_\_\_\_\_ days/week

Number of 8-hr shifts per 24-hr period (circle one): 1    2    3

Number of full time employees: \_\_\_\_\_

Number of part time employees: \_\_\_\_\_

Employee food safety training (circle all that apply):

On the Job

Employee Handbook

Video Tape

Outside Contractor

Other: \_\_\_\_\_

How many days per week is a state or federal inspector on site? \_\_\_\_\_

Approximately how many hours per day is an inspector on site? \_\_\_\_\_

Does your plant do custom slaughter? (circle one)    Yes    No

If yes, what is the rate per pound for: beef processing? \_\_\_\_\_ pork processing? \_\_\_\_\_

## Daily Sanitation and Pre-Op

---

Circle all the processes/products you regularly use:

Warm (>90 F) Water

Hot (>160 F) Water

Soap and Water

Commercial De-Greaser

Chlorine Bleach

Quaternary Ammonia

Other (please describe): \_\_\_\_\_

Water temperature and pressure: \_\_\_\_\_

Sanitation chemical(s) brand name: \_\_\_\_\_

Cost of sanitation chemical(s): \$ \_\_\_\_\_/month OR \$ \_\_\_\_\_/year

Labor hours per day for sanitation: \_\_\_\_\_ hours/day

## On Carcass Interventions

---

Circle those used:

Warm (>90 F) water spray

Hot (>160 F) water spray

Organic acid

Steam cabinet

Hot-water cabinet

Carcass trimming

Days of dry aging (if used): \_\_\_\_\_ days

If you use an organic acid, please circle what type: Acetic      Citric      Peracetic      Lactic

Other intervention (please describe): \_\_\_\_\_

Water temperature and pressure: \_\_\_\_\_

Do you use steam vacuuming: Yes \_\_\_\_\_ No \_\_\_\_\_

If yes, at what point in the process? \_\_\_\_\_

If you use any antimicrobial chemicals, can you please list the names of the products (brand name or chemical) and the approximate expenditure on that product per month.

Product name:

Approximate cost per month

\$ \_\_\_\_\_/month

\$ \_\_\_\_\_/month

\$ \_\_\_\_\_/month

\$ \_\_\_\_\_/month

## Pathogen Testing

---

### *E. Coli*

Number of Generic E. Coli Tests per year:

Number of O157 H7 E. Coli Tests per year:

Cost per test including shipping: \$\_\_\_\_\_/test

What laboratory performs the tests: \_\_\_\_\_

### *Listeria Monocytogenes*

Number of Listeria tests per year: \$\_\_\_\_\_/test

Cost per test including shipping: \$\_\_\_\_\_/test

What laboratory performs the tests: \_\_\_\_\_

### *Utilities*

What is your plant's average monthly bill for ....

Electricity: \$\_\_\_\_\_/month

Gas: \$\_\_\_\_\_/month

Water and Sewer: \$\_\_\_\_\_/month



## **Appendix B - Intervention Information**

### **Lactic Acid**

Lactic acid was first discovered in a vat of curdled milk by Carl Wilhelm Scheele, a Swedish chemist, which led to the name lactic, or “milk” acid. Lactic acid is one of the most commonly used antimicrobial rinses used in the United States beef industry. Lactic acid is also often associated with the ensiling process, as lactic acid is produced by bacteria in the silage, which allows it to remain a viable feedstuff for extended periods of time. Organic acids are the most commonly used intervention in the United States beef industry with lactic acid being the most common. It appears that lactic acid is used primarily in the red meat packing industry. Although recently it has been incorporated into antibacterial hand soaps in favor of a chemical called Triclosan which has been associated with increased microbial resistance.

It is incorporated into a water spray at concentrations between 3% and 5% based upon the individual Hazard Analysis and Critical Control Points of the individual plants. The spray is usually applied around a temperature of 50 degrees C. (Belk, )Lactic acid can be used alone or with other antimicrobial sprays such as Citric acid. Most commonly organic acid sprays are used in combination with a warm (55 degrees C) or hot water (> 74 degrees C) rinse.

