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DISSERTATION

INVESTIGATION OF MICROBIOLOGICAL COUNTS ON CARCASSES IN  
U.S. LAMB SLAUGHTER PLANTS AND DEVELOPMENT OF A MODEL HACCP  
PLAN FOR LAMB FEEDING, TRANSPORTATION, RECEIVING AND  
SLAUGHTERING/DRESSING

Submitted by

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In partial fulfillment of the requirements

for the Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

Summer, 1999

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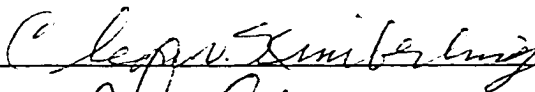
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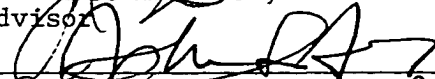
WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY STEPHEN BYRON LEVALLEY ENTITLED "INVESTIGATION OF MICROBIOLOGICAL COUNTS ON CARCASSES IN U.S. LAMB SLAUGHTER PLANTS AND DEVELOPMENT OF A MODEL HACCP PLAN FOR LAMB FEEDING, TRANSPORTATION, RECEIVING AND SLAUGHTERING/DRESSING" BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.


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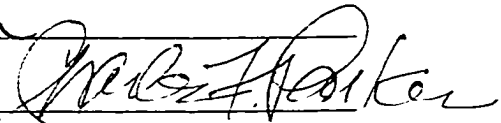
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## ABSTRACT OF DISSERTATION

### INVESTIGATION OF MICROBIOLOGICAL COUNTS ON CARCASSES IN U.S. LAMB SLAUGHTER PLANTS AND DEVELOPMENT OF A MODEL HACCP PLAN FOR LAMB FEEDING, TRANSPORTATION, RECEIVING AND SLAUGHTERING/DRESSING

Carcass microbiological counts (2,159 Total Coliform Counts and 2,146 Aerobic Plate Counts) were taken at six U.S. lamb slaughter facilities during Fall (September to November) and Spring (April to June) seasons. Microbiological sampling was at four carcass sites; the leg, loin, breast and axillary area of shoulder. Microbiological samples were obtained at four plant stations, Post-depelting; Pre-first wash (Station 1), Post-first wash; Pre-evisceration (Station 2), Post-evisceration; Pre-final wash (Station 3), Post-final wash; Pre-cooler (Station 4). Station and the Season by Station interaction had highly significant ( $P < .01$ ) effects on Total Coliform Counts. Total Coliform Counts increased significantly ( $P < .01$ ) between Post-first wash; Pre-evisceration ( $1.52 \log_{10} \text{CFU}/20 \text{cm}^2$ ) and ( $4.34 \log_{10} \text{CFU}/20 \text{cm}^2$ ) Post-evisceration; Pre-final wash. Seasonal effects were significant ( $P < .01$ ) for Total Coliform Counts at Post-depelting; Pre-first wash and nonsignificant at all other plant stations. Significant fixed effects for Aerobic Plate Counts included Station, Carcass Site and the Station x Carcass Site interaction. Aerobic Plate Counts increased ( $P < .01$ ) between Station 1 (Post-depelting; Pre-first wash) and Station 2 (Post-first wash; Pre-evisceration) and again between Station 2 and Station 3 (Post-evisceration; Pre-final wash). The lowest Aerobic Plate Counts were at the loin carcass site; Aerobic Plate Counts there were lower ( $P < .01$ ) than those from the leg, breast and axillary area of the shoulder at

Station 2. Initially low Aerobic Plate Counts on the loin carcass site reached levels comparable to those on the leg, breast and axillary carcass sites between Station 1 and Station 2.

Correlation coefficients between Total Coliform Counts, Aerobic Plate Counts and Chain Speeds (carcasses processed per hour) were calculated. There was a strong correlation (.863) between Total Coliform Counts and Chain Speed, but no apparent relationship between Aerobic Plate Counts and Chain Speed (-.058).

A HACCP-based plan was developed specifically for sheep slaughtering and dressing. Six Control Points (CPs) and three Critical Control Points (CCPs) were identified in the model HACCP plan. Critical Control Points for the model HACCP plan include final washing and/or bactericidal spraying (CCP-1), "Zero Tolerance" Inspecting (CCP-2), and Carcass Chilling (CCP-3). Critical Control Points were identified as areas along the process chain where measurable and effective interventions could be put in place with an expected reasonable degree of success in controlling what are primarily microbiological hazards.

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## DEDICATION

This dissertation and degree program are dedicated to my mother, Joann, whose long-term support and encouragement towards higher education will be appreciated forever. Secondly, to my wife Tracy and children for their support and encouragement.

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# CHAPTER I

## INTRODUCTION

During conduction of the National Sheep Quality and Food Safety Audit, Cunningham et al. (1994) identified a number of things in the packing sector that have the potential to cause economic losses to the industry and to increase human health risks. The majority of these concerns arise from carcass contamination that occurs during depelting and evisceration. Contamination is compounded by the conditions (dry vs wet; clean vs covered with manure or mud) in which lambs are received by abattoirs. When lamb carcasses are contaminated during slaughtering/dressing, FSIS inspectors require trimming and removal of areas of the carcass that are contaminated; trim-loss may amount to 1.3 to 2.25 kg per carcass. In some slaughter plants, virtually every lamb carcass sustains some amount of trimming, while in other operations, trim losses are minimal. Defining where contamination occurs on the slaughter line and what pre-existing conditions (on the live lamb) potentiate contamination problems will be the impetus for the development of HACCP programs for the lamb packing industry. Benefits from these efforts might include: (1) reduced loss due to contamination trim, (2) increased lamb product shelf-life, and (3) reduced human health risks. The present study is complementary to the USDA's pre-harvest pathogen reduction program and the "Zero Tolerance for contamination" policy.

Per capita consumption of domestic lamb has decreased from 2.2 kg per capita in the mid-1960s to 0.5 kg in 1998 (USDA AMS, 1998). As a consequence — perhaps — of its limited popularity of lamb as a food among U.S. citizens, research efforts to identify points of lamb carcass contamination during the slaughter and dressing phases of lamb processing

have received limited interest, particularly when compared to similar research efforts with beef and pork. Lamb distribution, until recently, has followed the traditional approach of fabrication of the carcass by the packer into wholesale or primal cuts and sale of those cuts to wholesale distributors and wholesale purveyors with limited interest in developing case-ready lamb products. Emphasis on standard cutting procedures rather than on use of muscle-boning and further processing of lamb products limited the attention paid by meat scientists to conducting research on value-added entrees/items. Recently, though, consumer demands for case-ready products and the concomitant need for longer shelf-life in such products have prompted investigation of interventions that will reduce microbial contamination during the slaughter and dressing process.

Implementation of the 1996 USDA mandatory HACCP rule directly signaled the need for increased emphasis on microbiological evaluation of pre-harvest and harvest, (slaughter and dressing) procedures/practices in current use by domestic lamb processors.

According to Smith (1998), consumers are acutely aware of product safety. In "Trends in the United States...Consumer Attitudes and the Supermarket 1998" (Food Marketing Institute, 1998), Product Safety (75%) ranked third behind taste, (89%) and nutrition (76%) in a nationwide survey of supermarket shoppers. By way of perspective, the concern about Product Safety ranked fourth in 1992, 1993, 1994 and 1995, and third in 1991, 1996, 1997 and 1998 (Food Marketing Institute, 1991, 1992, 1993, 1994, 1995, 1996, 1997 and 1998). The Food Marketing Institute (1998) asked supermarket shoppers "How important is food safety when you shop for food?" Seventy-five percent responded "Very Important," 18% said "Somewhat important," 5% said "Not too important," and 2% said "Not at all important" (Smith, 1998).

Based upon results of the supermarket-shopper surveys described above, confidence in the safety of the food supply is relatively stable. Nevertheless, microbiological testing of carcass and meat products should continue, not only to assure consumer confidence but also to compliment efforts of the Pathogen Reduction; Hazard Analysis Critical Control Point (HACCP) Systems; Final Rule (USDA FSIS, 1996).

This dissertation describes results of a carcass mapping study, funded by USDA-ES and conducted by scientists at Colorado State University, that was designed to identify those areas of the lamb slaughter and dressing process that contribute to carcass contamination. Six major lamb processors were cooperators in this study. Those six processors generate more than 90% of the annual domestic lamb slaughter. It was the intent of this study to identify specific carcass and plant sites where microbial contamination can be reduced. In addition, this dissertation describes development of a model HACCP plan for lamb feeding, transportation, receiving and slaughtering/dressing.

## CHAPTER II. GENERAL REVIEW OF LITERATURE

### MICROBIOLOGICAL INVESTIGATIONS OF LAMB CARCASS CONTAMINATION

Carcass contamination is primarily determined by the skill with which workers remove the pelt or hide and the gastrointestinal tract (Gill, 1995). Bacteria capable of causing either disease or meat spoilage can be inadvertently transferred to previously sterile edible tissue during the slaughter and dressing of lambs and concurrent with the breakdown of carcasses (Grau, 1986). Bacterial contamination associated with slaughter, dressing and handling of carcasses has been studied by previous investigations (Empey and Scott, 1939; Ayres, 1955; Fournaud et al., 1978; Newton et al., 1978; Patterson and Gibbs, 1978a;

Kelly and Lynch, 1980; Nottingham, 1982; Brown, 1982; Kraft, 1986; Rao and Ramesh, 1992; Biss and Hathaway, 1995; Kochevar et al., 1997; Hadley et al., 1997).

In normal healthy animals, most of the tissues which are destined to become meat or meat products are sterile (Nottingham, 1982). During the slaughter and dressing process all potentially edible tissues are subject to contamination from a variety of sources within and on the outside of the animal (Ayres, 1955). The inadvertent contamination of carcasses from red-meat animals has emerged in the last decade, as the most important aspect of meat inspection and meat hygiene in modern meat production systems (Hathaway and McKenzie, 1991; Mackey and Roberts, 1993; Snijders et al., 1993; Hathaway, 1993). The hide, fleece and gastrointestinal tract are recognized as the principal sources of contamination on or within a carcass (Newton et al., 1978; Eustace, 1981; Mackey and Roberts, 1993; Huis in't Velt et al., 1994). Activities on the slaughter floor, particularly those associated with removal of the pelt and the gastrointestinal tract, are the principal methods by which contamination is transferred to previously sterile tissue (Eustace, 1981; Roberts et al., 1984; Mackey and Roberts, 1993; Biss and Hathaway, 1996).

A study conducted by Bell and Hathaway (1996) revealed that line workers' hands and knife blades were also a significant source of contamination. Similar results were reported by Patterson (1967). Bell and Hathaway (1996) also ranked major slaughter-line bacterial contamination in an increasing order of significance as knife blades, fecal pellets, workers' hands and wool fleeces, noting that contamination from both knives and workers' hands (suitably protected from direct contact with hot water) can be significantly reduced with immersion in 82°C water. Nottingham (1982) also states that commercial slaughter practices have evolved from an individual process (one man, one animal) to labor-intensive chain systems where every carcass is handled repeatedly. Any efficiencies realized by a

modern chain processing may be nullified by increased handling and subsequent carcass contamination (Nottingham, 1974). Field et al. (1991) reported that lamb carcasses that were depelted mechanically as opposed to dressed by hand exhibited significantly lower contamination on the hind legs but were similarly contaminated on the shoulders where hand work is necessary.

Numerous studies that relate to pre-slaughter condition of the hide and fleece are simply summarized by Nottingham (1982) in that it is very difficult to obtain a clean product from dirty animals. Hadley et al. (1997) in a study designed to investigate fleece soiling and skinning methods, on the microbiology of sheep carcasses, reported that the condition of the fleece significantly affected the microbial load on the dressed carcass. On a scale of 1-5 (1 = clean and dry; 5 = wet and muddy), carcasses derived from sheep with increasingly dirty fleeces carried up to 1000 times more microorganisms, and a higher proportion of the carcasses were contaminated with *Enterobacteriaceae*. This study is in agreement with Leach (1971), Patterson and Gibbs (1978a), who considered wet animals to be more of a hygiene risk than dry animals.

Empey and Scott (1939) found that the microbiological population of a dry hide may increase by five to ten times with the addition of sufficient moisture. Sources of moisture could come from within the slaughter floor environment and from efforts to wash the carcasses. A study conducted in a modern Indian abattoir by Rao and Ramesh (1992) also acknowledges that the skin or fleece of sheep are heavily contaminated with bacteria. Rao and Ramesh (1992) reported Total Plate Counts of  $7.5 \log/\text{cm}^2$  on sheep fleeces. These microbial counts are consistent with those measured on sheep fleeces by Grau (1986). Of the many studies reviewed by Bell and Hathaway (1996) including those of Patterson (1967; 1968a,b; 1970; 1972), Nottingham (1979), Kelly and Lynch (1980) and Roberts (1980), a

general trend appears concerning sheep and lamb carcass contamination. Roberts (1980) states that in the past 25 years there has been little, if any, increase in the general hygiene quality of sheep and lamb carcasses. This statement would imply that pre-slaughter presentation, in terms of the presence of potential contamination from the hide or fleece has realized little improvement. Practically all researchers acknowledge the importance of heavy microbial pre-slaughter condition on subsequent microbial counts on carcasses but have few answers to alleviate the problem.

There appears to be some difficulty in reviewing and making valid microbiological comparisons between slaughter procedures, as noted by Ingram and Roberts (1976). A review of various studies connected with pre-slaughter washing and partial animal shearing by Biss and Hathaway (1996) in four slaughter plants, revealed that total aerobic bacteria counts and *Escherichia coli* counts were greater on carcasses which had been washed before slaughter. Pre-slaughter washing has been adopted in New Zealand as an effective method of reducing the visible contamination on carcasses (Peterson, 1978). Bacteria counts were higher on lamb carcasses with long wool as opposed to shorn lambs; there was less visible contamination reported on the carcasses of washed lambs than on those of unwashed lambs (Peterson, 1978). Biss and Hathaway (1996) concluded that the use of pre-slaughter washing to compensate for poor pre-slaughter presentation increased microbial loads on the lamb carcasses sampled. Biss and Hathaway (1996) also studied the effects of the presence of either wool or fecal material visibly present on lamb carcasses. They concluded that the presence of fecal material or wool alone should not be used as an indicator of the overall hygiene of the carcass. Also concluded from this study was that the microbiological effect

of visible contamination was limited to the area in which it was visibly noted; this is consistent with results of studies conducted by Kochevar et al. (1997).

Biss and Hathaway (1996), in a separate study to investigate partial and significant shearing in the hind leg area, found that both microbiological and visible contamination were increased with the shearing efforts. Although the increases were minor for bacterial loads, wool contamination was significant. These findings are consistent with crutching or removal of wool around the anal area, as reported by Roberts (1980).

Currently, several lamb slaughter facilities within the U.S. have converted from the domestic industry standard of a vertical carcass dressing system (lamb carcasses are processed secured to the chain by their hind legs) to an inverted system (carcasses travel along the chain suspended ventral side up by all four legs). Bell and Hathaway (1996) compared conventional and inverted dressing systems and concluded that reduced microbial counts favored the inverted system. Microbiological contamination from sheep that were shorn, clean and unwashed was five times lower [3.9 log colony forming units (cfu/cm<sup>2</sup>)] than those (4.6 log cfu/cm<sup>2</sup>) from sheep identified as wooly, dirty and washed. The latter findings are consistent with those of Longdell (1992). The inverted line dressing system was primarily introduced to reduce labor costs (Longdell, 1992) and is also designed to limit hindquarter handling of each carcass by eliminating hand operations of cleaning or initiation of skinning on the hind legs. Additionally, the inverted system eliminates the hand depelting process referred to as "fisting." The conventional dressing process is designed to fist or hand remove the pelt from the hindquarters to the shoulders and necessitates significant worker, pelt, carcass contact (Bell and Hathaway, 1996).

Presently, within-plant carcass decontamination technologies permitted by FSIS in the United States include: (a) steam vacuuming; (b) carcass washing by hand or pressurized cabinet which may be followed by rinsing with an organic acid solution; (c) final washing/spraying of carcasses with water or solutions of chlorine (20-50 ppm) or organic acid solutions such as acetic, lactic and citric (1.5-2.5%); food grade trisodium phosphate (8-12%) or hot water ( $>74^{\circ}\text{C}$ ), and (d) applications of pressurized steam following spray washing (Sofos and Smith, 1998).

Under practical conditions of sheep slaughter and subsequent dressing, it is difficult to prevent microbial contamination on the carcass (Kelly et al., 1981). Researchers from various scientific communities have studied spray wash intervention systems throughout the dressing phase of sheep processing. In some cases, these investigations have reached virtually opposite conclusions. Previous investigators have reported considerable differences with respect to the effects of spray washing on microbial numbers present on the surface of sheep carcasses. Patterson (1968b) found that washing sheep carcasses with hot ( $80^{\circ}\text{C}$ ) water did not reduce microbial numbers. Later, with beef carcasses, Patterson (1970) found that spray washing cattle carcasses with water at  $80\text{-}90^{\circ}\text{C}$  reduced bacterial numbers at the brisket from  $\log_{10}$  4.58 to 3.69. Bailey (1971) reported that reductions in microbial numbers were obtained by spray washing lamb carcasses with  $15^{\circ}\text{C}$  and  $63^{\circ}\text{C}$  water. Smith and Graham (1978) reported that total immersion of sheep carcasses in water at  $80^{\circ}\text{C}$  for 10 s reduced bacterial counts from  $\log_{10}$  3.93 to 2.49/cm<sup>2</sup>. Previous studies by Bailey (1971) indicated increased reductions in bacterial numbers as the chlorine levels in spray washes were increased up to 357 ppm.

Ellerbroek et al. (1993) conducted a study to evaluate microbial assessment of post-evisceration spray washing. The latter investigation sampled various sites on lamb carcasses immediately after skinning including dorsal mid-line, brisket, hindquarter, fore quarter and the head. Concluded from the Ellerbroek et al. (1993) study was that spray washing leads to bacterial contamination of the dorsal area of the sheep, a site less likely contaminated by workers or the dressing process. Areas where contamination was highest (ventral areas of the carcass) microbial contamination was not reduced by spray washing. Finally, Ellerbroek et al. (1993) concluded that overall spray washing does not improve microbiological contamination levels of sheep carcasses. Cold water (12°C) was used in this study over a 20 s period of time at a pressure of 6 bar (Ellerbroek et al., 1993).

