DEVELOPMENT OF A CARCASS SANITIZING SPRAY SYSTEM FOR SMALL AND VERY SMALL SLAUGHTERHOUSES

A Thesis

by

JOSE GABRIEL RODRIGUEZ

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2006

Major Subject: Food Science and Technology

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Approved by:

Chair of Committee,	Alejandro Castillo
Committee Members,	Gary R. Acuff
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ABSTRACT

Development of a Carcass Sanitizing Spray System for Small and Very Small Slaughterhouses. (December 2006)

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Chair of Advisory Committee: Dr. Alejandro Castillo

Small and very small slaughterhouses generally spray lactic acid for carcass decontamination utilizing a hand held sprayer. Even though this tool represents a very small investment, it may present important disadvantages such as uneven delivery of the spray over the carcass surface. If the decontamination treatment is not applied properly, the untreated areas of the carcass will still have high bacterial loads present and could be a source for recontamination of the areas that have been treated.

A sanitizer spraying system (sanitizing halo system) was designed and assembled. The sanitizing halo system was tested at the Rosenthal Meat Science and Technology Center, Texas A&M University. Thirteen carcasses were split in halves. Thirteen halves were sampled and used as control after knife trimming and water wash; then they were sprayed with 2% L-Lactic at 55°C with the sanitizing halo system. The other 13 halves were sprayed by the RMSTC employees utilizing a hand held sprayer. Counts of aerobic and mesophilic bacteria obtained from carcasses sprayed with the sanitizing halo system and the hand held sprayer were both significantly lower than the control counts. In addition, coliforms counts were below the detectable limit for the sanitizing halo system and the hand held sprayer.

After testing, the sanitizing halo system was installed at two small commercial slaughter plants processing beef and pork carcasses. At each slaughter plant, 24 carcass halves were treated with 2% L-Lactic at 55°C using the sanitizing halo system, and the other 24 halves were used as control. Mesophilic bacteria populations were reduced in beef and pork carcasses by 2.9 and 1.9 log cycles, respectively, after the lactic acid treatment. Also *E. coli* counts were significantly lower in the three regions sampled after application of the 2% L-Lactic acid with the sanitizing halo system.

From the data collected during this study, we recommend the sanitizing halo system as a tool to reduce the bacterial loads on the surface of beef and pork carcasses. The use of this system should help small and very small slaughterhouses to improve food safety performance while providing cost-efficiency, simplicity, and convenience.

DEDICATION

To my wife and my family, who are the reasons of my life.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr Alejandro Castillo, for his guidance and continuous support throughout my research. I would also like to thank my committee members, Drs. Gary R. Acuff, and Kerri B. Harris for their patience and advice leading to the successful completion of this research. I would also like to thank the members of the many laboratories and processing plants required to complete this work.

TABLE OF CONTENTS

Page

Page

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The main purpose of the food industry is to generate economic revenue throughout the transformation of raw agricultural materials into food. In order to reach this goal, the food industry must assure high quality products to the consumers.

Consumers expect variety and high quality products, as well as nutritious and safe foods at a reasonable cost from suppliers. The definition of high quality varies depending on the type of food, the region or country, and the individual's food preferences. However, quality can be described as a combination of characteristics such as wholesomeness, freshness, nutritional value, texture, color, aroma, and flavor. American consumers spend approximately $617 billion annually on food. Federal laws dictate food manufacturers, distributors and retailers, the responsibility for assuring that food are wholesome, safe and handled under sanitary conditions (Smith 2002).

Even though the meat industry has new tools to fight bacteria at all levels from farm to table, contamination of carcasses can still occur. With the implementation of Pathogen Reduction; Hazard Analysis and Critical Control Point (HACCP) Systems, Final Rule (USDA 1996), meat-processing plants employ various technologies for improving the microbiological quality of carcasses. Antimicrobial intervention methods are designed to reduce microbial contamination on carcasses.

Carcasses decontamination utilizing organic acids is a sanitation process widely used and extensively studied. Spraying organic acid solutions and/or hot or cold water is

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increasingly applied as sequential interventions for meat decontamination (Stopforth and others 2003).

Lactic acid cabinets are available nationwide. They represent a significant investment that only establishments with a large investment capacity can afford. Small and very small establishments represent approximately 70% of the total slaughter plants in the United States (USDA 2003). These establishments provide an important area of study where implementation of affordable technologies is needed to ensure quality products and consumers health. A hand held sprayer is typically used in these establishments; this is an inexpensive tool that presents some deficiencies. Among others, this method of decontamination is time consuming and when not applied properly, mostly unreliable, due to the difficulty in achieving an even spray leaving some areas of the carcasses untreated.

This project is aimed towards providing small and very small beef and pork slaughterhouses the ability to improve food safety performance through the implementation of a sanitizing halo system while maintaining cost effectiveness convenience and simplicity.

The goal of this project was to design and assemble a sanitizing halo system following three parameters. The first parameter was cost effectiveness; small and very small slaughterhouses do not have the same investment availability as large establishments do. Therefore, an inexpensive design is imperative. The second parameter was convenience; small slaughterhouses are generally located out of the urban perimeter. Consequently searching and purchasing for equipment can become a time

consuming and discouraging task. To overcome this problem the system was designed so that it can be built from materials purchased from any home-improvement retail store. Finally, the third parameter was simplicity; the sanitizing halo system can be assembled in a garage or small shop utilizing the most basic tools available in stores.

The sanitizing halo system has three main components. A frame, a handle, and a water pump. The polyvinyl chloride (PVC) square frame or halo with garden nozzles to distribute the L-Lactic acid solution. A large handle is attached to the halo enabling the displacement of the equipment from bottom to top of the carcasses. This handle allows reaching the highest and furthest points of the carcasses. Finally, a water pump is included for transferring the L-Lactic solution from an insulated tank to the surface of the carcasses.

OBJECTIVES

The main objective of this research is to assist small and very small beef and pork slaughterhouses to improve food safety performance through the implementation of a cost-efficient, convenient, and simple carcass's decontamination system.

Achieved by the following specific objectives:

- Designing and assembling an economical sanitizing spray system.
- Testing and adjusting the sanitizing spraying system.
- Validating the system at two different beef and pork slaughterhouses in Texas.

REVIEW OF LITERATURE

Importance of the meat industry

The food and beverage industry ranks fourth in size among all the industries of the United States. Americans spend an estimated $145 billion annually for food and beverages consumed both in and out of the home (MSU 2003).

The food processing and beverage industry accounts for about one-sixth of the U.S. manufacturing activity. In the year 2000, the food processing industry employed almost 1.7 million production workers (USDA 2002[a]). Direct and indirect employment in or related to the production and processing of beef supports over 1.4 million full-time-equivalent jobs in the U.S. (Otto and Lawrence 2002).

In 1997, the meat and poultry industry reported gross sales of approximately $110 billions. Cattle and hog slaughtering were by far the largest, accounting for about half of the industry gross sales, and raw meat processors without slaughter operations accounted for another quarter of the industry gross sales. The cattle slaughter industry had gross sales of about $28 billion in 1997 (USDA 2002[a]).

The beef industry is an important value added to the enterprise in U.S. agriculture. Over a million farms and ranches benefited directly from the sale of cattle and calves in 2000. Gross receipts from sales of cattle and calves in 2000 totaled $40.76 billion accounting for 21% of all agricultural receipts, making the beef sector the largest single agricultural enterprise (Otto and Lawrence 2002).

Cash receipts from hogs and pigs totaled $9.6 billion during 2002, down 23% from 2001. Marketing increased to 27.3 billion pounds in 2002, up 2% from 2001. The U.S. annual average price per 100 pounds live weight decreased from $44.30 in 2001 to $33.40 in 2002 (USDA 2003). Revenue from marketing of sheep and lambs in 2002 was $431 million, up 8 percent from 2001. Marketing increased 2 percent to 652 million pounds (USDA 2003*)*.

After a 20-year decline in consumer demand for beef, 1999 appeared to be a turning point in beef demand. Both 1999 and 2000 posted significant gains in beef demand with several quarters posting year-over-year increases in both per capita consumption and retail price. Farm level prices and profits improved at all production segments. A new emphasis on consumer friendly beef products began to appear at the retail meat counter. It is expected to strengthen demand further as consumers have greater selection on how to purchase and consume beef (Otto and Lawrence 2002).

Exports of beef commercial carcass weight were expected to reach in 2003 2.5 billion pounds, valued at $3.266 billion; having as top markets Japan, Mexico, and South Korea. The U.S. exported 1.6 billion pounds of pork in 2002, an increase of 3.5 percent over the previous year. The first-ever reported case of a Bovine Spongiform Encephalopathy (BSE) infected cow in the United States was announced by agriculture secretary Ann Veneman on December 23, 2003, which resulted in more than fifty countries banning imports of meat products of livestock from the United States. Many major companies were severely affected, especially those whose business centered on

international markets. However, about 90 percent of the meat produced in United States has as its final destination within the country markets. (Savell 2004).