Lactic acid is used in every size beef processing facilities from small locker plants to large plants processing more than 1,000,000 head of cattle a year. For small plants that do not employ large carcass washing cabinets, the University of Wisconsin recommends that a lactic acid spray be applied from a distance of no more than twelve inches, with a gentle sweeping motion for no less than one minute per side of beef, allowing for five minutes after completion of the application for proper coverage. For several reasons lactic acid is preferred to other organic acids in these very small facilities where employees have more contact with the acid. Primarily, lactic acid is less caustic than acetic acid and causes less harm to floors and equipment. It is also more gentle on the skin if employees were to come in contact with it. The process of hand spraying a carcass clearly has a larger variable cost than using an automated cabinet due to the labor involved in spraying the carcass. However, cabinets simply present too high of a fixed cost for many small producers to purchase one.

Lactic acid works by lowering the pH on the surface of the carcass below a level that bacteria can live at. According to Laury, et al. 2009, lactic acid decreases the ionic concentration

within the bacterial cell membrane which leads to the accumulation of acid within the cell and eventually death of the bacteria. Studies been contradictory on whether or not lactic acid rinses in combination with hot water are more effective than a >74 degree C. water wash (Koochmaraie et al., 2005, Snijders et al., 1985). These combination washes have been shown to reduce the number of generic E. Coli by 1.5 log cycles (Huffman, 2002). Currently lactic acid is primarily used pre chilling of the carcasses as it has been demonstrated to be more effective at higher temperatures, however it has been shown that if the solution is warmed and sprayed on chilled carcasses it can still be effective (Castillo et al., 2001).

**Table B.1**

Author	Year	Pathogen	Product	Context	Result
Gill et al.	2004	E. coli 0157:H7	Beef trimmings	2% and 4% lactic acid applied to beef trimmings	Both showed reduction in E. coli but 4% was more effective
Castillo et al.	2001	E. coli 0157:H7 and S. Typhimurium	Beef sub primals	4% lactic was applied to sub primals	pathogens were reduced on both the sub primals and were lower in ground beef made from products
King et al.	2005	E. coli 0157:H7 and S. Typhimurium	Beef carcasses	2% lactic acid was applied	Showed a significant bacterial reduction
Dorsa et al.	1997	E. coli 0157:H7, Listeria innocua, and Clostridium sporogens	Beef carcasses	3% lactic sprayed on beef carcass	significant reductions after 21 days of observation
Hardin et al.	1995	E. coli 0157:H7 and S. Typhimurium	Beef carcasses	2% lactic acid, acetic acid, hot water, and trimming were used	Lactic acid was more effective than acetic acid, and more effective in conjunction with hot water wash

Lactic acid is sold by Birko at a price of \$1.456 per pound and is sold at a concentration level of 88%. According to Birko, the cost of operating a Chad carcass spray cabinet with an antibacterial rinse is \$0.60 per head at a chain speed of 125 head an hour. 3.515 gallons of water dilutes one pound of 88% Lactic acid to a 3% concentration. This leads a cost per gallon of \$0.414/gallon. A report from the USDA estimated that the cost per gallon of a 2% lactic acid spray was \$0.64/gallon. According to their calculations for procedures in a small plant, the per carcass cost was \$0.128/head.

There are two major drawbacks to using lactic acid as a food safety intervention. The primary one being cost, as lactic acid is among the more expensive organic acid rinses. The other reason is that currently, carcasses sprayed with lactic acid are banned from export to the European Union. However, in December 2012 the European Union Parliament failed to extend a ban on the use of lactic acid allowing to be approved for use. It is anticipated that the European Commission will approve the use of lactic acid in European meat plants in the coming months. This is a highly anticipated move by the American meat industry, as it will open the European market to more producers. The only downfall of this opening of regulation is it may drive the price of lactic acid even higher as demand increases.

### **Dry Aging Information**

Dry aging of beef is the process of hanging a side of beef, or sub-primal, at refrigerated temperatures for an extended period of time (from 4-35 days). This is in contrast with the process of wet aging which entails placing sub-primals in vacuum sealed bags for a similar period of time. The goal of aging beef in either method is to increase the tenderness of the product through enzymatic break down of proteins. There is no difference between tenderness benefits for the two aging methods. The primary reason major beef producers have switched to wet aging is the beef does not lose any moisture and they can sell more pounds with less trimming.