A study conducted by Kelly et al. (1981) investigated the effect of temperature, pressure and chlorine concentration of spray washing on bacterial contamination on lamb carcasses. The combined analysis of the results in this study indicated that reductions in bacterial numbers greater than  $\log_{10} 0.5/\text{cm}^2$  were obtained only when the temperature of the water used for spray washing exceeded 57°C, while temperatures equal to or higher than 80°C were required to realize reductions of equal to or more than  $\log_{10} 1.0$ . Chlorine levels of 30 ppm reduced bacterial numbers by  $\log_{10} 0.66/\text{cm}^2$ , increasing the chlorine concentration to 450 ppm only reduced bacterial numbers by an additional  $\log_{10} 0.29$ . Pressure did not appear to be a factor regardless of which combination of temperatures and spray wash concentration were used.

Recently, a spray wash project on lamb adipose tissue by Kochevar et al. (1997) found results similar to those of Kelly et al. (1981). Lamb adipose tissue from the brisket area was treated with fecal material containing a known strain of *Escherichia coli* (ATCC

11370). Consistent with findings of Kelly et al. (1981), the effect of water pressure was considered a non-factor in this experiment. Kochevar et al. (1997) found that spray washing with any temperature and pressure combination reduced visible fecal contamination. More importantly, bacterial reductions of from 12.48 to 3.83  $\log_{10}$  cfu/cm<sup>2</sup> were realized at the inoculation site. High temperature (74°C) water was more effective in decreasing bacterial counts than were water temperatures of 16 and 35°C. The use of 2% acetic acid reduced bacterial counts more than did use of 12% trisodium phosphate, 5% hydrogen peroxide or .003% chlorine. Kochevar et al. (1997) concluded that water temperature and acetic acid were the most important factors in reducing fecal contamination. Another important question answered by the Kochevar et al. (1997) study involved movement of contamination on a carcass by spray washing. Kochevar et al. (1997) reported that there was no measurable spread of inoculated fecal material to adjacent sites on the carcass. The overall effect of spray wash findings by Kelly et al. (1981) and Kochevar et al. (1997) appear to be contradictory with findings by Ellerbroek et al. (1993); however, the cold water temperature used by Ellerbroek et al. (1993), may have led to their conclusions concerning the minimal effects of spray washing of sheep carcasses on reductions in bacterial contamination.

A large if not unanimous number of researchers that have investigated contamination within lamb slaughter plants have identified pre-slaughter fleece condition as a major factor in subsequent plant and carcass contamination. There also appears to be very little research in the scientific literature that would offer solutions to the very important concept of pre-slaughter hide or pelt contamination. It does appear that, world-wide, one of the major sources of sheep and lamb slaughter contamination has been identified, but real solutions appear to be forthcoming.

## HISTORY AND DESCRIPTION OF HACCP

Federal meat inspection was instituted in the U.S. in 1906 in reaction to wide-spread concern about meat safety among U.S. consumers and because some European traders were refusing to accept meat from the United States because of its poor condition (Adams, 1990). For the next 80 years, the government branch responsible for meat inspection, which had evolved in the current U.S. Department of Agriculture (Food Safety and Inspection Service - FSIS), relied upon its organoleptic carcass-by-carcass inspection program to assure meat and poultry safety (USDA FSIS, 1995). The primary goals of FSIS inspection programs are to prevent adulterated or misbranded animals and products from being sold as food, and to ensure that meat and poultry are slaughtered and processed under sanitary conditions (Rawson, 1998). Uninspected and condemned products cannot be sold for human consumption (Rawson, 1998). FSIS requirements also apply to intrastate commerce and to imports from foreign countries which have equivalent inspection systems (Rawson, 1998). Rawson (1998) further states that USDA-FSIS has more broad-based requirements and expectations that include the following items: (A) Plant Sanitation: No meat or poultry establishment can slaughter or process products for human consumption until FSIS approves, in advance, its plans and specifications for the premises, equipment and operating procedures. After FSIS approval, a specific plant must continue to follow a detailed set of rules that may cover lighting, ventilation and water supply, the hygiene of equipment and employee sanitation procedures; and (B) Slaughter Inspection: FSIS must inspect all meat and poultry at slaughter on a continuous basis. An inspector must be on hand to inspect each carcass during the slaughtering and dressing process. Inspectors conduct both antemortem and postmortem evaluations (Rawson, 1998).

The HACCP system of food safety was first used by the Pillsbury Company in the 1960s to produce the safest food possible for astronauts on extended-duration space missions (Sperber, 1991a). Also of concern to the National Aeronautics and Space Administration (NASA), was potential contamination from metal, glass and other chemicals that could affect the electronic operation of a spacecraft (Vail, 1994).

During the early 1980s, FSIS asked the National Academy of Sciences (NAS) to consider a science-based approach to food safety (Adams, 1990). Subsequently, the National Academy of Sciences issued a series of reports outlining an alternative method to ensuring the safety of meat and poultry products (NAS, 1985a; NAS, 1985b). The Hazard Analysis and Critical Control Point (HACCP) concepts emerged as the recommended scientific-based food safety system. The Hazard Analysis and Critical Control Point (HACCP) system was first described in detail at the Food Protection Conference (Anonymous, 1971). HACCP, simply stated, is a process control system that identifies where hazards might occur in the food production process and puts into place stringent actions to prevent the hazard from occurring.

The roots of the modern day HACCP system had its origin with the philosophies of W. Edward Deming's "Principles of Total Quality Management" (TQM). Deming was trained as a statistician and assisted the Japanese in post-World War II efforts of reconstruction. A number of manufacturing companies, world-wide, began to pursue the TQM system to try to match the Japanese in efficiency and quality in mass production of various materials and products (Sperber, 1991b).

In 1985, a National Academy of Sciences subcommittee recommended that the HACCP approach be adopted by regulatory agencies (NAS, 1985a). This recommendation

led to the formation, in 1987, of the National Advisory Committee on Microbiological Criteria for Foods (NACMCF). The NACMCF expanded the HACCP protocol from the three original principles to seven (Sperber, 1991a).

Following a 1993 foodborne outbreak of *Escherichia coli* 0157:H7 where hundreds of people became ill and four children died, the Clinton administration organized the President's Food Safety Initiative which reinstated the driving force behind HACCP (Rawson, 1998). In 1996, FSIS developed new requirements for meat and poultry processing facilities to improve food safety and ultimately to modernize the 90-year-old USDA meat and poultry inspection system (Rawson, 1998). The USDA FSIS (1996) legislation consisted of two parts; (a) Pathogen Reduction; Hazard Analysis and Critical Control Point Systems; Final Rule (PR; HACCP; FR) and (b) the Sanitation Standard Operating Procedures and Generic *E. coli* testing parts of the PR; HACCP; FR (1996) which went into effect in January, 1997. The all-encompassing legislation of the PR; HACCP; FR, more commonly known as the "Mega-Reg" also required *Salmonella* testing and the implementation of in-plant HACCP systems that had effective dates of January 1998, 1999 or 2000 for large, medium and small plants, respectively (USDA FSIS, 1996).

According to Smith (1998), since implementation of the PR; HACCP; FR as a USDA FSIS (1996) regulation in the 312 largest meat plants, numerous industrial and technological innovations and most of their original scientific – HACCP programs have remained in place; and, as a result, beef carcasses are many-fold cleaner and safer than they were a decade ago. It is assumed that similar efforts in the lamb industry will also result in significantly cleaner and safer lamb products for the American consumer.

The Hazard Analysis and Critical Control Point (HACCP) system has been defined by the National Advisory Committee on Microbiological Criteria for Foods (NACMCF) as “a systematic approach used in food production and a means to assure food safety that is relevant to all phases of the food chain from preharvest, harvest, processing, manufacturing, distribution and merchandising to preparation, and ultimately to consumption. The NACMCF (1992) has further outlined seven principles that are the framework for successful HACCP programs. Bauman (1990) explains HACCP as a system that can be used to monitor and control any area or point in a food production system that potentially could contribute to a hazardous situation. Included among these hazards could be contaminants, microorganisms, raw materials, a specific process, distribution, storage or even preparation directions to the consumer.

Archer (1990) states that the complexity of today’s food system even further dictates the need for HACCP by recognizing that some foods within the United States are being produced without sufficient barriers to microbial contamination and growth.

Internationally, Baker (1995) states that HACCP, in the initial stage of food product development, allows for the assessment of risk and severity of hazards, and that hazards may be associated with the raw materials used, their processing, the system of distribution and the intended use. Implementation of a HACCP plan provides a mechanism to ensure that product safety is continuously achieved. HACCP can assist with, and provide a method to demonstrate and document that, government, company and product safety objectives are continuously achieved. The HACCP approach to minimizing microbiological contamination should replace or minimize costly and less effective inspection processes and/or end-product testing that currently exists in the U.S. lamb industry. A well-designed HACCP plan will

thoroughly analyze the entire production process so that in any one particular location where a safety hazard might occur or exist, precautionary actions and activities have been identified.

The NACMCF (1992) has very simply outlined certain definitions and principles as measures which eliminate or limit the risk from a potential hazard as a primary goal of HACCP development plans. Preventive measures are implemented at Critical Control Points (CCP) where a potential Hazard associated with a food or food material, environmental location, manual procedure or mechanical process can be controlled. Critical Control Point parameters are described by a Critical Limit and a target value with desired or acceptable Control Limits. A Critical Limit differentiates things that are acceptable vs. unacceptable. HACCP plans require that CCPs are monitored. Deviations above or beyond Critical Limits would initiate Corrective Actions as described in the HACCP plan. Critical Limits as described in the HACCP plan, should be tested on a regular basis to apply Verification to the control operation. HACCP plans require very specific Record Keeping systems to ensure, over time, process Verification.

The Hazard Analysis Critical Control Points (HACCP) system is described by seven principles (NACMCF, 1992); a brief overview of the HAACP system follows while extensive detail about HACCP is provided in Appendix B.

Principle I. Conduct A Hazard Analysis: Principle 1 outlines the need to prepare a product/process flow diagram that lists the steps in the particular lamb processing facility where significant Hazards can or do occur. Principle 1 helps to identify where the HACCP team in a lamb facility should start to develop its HACCP plan.

Principle 2. Identify The Critical Control Points (CCPs): Following compilation of a

description of all known or potential Hazards the HACCP team can establish where points of control are located that are Critical Control Points (CCP) for managing the safety of the lamb products.

Principle 3. Establish Critical Limits For Preventive Measures Associated With Each Identified CCP: The Critical Limits describe the difference between safe vs. hazardous product at the CCP. Critical Limits must be measurable parameters.

Principle 4. Establish CCP Monitoring Requirements: Specific Monitoring requirements are addressed in Appendix 1 for Critical Control Points 1 and 2. These Monitoring requirements are daily or hourly.

Principle 5. Establish Corrective Actions To Be Taken When Monitoring Indicates A Deviation From the Established Critical Limit: The HACCP team must establish procedures which, from the results of monitoring, can be implemented to adjust the process and maintain control at the Critical Control Point. Specific Corrective Action procedures and the specific person on the HACCP team that is responsible for these actions must be documented. An action plan should be available to bring back under control, a process that is outside the Critical Limits.

Principle 6. Establish Procedures For Verification That The HACCP System Is Working Correctly: Verification procedures, statistical or otherwise, must be developed to maintain the HACCP system and to provide continuity to a dynamic process.

Principle 7. Establish Effective Record Keeping Procedures That Document the HACCP System: Recognizing that lamb plant operations must have records available for governmental inspection documentation is a key step in developing successful HACCP plans.

Mortimore and Wallace (1994) outline in a very logical manner the justification for implementation of HACCP. Following their outline and topic heading sequence, a discussion of justification for HACCP system implementation is presented below:

1. *Management of Product Safety*

The number one goal of a food-producing company must be product safety. Responsibility for food safety must occur at every stage of the production system. Vail (1994) believes that, as with any other food safety program documentation, good intentions will not provide food protection — only commitment by the people will. HACCP systems are only as good as the commitment of the personnel implementing and managing the programs. Successful implementation of a HACCP system begins with executive management commitment, particularly that of the president or chief executive officer; without such commitment, HACCP is “just another paper program” with little or no importance in daily operations.

2. *Government and Enforcement Authorities*

The PR; HACCPs; FR (USDA FSIS, 1996) detailed in the Code of Federal Regulations (CFR) specified that all plants must develop, adopt and implement a HACCP plan for each of their processes. To be effective, HACCP-based process control must be combined with objective means of verifying that meat and poultry plants are achieving acceptable levels of food safety performance (USDA FSIS, 1996). FSIS requires all slaughter plants to conduct microbial testing for generic *E. coli*. The testing requirement was effective six months after publication of the Final Rule (which occurred in 1996), and is intended to assist plants in maintaining adequate process control for fecal contamination. FSIS established verification performance criteria that reflect the prevalence and levels of

contamination with *E. coli* on carcasses in comparison to levels of that microorganism in FSIS baseline surveys. Beyond the mandatory PR; HACCPs; FR dictates are government expectations for safe handling beyond the plant. The implications for distributors, for employees in retail stores and restaurants, and for consumers will expand.

### 3. *Consumers*

Trends in the United States — Consumer Attitudes and the Supermarket, 1998 (Food Marketing Institute, 1998) reported that 75% of consumer respondents view product safety as “very important.” This level of response has differed little, up or down by less than 7%, since the survey began. It can be expected that the concern by consumers for food safety probably will not deviate much over time.

### 4. *Media*

The lamb industry, by virtue of its small size and limited stature among others in the red meat industry, has largely escaped the mass media scrutiny placed on the beef industry. The U.S. lamb industry is potentially susceptible to negative mass media scrutiny, and the outcome from even one isolated instance of a compromise in product safety could be devastating.

### 5. *International Standardization*

While the U.S. industry is a net importer in terms of total tonnage of lamb and mutton, offal products from those animals are exported internationally (USDA AMS, 1999). Kidneys, hearts and livers from lambs and mutton are exported to Mexico and several middle eastern countries. Since the first HACCP concepts were introduced by Pillsbury, these principles for assuring meat safety have been accepted internationally. Through international trade agreements, such as NAFTA, GATT and those with WTO, it appears that the U.S. will

continue to have an interest in the international trading of red meat. Functional HACCP programs throughout the domestic sheep industry will position lamb for more significant export consideration.

USDA has targeted a 25% reduction in foodborne illness attributed to meat and poultry by the end of the year 2000 (Buntain, 1998). Preharvest strategies to reduce contamination and microbiological interventions by livestock producers must become an integral part of this lofty USDA goal. Hancock and Dargatz (1996) outlined the justification for considering preharvest control of foodborne agents in that, one or more livestock species are the reservoirs for several of the most important foodborne disease agents, (*Salmonella*, *Campylobacter* and *Listeria*) and stated that, in controlling any infectious disease, one considers control at the reservoir level if possible. The Hancock and Dargatz (1996) evidence that livestock serve as a reservoir for foodborne agents is three-fold:

1. Exposure studies which have epidemiologically linked consumption of animal-origin foods to specific foodborne diseases in humans.
2. Isolates of potential foodborne pathogens (*Salmonella*, *E.coli* 0157:H7, *Campylobacter* and *Listeria*) obtained from livestock have been found to share indistinguishable genetic fingerprints with those found in human foodborne disease cases.
3. Major foodborne agents harbored by livestock seldom produce signs of disease in livestock which would be observed during antemortem or postmortem inspection.

Current HACCP regulations are only one piece of the entire red-meat matrix of procedures/programs for ensuring safety. Cross (1996) states that, once the product leaves the plant and the site of the HACCP plan, it is still the responsibility of the wholesaler,

retailer and consumer to properly handle, store and cook the product to make it safe and, while the slaughter and processing sector of the meat industry is important, the present HACCP regulations are not an all-encompassing, farm-to-table guarantee of food safety. Cross (1996) says that FSIS recognizes that to improve the overall food safety chain, animal production at the farm level and at intermediate stages before slaughter (e.g., the sheep feedlot) must be further investigated to identify significant sources of contamination. Alliances with industry, academia and other government agencies will be needed to assure food safety emphasis in all sectors of the entire animal/meat production system. Proper presentation of sheep for slaughter has prompted the Sheep Meat Council of Australia (1996) to define essential elements in the preparation, presentation and transportation of sheep and lambs. Discounts or refusal of livestock are penalties recommended for poor presentation of live sheep (Sheep Meat Council of Australia, 1996). In the United States, use of bedding (such as straw and forage aftermath) has gained popularity as a strategy for reducing pelt contamination. These bedding treatments may have further ramifications relative to microbial quality of carcasses and offal in the processing plant.

FSIS presently does not intend to mandate production practices at the farm level that may be concerned with up-line product safety (Buntain, 1998). But, voluntary on-farm quality assurance programs and production practices based on HACCP principles will contribute to overall food safety. Eventually, performance standards for animal presentation may reach the farm level. Potential discounts invoked by packers and processors will accelerate food safety interest at the farm level. Total Quality Management (TQM) and even the basic awareness of live animal Quality Assurance (QA) programs/principles have made inroads in the beef industry and are imminent scenarios for sheep producers in the United

States. The slogan “Food Safety From Conception to Chops” should be well-suited for use by the domestic sheep industry as it seeks to improve consumer perceptions of its products.

Current research efforts funded by USDA-FSIS and the American Sheep Industry (ASI) and being conducted at Colorado State University, directed toward Sheep Pathogen Reduction, reveal the extent of interest of several entities in the investigation of preharvest interventions to improve the microbiological quality of lamb and lamb products.