Meat contamination

The contamination of beef during slaughter and processing of carcasses is a major risk for subsequent food borne infection in humans. It is estimated that food borne diseases cause approximately 76 million illnesses, 325,000 hospitalizations, and 5,000 deaths in the United States each year (Mead and others 1999). It is estimated that at least one third of the 5,000 deaths each year from food borne illness can be attributed to meat and poultry products (Frontline 2002).

Beef carcasses, which are initially sterile, become contaminated with bacterial pathogens via transmission of organisms from the exterior of the live animal, and/or from the environment, to the product surface (Belk 2001). Microbial contamination of beef carcasses occurs during the conversion of live animals to meat. After killing and eviscerating, most of the microbial characteristics of the carcass remain unaltered. In a healthy animal, it is expected that that inner layers of muscle tissue are free of any contamination from air, soil, and water. However, a large number of microorganisms find their way to reach the carcass surface during evisceration and by contact of the carcasses with knives, hooks, walls, floors as well as by human contact (Guerrero and Taylor 1994). Main sources of bacterial contamination include feces from the hide, hair, and hooves of the animals (Mies and others 2002). During processing workers and equipment may spread bacterial contamination from the hide to the product.

The food safety and inspection service and the meat industry

Food companies, regardless of size, make an effort to accomplish a high standard of quality. United States has one of the world's safest food supplies; a status maintained thanks in a large part, to a quality and safety monitoring system that oversees food production and distribution at every level (Vasconcellos 2004).

In July 1996, the United States government published the Pathogen Reduction; Hazard Analysis and Critical Control Point Systems (HACCP); Final Rule to improve food safety of meat and poultry products; motivated by the lack of adequate measures to address the problem of pathogenic microorganisms on raw meat and poultry products (Schlosser and others 2000). Prior to the Final Rule, such bacteria including *Salmonella* and *Escherichia coli* O157:H7, *Campylobacter,* and *Listeria monocytogenes*, were significant food safety hazards associated with meat and poultry products. One of the issues that promoted the HACCP requirement was the Jack in the Box outbreak. In the 1993 Jack in the Box Restaurant outbreak, seven hundred people became ill and four children died due to the consumption of *E. coli* O157:H7 (Golan and others 2004). The Food and Drug Administration (FDA 2001) raised the recommended internal temperature for hamburgers cooked in restaurants to 68.3°C. USDA-FSIS initiated programs like a safe-food-handling label with instructions for consumers on packages of raw meat and poultry sold in supermarkets, an information campaign alerting school children to eat hamburgers cooked well-done, and tests for *E. coli* O157:H7 in raw ground beef prepared in federally inspected establishments and in retail stores. FSIS also changed the status of *E. coli* O157:H7, declaring it an adulterant in raw ground beef.

Because of the outbreak, the Centers for Disease Control and Prevention (CDC 2004) obtained additional funding for the FoodNet program to identify food borne pathogens causing intestinal illness. The outbreak also accelerated efforts to modernize federal requirements for food safety using the Pathogen Reduction and Hazard Analysis and Critical Control Point (HACCP) system (Golan and others 2004).

Interventions for carcass decontamination

Although the meat industry has new tools to fight bacteria at all levels from farm to table i.e., Good Agricultural Practices (GAPs), Good Manufacturing Practices (GMPs), HACCP; contamination of carcasses can still occur (Sofos and Smith 1998). Antimicrobial intervention methods are designed to reduce microbial contamination on the carcasses and are often implemented as critical control points within HACCP plans in slaughter operations.

Knife trimming

Because the microbial pathogens associated with fecal contamination are the single most likely source of potential food safety hazard in slaughter establishments (USDA 1996), FSIS requires that all visible fecal contamination must be removed from the carcass. Removal of the fecal contamination is done by knife trimming. The National Meat Association recommends that all trim employees must be properly trained and all equipment such as hooks and knives should be sanitized between each use to reduce cross-contamination between areas (National Meat Association 2003). In previous studies Hardin and others (1995) reported a reduction of 3.2 – 4.4 log CFU/cm^2

on *E. coli* O157:H7, Phebus and others (1997) reported a 3.1 log CFU/cm^2 on *E. coli* O157:H7, but according to Prasai and others (1995) the fact that there is no visual evidence of fecal contamination on the carcass surface does not mean that it is free of pathogenic microorganisms. The National Meat Association recommends treating carcasses that have been separate for visible fecal contamination with an additional sanitizing intervention i.e., organic acid spray.

Steam vacuum

In April of 1996, the FSIS approved for use in commercial slaughtering beef operations the process of spot cleaning and decontamination of carcasses with hand held equipment applying steam and vacuum, or water, steam and vacuum (Kochevar and others 1997). Removal of visible contamination was usually accomplished by trimming the contaminated tissue from the carcass; however, trimming usually results in significant waste for plants with high levels of production (Castillo and others 1998[a]). Steam vacuum eliminates waste due to trimming and improves the visual appearance of carcasses that would have to be trimmed in order to comply with federal regulations. The original steam vacuum was designed to take advantage of both hot water and steam, in combination with a physical removal of bacteria and contamination via vacuum. It has been reported that vacuum sanitizing equipment effectively reduced nonspecific strains of *E. coli* O157:H7. Coliforms at initial levels of 5 log CFU/cm^2 were reduced to 1 log CFU/cm^2. *E. coli* counts of 4.8 log CFU/cm^2 were reduced to 0.8 log CFU/cm^2 (FSIS 2002). According to FSIS (2002), the use of steam vacuum technology in slaughter plants has reduced the amount of knife trimming required to meet the zero

tolerance policy. Additionally, the use of steam vacuuming has resulted in an improvement of the microbial constitution of beef carcasses. Although the excellent results that steam vacuum technology delivers, it has been determined, that fecal contamination was often distributed to other areas of the carcass. In some cases, fecal material was not removed completely, but was spread to other areas of the carcass surface and, in some cases, was propelled by the steam nozzles to the floor or other locations in the slaughter area. (Castillo and others 1999)

Hot water

Decontamination of red meats carcasses using hot water washes (70°C - 96°C) has shown significant reduction on microbial loads. Gorman and others (1995) reported that application of hot water at 73.8°C after trimming can have 1.4 log CFU/cm^2 reduction on *E. coli*. Davey and Smith (1989) reported the same reduction and also noted, that if the washing time was extended up to 20 s, reduction could reach 2.2 log CFU/cm^2. Castillo and others, (1998[b]), and Gill and Bryant (1997) reported much higher reductions than those reductions reported by Davey, 3.7 and 3.8 log reductions for *E. coli* and *Salmonella typhimurium,* respectively. In addition, Davey reported that the use of hot water washes could disperse the microorganisms to areas outside to the 400 cm^2 that were inoculated. Another problem that can be associated with the hot water washes is the creation of condensation in the plant (Buege and Ingham 2003).

Steam pasteurization

Comprehensive studies aimed to determine the ability of steam pasteurization in decontaminating beef surface tissue, have been published (FSIS 2002). A reduction in *E. coli* O157:H7 of 3.5 log CFU/cm^2 was observed with an initial inoculation of 5.0 log CFU/cm^2 and 3.7 log CFU/cm^2 reduction of *S. typhimurium* with an initial contamination of 5.1 log CFU/cm^2. They concluded that steam pasteurization could be an effective intervention in an overall system of pathogen reduction on surface tissue freshly slaughtered beef. Its greatest effectiveness is achieved when used in combination with other decontamination treatments (Gill and Landers 2003, Kastner and others 1997).

Antimicrobial effect of organic acids

Organic acids or carboxylic acids occur widely in nature. These acids contain a carboxyl group and are generally written RCOOH. Ethanoic acid better known as acetic acid is widely used. Acetic acid is present vinegar at a concentration of about 7%. Other carboxylic acids that occur naturally in foods are citric acid and L-Lactic acid. Citric acid is present in berries, citrus and tropical fruits. L-Lactic acid is present in foods such as fermented meat products, yogurt, and cheese. These acids can also be used to lower the pH of foodstuffs, which helps to preserve the product as microorganisms all have pH levels below which they can no longer grow (Everis 2001).

Acids have different antimicrobial effects. Strong acids concentrate their antimicrobial effects by lowering the pH. Microorganisms have adapted to survive these low conditions (Hill and others 1995, Greer and Dilts 1992). Growth may stop but the

cells can be still metabolically active. The energy requirements of a microorganism in a low pH environment are greater than the energy requirement at optimal pH values. In high pH conditions, protons may be pumped into the cell. If the pH is not balanced then the cell is unable to synthesize normal cellular components and is unable to divide. Besides, in a reduction of the external pH, weak acids pass an undissociated molecule into the cell. When the undissociated molecule passes though the cell membrane, it dissociates and H^+ is released into the cell. This acidifies the interior of the cell (Everis 2001).

FSIS has recently stated they have no objection to the use of 5% at 55°C L-Lactic acid when applied as an antimicrobial agent to treat beef carcasses prior to fabrication i.e., pre- and post-chill. In this case, data submitted to FSIS demonstrated no lasting effect of the lactic acid under the specified conditions of used. Consequently, FSIS determined that the proposed use is consistent with the definition of a processing aid. Therefore, its use would not need to be reflected on the labeling for treated carcasses or products produced from treated carcasses (Mohr 2004).