Currently dry aged beef is usually regarded as a high end product that fetches a major premium at formal dining establishments. Dry aging leads to a product that has a beefier, nuttier,

more buttery flavor than its wet aged counterparts. The vast majority of dry aged beef in the U.S. is sold at the foodservice level although some high end grocery stores, such as Whole Foods offer limited supply of dry aged beef. This was not always the case, prior to the 1970s all beef in the U.S. was dry aged for some period of time. It was the invention of the vacuum sealable bag that led to boxed beef and wet aging.

Small locker plants will still dry age the majority of their beef, simply because they do not have to keep up with the production schedules that major plants must keep up with. They carcasses are held on average between 7-10 days. Additional aging beyond this point is usually met with an additional charge by the locker plant.

The University of Wisconsin has released several departmental research reports along with one journal article documenting that dry aging for at least six days at a relative humidity less than 90% can serve as an antimicrobial intervention in a HACCP plan. The temperature in the cooler must also be below 41 degrees F for the entirety of the six day period. Dry aging is believed to act as an antimicrobial in two ways. The primary is that the surface of the carcass dries out essentially starving the bacteria, the other is that at low temperatures the bacteria must exert more energy to survive speeding this process. In practice most small plants dry age for more than six days and maintain a cooler temp between 32-40 degrees F as well as a cooler humidity between 75 and 80% which makes a dry aging a cheap and easy way to decrease bacterial loads and meet governmental regulations.

**Table B.2**

Author	Year	Pathogen	Product	Context	Result
Calicioglu, et. al.	1999	Generic E. Coli	Beef Carcass	Manure slurry inoculation with 1 and 7 day dry aging periods	1 day resulted in a 1.3 log reduction with 7 days resulting in a 2.1 log reduction in generic E. Coli
Calicioglu, et. al.	2002	Generic E. Coli	Beef Carcass	Testing dry aging in conjunction with multiple other interventions	Collected data at 1, 3, and 7 days of dry aging for all combinations of interventions with the 7 day period always resulting in a larger reduction of between 2.1 and 3.3 log
Inham and Buege	2003	Generic E. Coli and E. Coli O157 H7	Beef Carcass	Verifying dry aging as an effective intervention for E. Coli O157 H7	Collected data before and after 6 days of aging with reductions of generic E. Coli ranging from 1.3 to 3.3 log reductions. Reduction of O157 H7 ranging from 2.6 to 3.4 log.

## **Peracetic Acid**

Peracetic acid also known peroxyacetic acid was initially approved as an antimicrobial intervention in the 1950s for use in the fruit and vegetable industry to reduce bacterial spoilage and mold growth. In the 1980s it became a preferred sanitizer due to the short amount of time it takes peracetic acid to disinfect a surface. This process is so fast because peracetic acid is a very strong oxidant. In fact it has a higher oxidation potential than both chlorine and chlorine bleach which led to its adoption. Peracetic acid is formed from a chemical reaction between acetic acid, more commonly known as vinegar, and hydrogen peroxide. This leads peracetic acid to be relatively environmentally friendly. It can simply we washed down the drain, because when it breaks down it just become a mix of carbon, oxygen, and hydrogen molecules. Because it breaks down very easily, it has also been adopted in other major sectors of the food industry, as it is the primary chemical used to aseptically sanitize drink containers prior to filling. It is also used to sanitize water used in food making processes and for disinfecting water from cooling towers. Peracetic acid is also approved for sanitation of food contact surfaces and is often used when conducting clean in place practices of large equipment in food processing plants. It can also be used as a chemical peeler for fruits in the canning industry, for products such as pears, peaches, tomatoes.

One of the major downfalls of peracetic acid is that unless it is mixed with an anti-corrosive agent, it can lead to deterioration of machinery and is very damaging to concrete. Additionally, it is highly irritating to human skin, eyes, mucous membranes, and respiratory tract. It is currently listed on the EPA's Extremely Hazardous Substance list. Peracetic acid becomes extremely dangerous when heated to high temps such as in a fire as it emits carbon monoxide and di oxide, which can lead to asphyxiation and death. There is also an acrid smoke released which can lead to permanent damage of the respiratory tract. One final negative associated with

the product is that it must be stored at refrigerated temperatures as opposed to other chemicals which can be stored at room temperature.