### CHAPTER III. INVESTIGATION OF MICROBIOLOGICAL COUNTS ON CARCASSES IN U.S. LAMB SLAUGHTER PLANTS

#### INTRODUCTION

The National Sheep Quality Assurance and Food Safety Audit (Cunningham et al., 1994) was an investigation of the sheep production system from birth through case-ready product. On-site visits were conducted with range and farm flock producers, lamb feeders, packers and purveyors. During the two-year audit, it became apparent that one of the key areas of the sheep production system, although it involves a small number of entities, is the slaughter/processing sector. In 1992, six US lamb packers processed in excess of 85 percent of the domestic lamb produced in this country (USDA AMS, 1992). Lamb packers and processors are a critical link in the sheep production system.

Grau (1986) states that bacteria causing either disease or meat spoilage can be inadvertently transferred to previously sterile edible tissue during the slaughter/dressing and breakdown of carcasses. It was then logical, to conduct a microbiological audit to identify slaughter/dressing procedures that could contaminate otherwise sterile lamb tissue. A review of previous investigations of lamb carcass contamination, particularly that of Biss and Hathaway (1995) indicated a need to identify specific carcass sites and locations within each plant as sources of potential carcass contamination. The carcass mapping plan for each plant

location and carcass site was consistent across plants. Although each plant from which microbiological samples were obtained was unique in design and construction, plant sampling locations were as nearly the same as possible. The primary objective of the carcass/plant mapping project was to (a) identify sources of contamination; (b) isolate those factors which cause contamination; and (c) correct actions which cause contamination either pre- or post-slaughter.

Purcell (1991) states that the primary need in revitalizing the demand for lamb is in the form of product and market development, focusing on offering a product that meets current and changing consumer demands, that is convenient to prepare and use, and which fits the 1990s perception of a safe, healthy diet. It is with regard to assuring safety of the product that this study is directed.

## MATERIALS AND METHODS

Six major lamb packing facilities in the U.S. participated in carcass microbiological mapping/plant audits to investigate Total Coliform Counts and Aerobic Plate Counts. A total of 4,305 carcasses were sampled; 2,146 Aerobic Plate Counts and 2,159 Total Coliform Counts were obtained. Carcasses were sampled during both Fall (September - November) and Spring (March - May) seasons. Samples were obtained from the surfaces of randomly selected carcasses passing through a conventional sheep carcass slaughtering/dressing process. Four sites were sampled on each carcass: (a) center of leg, (b) center of loin, (c) breast area and (d) axillary area of shoulder (Figure 3.1). Carcass samples were obtained from four stations within each plant (Figure 3.2). The four stations were consistent across plants and included: Station 1 (Post-depelting; Pre-first wash); Station 2 (Post-first wash; Pre-evisceration); Station 3 (Post-evisceration; Pre-final wash); and Station 4 (Post-final

wash; Pre-cooler). Carcass samples were obtained using the Petrifilm™ Plate, (3M™ St. Paul, MN) to determine Total Coliform Counts and Aerobic Plate Counts.

Per manufacturer's directions, Petrifilm™ plates were hydrated (1 ml .1% peptone and sterile water) prior to use. Carcass samples were obtained throughout a one-day period of time during both Fall and Spring seasons. The number of carcasses sampled from each plant was predetermined to be approximately 15% of the daily kill. The direct contact method, as described by 3M™ Petrifilm manufacturer's directions, was used to sample carcasses. Samples were then immediately chilled to 2-8°C and transported to the laboratory for incubation at 32-35°C for 24-48 h for Total Coliform Counts and at 32-35°C for 48 h for Aerobic Plate Counts.

All bacteria counts were transformed to  $\log_{10}$ . Analyses were performed using the Mixed Model Procedure of the Statistical Analysis System (SAS, 1996) and used to partition and identify variance factors (Table 3.1). Due to the uniqueness of each lamb facility in terms of size, geographical location, level of automation, and source of lambs, plant was identified as a random effect in the analysis model. Season, station, carcass site, and combinations (as two-way and three-way interactions) of those factors were analyzed as main effects in the model (Table 3.1).

## RESULTS AND DISCUSSION

Total Coliform Counts: Results of least squares analysis of variance for 2,159 Total Coliform Counts are presented in Table 3.1. Station and the Season by Station interaction were highly significant ( $P < .01$ ) sources of the observed variability in Total Coliform Counts (Table 3.1). Least squares means for station are reported in Table 3.2 and Figure 3.3. There were no significant differences ( $P < .01$ ) in Total Coliform Counts between Stations 1 (Post-depelting;

Pre-first wash) and 2 (Post-first wash; Pre-evisceration) but there were highly significant increases ( $P < .01$ ) in Total Coliform Counts at Stations 3 (Post-evisceration; Pre-final wash) and 4 (Post-final wash; Pre-cooler). These results are consistent with those of Gill and Baker (1979) that revealed increases in Total Coliform Counts between the depelting and evisceration processes on sheep carcasses. The slight numerical decrease in Total Coliform Counts between Stations 3 and 4, although not statistically significant, indicates that final carcass washing reduced Total Coliform Counts by  $.75 \log_{10}$ . The important dressing steps between Stations 2 and 3 include the excision of the anus with a knife to allow the rectum to drop into the body opening of the gut cavity, splitting of the brisket and removal of the internal body cavity contents. The evisceration process offers the opportunity for coliform contamination from the intestinal tract to contaminate the carcass, line-workers' hands and equipment (Bell and Hathaway, 1996).

Least squares means for Total Coliform Counts arrayed by plant and station are presented in Table 3.3 and Figure 3.4. In plants 2, 4 and 5 there were slight, but not statistically significant, decreases in Total Coliform Counts from Station 1 to Station 2. These reductions in Total Coliform Counts may be due to comparatively more effective first-wash operations in Plants 2, 4 and 5 than in Plants 1, 3 and 6. Within plant comparisons by Station revealed significantly higher ( $P < .01$ ) Total Coliform Counts between Station 2 and Station 3 for all Plants except Plant 3. The Total Coliform Counts for Station 3 were higher than those for Station 2 in Plant 3 but the difference was not statistically significant.

The season by station interaction that was also statistically significant ( $P < .01$ ) in the analysis of variance is depicted in Table 3.4 and Figure 3.5. Fall and Spring season, Total Coliform Counts were significantly different at Station 1 and nonsignificantly different at

the Stations 2, 3 and 4. Significantly different Total Coliform Counts ( $P < .01$ ) were observed when comparing Fall and Spring seasons only at Station 1; these differences may be a reflection of seasonal variation in pelt contamination for a given day, week or month.

Aerobic Plate Counts: Results of analysis of variance for 2,146 Aerobic Plate Counts are reported in Table 3.1. Statistically significant fixed effects on Aerobic Plate Counts from the model include Station, Carcass Site and the Station x Carcass Site interaction (Table 3.5 and Figure 3.6). Aerobic Plate Counts (Table 3.5 and Figure 3.6) increased ( $P < .01$ ) between Station 1 (Post-depelting; Pre-first wash) and Station 2 (Post-first wash; Pre-evisceration) and again between Station 2 and Station 3 (Post-evisceration; Pre-final wash) but then stabilized (not different from counts at Stations 2 or 3) at Station 4 (Post-final wash; Pre-cooler). Aerobic Plate Counts arrayed by Plant and Station are presented in Table 3.6 and Figure 3.7. A trend similar to that for Total Coliform Counts was evident for Aerobic Plate Counts in that levels of contamination generally increased from Station 1 through Station 3, and then decreased, though not significantly ( $P > .01$ ), after the final carcass wash at Station 4. At plants 1, 2, 3 and 6, there was no difference ( $P < .01$ ) in Aerobic Plate Counts between Station 2 and Station 4 while, at Plants 4 and 5, Aerobic Plate Counts increased ( $P < .01$ ) between Station 2 and Station 4 (Table 3.6 and Figure 3.7).

Least squares means for Aerobic Plate Counts at each of four Carcass Sites are displayed in Table 3.7 and Figure 3.8. The loin Carcass Site had the lowest Aerobic Plate Counts and there was no difference between ( $P < .01$ ) Aerobic Plate Counts at the leg, breast and axillary Carcass Sites. Lower Aerobic Plate Counts at the loin Carcass Site can be explained by procedures involved in the slaughtering/dressing process in each packing plant. During and prior to the depelting process, the loin has very little, if any contact with

equipment, workers' hands or the fleece side of the pelts, consequently this Carcass Site has low aerobic plate counts. Initially low Aerobic Plate Counts on loin Carcass Sites (Table 3.8 and Figure 3.9) reach levels comparable to those of the leg, breast and axillary Carcass Sites between Station 1 and Station 2. Generally, in the packing plants surveyed, the amount of worker handling and distance between Station 1 and Station 2 is minimal. Several scenarios could contribute to increases in contamination at the loin site in such as short period of time and distance: (a) airborne contamination from the adjacent depelting process, (b) redistribution of contamination from the Post-depelting; Pre-first wash (Station 1), which may spread, rather than wash off, contamination. Four of the six plants sampled had automated wash cabinets, while the remaining two plants relied on hand washing at the first carcass wash site. There was no apparent relationship between Aerobic Plate Counts at Station 2 and the type of carcass wash (either automated or hand).

Least squares means for Aerobic Plate Counts arrayed by Station and Carcass Site are presented in Table 3.8 and described graphically in Figure 3.9. There were significant differences ( $P < .01$ ) in Aerobic Plate Counts at Station 1 among the loin Carcass Site and the leg, breast and axillary Carcass Sites. Carcass Site trends for Aerobic Plate Counts are similar to trends by Stations, whereby the four Carcass Sites (leg, loin, breast and axillary) reveal increasing levels of contamination from Station 1 to Station 3. Aerobic Plate Counts decrease, though nonsignificantly, between Station 3 and Station 4. The decrease in Aerobic Plate Counts at Station 4 indicates that the final carcass wash, either automated or hand, decreases Aerobic Plate Counts, although not statistically. Aerobic Plate Counts on lamb carcasses within the plants surveyed indicated very few statistical differences ( $P < .01$ ) regardless of Carcass Site after Station 1. Quality assurance efforts need to focus on several

areas in the lamb carcass slaughtering/dressing sequence to reduce Aerobic Plate Counts , including: (a) isolate the depelting phase with physical barriers from the remainder of the dressing process that follows; (b) improve the Post-depelting; Pre-first wash (Station 1) with higher water temperatures; (c) place air flow evacuation equipment at the depelting area of the dressing process to eliminate further contamination from the air; and (d) establish as the final, intervention hurdle during the slaughtering/dressing phase, an effective final carcass wash, by providing adequate water temperature, pressure and chemical interventions at the final wash station.

Correlation coefficients between Total Coliform Counts, Aerobic Plate Counts and chain speeds (carcasses processed per hour) in the six lamb plants investigated are presented in Table 3.9. The strong correlation between Total Coliform Counts and chain speed suggests that plants with faster chain speeds generate lamb carcasses with higher Total Coliform Counts (i.e., faster line speeds tend to elevate Total Coliform Counts). There appeared to be no relationship between Aerobic Plate Counts on carcasses and chain speed. It could be surmised that as chain speed increases: (a) one person, one job, (such as debunging) become tasks that take a certain amount of time to do properly, so a more hygienic evisceration process is compromised with increased line speed, and (b) during the skinning or depelting phase, fast chain speeds would promote additional contact between the pelt and the skin or it could scatter airborne particles that contaminate the same carcass or surrounding carcasses.

#### IMPLICATIONS

Grau (1986) states that most of the bacterial contamination on the dressed lamb carcass originated from the pelt of the sheep, and that bacteria are transferred to the meat

from the outer surface by both direct and indirect contact. Recognizing that the U.S. lamb packing industry will not likely implement pre-slaughter animal washing, and supported by evidence from Roberts (1980) that pre-slaughter washing of animals is of little value, within plant science-based identification of slaughtering/dressing contamination must increase.

It is evident from this study that the removal of the pelt and the evisceration process are the two most important contamination points in the slaughtering/dressing sequence in U.S. lamb packing plants. Minimizing pre-slaughter pelt and hide contamination must become a quality assurance priority for the U.S. sheep industry. Signals sent through the producer/feedlot sectors of the sheep industry need to communicate a partnership for adequate pre-slaughter presentation, and subsequent guidelines so that sheep producers/feeders can provide cleaner livestock to the packing industry.

Assuming that the U.S. sheep industry will continue to further process sheep meats into case-ready consumer friendly products, presentation and shelf-life will become increasingly important factors. Providing the cleanest possible lamb carcasses for further fabrication will be of benefit to the entire U.S. sheep industry.

Valuable process control data can be derived from analyzing lamb carcass contamination at various sites on the carcass and within the plant much like efforts in this study. As indicated by Bell and Hathaway (1996), the sheep fleece is the major source of carcass contamination. Data presented appear to isolate increases in coliform contamination on lamb carcasses to slaughtering/dressing procedures that occur after depelting, as evidenced by significant increases in Total Coliform Counts post-depelting through post-evisceration. Once the pelt is removed there are increases in Total Coliform Counts on the carcass that may come primarily from: (a) the evisceration process; (b) contamination from

equipment or workers' hands; (c) first carcass wash redistribution; and/or (d) airborne contamination. The pre-evisceration-post depelting wash efforts may spread coliform contamination from the perianal and hind leg region of the carcass to various other carcass locations. Biss and Hathaway (1994) have noted this latter phenomenon in their sheep carcass studies. Recognizing that Carcass Site, in the analysis of variance for Total Coliform Counts (Table 3.1), was not significant ( $P=.3688$ ), there is evidence that indicates that redistribution of coliform contamination from the first carcass wash cannot be the sole source of increases in Total Coliform Counts at Station 2 (Pre-first wash; Pre-evisceration) and cannot account for the significant increase in Total Coliform Counts ( $P<.01$ ) between Pre-first wash; Pre-evisceration (Station 2) and Post-evisceration; Pre-final wash (Station 3). Gill and Baker (1998) found large numbers of aerobic bacteria, which included coliforms, on the rumps and shoulders of carcasses during the depelting process. They also noted that, during the evisceration process, bacterial counts did not appear to increase significantly. Gill and Baker (1998) additionally concluded from their data that carcasses are contaminated during the evisceration process by bacteria from sources other than those from which contaminants were derived during depelting. It is likely that contamination deposited post-depelting on sheep carcasses is from a combination of sources including equipment, workers' hands, redistribution from the first carcass wash and airborne contamination. Recognizing that within this particular data set, coliform contamination reached maximum levels Post-evisceration; Pre-final wash (Station 3), the area in the carcass dressing process between Post-depelting; Pre-first wash (Station 1) and Post-evisceration; Pre-final wash (Station 3) should become a series of identified Control Points (CP) for HACCP-based process control. Quality assurance efforts could then be isolated to very specific processing steps between

Post-depelting; Pre-first wash (Station 1) and Post-evisceration; Pre-final wash (Station 3) to identify specific action points of carcass contamination. A closer evaluation of carcass wash efforts, worker equipment handling procedures, and strategies to identify airborne contamination are areas that need to be explored. Furthermore, hot water (80°C) wash basins should be installed along the sheep dressing chain to allow workers to sanitize their hands and equipment between Post-depelting; Pre-first wash and Post-evisceration; Pre-final wash. Post-evisceration; Pre-final wash (Station 3) Total Coliform Counts could then be used to objectively evaluate process control efforts that would be implemented between Post-depelting; Pre-first wash and Post-evisceration; Pre-final wash stations. Ultimately, through analysis of individual dressing procedures, areas of coliform contamination can be identified and procedures implemented to reduce such contamination.

**Table 3.1. Analysis Of Variance (Fixed Effects) For Total Coliform Counts And Aerobic Plate Counts.**

Source	Total Coliform Counts		
	DF	MS	F
Season	1	5.75	0.0618
Station	3	53.44	0.0001*
Season x Station	3	5.74	0.0010*
Carcass Site	3	1.06	0.3688
Season x Carcass Site	3	.13	0.9415
Station x Carcass Site	9	1.27	0.2574
Season x Station x Carcass Site	9	.52	0.8548

Source	Aerobic Plate Counts		
	DF	MS	F
Season	1	7.78	0.385
Station	3	30.15	0.0001*
Season x Station	3	2.28	0.0813
Carcass Site	3	9.37	0.0001*
Season x Carcass Site	3	.42	0.7423
Station x Carcass Site	9	8.22	0.0001*
Season x Station x Carcass Site	9	.36	0.9526

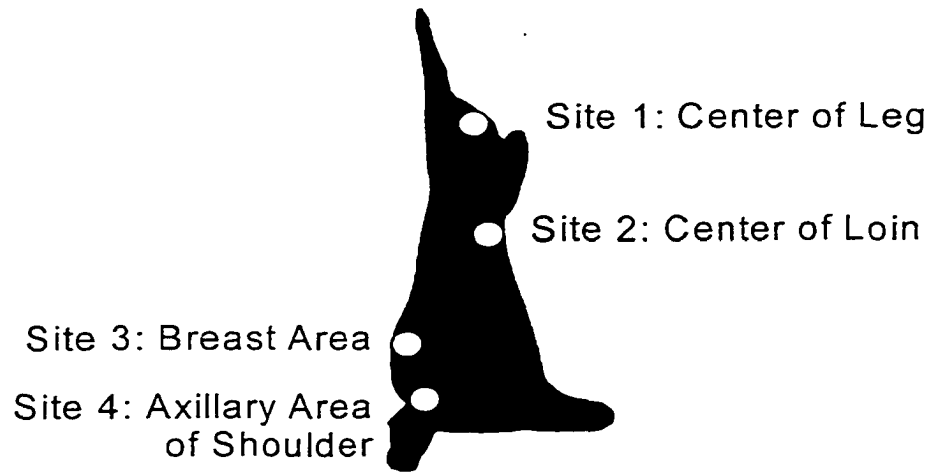
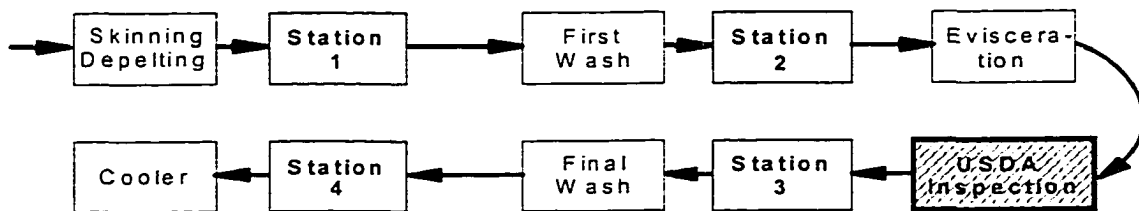


Figure 3.1. Lamb Carcass Sampling Sites.