Carcass decontamination utilizing organic acids is a sanitation process that is widely used in the industry, and has been studied deeply. Netten and others (1995), found that lactic acid decontamination was capable of eliminating salmonellae from pork, veal and beef carcasses, is also likely to be effective against *Campylobacter jejuni*. This bacterium is at least 10-fold more sensitive to lactic acid than salmonellae. Furthermore, counts of *C. jejuni* on freshly slaughtered veal, pork, and beef carcasses are also up to l00-fold lower than those of salmonellae. A major disadvantage of lactic acid

decontamination capable of eliminating salmonellae from pork carcasses is the adverse effect on their appearance. It has been observed that the initially impaired appearance of beef and broiler carcasses subjected to lactic acid decontamination, unlike that of pork, improves during chilled storage. Medynski and others (2000) found that an increase of the lactic acid concentration in meat above the level of 0.5% enhanced water-holding capacity and reduced thermal loss.

In another study, Jimenez-Villareal and others (2003[a,b]) found that lactic acid treatments on beef trimmings before grinding could improve or maintain the same sensory and instrumental color, sensory odor, lipid oxidation, sensory taste, shear characteristics, and cooking characteristics as traditionally processed ground beef patties. Therefore, the use of these antimicrobial treatments could be used in industry as a measure of safety improvement without negatively affecting the fresh product.

The combination of being an effective antimicrobial agent and remaining neutral to quality changes such as color or odor characteristics are primary concerns for the decontamination of beef trimmings destined for ground beef due to the increased surface area exposed to antimicrobial treatments. Results from Stivarius and others (2002), suggested that lactic acid could be used to reduce *E. coli*, coliforms and aerobic plate counts, and therefore provide an added measure of safety in the production of ground beef; however, different concentration levels need to be tested on beef trimmings to achieve larger microbial reductions while maintaining color stability during refrigerated display.

Combined interventions

Integration of sanitizing methods, such as knife trimming in combination with other antimicrobial decontamination methods such as steam vacuuming, hot water and acid sprays systems and steam pasteurization can help to improve the microbial safety of carcasses after slaughter (Gorman and others 1995), (Castillo and others, 1998[a]), (Castillo and others 1999) and (Pipek and others 2005). Several studies used a combination of two or more intervention methods to reduce the number of *E. coli* O157:H7 and *Salmonella* during slaughter operations, Delazari and others (1998) combined different interventions and found that combination of water and 2% L-Lactic acid at 55°C (131°F) can reduce *E. coli* O157:H7 2.7 to 3.7 log CFU/cm^2, and a reduction of 3.4 to 5.1 log CFU/cm^2 on *S. typhimurium* (Table 1). A similar experiment was conducted by Castillo (1998[a]) in this case, a combination of trimming, hot water and lactic acid had reductions of >4.8 to >5.0 on *E. coli* O157:H7 log CFU/cm^2 and >4.7 to >5.0 log CFU/cm^2 on *S. typhimurium.* According to Castillo and others (2001) the combination of two or more decontamination interventions have a significant effect on pathogen reduction, and is an important tool to assure the safety of the carcasses.

Table 1 - Reductions of *E. coli* O157:H7 and *S. typhimurium* populations on beef by different antimicrobial interventions (USDA 2002[b])

Treatment	Microbial Contaminant	Reduction (log CFU/cm^2)
Trimming	*E. coli* O157:H7 in feces	3.2 – 4.4
Trimming + Washing	*E. coli* O157:H7 in feces	4.7 ± 0.53
Trimming + Washing +Steam Pasteurization	*E. coli* O157:H7 in feces	4.4 ± 0.5
Trimming + Water (74°C 12s)	*E. coli* O157:H7 in feces	1.4
Steam Vacuum Sanitizer	*E. coli* O157:H7 in feces	5.5 ± 0.2
Washing	*E. coli* O157:H7 in feces	2.0 – 3.5
Washing + Steam Pasteurization	*E. coli* O157:H7	4.2 ± 0.5
Water + 2% Lactic acid (55°C, 40 lb/in^2)	*E. coli* O157:H7 in feces	2.4 – 3.7
5% Acetic Acid	*E. coli* O157:H7	2.0
5% Citric Acid	*E. coli* O157:H7	1.8
5% Lactic Acid	*S. typhimurium* in feces	2.6
Water + 2% Lactic acid (55 °C, 40 lb/in^2)	*S. typhimurium* in feces	3.4 – 5.1

MATERIALS AND METHODS

Sanitizing halo system design and construction

The main objective of designing and assembling the sanitizing halo system was to help very small and small establishments to improve their food safety performance. A very small establishment has fewer than 10 employees or less than $2.5 millions in annual sales, and a small establishment is the one that has 10 or more but fewer than 500 employees. These kind of businesses do not have the same investment capacity, as the large establishments do, therefore is very important to assemble a sanitizing system that can be afforded by any type of business regardless of its size. Another relevant characteristic of these types of establishments is that they are generally located out of the urban perimeter. Searching and purchasing for materials can become a time consuming and discouraging task. To overcome this problem all materials were bought only at one store. A large home improvement retailer with stores easily found across the nation was selected as the material's provider for the construction of the sanitizing halo system. Another problem that had to be considered, was the fact that these type of businesses do not have an engineering or maintenance department to assemble the system. The system had to be designed in a manner that its assembling can be done in a garage or small shop utilizing the most common and basic tools that are available in the market.

Components and characteristics of the sanitizing halo system

Square frame or halo

The sanitizing halo system has two square frames; one square frame is for spraying beef carcasses, and the second and smallest square frame is used for spraying pork carcasses. Difference in size of the square frames is because beef carcasses are much wider than pork carcasses.

Nozzles and handle

Delivery of the solution is made through a series of plastic nozzles (Table 2) arranged in such a way that all regions of the carcass will receive the same amount of solution. The square frame used to spray the pork carcasses has total number of eight nozzles and that for spraying beef carcasses has 12 nozzles. The square frame is attached to a large handle. This handle allows the displacement of the square frame from bottom to top of the carcass. The handle allows the operator to easily reach the furthest regions of the carcass. The handle is attached to a pumping system, which impels the lactic acid solution from an insulated Rubbermaid® cooler.

System adjustment

Temperature

The L-Lactic acid solution should be heated to 55°C and then transferred to an insulated tank. In this study, a Rubbermaid® (Rubbermaid Inc, Atlanta, GA) water container was used. This container was used to hold the L-Lactic acid solution; the tank

was able to maintain the temperature for about 1½ h. After that, a decrease of 3°C to 5°C was detected. The solution was heated to 58°C and the lowest temperature detected after 1½ h was 53°C therefore, the solution needed to be reheated. It is recommended to prepare the L-Lactic acid immediately before the system is used to keep the temperature at 55°C.

Spraying pressure

The pumping system utilized in the sanitizing halo system delivered the L-Lactic acid solution at a maximum pressure of 40 psi. FSIS has no current requirements concerning the minimum and maximum pressure for organic acids (i.e., L-Lactic, acetic, and citric acid) when they are applied onto livestock carcasses. However, FSIS Directive 6340.1—Acceptance and Monitoring of Pre-Evisceration Carcass Spray Systems (PECS), stated that the spray pressure should be limited to 50 psi (USDA 1992). A water pressure test gauge, model 45171(Ez-Flo International., Sunny Ontario, CA) was used to measure the pressure of each sanitizing halo system. One of the nozzles was randomly selected and replaced for the gauge. The sanitizing halo system designed for pork carcasses had a pressure of 40 psi, and the sanitizing halo system for beef carcasses reached a pressure of 32 psi.

System assembly

The sanitizing halo system has four main components: an aluminum structure or skeleton, a 1.27 cm PVC pipeline circulation system, a complete set of plastic nozzles, 8 nozzles for the pork carcasses and 12 for the beef carcasses, and a hose connector. The halo's sizes were arranged after in-plant measurements of several beef and pork carcasses at the RMSTC. The dimensions of the halo were determined by adding a total of two inches on each side to the widest beef carcasses that were measured. The same procedure was applied to determine the dimensions of the halo for spraying pork carcasses. The difference between pork and beef halos was four inches and four nozzles. Table 2, provides the detail list of materials that were necessary to assemble the sanitizing halo system for pork and beef carcasses.