In the meat industry peracetic acid is used in both the red meat and poultry industry although it is used more effectively in the poultry industry. Regulations dictate that concentrations of peracetic acid cannot exceed 220 PPM in the rinses. At these levels and even up to levels three times the regulated limit, peracetic acid has not been found to be an effective antimicrobial when sprayed directly onto a carcass. It was never found to be more effective than lactic acid, and more commonly had almost a negligible reduction in overall bacterial load.

**Table B.3**

Author	Year	Pathogen	Product	Context	Result
Ellebracth et al.	2005	E. coli 0157:H7 and Salmonella Typhimurium	Beef Trimmings	beef trimmings dipped in 200, 500, and 1000 PPM of peracetic acid	Less effective than lactic acid
King et al.	2005	E. coli 0157:H7 and Salmonella Typhimurium	Beef Sides	200 PPM peracetic acid applied to chilled carcasses	No statistically significant reductions
Gill et al.	2004	natural flora	Brisket from chilled beef carcasses	0.02% paracetic acid applied via spray	No statistically significant reductions
Ransom et al.	2003	E. coli 0157:H7	Beef fat and trimmings	spray of 0.02% peracetic acid on product	No more effective than cold water rinse

The major benefit to peracetic acid is the cost per head associated with the intervention. A USDA report comparing both lactic and peracetic acid when used in small plants found that a solution with 200 PPM of peracetic acid would cost \$0.0282 with the cost per head being \$0.00565. This is significantly lower than their estimated cost of \$0.128 per head when using lactic acid. Peracetic acid can be purchased from a wide range of companies due to its wide

spectrum of use. Birko provides a 15% peracetic acid solution for \$25.63/gal. The chemical is sold in liquid form with water and hydrogen peroxide as the other two portions of the solution. FMC corporation sells a product they call Blitz which is a peracetic acid product which 8.5 oz mixed with 50 gallons of water will achieve a 200 PPM solution.

### **Sprayer Information**

The spraying of a carcass to decrease microbial contamination occurs at every meat plant in the country no matter the size or capacity. However, the method of spraying and the chemicals applied to the carcasses can vary not only between companies but even between plants within a given company. A recent report by the USDA entitled *Slaughter and Processing Options and Issues for Locally Sourced Meat* classified plants as follows: small plants slaughter < 10,000 head a year, medium slaughter plants 10,000 < x < 1,000,000, and larger plants slaughter > 1,000,000 head a year. The majority of the small plants will spray carcasses by hand simply because they do not move the quantity of meat necessary to justify using a spray cabinet. There are also a large number of the medium sized plants which will also use the technique of hand spraying. However, the higher capacity plants will utilize spray wash cabinets in order to be able to move a high number of cattle through the plant in a given day.

The spray wash cabinets are primarily constructed by two companies, Chad and W. R. Cary Engineering Company. Chad was recently purchased by Birko Chemical Company so now the cabinet is supplied by the same company which supplies many of the chemicals for sanitation of the carcasses. Below are the costs associated with using a variety of the Chad System machines, this information was provided by the manufacturer:



**Table B.4**

<b>Description of Product</b>	<b>Equipment Cost</b>	<b>Installation Cost</b>	<b>Annual Maintenance Cost (4)</b>	<b>Operating Cost Per Head</b>
Hide-On Carcass Wash	\$275,000	\$140,000	\$25,000	0.4 (5)
"Convention" Preevisceration Carcass Wash and Antimicrobial Spray	\$180,000	\$90,000	\$20,000	0.6 (6)
Hot Water Preevisceration Carcass Wash (9)	\$215,000	\$130,000	\$25,000	0.25 (7)
Final Carcass Wash	\$120,000	\$50,000	\$20,000	\$0.45
Final Hot Wash Pasteurization System	\$210,000	\$125,000	\$30,000	0.35 (7)
Final Antimicrobial Spray	\$70,000	\$25,000	\$5,000	0.25 (6)