Station 1: Post-depelting; Pre-first wash  
 Station 2: Post-first wash; Pre-evisceration  
 Station 3: Post-evisceration; Pre-final wash  
 Station 4: Post-final wash; Pre-cooler

Figure 3.2. Process Flow - Plant Sampling Stations.

**Table 3.2. Least Squares Means For Total Coliform Counts At Each Of Four Stations and Standard Deviations.**

Station	Total Coliform Counts (log <sub>10</sub> CFU/20 cm <sup>2</sup> )	Standard Deviation
Post-depelting; Pre-first wash	1.34 <sup>a</sup>	1.75
Post-first wash; Pre-evisceration	1.52 <sup>a</sup>	2.72
Post-evisceration; Pre-final wash	4.34 <sup>b</sup>	2.12
Post-final wash; Pre-cooler	3.62 <sup>b</sup>	2.19

<sup>ab</sup> Least squares means with a common superscript letter are not different (P>.01).

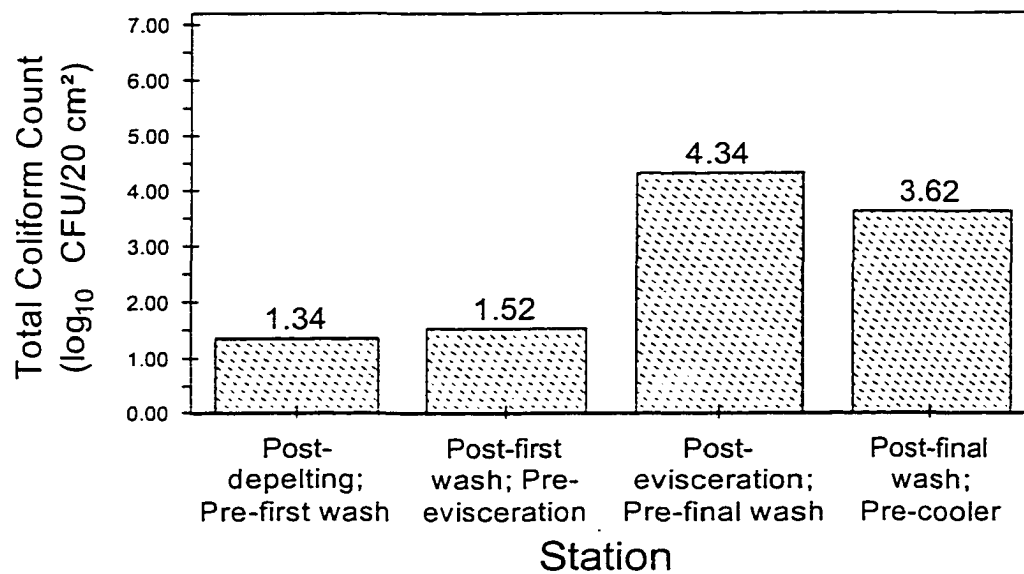


Figure 3.3. Total Coliform Counts At Each Of Four Stations.

**Table 3.3. Least Squares Means For Total Coliform Counts Arrayed By Plant And Station and Standard Deviations.**

Station	Total Coliform Counts ( $\log_{10}$ CFU/20 cm <sup>2</sup> )					
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
Post-depelting; Pre-first wash	.55 <sup>a</sup> (1.15)	.93 <sup>ab</sup> (1.03)	2.44 <sup>a</sup> (1.82)	2.15 <sup>ab</sup> (2.40)	1.09 <sup>a</sup> (1.25)	.88 <sup>a</sup> (1.10)
Post-first wash; Pre-evisceration	1.85 <sup>ab</sup> (2.23)	.65 <sup>a</sup> (1.11)	3.24 <sup>ab</sup> (1.77)	1.91 <sup>a</sup> (3.11)	.36 <sup>a</sup> (.76)	1.15 <sup>a</sup> (1.31)
Post-evisceration; Pre-final wash	3.77 <sup>c</sup> (2.00)	3.08 <sup>c</sup> (1.80)	5.12 <sup>b</sup> (1.59)	4.60 <sup>c</sup> (2.83)	4.61 <sup>b</sup> (1.84)	4.79 <sup>b</sup> (1.84)
Post-final wash; Pre-cooler	2.55 <sup>bc</sup> (1.58)	2.12 <sup>bc</sup> (1.52)	3.42 <sup>ab</sup> (2.11)	4.41 <sup>bc</sup> (2.68)	4.06 <sup>b</sup> (1.56)	5.08 <sup>bc</sup> (1.52)

<sup>abc</sup> Least squares means in the same column with a common superscript letter are not different ( $P > .01$ ).

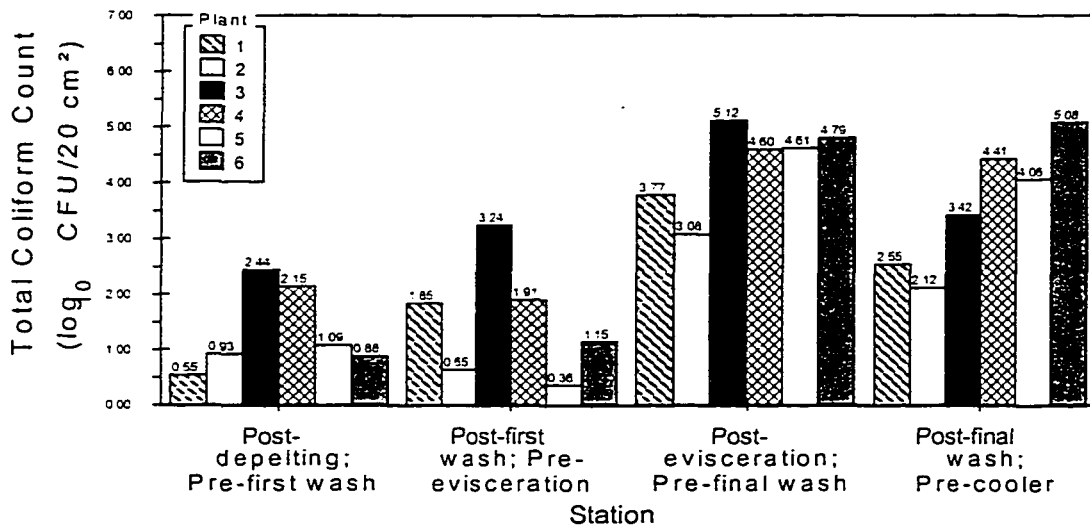


Figure 3.4. Total Coliform Counts Arrayed By Plant And Station.

**Table 3.4. Least Squares Means For Total Coliform Counts Arrayed By Season And Station and Standard Deviations.**

Station	Total Coliform Counts (log <sub>10</sub> CFU/20 cm <sup>2</sup> )		Standard Deviation
	Fall Season	Spring Season	
Post-depelting; Pre-first wash	2.00 <sup>ax</sup>	.68 <sup>ay</sup>	1.75
Post-first wash; Pre-evisceration	1.60 <sup>a</sup>	1.45 <sup>a</sup>	2.25
Post-evisceration; Pre-final wash	4.96 <sup>bx</sup>	3.71 <sup>by</sup>	2.12
Post-final wash; Pre-cooler	3.25 <sup>ab</sup>	3.99 <sup>b</sup>	2.19

<sup>ab</sup>Least squares means in the same column with a common superscript letter are not different (P>.01).

<sup>xy</sup>Least squares means in the same row with a common superscript letter are not different (P>.01).

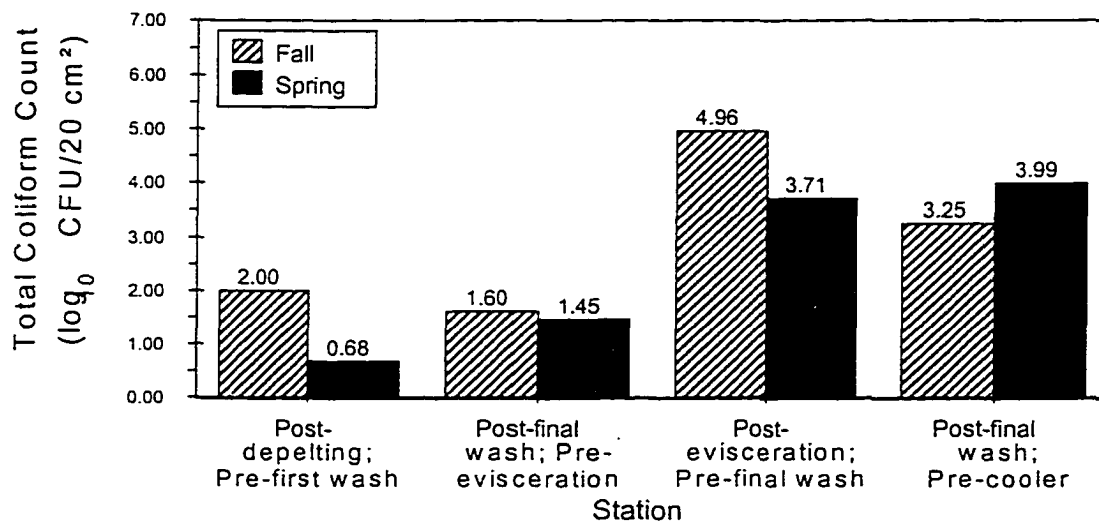


Figure 3.5. Total Coliform Counts Arrayed By Season And Station.

**Table 3.5. Least Squares Means For Aerobic Plate Counts At Each Of Four Stations and Standard Deviations.**

Station	Aerobic Plate Counts ( $\log_{10}$ CFU/20 cm <sup>2</sup> )	Standard Deviations
Post-depelting; Pre-first wash	4.66 <sup>a</sup>	2.27
Post-first wash; Pre-evisceration	5.60 <sup>b</sup>	1.86
Post-evisceration; Pre-final wash	6.53 <sup>c</sup>	.72
Post-final wash; Pre-cooler	5.88 <sup>bc</sup>	1.31

<sup>abc</sup> Least squares means with a common superscript letter are not different ( $P > .01$ ).

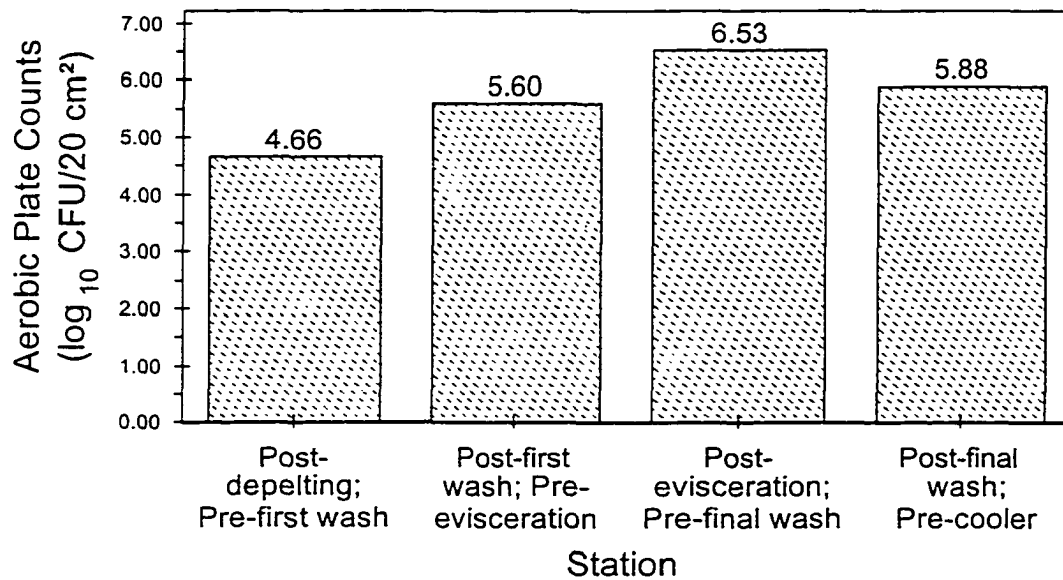
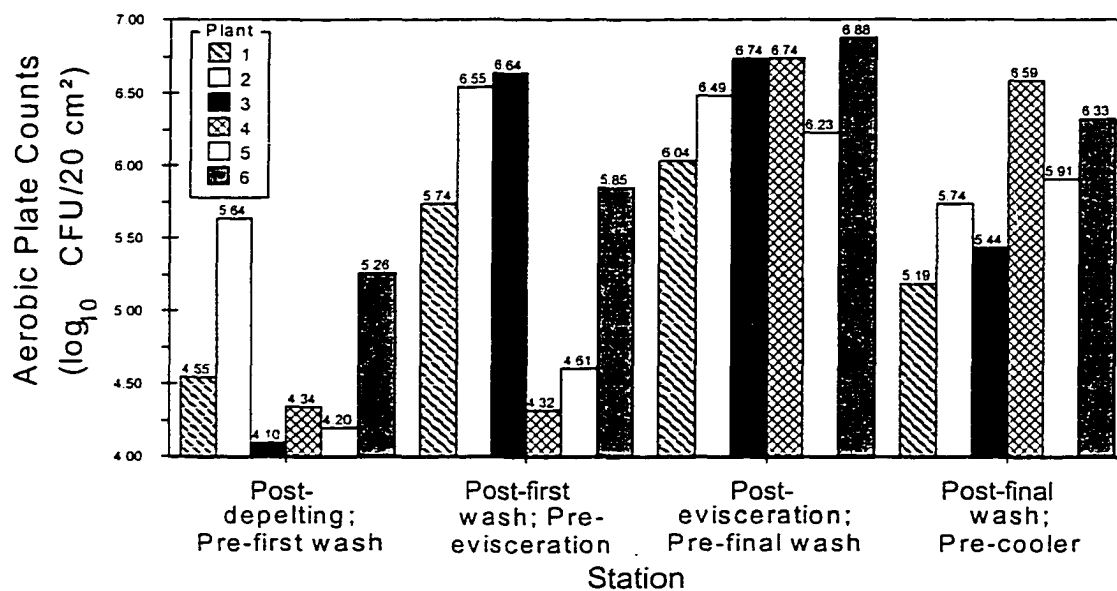


Figure 3.6. Aerobic Plate Counts At Each Of Four Stations.

**Table 3.6. Least Squares Means For Aerobic Plate Counts Arrayed By Plant And Station and Standard Deviations.**

Station	Aerobic Plate Counts ( $\log_{10}$ CFU/20 cm <sup>2</sup> )					
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
Post-depelting; Pre-first wash	4.55 <sup>a</sup> (1.77)	5.64 <sup>a</sup> (1.65)	4.10 <sup>a</sup> (2.59)	4.34 <sup>a</sup> (1.96)	4.20 <sup>a</sup> (2.25)	5.26 <sup>a</sup> (2.53)
Post-first wash; Pre-evisceration	5.74 <sup>b</sup> (.44)	6.55 <sup>b</sup> (.49)	6.64 <sup>b</sup> (.92)	4.32 <sup>a</sup> (2.50)	4.61 <sup>a</sup> (1.72)	5.85 <sup>bc</sup> (.62)
Post-evisceration; Pre-final wash	6.04 <sup>bc</sup> (.52)	6.49 <sup>ab</sup> (.57)	6.74 <sup>b</sup> (.67)	6.74 <sup>b</sup> (.72)	6.23 <sup>b</sup> (.74)	6.88 <sup>c</sup> (.61)
Post-final wash; Pre-cooler	5.19 <sup>ab</sup> (.86)	5.74 <sup>ab</sup> (1.42)	5.44 <sup>ab</sup> (1.60)	6.59 <sup>b</sup> (1.16)	5.91 <sup>b</sup> (.88)	6.33 <sup>bc</sup> (.90)

<sup>abc</sup> Least squares means in the same column with a common superscript letter are not different ( $P > .01$ ).



**Figure 3.7. Aerobic Plate Counts Arrayed By Plant And Station.**

**Table 3.7. Least Squares Means For Aerobic Plate Counts At Each Of Four Carcass Sites and Standard Deviations.**

Carcass Site	Aerobic Plate Count ( $\log_{10}$ CFU/20 cm <sup>2</sup> )	Standard Deviations
Leg	5.67 <sup>b</sup>	1.73
Loin	5.06 <sup>a</sup>	2.28
Breast	5.97 <sup>b</sup>	1.63
Axillary	5.98 <sup>b</sup>	1.35

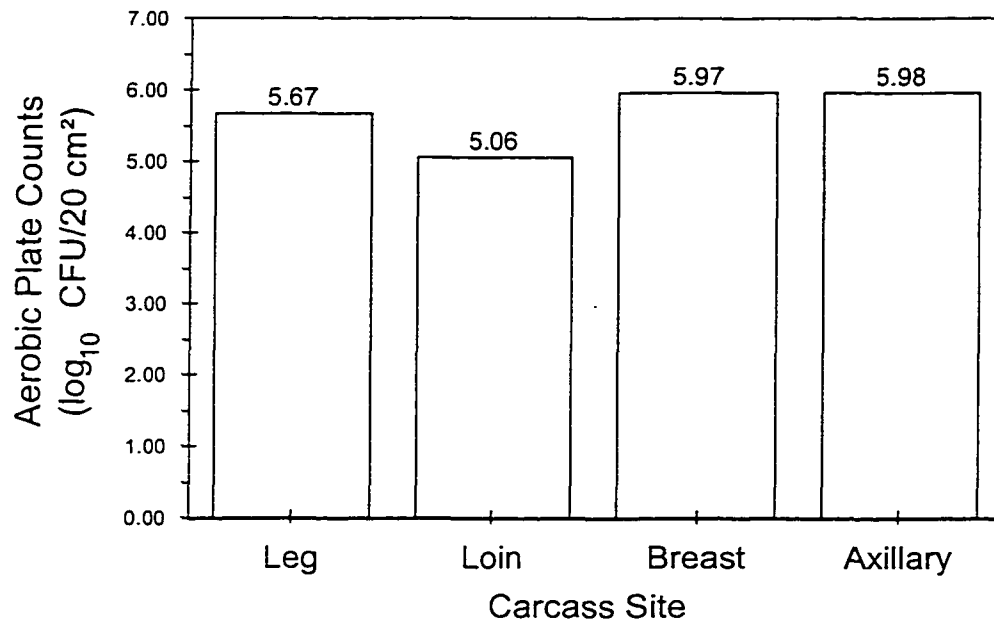


Figure 3.8. Aerobic Plate Counts At Each Of Four Carcass Sites.