Table 2 - List of materials for halo assembly

Description	Pork	Beef
Aluminum angle 1.27 cm	4 pieces of 180.3 cm long each 2 pieces of 8 ¼-in long each	4 pieces of 101.6 long each
J-M PVC pipe 1.27 cm	3 pieces of 29.2 cm long each 8 pieces of 41.9 cm long each.	8 pieces of 76.2 cm long 8 pieces of 41.9 cm long
Rain bird 0.63 cm pattern plastic nozzle	8 Units	12 Units
1.27 cm X1.27 cm X1.27 cm schedule PVC tees	9 Units	13 Units
Nibco 1.27 cm slip X 90° slip PVC elbow	4 Units.	4 Units
Nibco 1.27 cm male street adapter	1 Unit	1 Unit
Nibco	1 Unit	1 Unit
Orbit 1.27 cm barb coupling	8 Units	12 Units
1.27 cm Hose adapter	1 Unit	1 Unit
Nibco 1.27 cm PVC 90° street elbow	--------	1 Unit
Hillman 0.63 cm -X 2.5 cm USS Zinc coated low carbon hex bolts, coarse thread	8 Units	8 Units
Hillman 0.63 cm - 20 stainless steel hex machine screw nuts	8 Units	8 Units
Hillman 0.63 cm X 2.5 cm fender washer	8 Units	8 Units
Gardner bender 27.9 cm	12 Units	12 Units

Construction guidelines for the halo

Aluminum structure or skeleton

The assembling of the aluminum structure has three major steps, which are:

1- To drill a 0.63 cm hole, 0.63 cm away from the edge of each aluminum angle.

2- To make a square utilizing the 4 pieces of aluminum.

3- To fasten each side using one bolt, one washer, and one nut on each side of the square as shown in Figures 1 and 2.

Figure 1 – Assembly of the aluminum structure

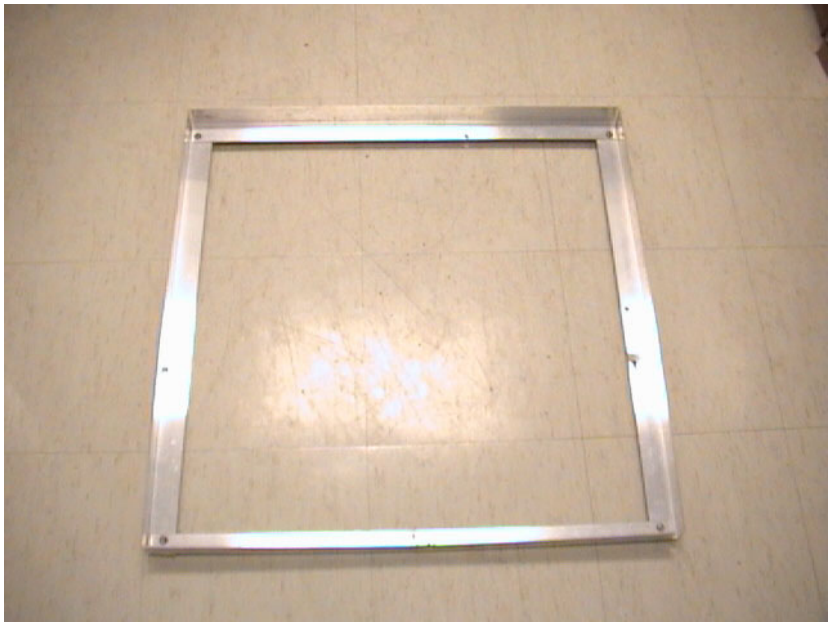

Figure 2 - Aluminum structure assembled

PVC pipeline circulation system assembly

Before assembling the circulation system is important to clean all pipes and parts that are going to be joined. PVC cement will work effectively when pipes and parts are free of dust or grease. To join the PVC pieces six steps are necessary:

Step 1: Join a 90° elbow to the end of the 29.2 cm PVC pipe, on the other end of the pipe place the schedule tee. (It is important to leave the thread end facing up).

Step 2: On the other end of the tee put a 41.9 cm PVC pipe.

Step 3: Place another tee at the end of the pipe.

Step 4: Then, to the free end of the tee put an 29.2 cm PVC pipe.

Step 5: Repeat the previous steps (1-4) two more times. For the last side of the circulation two 29.2 cm PVC pipe pieces and two 20.9 cm PVC pipe are needed.

Step 6: Do the same starting with one 29.2 cm PVC pipe, and then put one tee. Place one 20.9 cm PVC pipe to tee, and in the other end put another tee with the thread end facing perpendicular to other tees. Complete this segment adding an 20.9 cm PVC, one more tee, and the last 29.2 cm PVC pipe. Do not forget to place the 90° elbow at the each end of the segments. Figures 3 and 4 illustrate the assembling of the four segments of PVC pipe necessary for completing the circulation system.