**NOTES**

1. Above information is for a 1,000 head per day operation; eg, 125 head per hour.
2. All dollars are US dollars.
3. All equipment has 20+ years of life with proper, regular maintenance.
4. Estimate based on Chad Equipment performing at least 2 service calls per year.
5. Antimicrobial solution is an inexpensive option; eg, sodium hydroxide.
6. Antimicrobial solution is lactic acid at approximately 4% concentration.
7. Estimate includes water, electrical and steam usage.
8. Cost of water was estimated at \$7 per 1,000 gallons for all operating cost estimates.
9. The Hot Water Preevisceration Carcass Wash is a replacement for the "conventional" system.

It generally does not include an antimicrobial spray.

The W. R. Cary Engineering Company also provides a variety of products for sanitizing carcasses in commercial meat packing plants. Unfortunately, they would not provide installation costs on the grounds that each system is custom built for the facility into which it is installed and therefore the cost will vary significantly between plants for installation. The following are specifications on the machines, water costs were estimated by myself based on the value associated with number (8) above of \$7.00 per 1000 gallons.

<b>Description of Equipment</b>	<b>Nozzle Pressure</b>	<b>Water Temperature</b>	<b>Water Cost/head</b>
Pre-Evisceration Carcass Wash (High Temp System)	35+- 2	>205	0.13
Pre-Evisceration Carcass Wash (Low Temp System)	40 - 85	85 +- 2	0.13
Head Wash	30+- 5	85 +- 2	0.13
Carcass Was	85	85 +- 2	0.13
Hot Water Pasteurization	25 +- 2	>205	0.13

1. All pressures are in PSI
2. All temperatures are in degrees Fahrenheit
3. All water costs are in dollars

Steam is also an important intervention used in the beef cattle industry, the process of steam vacuuming is used in the majority of beef plants to significantly decrease the amount of fecal material and E. coli transferred from the hide of the animal to the carcass. When the USDA instated a zero tolerance policy for fecal contamination of beef carcasses, large amount of money was lost due to trimming of regions with visible contamination. Steam vacuuming was then developed as a method used to remove the fecal contamination and sterilize the area. Today it is not only used for this purpose but, carcasses are often vacuumed around the patterns of incision

into the hide. This process is now used in nearly every beef plant in the United States.

Kentmaster produces the Vac-San system and specifications are forthcoming from them.

Steam is also used in steam pasteurization systems which use high temperature steam to pasteurize the exterior of carcasses as a final intervention step. This is a process employed by Cargill Meat Solutions. The cabinets used by Cargill are considered proprietary and therefore the cost and process associated with them was not available for analysis.

Low dose irradiation is another intervention which could be employed by the beef industry. It has been approved for use by the USDA and has proven to be extremely effective in reducing the bacterial loads in large lots of beef such as trim and non-intact muscle. Recent advances in radiation technology even allow for the application of the treatment to non-uniform surfaces such as whole sides of beef. However, currently there is not a single meat plant that utilizes low dose irradiation as a food safety intervention. It would be considered extremely cost effective as the marginal cost associated with using the machines would be much lower than those associated with purchasing chemicals. The primary industry utilizing irradiation as a sterilization practice is the spice industry.

## Appendix C - List of Sanitation Chemicals

**Table C.1**

Chemical Name	Number of Plants Responding With Use
Clorox	11
Dawn	5
SaniQuat by Birko	4
BiQuat	4
Spartan Sani 10	3
Peroxy Protein Clean by Spartan	3
Zep	3
Summit Pot and Pan	3
Neutra Sol	3
Generic Bleach	2
Betco Sanibet	1
Sysco Bleach	1
Sysco Liquid Dish Soap	1
Servco 57-Degreaser	1
Devour	1
Sani Clean	1
Bio Foam	1
Diverse	1
Berkel	1
Bunzel Smoke House Cleaner	1
WysiWash Sanitizer	1
Always Safe Bleach	1
Medtrel	1
Vanquish	1
Sani Sense	1

Chlora Foam	1
F-20 Sanitizer	1
Grease X	1
Q-42	1
White Vinegar	1