**Table 3.8. Least Squares Means For Aerobic Plate Counts Arrayed By Station And Carcass Site and Standard Deviations.**

Station	Carcass Sites			
	Leg	Loin	Breast	Axillary
Post-depelting; Pre-first wash	4.99 <sup>ay</sup> (2.17)	2.29 <sup>ax</sup> (1.84)	5.72 <sup>aby</sup> (1.50)	5.65 <sup>ay</sup> (1.44)
Post-first wash; Pre-evisceration	5.60 <sup>ab</sup> (1.62)	5.34 <sup>b</sup> (1.78)	5.52 <sup>a</sup> (2.21)	5.94 <sup>a</sup> (1.69)
Post-evisceration; Pre-final wash	6.39 <sup>b</sup> (.78)	6.51 <sup>bc</sup> (.83)	6.69 <sup>b</sup> (.63)	6.53 <sup>a</sup> (.59)
Post-final wash; Pre-cooler	5.69 <sup>ab</sup> (1.60)	6.09 <sup>b</sup> (1.09)	5.94 <sup>b</sup> (1.23)	5.81 <sup>a</sup> (1.21)

<sup>abc</sup> Least squares means in the same column with a common superscript letter are not different (P>.01).  
<sup>xy</sup> Least squares means in the same row with a common superscript letter are not different (P>.01).

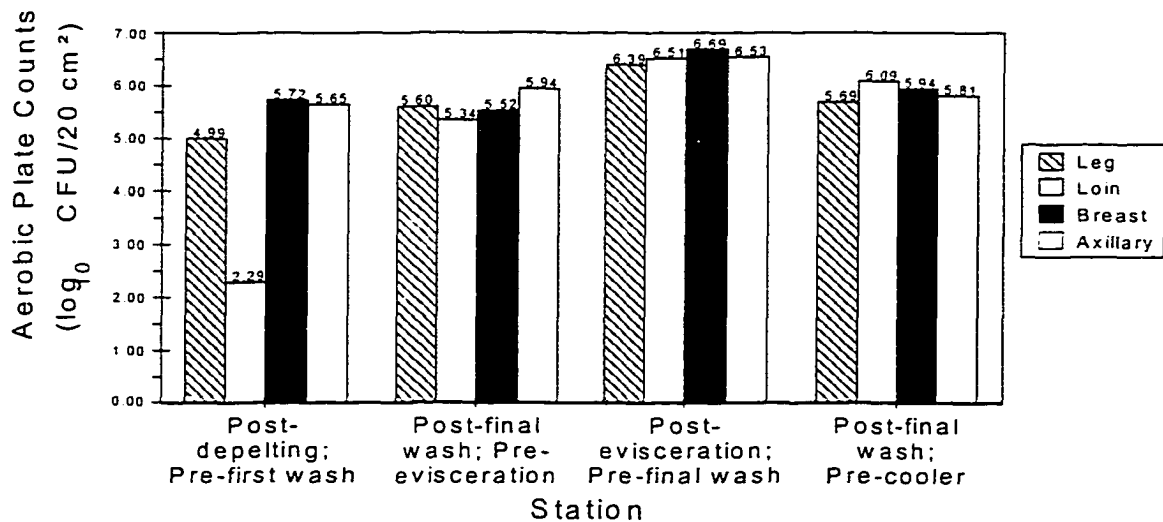


Figure 3.9. Aerobic Plate Counts Arrayed By Station x Carcass Site.

**Table 3.9. Correlation Coefficients Between Total Coliform Counts, Aerobic Plate Counts And Chain Speeds.\***

	Chain Speed (n=6)	P
Total Coliform Counts	.863	.027
Aerobic Plate Counts	-.058	.934

\* n = 90, 125, 275, 300, 300, 450 carcasses per.h.

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## CHAPTER IV

### DEVELOPMENT OF A MODEL HACCP PLAN FOR LAMB FEEDING, TRANSPORTATION, RECEIVING AND SLAUGHTERING/DRESSING

#### INTRODUCTION

The development of HACCP-based plans specific to sheep slaughter and dressing was prompted in part, by the Pathogen Reduction; Hazard Analysis and Critical Control Point Systems; Final Rule (PR; HACCP; FR) (USDA FSIS, 1996). According to Smith (1999), to comply with the Pathogen Reduction; Hazard Analysis and Critical Control Point Systems; Final Rule: (1) All plants must adopt HACCP; HACCP is defined as "a system of process controls to prevent food safety hazards." (2) To verify that HACCP systems are effective in reducing contamination with harmful bacteria, FSIS/USDA has set pathogen reduction performance standards for *Salmonella*. (3) To verify that process control systems are working, slaughter plants must conduct microbial testing for generic *E. coli*. (4) FSIS/USDA has required that all plants adopt and follow, written Standard Operating Procedures for Sanitation, to reduce the likelihood that harmful bacteria are on finished product (Smith, 1999).

Currently, research efforts by Colorado State University (LeValley et al., 1998) and the American Sheep Industry (ASI) contracted by APHIS/USDA will establish baselines for Generic *E. coli*, *Salmonella* and *Campylobacter*. The microbiological baselines will be correlated with preharvest condition of the sheep fleece and source of lambs sampled (e.g., range, farm flock, feedlot).

Previous studies conducted by Kochevar et al. (1997) investigated the effect of water temperature, pressure and chemical solutions on removal of fecal material from lamb adipose tissue by spray washing and revealed positive reductions in bacterial counts. In general, acetic acid (2%) and hot water (74°C) provided the combination of microbiological interventions that most effectively reduced bacterial counts on lamb adipose tissue.

The National Sheep Quality Assurance and Food Safety Audit (Cunningham et al., 1994) provided further pre-harvest information to facilitate development of a complete HACCP-based program from the lamb feedlot through carcass chilling. Biss and Hathaway (1995) state that the effective design and implementation of Hazard Analysis and Critical Control Point (HACCP) systems for fresh meat are dependent on identification of those process steps that determine the location of most of the contamination on the carcass, and identification of appropriate Critical Limits. The following model HACCP plan for lamb feeding, transportation, receiving and slaughtering/dressing is an accumulation of pre-slaughter observations plus studies of lamb slaughtering/dressing procedures as well as microbiological investigations of lamb carcasses.

## MATERIALS AND METHODS

A step-wise plan was formulated to design and develop the model HACCP plan for lamb feeding, transportation, receiving and slaughtering/dressing, based upon: (a) comprehensive visits to range and farm flock sheep production units, (b) feedlot consultations and consideration of numerous feeding and carcass research trials, (c) results of the National Sheep Quality Assurance And Food Safety Audit, (d) carcass and packing plant microbial mapping studies, and (e) lamb carcass spray-washing research results.

The sequential step-by-step format for developing a HACCP plan is based on suggestions by Mortimore and Wallace (1994) and consists of: (1) The HACCP Plan. (2) Types of Hazards. (3) Process Flow Diagram. (4) Hazard Identification. (5) Identification of Preventive Measures. (6) Location of Critical Control Points. (7) Design of HACCP Control Charts. (8) Establish Critical Limits. (9) Design of Monitoring Procedures at Critical Control Points. (10) Establishment of Corrective Actions at Critical Control Points. (11) Verification Procedures at Critical Control Points. (12) Record Keeping Logs.

## RESULTS AND DISCUSSION

In Table 4.1, Control Points for receiving of feeder lambs for feeding lambs and for transportation of slaughter lambs to the packing plant are characterized. Control Points identified for use at the feedlot or for implementation during the pre-slaughter segment of the animal-to-carcass conversion process are essential elements of the HACCP plan and are extremely important for later in-plant quality assurance. Biss and Hathaway (1994) state that pre-slaughter presentation status of the animal is an important determinant of the

subsequent contamination of the carcass; correspondingly, a comprehensive HACCP plan will include process control of pre-slaughter risk factors.

Four Process/Step items are listed in Table 4.1. It is important to assure that lambs are clean and healthy at the time they are received; so, a Control Point to facilitate monitoring such conditions is justified. During lamb processing, use of sterile vaccination equipment should be assured and complete record-keeping for vaccines and drugs administered to incoming lambs should be achieved because of the importance of these items in a quality-assurance context. During the feeding period, fresh water, fresh feed and adequate bedding should be provided to lambs and careful consideration should be given to use of drugs (growth promotants, antibiotics) at subtherapeutic dosages. The fourth Control Point involves examination of health of lambs, assuring that recommendations are followed for drug-withdrawal periods, attempts to keep pelts dry, preventing consumption of feed and water for 12 h prior to shipment and assuring that trucks used to transport lambs to the slaughter plant are clean and dry. In a farm-to-fork approach to lamb quality assurance endeavors, it is essential to think in a context that starts as early in the lamb production process as is possible.

Although the National Sheep Quality Assurance And Food Safety Audit (Cunningham et al., 1994) indicates that the volatile residues (antibiotics/hormones) in slaughter lambs, is less than 0.3%, attention to residues must remain a priority to assure continued low level use of drugs. Sterile vaccination equipment is a criterion that should be followed by all segments of the sheep industry (Cunningham et al., 1994). The importance of clean bedding issues has shifted from being based on the added-value of

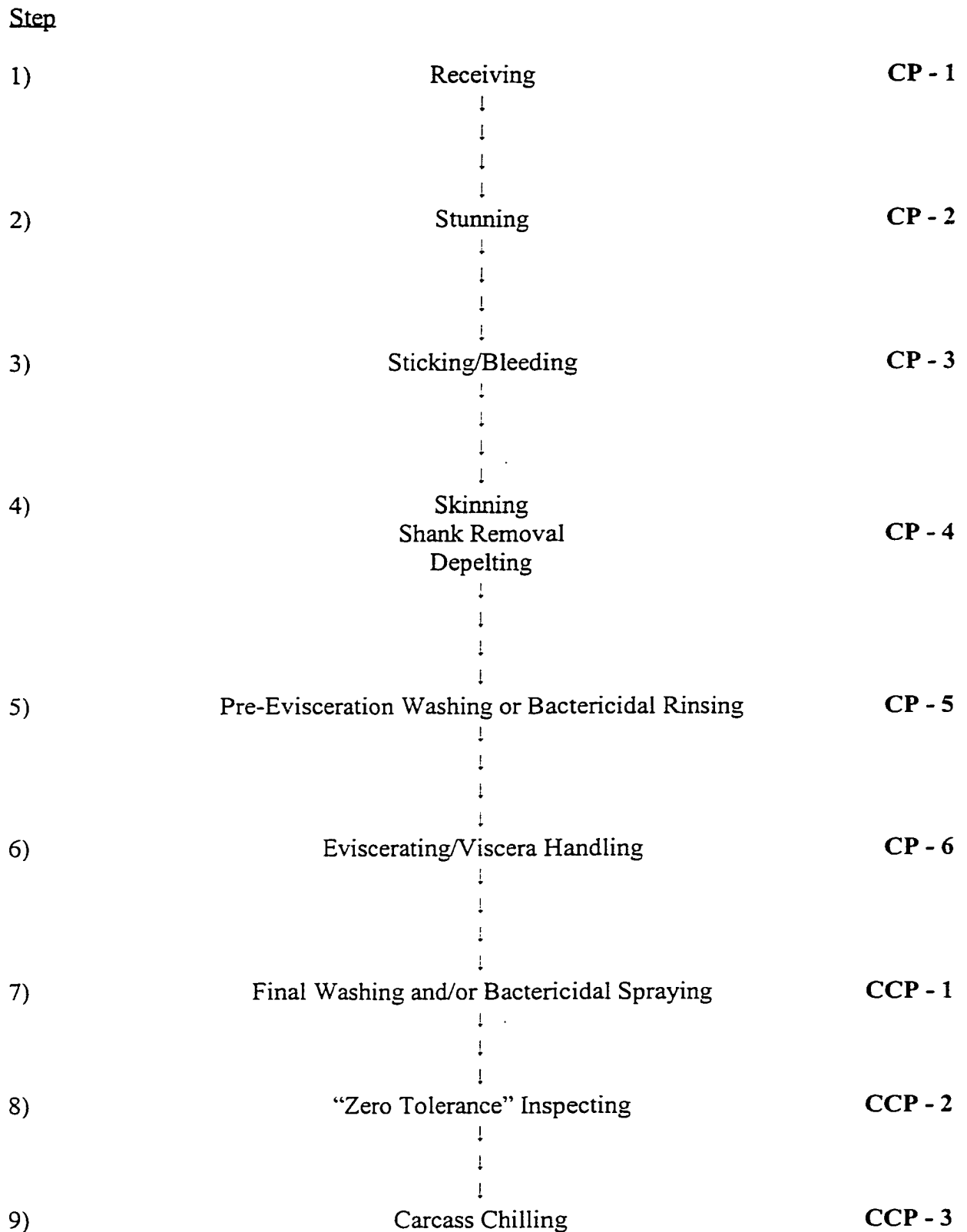
clean lamb skins or pelts, to being premised upon the importance of clean pelts in generating clean carcasses. Currently, lamb pelts have virtually no value (USDA AMS, 1999). All practices concerned with use of pre-slaughter bedding are focused on anticipated net gains in the lamb slaughter/dressing process from reduced pelt contamination. As future food safety risk factors are identified such as pelt contamination, injection-site lesions, drug withdrawals, Good Manufacturing Practices at the range, farm flock and feedlot will be important through their contribution to quality increases in lamb products.

In Figure 4.1, a Flow Chart for receiving and slaughtering/dressing of lambs is presented. Development of a process flow diagram is the first step in describing a HACCP plan (Mortimore and Wallace, 1994). In Table 4.2 are presented Control Points and Critical Control Points for Lamb Receiving and Processing at Slaughter Facility. Steps 1a and 1b in Table 4.2 are designed to provide a guide for farm or feedlot operations to address management issues that will further impact the lamb slaughter/dressing process that follows. Figure 4.1 describes the processing flow of lambs from receiving them out of pastures/feedlots through carcass chilling. Control Points (CPs) are designated at Steps 1, 2, 3, 4, 5 and 6, for the specific purpose of alerting plant quality assurance personnel of the importance of these process steps in maintaining microbiological quality. These Control Points can also be used to segment or subdivide the entire slaughter/dressing process into subunits where specific actions, that might contribute to potential carcass contamination, can be analyzed. Potentially, microbiological analyses, similar to those described in Chapter III, could reveal the effectiveness of the post-depelting wash, or other

specific microbiological interventions that could be implemented (such as changes in air flow). Steps 7, 8 and 9 in Figure 4.1 represent three Critical Control Points (CCPs) that, by definition, are processes where control can be applied and a hazard can be prevented, eliminated or reduced to acceptable levels (Mortimore and Wallace, 1994). At Steps 7, 8 and 9, which are Critical Control Points, there are very specific Critical Limits (CLs), Monitoring procedures, Corrective Actions, requirements for Verification and for Record-Keeping. Collectively, Steps 7, 8 and 9 (shown in Figure 4.1) identify the most logical point within the slaughter/dressing sequence at which to apply microbiological controls. At this focal point, the three consecutive Steps (7, 8 and 9) offer opportunities for checks and balances, particularly between CCP-1 and CCP-2, which -- together -- can improve the microbiological quality of the carcass. The effectiveness of the carcass wash can, to some degree, be evaluated at CCP-2 ("Zero Tolerance" Inspecting) by virtue of the results of "Zero Tolerance" inspection each hour. If the Critical Limits of CCP-2 are exceeded, then by deduction, the CCP-1 Final Washing and/or Bactericidal Spraying microbiological intervention must be modified. Table 4.2 also includes detailed descriptions of the recommended Criteria or Critical Limits, Monitoring Procedures/Frequencies, Corrective/Preventive Actions, Records/Measurements and Verification Procedures for Control Point process Steps 1 through 6. Details for water temperatures, pressures and chemical concentrations were derived from actual in-plant conditions or carcass spray-washing research efforts by Kochevar et al. (1997). It is documented by Grau (1987) that hands, knives, steels and aprons of line workers who handle the carcass before the hide is removed are more often highly contaminated than are those of workers who handle the

**Table 4.1 Control Points (CP) for Receiving of Feeder Lambs, for Feeding Lambs and for Transportation of Slaughter Lambs to the Packing Plant**

<b>Process/Step</b>	<b>CP</b>	<b>Criteria or Critical Limits</b>	<b>Monitoring Procedure/Frequency</b>	<b>Corrective/Preventive Action</b>	<b>Records/Measurements</b>	<b>Verification</b>
Lamb receiving	CP	Lambs should be clean and healthy	Check each load or lot	Communication back to buyer, supplier or trucker	Receiving log, buyer records, document transporter	Supervisory review of records (daily)
Lamb processing	CP	Sterile vaccination equipment	Review vaccination records after each processing function	Communication with processing crew	Record use of vaccines and other drugs	Supervisory review of records (daily)
Lamb feeding period	CP	Fresh water/feed; provide bedding if necessary; review use of subtherapeutic drugs	Monitor withdrawal dates on vaccines, wormers or drugs used during feeding period; daily or weekly as necessary	Coordinate slaughter date with proper drug withdrawal times	Feeding logs for each pen of lambs (to include treatment regimen)	Supervisory review of records (daily)
Sorting and transportation of lambs to slaughter facility	CP	Examine lamb health; adequate drug withdrawal periods followed; dry pelts; transportation units clean and dry; 12 h removed from feed and water	Examine feeding and medication logs for appropriate pens; review receiving records from processing plant(s)	Communication with feedlot employees and livestock truckers	USDA antibiotic residue results; pelt condition; USDA trim or condemnation record; internal plant records for trim and condemnation	Feedlot and supervisory review of records from feedlot to processing facility (weekly)



**Figure 4.1 Flow Chart For Receiving And Slaughtering/Dressing Of Lambs**

carcass after the hide is removed. Such findings explain the need for additional wash basins or drop hoses to keep worker equipment as clean as possible.