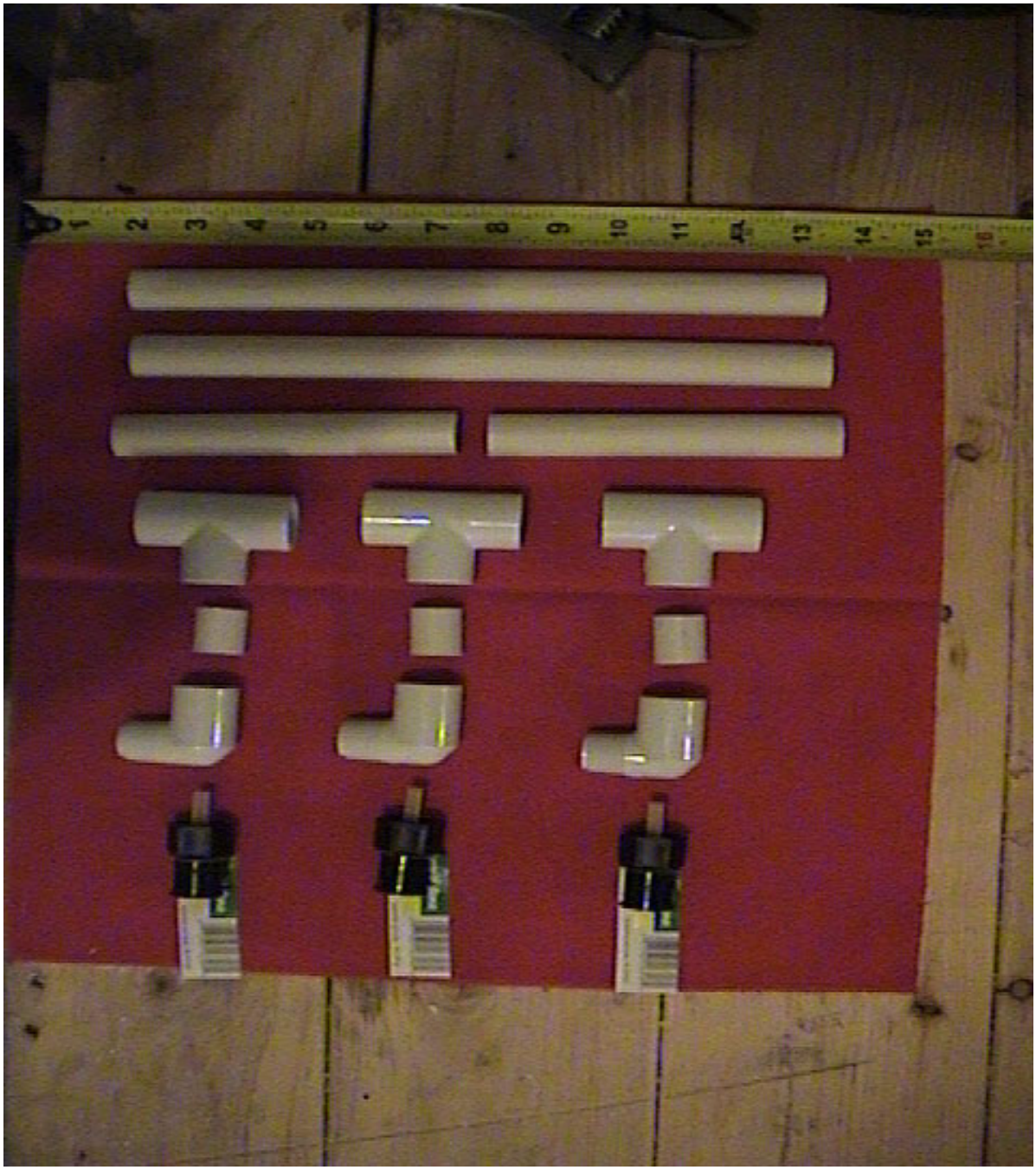

Figure 3 - PVC parts need to construct the circulation system

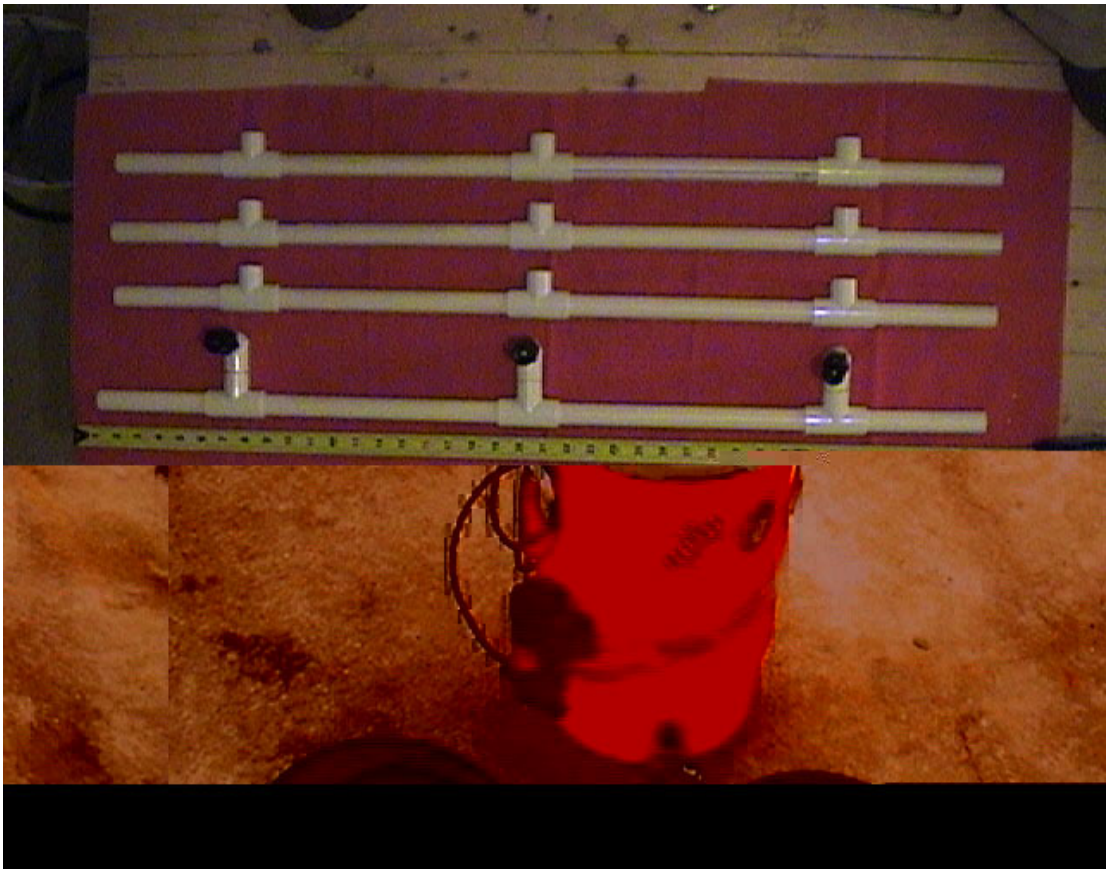

Figure 4 - Circulation system assembly

Nozzles assembly

Each nozzle requires one 1.27 cm barb tee coupling. To assemble the nozzles, first, screw the 1.27 cm barb tee coupling to the PVC tee. Then screw the nozzle to the 1.27 cm barb tee coupling, see Figure 4. Repeat this process for each of the nozzles.

Hose connector assembly

To assemble the hose connector, first, on the PVC tee that is facing out; join the 1.27 cm schedule tee and the PVC fitting plug. Then, screw the male adapter to the fitting plug. Screw the hose connector to the male adapter, Figure 5. Let the circulation system dried for at least 24 h before testing it.

Figure 5 - Hose connector

Handle assembly

The length of the handle is critical because the sanitizing halo system has to reach all regions of the carcasses, in order for the treatment to be even and reliable. Americans have an average (combined female and male) height of 173.7 cm (CDC 2004). The length of the aluminum pole was chosen considering the height of the hanging rail at the RMSTC and the height average mentioned before. The sanitizing halo handle consist of a large aluminum pole, 154 cm long and 1.9 cm width, and two storage hangers that were used as handlers (Figure 6).

Materials needed for handle assembling are listed in Table 3. For handle assembly, begin by attaching the 27.9 cm storage hanger at the very end of the aluminum tube, then leave a 12.7 cm space to place the 47 cm hanger as it is shown on Figure 4.

Pumping system assembly

Materials needed for the pumping assembling are listed in Table 4. A pumping system was required to transport the L-Lactic acid solution from the storage tank through the circulation system and nozzles to the carcasses surface. A five gallon Rubbermaid® cooler (Rubbermaid Inc, Atlanta, GA) was used as the storage tank (Figure 7). It provided the required insulation to keep the solution temperature at 55°C. The cooler had to be modified so the liquid dispenser was replaced by a 1.9 cm hose connector as shown in Figure 8.

Figure 6 - Sanitizing system handle

Table 3 - List of materials for handle assembly

Description	Quantity
1.9 cm width aluminum tube 152.4 cm long	1
Crawford 27.9 cm storage hanger	1
Crawford 47 cm storage hanger	1
Hillman 1.9 cm X 2.5 cm USS Zinc coated low carbon hex bolts, coarse thread.	5
Hillman 1.9 cm X 5.1 cm stainless steel hex machine screw nuts.	5

Figure 7 - Pumping system parts

Figure 8 - Hose connector at the storage tank

Table 4 - List of materials for assembly of the pumping system

Description	Quantity
Water pump	1
5 gallons Rubbermaid® cooler	1
1.9 cm Hose connector	1
91.4 cm garden hose	1
457.2 cm garden hose	1
Silicone sealant	1
Sealing tape	1

To assemble the pumping system, the water dispenser that is located at the bottom of the storage tank was replaced by a 1.9 cm hose connector. Silicone was applied to avoid leaks and allowed to dry for 24 h. Then, the pump was attached to the Rubbermaid® cooler. A 91.4 cm garden hose was connected to the storage tank and the other extreme to the outlet in the pump that is labeled as "IN". One end of the 457.2 cm garden hose was connected to the outlet labeled "OUT", and the other end was connected to the halo.

After putting together all the parts, the system was set in wheel structure to facilitate its movement among different areas of the slaughter floor (Figure 9).

Figure 9 - Sanitizing halo spraying system

System implementation

System testing

The sanitizing halo system was tested at the RMSTC; the objective was to test the performance of the system at the slaughter floor. A detailed review of all joints, hose connections, and spraying angles was made to confirm the correct design of the sanitizing halo system. In addition, microbiological samples were collected to verify the effectiveness of the sanitizing halo system.

Typical fed steers or heifers entering to the United States food supply and slaughtered at the RMSTC were selected for testing the system. The cattle were transported, slaughtered, and dressed at the slaughter floor of the RMSTC, following USDA-FSIS procedures and regulations for commercial slaughter. The testing was done on three slaughter days. During the first two slaughter days, four cattle each day were used to test the system. In the next slaughter day, five cattle were necessary to complete the set of thirteen carcasses. The system was only tested on beef carcasses.

L-Lactic acid solution preparation

L-Lactic acid 88% (Purac, Lincolnshire, IL) was used to prepare a 2% L-Lactic acid solution; the L-Lactic was diluted with distilled water. The lactic acid was heated to 55°C, and then transported from the food microbiology laboratory located in room 313 Kleberg building at Texas A&M University (College Station) to the RMSTC. Hot plates were used to maintain the solution temperature while waiting for the carcasses to be

ready for the test. Concentration of the L-Lactic solution was measured by titration and was equal to 2%.

Carcass spraying

Thirteen carcasses were separated after splitting and dressing, prior to chilling. The testing of the system was done in three different processing days. Two groups of 4 carcasses halves were used to test the sanitizing halo system during the first two processing days, and one group of five carcasses halves was used in the third processing day to complete a total of 13 beef carcasses.

Each day, a group of carcasses halves was hand sprayed with L-Lactic acid solution by the RMSTC employees following establishment procedures. Concentration and temperature of the L-Lactic solution used by the RMSTC were between 2.1% – 2.5% and 55°C – 71.1°C respectively. Measurement of L-Lactic concentration and temperature was done by the RMSTC employees at the beginning and at the end of each processing day. Table 5, shows the concentration and temperature values of the L-lactic solution used by the RMSTC each day of testing. The other group of carcasses halves was sprayed with the sanitizing halo system, utilizing the 2% L-Lactic solution at 55°C prepared at the food microbiology laboratory.

Table 5- Concentration and temperature of L-Lactic solution used by RMSTC during testing of the sanitizing halo system

Day	Concentration of L-Lactic		Temperature of L-Lactic	
	Beginning	End	Beginning	End
Day 1	2.5%	2.2%	55°C	67.2°C
Day 2	2.3%	2.3%	71.1°C	55°C
Day 3	2.1%	2.3%	64.4°C	61.6°C

Spraying time and amount of solution delivered

Each carcass was sprayed for a total time of 20 s. Starting from the bottom, to the highest point for 10 s, and coming down and spraying for 10 more s. During the spraying time, the system delivered 5.7 liters of L-Lactic solution on each carcass side.

Carcass sampling

Microbiological samples were collected from each carcass half using a sponge to collect 100-cm^2 samples each from the rump, brisket, and clod regions following FSIS procedure (FSIS, 1996). The sponge was moistened with 25 ml of sterile 0.1% peptone water, and the sample collection was completed by rubbing the sponge over the 100-cm^2 regions of the carcass mentioned above. Then the sponge was transferred to a sterile whirl-pak® bag (Nasco, Fort Atkinson, WI) and placed in an insulated container, and transported to the food microbiology laboratory located in Kleberg building at Texas A&M University, a building adjacent to the RMSTC. Analysis of the samples was conducted within 24 h.