Table 4.2 also includes detailed descriptions of the specific Critical Limits, Monitoring Procedures/Frequencies, Corrective/Preventive Actions, Records/Measurements and Verification Procedures for each of the Critical Control Points at Steps 7, 8 and 9. Critical Limits for CCP-1 at Step 7 (final washing and/or bactericidal spraying) are based on research findings of Kochevar et al. (1997) and specific limits as prescribed by USDA FSIS (1996). Critical Control Point 2 (Step 8) is specific in its criteria for Critical Limits. Visual observation by quality assurance personnel will determine if the Critical Limit has been exceeded. Corrective/Preventive Actions, Records/Measurements and Verification Procedures link CCP-1 and CCP-2.

Control of the growth of microbes contaminating the carcass is achieved by reducing the carcass temperature and by the drying of the carcass surface that occurs during chilling (Mackey and Roberts, 1993). Critical Control Point 3 under high production level conditions, is evaluated in large refrigerated cooling rooms. Gill et al. (1991a) states that carcass temperatures must be recorded for the persistently warmest point on the carcass. The 3" deep muscle Critical Limit of  $\leq 2^{\circ}\text{C}$  will ensure that the remaining areas of the carcass are at or below that temperature. In summary, three back-to-back Critical Control Points offer checks and balances between CCP-1 and CCP-2 and provide step-wise controlled process points that can be evaluated, documented, audited and verified.

Specific details of Critical Control Points (CCPs), Control Points (CPs), Standard Operating Procedures (SOPs) and Critical Limits (CLs) for lamb slaughter facility are outlined in detail on pages 50 through 62. The identification of specific hazards as either biological, chemical or physical will alert plant employees to potential problems. Standard Operating Procedures (SOPs) should provide a short, concise description by which a task or procedure is repeated, hourly, daily or weekly. Details of Monitoring, Recording and Verification complete the step-by-step process of outlining a HACCP plan as described by Mortimore and Wallace (1994). HACCP plans must be simple to understand yet yield enough detail at Control Points or Critical Control Points that line supervisors and quality assurance personnel can easily communicate details to line workers. Details on Control Points (CPs) and Critical Control Points (CCPs), in addition to those for Standard Operating Procedures (SOPs) were developed by a consideration of findings from the National Sheep Quality Assurance And Food Safety Audit (Cunningham et al., 1994). Critical Control Points were identified as areas along the process chain where measurable and effective interventions could be put in place with an expected reasonable degree of success in controlling what are primarily microbiological hazards.

**CRITICAL CONTROL POINTS (CCPs), CONTROL POINTS (CPs), STANDARD OPERATING PROCEDURES (SOPs) and CRITICAL LIMITS (CLs) FOR LAMB SLAUGHTER FACILITY**

1. Receiving - CP-1
  - A. Biological Hazards
    - Fecal material or excessive moisture in livestock trucks.
    - Fecal material or moisture in receiving pens.

B. Physical Hazards

- Metal from syringes, vegetable matter, subcutaneous injection-sites or grass awns.

C. Chemical Hazards

- Antibiotic residues, drugs, vaccines.

Standard Operating Procedure (SOP) for CP-1 - Receiving

Monitoring - Trucks clean and free of excessive fecal material and/or moisture (as needed).

- Truck pens bedded with fresh material daily, washed (as needed).

- Visual inspection of each lot delivered, for fecal material, soil or moisture attached to feet, legs or pelt (as needed).

Recording - Receiving log documentation after each load.

Verification - Compare physical appearance of truck and lambs with documentation of receiving log (as needed).

2. Stunning - CP-2

A. Biological Hazards - None.

B. Physical Hazards - None.

C. Chemical Hazards - None.

Standard Operating Procedure (SOP) for CP-2 - Stunning

- Consistent placement of stun device on the neck area of the lamb.

Monitoring - Check voltage output of equipment (hourly).

Recording - Document voltage output (daily).

**Table 4.2 Control Points (CP) and Critical Control Points (CCP) for Lamb Receiving and Processing at Slaughter Facility**

<b>Process/ Step</b>	<b>CP/ CCP</b>	<b>Criteria or Critical Limits</b>	<b>Monitoring Procedure/ Frequency</b>	<b>Corrective/ Preventive Action</b>	<b>Records/ Measurements</b>	<b>Verification Procedures</b>
(1a) Lamb receiving from feedlot or pasture	CP	Lambs should be as free as possible of feces, soil, moisture and vegetable matter	Check each load or lot	Communication back to buyer, supplier or trucker	Receiving log; purchase records; record lot and condition	Supervisory review of records (daily)
(1b) Holding pens	CP	Receiving pens should be clean and bedded if necessary	Visual check at start and end of shift	Cleaned and rebedded as necessary	Receiving and holding log	Supervisory review of records (daily)
(2) Stunning	CP	All procedures per equipment manufacture recommendations	Visual check of carcass and pelt	Train employees to use proper stunning procedure	Records to document carcass bruises and pelt damage	Supervisory review of records (daily)
(3) Sticking/ bleeding	CP	Sanitize knife (180°F water) between sticks	Visually check knife decontamination and water temperature each shift	Correct procedure for knife decontamination and maintaining proper water temperature	Knife decontamination; water temperature monitored with calibrated thermometer	Supervisory review of records (daily)
(4) Skinning, shank removal, depelting	CP	Carcasses should not have dressing defects, i.e., wool, blood clots, dirt, feces, ingesta, other	Line foreman observes effectiveness of dressing and depelting process for each carcass. Visual analysis should be conducted under adequate lighting per USDA	Train operators to use proper procedures; conduct carcass trimming, add operators, reduce chain speed	Post-depelling carcass examination; document incidence of trimming	Supervisory review of records (daily)

**Table 4.2 Control Points (CP) and Critical Control Points (CCP) For Lamb Receiving and Processing at Slaughter Facility (Continued)**

<b>Process/Step</b>	<b>CP/ CCP</b>	<b>Criteria or Critical Limits</b>	<b>Monitoring Procedure/ Frequency</b>	<b>Corrective/ Preventive Action</b>	<b>Records/ Measurements</b>	<b>Verification Procedures</b>
(5)Pre- evisceration washing or bactericidal rinsing	CP	A) Washing: 1. 90-100°F 2. 50-30 psi  Other applications (e.g. solution of organic acid) per USDA-FSIS Guidelines	Continuous monitoring of temperature and pressure	Washing; adjust pressure or temperature; train employee(s)	Post-depelting wash/spray log  Log of preventive maintenance	Supervisory review of records (daily)  Conduct microbiological analyses at sites on carcasses; compare with results at CCP (1)  Periodic testing of equipment to verify operational level is according to design

**Table 4.2 Control Points (CP) and Critical Control Points (CCP) For Lamb Receiving and Processing at Slaughter Facility (Continued)**

<b>Process/Step</b>	<b>CP/ CCP</b>	<b>Criteria or Critical Limits</b>	<b>Monitoring Procedure/ Frequency</b>	<b>Corrective/ Preventive Action</b>	<b>Records/ Measurements</b>	<b>Verification Procedures</b>
(6a) Eviscerating	CP	0% occurrence of the following defects for each carcass; fecal material, ingesta, urine, abscesses	Employee and/or supervisor observes contamination.	1-Trained employee immediately trims carcass defect 2-Train employees to limit eviscerate contamination 3-Reduce chain speed 4-Sanitize soiled evisceration tools with 80°C water 5-Sanitize soiled aprons/boots with 50°C water or appropriate sanitizer	Random post-evisceration carcass examination; records of carcasses side-railed for trim due to eviscerate contamination	Supervisory review of records with appropriate personnel; microbiological analysis at carcass sites consistent with CCP 1 & 2 2 times weekly
(6b) Viscera handling	CP	No viscera contamination on carcasses	Visual monitoring	Wash knives in 80°C water. Wash apron, hands, boots in 50°C water	Floor supervisor checks twice daily	Supervisory review of SOP with appropriate personnel

Table 4.2 Control Points (CP) and Critical Control Points (CCP) For Lamb Receiving and Processing at Slaughter Facility (Continued)

Process/Step	CP/ CCP	Criteria or Critical Limits	Monitoring Procedure/ Frequency	Corrective/ Preventive Action	Records/ Measurements	Verification Procedures
(7) Final washing and/or bactericidal spraying	CCP 1	A) Washing 1. > 50°C ≤ 60°C water 2. 50-160 psi B) Bactericidal 1. Organic acid ≤ 2.5 2. Chlorine 50- 60 ppm C) Other guidelines as per USDA-FSIS	Hourly monitoring of temperature, pressure and bactericidal rinse concentrations  Document with thermometer, litmus paper, pressure gauges.	Washing; Adjust temperature or pressure  Bactericidal spray; Adjust temperature, pressure or concentration  Monitor spray wash equipment; repair as needed	Final wash and bactericidal spray log  Documented; and, log equipment maintenance	Supervisory review of records with appropriate QA personnel (daily)  Conduct microbiological analyses; confirm bacterial counts as compared to CCP-1 3 times weekly
(8) "Zero Tolerance" Inspecting	CCP 2	No visual presence of ingesta, fecal material, wool.	Check 5 carcasses per hour for any deviation from "Zero Tolerance"	Trim crew tracks down carcasses in hot cooler and performs adequate trimming.	Document carcasses trimmed since the last successful "Zero Tolerance" CCP check	Daily inspection of - "Zero Tolerance" records by lot.

**Table 4.2 Control Points (CP) and Critical Control Points (CCP) For Lamb Receiving and Processing at Slaughter Facility (Continued)**

<b>Process/Step</b>	<b>CP/ CCP</b>	<b>Criteria or Critical Limits</b>	<b>Monitoring Procedure/ Frequency</b>	<b>Corrective/ Preventive Action</b>	<b>Records/ Measurements</b>	<b>Verification Procedures</b>
(9) Carcass chilling	CCP-3	<p>1. Deep muscle (3") chill temperature <math>\leq 2^{\circ}\text{C}</math> within 12 h</p> <p>Cooler ambient temperature <math>&gt; 0^{\circ} \leq 3^{\circ}\text{C}</math></p>	<p>Hourly monitoring of cooler environmental conditions; temperature, air, humidity.</p> <p>Monitor carcass spacing</p> <p>Conduct random temperature checks a.m. and p.m. throughout cooler to monitor carcass chill</p>	<p>Adjust cooler chill air flow</p> <p>Chill carcasses to <math>&lt; 2^{\circ}\text{C}</math> within 24 h post-slaughter) in deep muscle tissue (3")</p>	Log of chill temperatures	<p>Supervisory review of records with appropriate personnel (daily)</p> <p>Calibrate thermometers; review spacing</p> <p>Monitor (a.m. and p.m.) deep muscle tissue chill</p>

Verification - Audit voltage output (daily).

3. Sticking/Bleeding - CP-3

- A. Biological Hazards - None.
- B. Physical Hazards - None.
- C. Chemical Hazards - None.

Standard Operating Procedure (SOP) for CP-3 - Sticking/Bleeding

- Sanitize knife between sticks in 80°C water (as needed)

Monitoring - Check water temperature in knife dip (hourly).

Recording - Knife decontamination water temperature log (daily).

Verification - Audit knife decontamination log (2 times per day).

4. Skinning, Shank Removal, Depelting - CP-4

- A. Biological Hazards - Potential contamination of carcass from soil, fecal material or moisture from pelt, feet and legs.
- B. Physical Hazards - Vegetable matter transferred from pelt to carcass, physical contaminants from plant or employees.
- C. Chemical Hazards - Pesticide, insecticide or other chemical contaminants from pelt or plant environment.

Standard Operating Procedure (SOP) for CP-4 Skinning, Shank Removal, Depelting

- All operations are to be performed in a sanitary manner (e.g., knives and hands disinfected between procedures or carcasses). No dressing defects (wool, blood clots, dirt, ingesta, feces, etc.) retained on the carcass.

- Monitoring - Line foreman to continuously observe effectiveness of skinning process for each carcass (pelt is to be kept away from exposed carcass; paper is to be used to separate hide from carcass; paper should be of non-porous material to be discarded after one use) (as needed).
- Recording - Review of USDA FSIS records for line defects that cause trimming and visual defects as noted by the line foreman (daily)
- Verification - Summary displayed graphically of USDA FSIS records for line defects that cause trimming and visual defects (weekly).

5. Pre-Evisceration Carcass Washing or Bactericidal Rinsing - CP-5

- A. Biological Hazards - Contamination from fecal material, wool, blood clots, dirt, ingesta, etc., could be redistributed by spray washing the entire carcass.
- B. Physical Hazards - None.
- C. Chemical Hazards - Contamination from water used in spray washing.

Standard Operating Procedure (SOP) for CP-5 Pre-Evisceration Carcass

Washing or Bactericidal Rinsing

Water temperature  $\geq 50 \leq 60^{\circ}\text{C}$

Pressure  $\geq 60 \leq 80 \text{ psi}$

- Monitoring - Monitoring of water temperature, pressure (hourly).
- Recording - Log temperature, pressure, line speed (hourly).
- Verification - Review log of spray wash (daily).

6. Eviscerating/Viscera Handling - CP-6

- A. Biological Hazards - Contamination from fecal material, ingesta, urine and abscesses.
- B. Physical Hazards - None.
- C. Chemical Hazards - None.

Standard Operating Procedure (SOP) for CP-6 Eviscerating/Viscera Handling

All evisceration operations are to be implemented under “Zero Tolerance” for ingesta, feces, urine.

- Operators are expected to wash evisceration tools, knives and hands between carcasses.
  - Debunging operator to sanitize hands, knife and other materials between carcasses.
  - Breast knife or saw to be sanitized (80°C) water between each carcass.
  - Operators that handle viscera are to wash gloved hands between each carcass in 70°C water.
  - All employees that handle carcasses between CP-2 and CP-3 should wash hands or equipment between carcasses.
- Monitoring
- Continuous visual inspection and examination of carcasses for defects or contamination from evisceration procedure (as needed).
  - Contaminated carcasses are to be routed to an off-rail for additional trimming and cleansing (as needed).

- Spot check by line supervisor (as needed).
- Recording** - Evaluation of CP-6 log for water temperatures in disinfectant baths (daily).
- Random check by line supervisor of up-to-date logs (as needed).
- Review of monitoring program for coliform contamination (daily).
- Verification** - Review by USDA-FSIS at carcass inspection site. Document and plot (weekly).

7. Final Washing and/or Bactericidal Spraying - CCP-1

- A. Biological Hazards - Contamination of carcass along the processing chain due to poor hygiene.
- B. Physical Hazards - None.
- C. Chemical Hazards - Any exposure to carcass of plant environment that might contain chemicals, cleaning solutions, etc.

Standard Operating Procedure for CCP-1 Final Washing and/or Bactericidal Spraying

- Pressure, temperature and bactericidal spray wash concentrations are in tolerance with Critical Limits (see specific Critical Limits at each CCP).
- Monitoring** - Monitoring of temperature, pressure and concentration of bactericidal rinse concentration (hourly).
- Recording** - Documentation of log for CCP-1(hourly).
- Verification** - Monitoring by line supervisor and QA personnel (daily).

8. “Zero Tolerance” Inspecting - CCP-2

- A. Biological Hazards - Microbiological contamination after the final wash - ingesta, fecal material, wool.
- B. Physical Hazards - None.
- C. Chemical Hazards - Residual bactericidal solution from CCP-1.

Standard Operating Procedure (SOP) for CCP-2 “Zero Tolerance” Inspecting

- Monitoring - Check five carcasses for the presence of ingesta, fecal material or wool (hourly).
- Recording - Check five carcasses for any deviation from “Zero Tolerance” - document carcasses trimmed since last “Zero Tolerance” check (hourly).
- Verification - Inspection of “Zero Tolerance” by lot (daily).

9. Carcass Chilling - CCP-3

- A. Biological Hazards - Contamination of carcasses due to handling by employees, contaminated equipment or improper carcass spacing.
- B. Physical Hazards - None.
- C. Chemical Hazards - Potential for contamination from a series of sprays designed to chill or hydrate carcasses in cooler.

Standard Operating Procedure (SOP) for CCP-3 Carcass Chilling

- Cooler temperature  $\geq 3 \leq 6^{\circ}\text{C}$  at all times.
  - Deep muscle tissue  $\geq 3 \leq 6^{\circ}\text{C}$  24 h post-slaughter.
- Monitoring - Random checking of 24 h post-slaughter deep muscle temperature probes on carcasses from five carcasses (hourly).

Recording - Chart 24 h deep muscle temperatures (daily).

Verification - QA personnel review deep muscle temperatures (two times per day).

Critical Control Points (CCPs) and Standard Operating Procedures (SOPs) for lamb slaughter are summarized on pages 63-65.

Specific parameters are provided in this HACCP plan for Critical Limits (CLs), for Monitoring CCPs and for time-frames to be used for Recording and Verification. Mortimore and Wallace (1994) state that Critical Control Points (CCPs) must have Critical Limits or criteria which must be met — these are the absolute tolerance for safety. Gill (1995) states that inspection of a process during its normal operation should allow for identification of those operations where direct or indirect contact between the pelt and the meat, or intestinal contents and the meat, are frequent or wholly unavoidable; those operations would be expected to pose the highest risk. Gill (1995) further states that consideration can then be given to means of controlling and improving high-risk process line operations. This is the approach that was followed in this HACCP plan inasmuch as Critical Control Points were positioned at Final Washing and/or Bactericidal Spraying, “Zero Tolerance” Inspecting and Carcass Chilling. Based on data presented previously in Chapter II, the original intent of placing a Critical Control Point (CCP) at the Skinning, Shank Removal, Depelting site was abandoned. Recognizing that, at present, in all six of the plants that were surveyed, there are significant levels of contamination post-depelting, it is unlikely that process control could be achieved at a site prior to final carcass washing. Evisceration is documented to provide additional potential for carcass contamination as do additional process steps post-evisceration and prior to final carcass washing. There seems

to be evidence that further technology is available to refine the carcass slaughtering/dressing process. Bell and Hathaway (1996) found that the different capabilities of conventional and inverted dressing systems to control fleece/carcass contact can be expected to be reflected in the number and distribution of bacteria found on freshly dressed carcasses. Longdell (1992) also found that inverted dressing is hygienically superior to conventional dressing. Further efforts to control contamination at depelting and evisceration sites must continue. In the present HACCP plan, sites considered to be Critical Control Points (CCPs) were identified based on composite plant audit data, which directly implicated specific plant sites where carcass contamination levels are highest (i.e., evisceration and depelting) and where meaningful controlled efforts to prevent contamination or to decontaminate carcasses are available.

#### Critical Control Points (CCPs) and Standard Operating Procedures (SOPs) for Lamb Slaughter Facility

##### 7. Final Washing and/or Bactericidal Spraying - CCP-1

- A. Biological Hazards - Microbiological contamination on the carcass due to slaughter or dressing procedures prior to CCP-2.
- B. Physical Hazards - None.
- C. Chemical Hazards - Contamination of carcass with residual bactericidal solution.

Critical Limit - Spray wash concentrations  $\leq$  5 ppm remaining on carcass.

Monitoring - Monitoring (hourly) of:

Water Temperature	≥ 40° ≤ 50°C
Spray Pressure	≥ 100° ≤ 120 psi
Spray Wash Concentration	≥ 50 ≤ 60 ppm-Chlorine
	≥ 2% ≤ 2.5% Acetic Acid

Recording - Documentation of temperature, pressure, concentration (hourly).

Verification - QA personnel and shift supervisor review records at end of shift (daily).

8. “Zero Tolerance” Inspecting - CCP-2

A. Biological Hazards - Microbiological contamination after the final wash-ingesta, fecal material, wool.

B. Physical Hazards - None.

C. Chemical Hazards - Residual bactericidal solution from CCP-1.

Critical Limit - No deviations from the “Zero Tolerance” for visual presence of ingesta, fecal material, wool.

Monitoring - Check five carcasses for presence of ingesta, fecal material or wool (hourly).

Recording - Check five carcasses for any deviation from “Zero Tolerance” - document carcasses trimmed since last “Zero Tolerance” check (hourly).

Verification - Inspection of “Zero Tolerance” by lot (daily).

9. CCP-3 - Carcass Chilling - CCP-3

- A. Biological Hazards - Microbiological contamination of carcasses due to equipment or employee handling after spray wash.
- B. Physical Hazards - None.
- C. Chemical Hazards - Potential for residual spray wash contamination from CCP-1.

- Critical Limit - Deep muscle tissue temperature:  $\geq 3 \leq 6^{\circ}\text{C}$  24 h post-slaughter.  
Cooler temperature:  $\geq 3 \leq 6^{\circ}\text{C}$  at all times.
- Monitoring - Random checking of 24 h deep muscle temperature probes from five carcasses (hourly).
- Recording - Chart 24 h deep muscle temperatures 24 h, continuous monitoring of ambient cooler temperature (daily).
- Verification - QA personnel review deep muscle temperature (a.m. and p.m.), shift supervisor review cooler temperature at initiation and end of each shift (twice daily).

Corrective Actions as defined by Mortimore and Wallace (1994) must be taken when Monitoring results at Critical Control Points (CCPs) show a deviation from the stated Critical Limits (CLs). Corrective Actions should be designed initially to prevent deviations from occurring at the Critical Control Points. Corrective Actions should provide levels of effect for: (a) actions to prevent deviations from the Critical Limits (CLs) and (b) actions to correct deviations from the Critical Limits (CLs) (Mortimore and Wallace, 1994).

The three Critical Control Points (CCPs) in this HACCP plan — Final Washing and/or Bactericidal Spraying (CCP-1), “Zero Tolerance” Inspecting (CCP-2), and Carcass Chilling (CCP-3) — all contain measures to control deviations from the Critical Limits

(CLs). Actions to prevent deviations would include long-term monitoring of Critical Limits (CLs) and adjustments to spray washing and refrigeration equipment. Detailed records are necessary and will assist in the investigation of deviations and in refinements of Corrective Actions that will prevent future deviations from Critical Limits (CLs).

#### CORRECTIVE ACTIONS

7. Final Washing and/or Bactericidal Spraying - CCP-1
  1. If temperature of water is above or below critical limits  $\geq 40 \leq 50^{\circ}\text{C}$ , adjust water temperature accordingly, assure pressure  $\geq 100 \leq 120$  psi and/or assure concentration of  $\geq 50 \leq 60$  ppm chlorine or of  $\geq 2 \leq 2.5\%$  acetic acid.
  2. Hold product potentially affected until it is determined to be safe.
  3. Determine why water temperature or pressure or concentration deviated.
  4. Correct hot water temperature or pressure or concentration.
  5. Establish plan to prevent recurrence of problem.
8. "Zero Tolerance" Inspecting - CCP-2
  1. If "Zero Tolerance" for ingesta, fecal material, wool is exceeded, track down carcasses in cooler and trim appropriately.
  2. Depending upon what contaminant is present, proceed to area on the line where problem originated and determine probable cause of the problem.
  3. Establish plan to prevent recurrence of problem.
9. Carcass Chilling - CCP-3
  1. If cooler temperatures fall below or exceed  $\geq 3 \leq 6^{\circ}\text{C}$ , adjust refrigeration units accordingly.

2. Hold product affected until it is determined to be safe.
3. Determine why temperature deviation occurred.
4. Correct temperature deviation.
5. Establish plan to prevent recurrence of problem.

Critical Control Point audits, as defined by Mortimore and Wallace (1994), are independent and systematic examinations which are implemented in order to determine whether what is actually happening complies with what is documented and is supposed to happen. The Critical Control Point audit has direct linkage to the Critical Limits (CLs) at Critical Control Points (CCPs) and historical logs and documentation at specific Critical Control Points.

According to Mortimore and Wallace (1994) there are several benefits to audits of Critical Control Points (CCPs).

1. Providing documented evidence of diligence in managing food safety.
2. Employing an independent and objective review of the HACCP system.
3. Maintaining confidence in the HACCP system through verification.
4. Identification of areas where the system could be improved.
5. Continual re-enforcement and awareness of food safety.
6. Identification and removal of obsolete control systems.

**Critical Control Point Audit Checklist**

7. Final Washing and/or Bactericidal Spraying - CCP-1	Temperature, °C	Pressure, psi
1. Washing	≥ 40 ≤ 50	≥ 100 ≤ 120
2. Bactericidal spray:		
a. > 2.0 ≤ 2.5% organic acid	≥ 40 ≤ 50	≥ 100 ≤ 120
b. ≥ 50 ≤ 60 ppm chlorine	≥ 40 ≤ 50	≥ 100 ≤ 120
<hr/>		
8. "Zero Tolerance" Inspecting - CCP-2		
<hr/>		
"Zero Tolerance"	No visible signs of ingesta, fecal material, wool	
<hr/>		
9. Carcass Chilling - CCP-3		
<hr/>		
Temperature, °C		
<hr/>		
1. Cooler temperature	≤ 50	
2. Deep muscle temperature 8 h post-slaughter	< 3	
<hr/>		

Good Manufacturing Practices (GMPs) should be viewed as a general support program for a well-instituted HACCP plan (NACMCF, 1992). GMPs are the right way to educate plant employees and management in sometimes simple operational tasks. These operations, tasks or behaviors should become everyday management protocol over time. GMPs could be perceived as rules and procedures by which all employees and management will proceed with their everyday responsibilities. GMPs should be viewed as the right or acceptable way to perform operational tasks within a production system. GMPs must be easily understood, practical and achievable work standards or practices that provide support for the comprehensive HACCP plan.

**Good Manufacturing Practices (GMPs)  
for Lamb Slaughter Facility**

**(1) Facilities**

**a. Control Movement of Product**

- carcass movement should be from the most contaminated areas of the plant (i.e., washed carcasses should move away from areas such as depelting).

**b. Control Movement of People**

- maintenance crew must sanitize, (e.g., use a footbath between jobs or areas of the plant).
- cleaning crew must follow the same SOPs as are required for all other workers.

**c. Minimize Air Flow, Dust, Aerosols**

- airflow should be towards areas of highest potential contamination (e.g., depelting area, area of entry to slaughter floor).
- receiving pens should be bedded and cleaned daily.

**d. Monitor Receiving Area for Rodents, Birds, Insect, Excessive Moisture**

- inspect receiving area weekly for additional contaminants.

**e. Prevent Contamination of Carcasses by Contacting Doors and/or Doorway Openings**

- provide door opening and closure mechanisms that are sanitized daily.

(2) Equipment

- a. Assure Surfaces Are Smooth to Prevent Product Contamination, (e.g., stainless steel, smooth plastic)
  - wash with 80°C water.
- b. Provide Clear Instructions for Disassembly, Cleaning and Reassembly of Equipment
  - check list for lost parts.
- c. Install Temperature Verification Equipment in Cooler
  - continuous monitoring of cooler temperatures.

(3) People

- a. Organize and Hold Training Sessions
- b. Control Movement of People and Product Within Plant
  - maintenance and cleaning crews must comply with the same SOPs as plant workers.
  - implement mandatory use of a foot bath at all entrance/exits.
- c. Identify Acceptable Clothing Procedures
  - clean attire — throughout entire plant.
  - hair nets — all workers — male/female.
  - frocks or aprons where necessary — frocks where water is not used; rubber aprons where excessive blood and/or water is used.
- d. Describe Glove Procedures
  - latex or plastic.

- change twice per day, and after breaks.
- provide glove rinses (80°C water) along processing chain.
- e. Define Sanitation Procedures for Knife, Air Knife, Steel, Scabbard, Sanitation
  - provide rinse basins with 80°C water for periodic washing of equipment.
- f. Define Boot Requirements
  - provide rubber steel-toed boots.
  - washed twice per shift and before re-entry to plant, provide footbath at all entrance and egress points in the plant (except in coolers).
- g. Eliminate Wipe Rags
  - use disposable towels.
  - use non-porous toweling during the skinning process.

(4) Sanitation

- a. Develop Total Sanitation Program to Include Employee Training
- b. Monitor Waste Receptacles
- c. Assure Inedible Product Movement Away Is from Edible Product
  - clean containers daily.
- d. Avoid Floor Splash

(5) Temperatures

- a. Establish Means for Record-Keeping in Product Cooler and Chill Rooms
  - see SOP's.

- b. Monitor Carcass Temperature to Verify Uniform Cooling and Carcass Spacing
    - see SOP's.
  - c. Monitor Carcass Temperature 24 h Post-Slaughter
    - see SOP's.
  - d. Check Room and Containers of Carcass Trim
- (6) Product Identification
- a. Continue Current Lot Tagging and Identification System
  - b. Assign Lot Number That Will Track Product from Slaughter to Fabrication
  - c. Assure Identification from Live Animal to Carcass to Fabricated Product to Finished Product, by Use of Carcass Tags on Individual Carcasses with Lot No., Carcass No., Hot Weight
- (7) Restroom and Dining Areas
- a. Maintain Clean Restroom Facilities as a Plant Requirement
  - b. Require all Workers to Wash and Sterilize Hands after Using the Restroom and after Eating Meals
  - c. Install Automated Hand-Washers at Entry to Work Area

Records or daily logs are a strict and important requirement of a HACCP system (Mortimore and Wallace, 1994). Records are mandatory at Critical Control Points and help to verify that the HACCP plan is working correctly. Records can also put into perspective analyses or trends overtime. Records, particularly those kept on-site, must be easily accessible to those responsible for documentation and simple to complete. Logs or

records at Critical Control Points (CCPs) should be specific to each CCP and should be designed to reflect either a time-frame or specific production phase. The need for uniformity across logs may be necessary if a deviation occurs at one CCP then circumstances or relationships could be developed. Records tell a story or may be used to solve a chronic operational problem. Records may also be the key to answers if litigation is involved over product integrity. Records at Critical Control Points (CCPs) should include temperature calibration. Standardized forms stored in an organized manner will facilitate inspection by regulatory agencies.





Daily Log Final Washing and/or Bactericidal Spraying - CCP-1						
Date/Time	Temperature	pH	psi	Initials		
				(A)	(B)	(C)
7:00						
8:00						
9:00						
10:00						
11:00						
12:00						
1:00						
2:00						
3:00						
4:00						

Critical Limits: water temperature wash cabinet  $\geq 50 \leq 60^{\circ}\text{C}$

Washing pressure 100 psi

Bactericidal spray concentration, organic acid  $> 2.0 \leq 2.5$  ppm or  
chlorine spray  $\geq 50 \leq 60$  ppm .

Three sets of initials are needed for pre-shipment records review:

(A) Employee, (B) QA Supervisor, and (C) Plant HACCP Coordinator.

Daily Log "Zero Tolerance" Inspecting - CCP-2						
"Zero Tolerance"						
Date/Time	Ingesta	Fecal Material	Wool	Initials		
				(A)	(B)	(C)
7:00						
8:00						
9:00						
10:00						
11:00						
12:00						
1:00						
2:00						
3:00						
4:00						

Critical Limits: "Zero Tolerance" on five carcasses inspected each h for ingesta, fecal material, wool.

Three sets of initials are needed for pre-shipment records review: (A) Employee, (B) QA Supervisor, and (C) Plant HACCP Coordinator.

Daily Log Carcass Chilling - CCP-3						
Date/Time	Cooler Temperature	3" Muscle Temperature	Calibrat. Therm.	Initials		
				(A)	(B)	(C)
7:00						
8:00						
9:00						
10:00						
11:00						
12:00						
1:00						
2:00						
3:00						
4:00						

Critical Limits:

Cooler temperature;  $\leq 4^{\circ}\text{C}$ .

Deep Muscle Temp;  $\leq 3^{\circ}\text{C}$ .

Calibrate Thermometer once daily.

Three sets of initials required for preshipment records/review:

(A) Employee, (B) QA Supervisor, and (C) Plant HACCP Coordinator.

## IMPLICATIONS

Food safety regulation may be justified by the existence of a failure in the market place for safety attributes (Unnevehr and Jensen, 1996). The Pathogen Reduction; HACCP Systems; Final Rule was enacted in 1996 (Smith, 1999). Upon implementation of the PR; HACCPs; Final Rule, industry's "Scientific HACCP Programs" were modified to drop back from 6 to 20 Critical Control Points (CCPs) in most plants to 1, 2 or 3 CCPs in the government's "Regulatory HACCP Programs," (Smith, 1999).

The lamb-production process, consisting of lamb feeding, transportation, receiving and slaughter/dressing may involve more than 30 distinct operations. Gill (1995) states that to give equal importance to each step in the production process is impractical; therefore, individual processes should be ranked according to risk using the Flow Chart for Receiving and Processing at Lamb Facility (Figure 4.1; Chapter IV). Subsequently, quality assurance personnel can then focus upon those operations where there is most probable cause for contamination. Moreover, in the risk assessment process, quality assurance teams must identify those areas where it is physically and economically practical to provide intervention systems to prevent or minimize carcass contamination. The development of a model HACCP plan for lamb feeding, transportation, receiving and slaughter/dressing offers a practical approach to control and reduce microbial contamination on domestic lamb carcasses. The analogy might be that management is in a war with microbial contamination, management must identify the battles it can win or risk losing the war.

Further consideration by plant management and quality assurance personnel should be given to means of controlling and improving high-risk line operations, e.g., depelting and evisceration. These two operations, as evidenced by elevated microbial counts, offer the opportunity to isolate within a specific operation, steps that contribute a significant level of contamination. Assigning a Critical Control Point (CCP) to a process that under current plant design may not be controlled by the CCP, dooms the entire system to failure. Improved line dressing systems (inverted vs conventional) will lead to removal of the depelting and evisceration processes from the list of uncontrolled operation sites.

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## APPENDIX A.

### EMPLOYEE EDUCATION AND TEAMWORK — THE KEYS TO A SUCCESSFUL HACCP PROGRAM

Recognizing that the domestic lamb packing industry must address a wide variety of demands with regards to its employees. Employee education sometimes receives too little attention. The adoption of HACCP principles/protocols/procedures by lamb packing facilities makes it even more important to have adequate employee education. Expectations for on-line worker performance will increase with an effective HACCP plan. All plant employees need to appreciate their key role in protecting product safety and improving its quality. Employee education is particularly critical for key supervisory individuals. The Quality Assurance team must promote the teamwork concept where applicable. Employee training should occur during business hours or be presented in a package where participation results in financial gain. Line-worker incentive programs based on the lack of quality defects, or adherence to GMPs and SOPs, can be designed in a "performance package" for employees.

Records visible to the workers for quality productivity may initiate even further job pride and performance. More meaningful employee rewards might include compensation time for outstanding units and/or, small but incremental increases in hourly compensation for goals met within the HACCP framework. Ultimately, company management personnel must understand that a successful HACCP program is premised upon involvement of the entire HACCP team, from the president to the newest employee. The HACCP plan should be a dynamic on-going process, not mandated by the leadership, but perceived by employees and middle management as a tool for company success.

#### APPENDIX B.

### HACCP AND TQM PROGRAM DEVELOPMENT FOR LAMB PACKING PLANTS

#### 1.0 TERMS AND DEFINITIONS (USDA FSIS, 1989)

- 1.01 *Continuous Monitoring*: Uninterrupted collection and recording of data such as temperature on a strip chart.
- 1.02 *Control*: (a) To manage the conditions of an operation to maintain compliance with established criteria. (b) The state wherein correct procedures are being followed and criteria are being met.
- 1.03 *Control Point (CP)*: Any point, step or procedure at which biological, physical or chemical factors or Hazards can be controlled.
- 1.04 *Corrective Action*: Procedures to be followed when a deviation occurs.
- 1.05 *Criterion*: A requirement on which a judgement or decision can be based.