Collection of control, RMSTC and sanitizing halo system samples

Thirteen carcasses halves were used as a control; they were sampled after knife trimming and water wash, but before spraying of the L-Lactic acid solution. These carcass halves were later sprayed using the sanitizing halo system, and samples were collected after the treatment. RMSTC samples were collected immediately after the carcasses were sprayed by the RMSTC employees with L-Lactic solution after knife trimming and water wash.

Plating

Each sample was hand massaged inside the whirl-pak® bag for one min before examination for aerobic plate counts (APC), coliform, *E. coli*, and mesophilic aerobes. APC counts were determined by plating appropriate dilutions of the composite onto corresponding Petrifilm™ aerobic count plates, incubating at 25°C for 48 h. Coliform and *E. coli* counts were conducted at the same time on Petrifilm™ *E. coli* by incubating at 37°C for 24 h. *E. coli* colonies appeared dark blue with a gas bubble, while coliform colonies appeared red with a gas bubble. Total coliform count was achieved by adding *E. coli* colonies and coliform colonies. Mesophilic aerobes counts were obtained by plating appropriate dilutions of the composite onto corresponding Petrifilm™ aerobic count plates, and incubating at 37°C for 24 h.

System validation

Procedure

A beef slaughter establishment located in New Ulm, TX was selected to validate the sanitizing halo system on beef carcasses. The establishment slaughters fed steers and heifers in amounts that vary from one to ten once per week. A total of six trips were necessary to complete the sampling set. Twenty-four carcass sides were treated utilizing the sanitizing halo system. 2% L-Lactic solution was prepared at the food microbiology laboratory two h before using it. Spraying time, temperature of the solution and spraying method were determined during the testing phase at the RMSTC and did not

have variations during this phase. The other 24 sides were not treated and were used as a control.

The sanitizing halo system was taken for validation to a pork slaughterhouse located in Navasota, TX. This establishment slaughters an average of 80 hogs every day. Two trips were necessary to complete the set of 24 samples. Because pork carcasses are not as wide as the beef carcasses, they were sprayed with the sanitizing halo designed for pork carcasses, which has 8 plastic nozzles instead of 12. Twenty-four carcasses halves with the skin on were treated utilizing the Sanitizing Halo. The other 24 carcass sides were not treated and were used as a control.

Temperature and pH

During the validation phase, temperature and pH of the carcasses were measured before and after spraying with the sanitizing halo system. A portable Markson model 612 (Markson science, Inc., Phoenix, AZ) pH meter with a flat probe was utilized to take the pH at two random areas of the carcasses. Each time, the probe was properly sanitized and calibrated before use. Temperature of the carcass was also measured before and after spraying with the sanitizing halo. A K-type thermocouple connected to a Traceable® digital thermometer (Control Company, Friendswood, TX), was used to measure the surface temperature of each treated carcass at two random regions.

Sampling

After application of the lactic acid solution, both treated and untreated carcasses were sampled following FSIS sampling requirements (FSIS 1996) as described for the

testing phase. A total of 300 cm^2 per carcass were collected from the rump, brisket and clod regions of beef carcasses, and jowl, bacon and ham regions of pork carcasses. The sponge samples were returned into their sterile whirl-pak® bag and placed in a refrigerated container and transported to the food microbiology laboratory and were analyzed within 24 h.

Plating

Microbiological analysis for the validation phase of the project was done by hand massaging each sample inside the whirl-pak® bag for one min before examination for aerobic plate counts (APC), coliform, *E. coli*, and mesophilic aerobes. APC counts were determined by plating appropriate dilutions of the composite onto corresponding Petrifilm™ aerobic count plates, incubating at 25°C for 48 h. Coliform and *E. coli* counts were conducted at the same time on Petrifilm™ *E. coli* by incubating at 37°C for 24 h. *E. coli* colonies appeared dark blue with a gas bubble, while other coliform colonies appeared red with a gas bubble. Total coliform count was achieved by adding *E. coli* colonies and coliform colonies. Mesophilic aerobes counts were obtained by plating appropriate dilutions of the composite onto corresponding Petrifilm™ aerobic count plates, and incubating at 37°C for 24 h.

Statistical analysis

Microbiological data were transformed logarithmically before statistical analysis. Means for each treatment were analyzed by analysis of variance (ANOVA) procedure of

SPSS 11.5 for Windows. Least square means were separated when treatment effect was significant in the ANOVA table ($p<0.05$)

RESULTS AND DISCUSSION

Designing and construction

Materials and parts

Due to its strength, lightweight, and its resistance to oxidation, aluminum was selected to build the handle and the square structure that supports the PVC circulation system for the sanitizing halo system. Aluminum is also available in different shapes and is less expensive than other materials i.e., stainless steel.

As soon as the sanitizing halo system is activated, the circulation system fills with the L-Lactic solution making the equipment heavier. PVC accessories were used to assemble this system. PVC accessories are lightweight and resist the working temperature of 55°C (131°F). No leaks were detected at the adjusting, testing validation phase of this study.

Garden nozzles with a dispersion angle of 40° were used. The 40° dispersion angle provides a lineal covering of 35.5 cm at 5.1 cm from the nozzle. Based on these data the final number of nozzles was calculated for each sanitizing halo system (beef and pork).

Construction cost and time

A total of $286 U.S. dollars were needed to build two sanitizing halo systems. This amount includes the cost of all materials and parts for the construction of two

sanitizing halo systems (beef and pork), two handles (beef and pork), and one pumping system as listed in Table 6. This is very affordable price that any small and/or very small slaughterhouse would be able to disburse.

Two days were needed to assemble the system, in the first day all connections were made. Then, and a 24 h period was necessary to allow the pipe joints to dry and seal properly. After that, the system was tested to make sure that no leaks were found. These steps are necessary in building the system to ensure proper functionality.

Temperature and pH

Data in Table 7 show measurement of pH and temperatures on the carcass surface. The data were taken prior and after each carcass was treated with the sanitizing halo system. pH and temperature values were obtained from two random areas of the carcass; the L-Lactic solution was applied on the carcass at 55°C, the temperature on the carcass surface had an average increment of 3°C. pH before applying the sanitizing treatment was in the range of 7.1-7.6. After applying the L-Lactic solution the pH was reduced on the carcass surface to 2.8-3.2.

Table 6 - Cost of the sanitizing halo system

Part	Description	Price
	Nozzles	$ 30
Beef Carcass Sanitizing Halo	PVC materials	$ 18
	Aluminum skeleton	$ 28
	Subtotal	**$ 71**
	Nozzles	$ 20
Pork Carcass Sanitizing Halo	PVC materials	$ 15
	Aluminum skeleton	$ 28
	Subtotal	**$ 63**
	Handlers	$ 26
Handle (Beef and Pork)	Aluminum rods	$ 18
	Subtotal	**$ 44**
	Pump	$ 65
	Rubbermaid tank	$ 20
Pumping System	Hoses and connectors	$ 18
	Subtotal	**103**
	Total	**$ 286**

Table 7 - Surface pH and temperature for beef and pork carcasses with or without L-Lactic

		Treatment	
Type of carcass	Determination	Control[1]	Sprayed[2]
Beef	Surface temperature (°C)	30.9	33.7
	Surface pH	7.1	2.8
Pork	Surface temperature (°C)	27.0	29.3
	Surface pH	7.6	3.2

[1] Control: Measurements taken before spraying the carcass with 2% L-Lactic at 55°C (131°F) utilizing the sanitizing halo system.
[2] Sprayed: Measurements taken immediately after spraying the carcass with 2% L-Lactic at 55°C (131°F) utilizing the sanitizing halo system.

Sanitizing halo system implementation

Microbial counts were obtained by sampling the rump, clod, and brisket regions with the sponge method. One half of the carcasses assigned for the implementation stage of the project were sampled after knife trimming and water wash, and after rinsing each carcass side with the L-Lactic solution utilizing the sanitizing halo system. The other half of the carcasses was sampled after RMSTC employees rinsed the carcasses with L-Lactic solution utilizing a hand held sprayer after knife trimming and water wash. As shown in table 8, APC and meshopilic counts for samples collected from carcasses treated with both the sanitizing halo and the RMSTC system were significantly lower ($P < 0.05$) than those counts obtained from control samples. This corroborates the efficacy of carcasses sanitizing, especially using lactic acid sprays. APC and mesophilic aerobic counts were significantly lower for carcasses sprayed with the sanitizing halo in comparison to RMSCT ($P < 0.05$).

Coliform counts were consistently below or close to the detectable limit of 0.5 log CFU/cm^2 for both lactic acid treatments; therefore, a statistical analysis of these data was not reliable. Control carcasses showed levels of 1.0 and 1.5 log CFU/100 cm^2 on the brisket and rump areas of control carcasses respectively. Counts obtained from the same regions on hand-sprayed carcasses were 0.6 log CFU/100 cm^2 and not detectable for carcasses sprayed with the sanitizing halo system for clod (Table 8).