- 1.06 *Critical Control Point (CCP)*: A point, step or procedure at which control can be applied and a food safety Hazard can be prevented, eliminated or reduced to acceptable levels.
- 1.07 *Critical Defect*: A deviation at a CCP which may result in a Hazard.
- 1.08 *Critical Limit*: A criterion that must be met for each preventive measure associated with a Critical Control Point.
- 1.09 *Deviation*: Failure to meet a Critical Limit.
- 1.10 *Food Safety*: Issues related to health problems associated with contamination of the food with microorganisms, chemical substances or physical materials--distinct from issues related to product quality.
- 1.11 *FSIS*: The Food Safety and Inspection Service which is under the jurisdiction of the United States Department of Agriculture.
- 1.12 *GMP*: Good Manufacturing Practices--describes general guidelines to be followed in an operation.
- 1.13 *HACCP*: Hazard Analysis Critical Control Point.
- 1.14 *HACCP Plan*: The written document which is based upon the principles of HACCP and which delineates the procedures to be followed to assure the control of a specific process or procedure.
- 1.15 *HACCP System*: The result of the implementation of the HACCP plan.
- 1.16 *HACCP Team*: The group of people who are responsible for developing a HACCP plan.

- 1.17 *HACCP Plan Revalidation*: One aspect of Verification in which a documented periodic view of the HACCP plan is done by the HACCP team with the purpose of modifying the HACCP plan as necessary.
- 1.18 *HACCP Plan Validation*: The initial review by the HACCP team to ensure that all elements of the HACCP plan are accurate and in place.
- 1.19 *Hazard*: A biological, chemical or physical property that may cause a food to be unsafe for consumption.
- 1.20 *Monitor*: To conduct a planned sequence of observations or measurements to assess whether a CCP is under control and to produce an accurate record for future use in Verification.
- 1.21 *Preventive Measure*: Physical, chemical or other factors that can be used to control an identified Health Hazard.
- 1.22 *Random Checks*: Observations or measurements which are performed to supplement the scheduled evaluations required by the HACCP plan.
- 1.23 *Risk*: An estimate of the likely occurrence of a Hazard.
- 1.24 *SOP*: Standard Operating Procedure--describes how a task should be performed.
- 1.25 *Sensitive Ingredient*: An ingredient known to have been associated with a Hazard and for which there is reason for concern.
- 1.26 *Severity*: The seriousness of a Hazard.
- 1.27 *Target Levels*: Criteria which are more stringent than Critical Limits and which are used by an operator to reduce the risk of a deviation.
- 1.28 *USDA*: United States Department of Agriculture.

- 1.29 *Verification*: The use of methods, procedures or tests, in addition to those used in Monitoring, to determine if the HACCP system is in compliance with the HACCP plan and/or whether the HACCP plan needs modification and revalidation.

## 2.0 PURPOSE AND PRINCIPLES

*HACCP is a systemic approach to food safety, consisting of the seven following principles:*

- 2.01 Assess Hazards and risks associated with growing, harvesting, raw materials and ingredients, processing, manufacturing, distribution, marketing, preparation and consumption of the food.
- 2.02 Determine CCPs required to control the identified Hazards.
- 2.03 Establish the Critical Limits that must be met at each identified CCP.
- 2.04 Establish procedures to Monitor a CCP.
- 2.05 Establish Corrective Action to be taken when there is a deviation identified by monitoring a CCP.
- 2.06 Establish effective Record-Keeping systems that document the HACCP plan.
- 2.07 Establish procedures for Verification that the HACCP system is working correctly.

## 3.0 EXPLANATION OF PRINCIPLES

- 3.01 *Principle No. 1*: Assess Hazards associated with growing, harvesting, raw materials and ingredients, processing manufacturing, distribution, marketing, preparation and consumption of the food.
- 3.02 *Description*: Provides for a systematic evaluation of a specific food and its ingredients or components to determine the risk from hazardous microorganisms or their toxins. Hazard Analysis is most useful for guiding the safe design of a food product and for defining the CCPs that eliminate or control hazardous

microorganisms or their toxins at any point during the entire production sequence. The Hazard assessment is a two-part process consisting of ranking a food according to six Hazard characteristics, followed by the assignment of a risk category which is based upon the ranking.

Ranking according to Hazard characteristics is based on assessing a food in terms of: (a) whether the product contains microbiologically sensitive ingredients, (b) whether the process does or does not contain a controlled processing step that effectively destroys harmful microorganisms, (c) whether there is significant risk of post-processing contamination with harmful microorganisms or their toxins, and (d) whether there is substantial potential for abusive handling in distribution or in consumer handling or preparation that could render the product harmful when consumed, or (e) whether or not there is a terminal heat process after packaging or when cooked in the home. Ranking Hazards according to the afore-mentioned five characteristics results in the assignment of risk categories based on how many of the characteristics are present.

The risk categories are utilized for recognizing the Hazard risk for ingredients and how they must be treated or processed to reduce the risk for the entire food production and distribution sequence.

The Hazard assessment procedure is ideally conducted after developing a working description of the product, establishing the types of raw materials and ingredients required for preparation of the product, and preparing a diagram for the food production sequence. The two-part assessment of Hazard Analysis and assignment of risk categories is conducted according to the following procedure:

### 3.1.1 Hazard Analysis and assignment of risk categories:

3.1.1.1 Rank the food according to Hazard characteristics A through F, using a plus (+) to indicate a potential Hazard. The number of pluses will determine the risk category. A model diagram outlining this concept is given under section 3.1.3. As indicated, if the product falls under Hazard class A, it should automatically be considered Risk Category VI.

**Hazard A:** A special class that applies to non-sterile products designated and intended for consumption by at-risk populations, e.g., infants, the aged, the infirmed or immunocompromised individuals.

**Hazard B:** The product contains "sensitive ingredients" in terms of microbiological hazards.

**Hazard C:** The process does not contain a controlled processing step that effectively destroys harmful microorganisms.

**Hazard D:** The product is subject to recontamination after processing and before packaging.

**Hazard E:** There is substantial potential for abusive handling in distribution or in consumer handling that could render the product harmful when consumed.

**Hazard F:** There is no terminal heating process after packaging or when cooked in the home.

### 3.1.1.2 Assignment of risk category (based on ranking by Hazard characteristics):

**Category VI** A special category that applies to non-sterile products designated and intended for consumption by at-risk populations, e.g., infants, the aged, the

infirm, or immunocompromised individuals. All six Hazard characteristics must be considered.

**Category V** Food products subject to the five afore-mentioned general Hazard characteristics, (i.e., Hazards A, B, C, D, E, F).

**Category IV** Food products subject to four of the general Hazard characteristics.

**Category III** Food products subject to three of the general Hazard characteristics.

**Category II** Food products subject to two of the general Hazard characteristics.

**Category I** Food products subject to one of the general Hazard characteristics.

**Category O** Hazard Class -- No Hazard.

*NOTE: Ingredients are treated in the same manner with respect to how they are received at the plant, BEFORE processing. This permits determination of how to reduce risk in the food system.*

3.1.2 It is recommended that a chart be utilized that provides assessment of a food by

Hazard characteristic and risk category. A format for this chart is given as follows:

**ASSESSMENT OF A FOOD BY HAZARD CHARACTERISTIC AND RISK  
USDA APHIS, 1989**

Food Ingredient or Product	Hazard Characteristics	Risk Category
T	A+ (Special Category)*	VI
U	Five +'s (B through F)	V
V	Four +'s (B through F)	IV
W	Three +'s (B through F)	III
X	Two +'s (B through F)	II
Y	One + (B through F)	I
Z	No +'s	O

*\*Hazard characteristic A automatically is risk category VI, but any combination of B through F may also be present.*

3.2 **Principle No. 2:** Determine CCP required to control the identified Hazards.

3.2.1 **Description:** A CCP is defined as any point or procedure in a specific food system where loss of control may result in an unacceptable health risk. A CCPs must be established where control can be exercised. All Hazards identified by the Hazard Analysis must be controlled at some point(s) in the food production sequence, from harvesting and growing raw materials to the ultimate consumption of the food (USDA FSIS, 1989).

CCPs are located at any point in a food sequence where hazardous microorganisms need to be destroyed or controlled. For example, a specified heating process, at a given time and temperature to destroy a specified pathogen, is a CCP. Likewise, refrigeration required to prevent hazardous organisms from growing, or the

adjustment of a food to a pH necessary to prevent toxin formation, is a CCP (USDA FSIS, 1989).

Types of CCPs may include, but are not limited to: cooking, chilling, sanitizing, formulation control, prevention of cross-contamination, employee hygiene and environmental hygiene (USDA FSIS, 1989).

CCPs must be carefully developed and documented. In addition, they must be used only for purposes of product safety. They should not be confused with control points that do not control safety. For comparison, a control point is defined as any point in a specific food system where loss of control might lead to an unacceptable health risk (USDA FSIS, 1989).

3.3 **Principle No. 3:** Establish the Critical Limits which must be met at each identified CCP.

3.3.1 **Description:** A Critical Limit (CL) is defined as one or more prescribed tolerances that must be met to ensure that a CCP effectively controls a microbiological, chemical or physical health hazard. There may be more than one Critical Limit for a given CCP. If any one of those Critical Limits is out of control, the CCP will be out of control, and a potential Hazard can exist. The criteria most frequently utilized for Critical Limits are temperature, time, humidity, moisture level, pH, titratable acidity, preservatives, salt concentration, available chlorine, viscosity and, in some cases, sensorial information such as texture, aroma and visual appearance. Many different types of CL information may be needed for control of a CCP (USDA FSIS, 1989).

3.4 **Principle No. 4:** Establish procedures to Monitor CCPs.

3.4.1 **Description:** Monitoring is the scheduled testing or observation of a CCP and its limits. Monitoring results must be documented. From the Monitoring standpoint, failure to control a CCP is a critical defect.

A critical defect is defined as a defect that may result in hazardous or unsafe conditions for individuals using and depending upon the product. Because of the potentially serious consequences of a critical defect, Monitoring procedures must be extremely effective.

Ideally, Monitoring should be at the 100% level. Continuous Monitoring is possible with many types of physical and chemical methods. For example, the temperature and time for the scheduled thermal processing of low-acid canned foods is recorded continuously on temperature recording charts. If the temperature falls below the scheduled temperature or the time is insufficient, as recorded on the chart, this is noted as a process deviation. Likewise, pH measurement may be done continually in fluids or by testing of a batch before processing. There are many ways to monitor CCP limits on a continuous or batch basis and to record the data on charts. The high reliability of continuous Monitoring is always preferred when feasible; it requires careful calibration of equipment.

When it is not possible to Monitor a Critical Limit on a full-time basis, it is necessary to establish that the Monitoring interval will be reliable enough to indicate that the Hazard is under control. Statistically designed data collection systems or sampling systems lend themselves to this purpose. However, statistical procedures are most useful for measuring and reducing the variation in food formulations,

manufacturing equipment and measuring devices. Thus, they increase the reliability of the system.

When using Statistical Process Control, it is important to recognize that there is no tolerance for exceeding a Critical Limit. For example, when a pH of 4.6 or less is required for product safety, no single product unit may have a pH above 4.6. To compensate for variation, the maximum pH for the product must be targeted for 4.7. Statistical Process Control can be applied to understand variation in the system, and assure that no unit exceeds a pH of 4.6. Statistical audits can be based on this concept.

Most Monitoring procedures for a CCP will need to be done rapidly because they relate to on-line processes and there will not be time for lengthy analytical testing. Microbiological testing is seldom effective for Monitoring CCPs due to its time-consuming nature. Therefore, physical and chemical measurements are preferred because they may be done rapidly and can indicate control of the process. *Physical and chemical measurements that may be utilized for monitoring include:* Temperature, time, pH, sanitation at CCP, specific preventive measure for cross-contamination, specific food handling procedures, moisture level, and other measurements.

Spot checks are useful for supplementing the Monitoring of certain CCP and their respective limits. They may be used to check incoming pre-certified ingredients, assess equipment and environmental sanitation, check airborne contamination and cleaning and sanitizing of gloves, as well as identifying any place

to check where follow-up is needed. Spot checks may consist of physical and chemical tests and, where needed, microbiological tests.

With certain foods, microbiologically sensitive ingredients, or imported goods, there may be no alternative to microbiological testing. However, a sampling frequency that is adequate for reliable detection of low levels of pathogens is seldom possible because of the large number of samples needed. For this reason, microbiological testing has limitations in a HACCP system, but is valuable as a means of establishing and randomly verifying the effectiveness of control at CCP, (challenge tests, spot checking or for troubleshooting.)

All records and documents associated with CCP Monitoring must be signed by the person doing the Monitoring and signed by a responsible official of the company.

3.5 **Principle No. 5:** Establish Corrective Action to be taken when there is a deviation identified by monitoring of a CCP.

3.5.1 **Description:** Actions taken must eliminate the actual or potential hazard which was created by deviation from the HACCP plan, and assure safe disposition of the product involved. Because of the variations in CCPs for different foods and the diversity of possible deviations, specific Corrective Actions must be developed for each CCP in the HACCP plan. The actions must demonstrate that the CCP has been brought under control. Deviation procedures must be documented in the HACCP plan and agreed upon by the appropriate regulatory agency prior to approval of the plan.

Should a deviation occur, the plant will place the product on hold pending completion of appropriate Corrective Actions and analyses. In instances where it may be difficult to determine the safety of the product, then the testing and final disposition must be agreed to by the government. In instances not associated with safety, government consultation is not required.

Identification of deviant lots and Corrective Actions taken to assure safety of these lots must be noted in the HACCP record and remain on file for a reasonable period after the expiration date or expected shelf-life of the product.

3.6 **Principle No. 6:** Establish procedures for Verification that the HACCP system is working correctly.

3.6.1 **Description:** Verification consists of methods, procedures and tests used to determine that the HACCP system is in compliance with the HACCP plan. Both the packer and the regulatory agency have a role in verifying HACCP plan compliance. Among other things, Verification confirms that all hazards were identified in the HACCP plan when it was developed. Verification measures may include physical, chemical and sensory methods and testing for conformance with microbiological criteria when those have been established.

3.6.1.1 Examples of Verification activities include, but are not limited to:

- ☐ Establishment of appropriate Verification inspection schedules.
- ☐ Review of the HACCP plan.
- ☐ Review of the CCP records.
- ☐ Review of deviations and dispositions.
- ☐ Visual inspections of operations to observe if CCPs are under control.

- ☐ Random sample collection and analysis.
- ☐ Written record of Verification inspections which certifies compliance with the HACCP plan, or deviations from the plan, and the Corrective Actions taken.

3.6.1.2 Verification inspections should be conducted:

- ☐ Routinely, or on an unannounced basis, to assure selected CCP are under control.
- ☐ When it is determined that intensive coverage of a specific commodity is needed because of new information on food safety issues requiring assurance that the HACCP plan remains effective.
- ☐ If foods produced have been implicated as a vehicle of foodborne disease.
- ☐ When requested on a consultative basis or if established criteria have not been met.

3.6.1.3 Elements which must be included in Verification inspection reports:

- ☐ Existence of an approved HACCP plan and designation of person(s) responsible for administering and updating the HACCP plan.
- ☐ All records and documents associated with CCP Monitoring must be signed by the person Monitoring, and approved by a responsible official of the firm.

-- Direct Monitoring data of the CCPs while in operation.

- Certification that Monitoring equipment is properly calibrated and in working order.
- Deviation procedures.

- ☐ Any sample analysis for attributes confirming that CCPs are under control; to include physical, chemical, microbiological or organoleptic methods.

3.7 **Principle No. 7:** Establish effective Record-Keeping systems that document the HACCP plan.

3.7.1 **Description:** The HACCP plan must be on file at the food establishment. Additionally, the plan must include documentation relating to each CCP and any action on critical deviations and disposition of product. These materials are to be made available to government inspectors upon request. The HACCP plan clearly designates records that will be available for government inspection. Certain records that deal with the functioning of the HACCP system and proprietary information are not necessarily available to regulatory agencies.

Generally, the types of records utilized in the total HACCP system will include the following:

*NOTE: Only those records pertaining to CCPs must be made available to regulatory agencies.*

#### 3.7.1.1 Ingredients

- ☐ Supplier certification documenting compliance with processor's specifications.
- ☐ Processor audit records verifying supplier compliance.
- ☐ Storage temperature record for temperature-sensitive ingredients.

### 3.7.1.2 Records relating to product safety

- ☐ Sufficient data and records to establish the efficacy of barriers in maintaining product safety.
- ☐ Sufficient data and records establishing the safe shelf-life of the product.
- ☐ Documentation of the adequacy of the processing procedures from a knowledgeable process authority.

### 3.7.1.3 Processing

- ☐ Records from all monitored CCPs.
- ☐ System records verifying the continued adequacy of the processes.

### 3.7.1.4 Packaging

- ☐ Records indicating compliance with specifications of packaging materials.
- ☐ Records indicating compliance with sealing specifications.

### 3.7.1.5 Storage and Distribution

- ☐ Temperature records.
- ☐ Records showing no product was shipped after expiration of the shelf-life date on temperature-sensitive products.

### 3.7.1.6 Deviation File

3.7.1.7 Modification to the HACCP plan file indicating approved revisions and changes in ingredients, formulations, processing, packaging and distribution control, as needed.

**APPENDIX C.**  
**CRITERIA FOR USE IN IDENTIFYING HAZARDS; RISK ASSESSMENT**

<b>Microbiological Hazards</b>		
A	High Risk Populations of Consumers	0
B	Sensitive Ingredients in the Product	0
C	No Kill Step in the Process	+
D	Recontamination of the Product	+
E	Abuse	+
F	No Terminal Heating	0
<b>Risk Category</b>		<b>III</b>
<b>Chemical Hazards</b>		
A	High Risk Population	0
B	Ingredients Contain Hazard	0
C	Not Removed in Manufacture	0
D	Recontamination - Manufacture	0
E	Recontamination - Consumer	+
F	Consumer Cannot Detect/Remove	+
<b>Risk Category</b>		<b>II</b>
<b>Physical Hazards</b>		
A	High Risk Population	0
B	Ingredients Contain Hazards	0
C	Not Removed in Manufacture	0
D	Recontamination - Manufacture	0
E	Recontamination - Consumer	+
F	Consumer Cannot Detect/Remove	+
<b>Risk Category</b>		<b>II</b>

0 = low potential risk

+ = increased potential risk