Sanitizing halo system validation

When the sanitizing halo system was tested under commercial slaughter conditions (small and very small establishments), bacterial counts obtained from sprayed carcasses were consistently lower than bacterial counts on control (non-sprayed) carcasses. On beef carcasses, there was an overall difference of 2.9 log cycles in mesophilic bacteria counts on sprayed vs. control carcasses. Likewise, coliforms and *E. coli* were >2.4 and >1.8 log cycles lower on sprayed carcasses than on control carcasses (Table 9). Similar differences were observed on pork carcasses, where mesophilic, coliform and *E. coli* counts were lower for sprayed carcasses by 1.9, >1.0 and >0.7 log cycles when compared to control carcasses (Table 10). This indicates that the proposed sanitizing halo system can improve considerably the quality of the beef and pork carcasses by reducing significantly the microbial load. The sanitizing halo system also reduces the risk of leaving any region of the carcass untreated, by delivering a consistent and even spray to all regions of the carcasses. Figures 10 and 11 show the efficacy of the sanitizing halo system on reducing the bacterial load throughout the regions on pork and beef carcasses.

Table 8 – Efficacy of the sanitizing halo system at the implementation stage

		Log cfu/100 cm^2 ± SD (N=13)		
	Count[a]	Control[1]	RMSTC[2]	Sanitizing halo[3] system
Rump	Mesophilic	2.1 ±0.4A[z]	1.7 ± 0.8B	1.2 ± 0.6C
	APC	2.3 ± 0.4A	2.0 ± 0.6B	1.4 ± 0.6C
	Coliforms	1.0 ± 0.9A	0.6 ± 0.2A	0.5 ± 0.1A
Clod	Mesophilic	2.4 ± 0.3A	2.1 ± 0.8B	1.2 ± 0.7C
	APC	2.7 ± 0.2A	2.3 ± 0.5B	1.5 ± 0.6C
	Coliforms	0.5 ± 0.0A	0.5 ± 0.0A	0.6 ± 0.4A
Brisket	Mesophilic	2.8 ± 1.00A	2.1 ± 0.7B	1.5 ± 0.6C
	APC	2.9 ± 0.85A	2.4 ± 0.6B	1.5 ± 1.1C
	Coliforms	1.5 ± 0.96A	0.6 ± 0.3A	0.5 ± 0.0A

[1] Control: Samples taken after trimming and water wash before application of 2% lactic acid solution at 55 °C.
[2] RMSTC: Samples taken after applying the lactic solution using the traditional spray method in Rosenthal Meat Science and Technology Center.
[3] Sanitizing halo system: Samples taken after applying the lactic acid solution using the proposed spray system.
[a] The microbial counts expressed are mean values in Log cfu/100 cm^2
[z] Values within rows with same letter are not different (A, B, C), P>0.05

Table 9 - In plant validation of the sanitizing halo system for reducing bacterial numbers on beef carcasses

		Log cfu/100 cm^2 ± SD (N = 24)		
	Count[y]	Control	Sanitizing halo system [a]	Log Difference
Rump	Mesophilic aerobes	4.9 ± 0.9A[z]	2.2 ± 1.0B	2.7
	Total Coliforms	3.6 ± 1.2A	1.1 ± 1.1B	2.5
	E. coli	3.0 ± 1.4A	<1.0 ± 0.8B	>2.0
Clod	Mesophilic aerobes	4.3 ± 0.8A	2.2 ± 0.8B	2.1
	Total Coliforms	3.0 ± 1.1A	<1.0 ± 0.5B	>2.0
	E. coli	2.2 ± 1.3A	<1.0 ± 0.3B	>1.1
Brisket	Mesophilic aerobes	5.1 ± 0.7A	1.9 ± 0.9B	3.2
	Total Coliforms	3.7± 1.2A	<1.0 ± 0.5B	>2.7
	E. coli	3.2 ± 1.1A	<1.0 ± 0.0B	>2.2
Overall	Mesophilic aerobes	4.8 ± 0.8A	1.9 ± 0.9B	2.9
	Total Coliforms	3.4± 1.2A	<1.0 ± 0.7B	>2.4
	E. coli	2.8 ± 1.3A	<1.0 ± 0.4B	>1.8

[a] Beef carcasses sampled by the FSIS sponge method at the end of the processing line, before chilling

[y] The microbial counts expressed are mean values in Log cfu/100 cm^2

[z] Values within rows with same letter are not different (A, B), P>0.05

Table 10 - In plant validation of the sanitizing halo system for reducing bacterial numbers on pork carcasses

		Log cfu/100 cm^2 ± SD (N = 24)		
		Control	Sanitizing halo system	Log Difference
Jowl	Mesophilic aerobes	4.8 ± 0.3A[b]	2.8 ± 0.7B	2.0
	Total Coliforms	2.0 ± 0.8A	<1.0 ± 0.4B	>1.0
	E. coli	1.7 ± 0.8A	<1.0 ± 0.2B	>0.7
Ham	Mesophilic aerobes	4.1 ± 0.3A	2.4 ± 0.6B	1.7
	Total Coliforms	1.9 ± 0.9A	<1.0 ± 0.6B	>0.9
	E. coli	1.5 ± 0.7A	<1.0 ± 0.4B	>0.5
Bacon	Mesophilic aerobes	4.3 ± 0.5A	2.3 ± 0.6B	2.0
	Total Coliforms	2.2 ± 1.0A	<1.0 ± 0.3B	>1.1
	E. coli	2.0 ± 0.9A	<1.0 ± 0.2B	>1.0
Overall	Mesophilic aerobes	4.4 ± 0.4A	2.5 ± 0.6B	1.9
	Total Coliforms	2.0 ± 0.9A	<1.0 ± 0.4B	>1.0
	E. coli	1.7 ± 0.8A	<1.0 ± 0.3B	>0.7

[a] Pork carcasses sampled by the FSIS sponge method at the end of the processing line, before chilling

[b] Mean values within rows followed by same letter (A, B) are not significantly different (P>0.05)

Generic *E. coli* is the best indicator of fecal contamination. *E. coli* is commonly found in the intestinal tract of food animals. The intestinal tract is also primary pathway for contamination of meat and poultry with pathogens such as *E. coli* O157:H7, *Salmonella*, and *Campylobacter*. *E. coli* testing is required for all slaughterhouses inspected by FSIS. A relevant finding in this study was the difference in *E. coli* counts on beef and pork carcasses with or without applying lactic acid treatment utilizing the sanitizing halo system. As shown in Figure 10, 24 (100%) of 24 non-sprayed beef carcasses had *E. coli* counts ranging between 1.0 and 4.8 log CFU/100 cm^2 regardless of the carcass region sampled. In contrast, *E. coli* was found on only 2 (8.3%) of the samples taken from the clod, 6 (25%) of the samples taken from the rump and none of the samples taken from the brisket, after spraying with the sanitizing halo system
A similar situation was observed on pork carcasses. Again, all carcasses presented detectable counts of *E. coli* when not treated with lactic acid, only 6 (25%) samples taken from the ham, 1 (4%) from the belly and 1 (4%) from the jowl regions produced detectable *E. coli* on carcasses after applying the lactic acid treatment with the sanitizing halo. *E. coli* counts on samples taken from the rump (fig. 10) and from the ham (fig 11) were higher than the counts from the other two regions sampled. Lower counts were obtained on clod and brisket samples for beef carcasses, and jowl and bacon samples for pork carcasses. Rump and ham regions are the farthest from the floor. When applying the treatment with the sanitizing halo on the carcasses, a tilt in the dispersion angle was drawn as the sanitizing halo was going up. This inclination of the sanitizing halo on the

highest part of the carcass could affect the distribution of the lactic acid on the highest regions of the carcasses. The uneven dispersion of the lactic acid on the rump and the ham could cause that 25% of the beef and pork carcasses sampled had higher *E. coli* counts.

Results obtained after treating the carcasses with the sanitizing halo confirm that this tool can help small and very small slaughterhouses to demonstrate that the establishment is maintaining adequate process control for fecal contamination and sanitary operations.

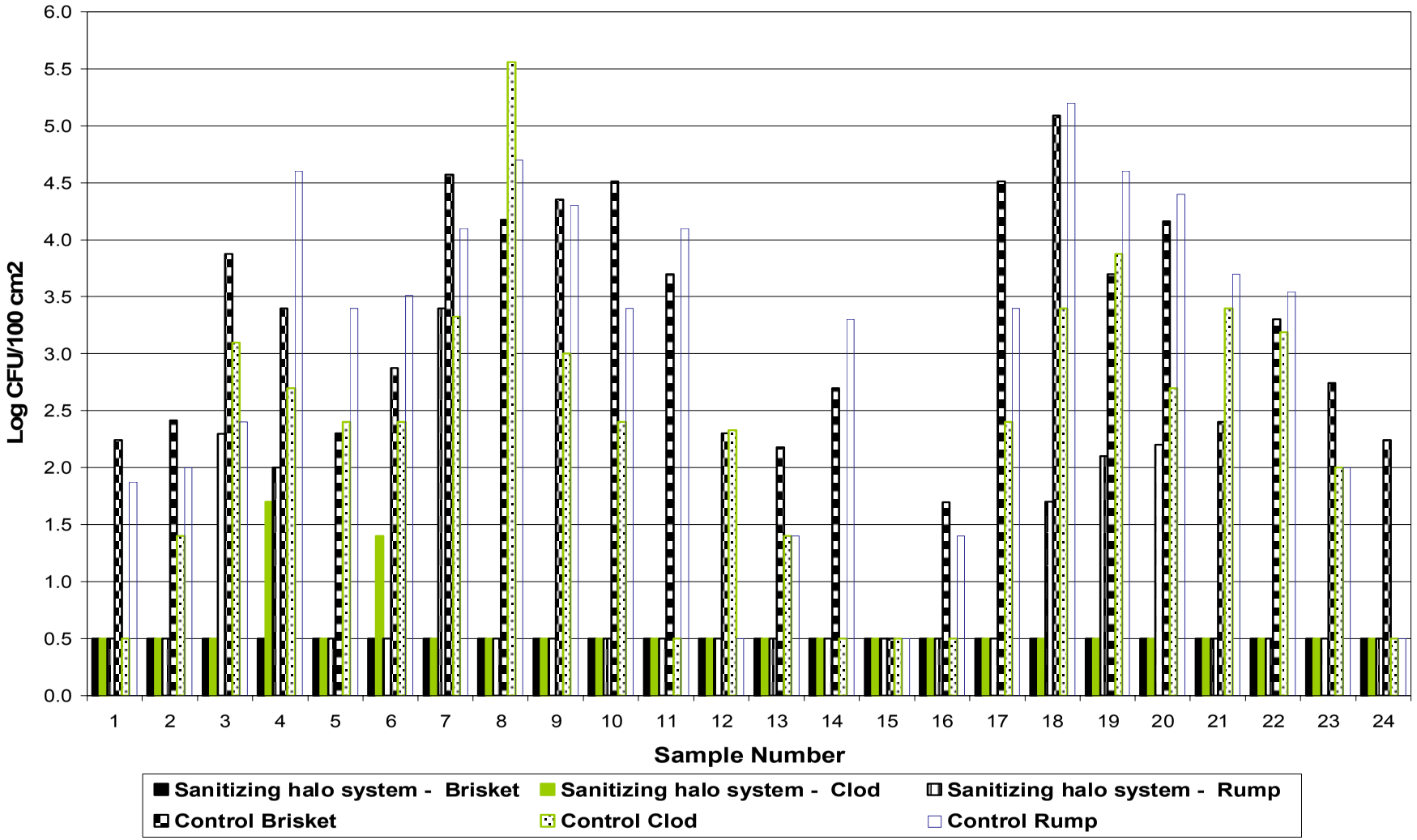

Figure 10 - Mean *E. coli* counts on beef carcasses after 2%L-Lactic acid treatment utilizing the sanitizing halo system at small slaughter plants in Texas.

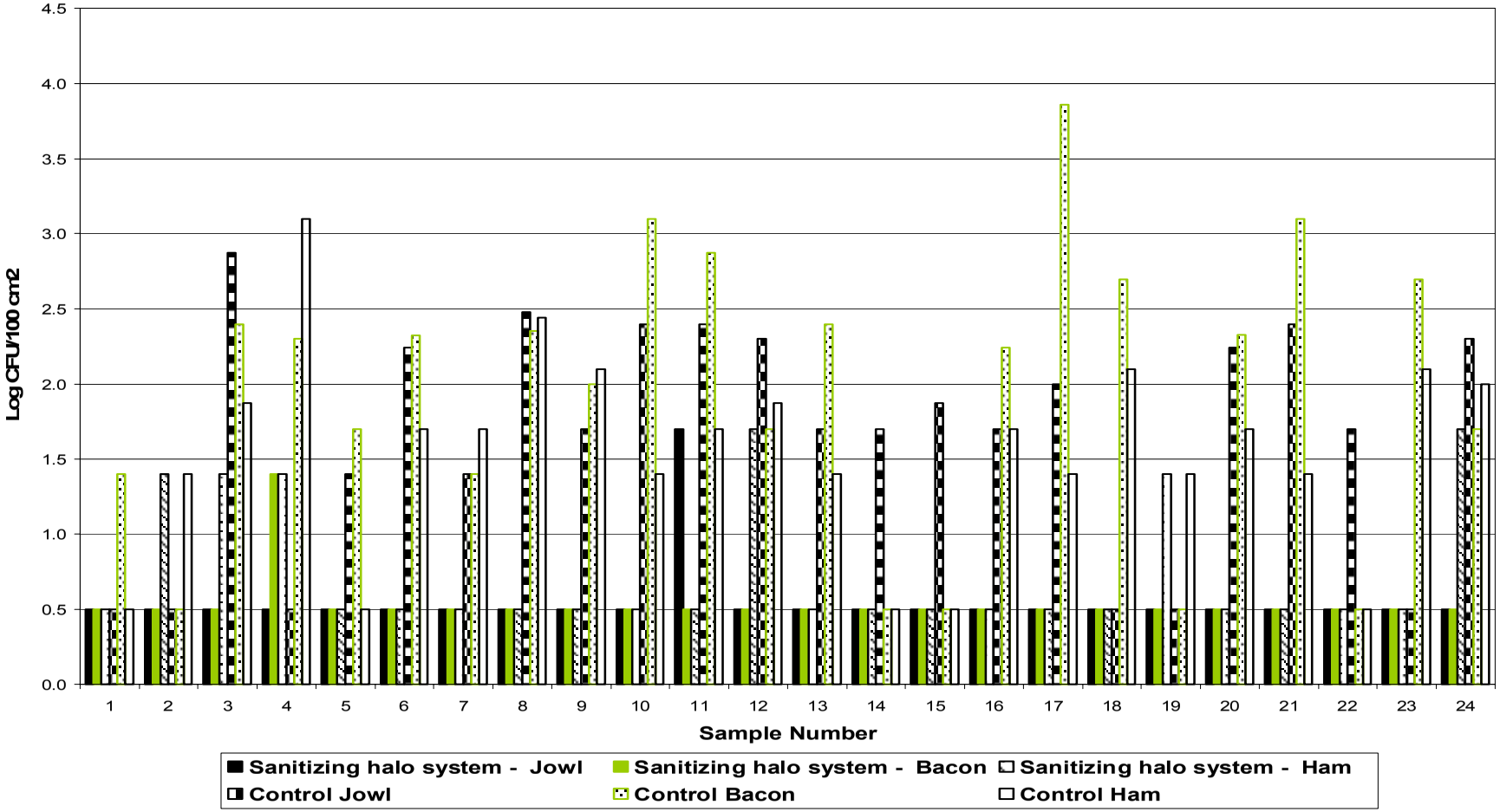

Figure 11 – Mean *E. coli* counts on pork carcasses after 2%L-Lactic acid treatment utilizing the sanitizing halo system at small slaughter plants in Texas.

CONCLUSIONS AND RECOMMENDATIONS

By investing just $286 and two days of labor, it is possible to assemble a reliable sanitizing system for beef and pork carcasses, which helps small and very small slaughterhouses to comply with food safety regulations yet providing cost efficiency, convenience, and simplicity.

Data collected at the implementation stage of the system at Rosenthal Meat Science and Technology Center, show that the proposed sanitizing halo system was effective at reducing coliforms, aerobic and mesophilic bacteria. Bacterial loads were reduced for the carcasses surface, verifying the even application of the spray achieved by using the sanitizing halo system. Furthermore, this reduction of bacterial load was corroborated after analyzing the data collected when the sanitizing halo system was taken to the slaughterhouses in Navasota and New Ulm, TX.

This system is an important tool that can help small and very small slaughterhouses to improve food safety performance by reducing bacterial populations and at the same time improving the microbiological quality of their products. However, care must be taken to encourage good hygiene before using this sanitizing halo system, or any other carcass sanitizing system, which are only complement and not substitute for required manufacturing practices.

Moving the sanitizing halo system around the different areas of the establishments is complicated. Kill floors at small and very small establishments have no space for a cart. Hoses, water, fat and meat pieces are other obstacles that make difficult the use of the cart. Instead of setting the sanitizing halo system in a cart, a

larger hose (size depends on the area of the killing floor) connecting the sanitizing halo system to the pumping system is recommended. This system can be also hung from a hook located strategically in one of the walls of the slaughter floor so it will not get contaminated by having contact with the floor.

The facilities where the sanitizing halo system was tested had hot water connections at the processing floor. The water temperature was approximately 60 C; this water can be used to prepare the L-Lactic solution before spraying the carcasses to apply adequately the treatment.

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APPENDIX

VIDEO SANITIZING HALO SYSTEM

This video shows how small establishments apply lactic acid rinses to sanitize beef carcasses utilizing a hand held sprayer. Also shows the inconsistency of this method and how some regions of the carcass are treated with different amounts of lactic acid solution. The video also shows the sanitizing halo system working at the implementation and validation stages.

The video file accompanies this thesis as a file available for downloading.

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