Validation of Acid Washes as Critical Control Points in Hazard Analysis and Critical Control Point Systems†

E. S. DORMEDY,1 M. M. BRASHEARS,1* C. N. CUTTER,2 AND D. E. BURSON3

1Department of Food Science and Technology, University of Nebraska, Lincoln, Nebraska 68583-0919; 2Department of Food Science, 111 Borland Laboratory, Pennsylvania State University, University Park, Pennsylvania 16807; and 3Department of Animal Science, University of Nebraska, Lincoln, Nebraska 68583, USA

MS 99-300: Received 4 October 1999/Accepted 11 December 1999

ABSTRACT

A 2% lactic acid wash used in a large meat-processing facility was validated as an effective critical control point (CCP) in a hazard analysis and critical control point (HACCP) plan. We examined the microbial profiles of beef carcasses before the acid wash, beef carcasses immediately after the acid wash, beef carcasses 24 h after the acid wash, beef subprimal cuts from the acid-washed carcasses, and on ground beef made from acid-washed carcasses. Total mesophilic, psychrotrophic, coliforms, generic Escherichia coli, lactic acid bacteria, pseudomonads, and acid-tolerant microorganisms were enumerated on all samples. The presence of Salmonella spp. was also determined. Acid washing significantly reduced all counts except for pseudomonads that were present at very low numbers before acid washing. All other counts continued to stay significantly lower (P < 0.05) than those on pre-acid-washed carcasses throughout all processing steps. Total bacteria, coliforms, and generic E. coli enumerated on ground beef samples were more than 1 log cycle lower than those reported in the U.S. Department of Agriculture Baseline data. This study suggests that acid washes may be effective CCPs in HACCP plans and can significantly reduce the total number of microorganisms present on the carcass and during further processing.

Meat animals can act as asymptomatic hosts to several enteric human pathogens, including strains of enterohemorrhagic Escherichia coli and Salmonella. These pathogens provide a significant hazard to human safety and a difficult challenge to the meat industry to control, reduce, or eliminate such pathogenic hazards in the production and processing of meat products for human consumption. Bean and Griffin reported that in the United States, Salmonella spp. account for 48% of all beef-related outbreaks (2). E. coli O157:H7 has been increasingly implicated in foodborne diseases and has been linked to the consumption of beef products or products cross-contaminated with bovine feces (2, 3, 12, 15, 22, 23, 30).

Traditional approaches to food safety have focused on prevention of pathogen growth. Today, the low infectious dose required of some pathogens dictates that successful prevention must focus on reducing, controlling, or eliminating the microorganisms with a hazard analysis and critical control point (HACCP) plan. Salmonella spp. are the most common causes of foodborne illness associated with meat and poultry products (2). While most Salmonella spp. have a high infectious dose, only a few cells (5 to 100) of some strains of Salmonella are enough to make someone sick (2). E. coli O157:H7 is more significant than other foodborne microorganisms because of the low infectious dose required (possibly less than five cells) and the severity of the disease it causes. Both E. coli O157:H7 and the more virulent strains of Salmonella display an unusual acid tolerance (2). In documented outbreaks involving these pathogens, the infectious dose has been consistently low as a direct result of acid tolerance (2). Several studies have documented the ability of E. coli O157:H7 to survive acidic conditions encountered in various foods, in the stomach, in vitro, as well as following the application of organic acid carcass washes or dips (1, 4, 6, 7, 18, 19, 21).

In a fresh meat system, microbial hazards can only be minimized, not wholly prevented or eliminated. Various intervention strategies have been shown to be effective measures for reducing microbial contamination on beef carcasses, including organic acid washes. These interventions are sometimes selected as critical control points (CCPs) in HACCP plans to reduce the number of microorganisms in a fresh meat system. Several studies have reported that acid washes reduce foodborne pathogens and spoilage organisms on inoculated beef surfaces (5, 8, 9, 10, 14, 17, 20). Additionally, acid washes are desirable in the beef industry because of the low cost and ease of application of the treatment.

It is imperative to the success of HACCP to assess and validate the effectiveness of implemented HACCP plans. HACCP systems require the objective measurement of biological hazards for validating the workings of an HACCP system and to evaluate the success of intervention strategies. One potential way to validate that microbial hazards are being controlled is by direct microbial evaluation. Microbial analysis can be used to validate the microbiological adequacy of the processes of production and chilling of carcasses in a slaughter operation, as well as further meat-
processing operations. These measurements can also provide an objective basis for comparing the surface contamination of carcasses throughout a process.

The objectives of this study were to establish microbial profiles of beef carcasses before an in-plant acid wash, after a 2% lactic acid wash, 24 h after acid washing and chilling, and on beef subprimal cuts and ground beef from the carcasses subjected to an acid wash. The microbial ecology of carcasses was characterized using standard plating techniques to enumerate at the species level before and after application of organic acid interventions, as well as further processing. The information derived will help determine if acid intervention strategies are effective in reducing microbial loads as a CCP in HACCP systems. While many laboratory studies exist that indicate acid washes reduce microbial loads on beef, we wanted to validate the use of acid washes in beef slaughter facilities as a CCP.

In order for an HACCP system to be effective in controlling microbial hazards, it must be validated by collecting scientific data in the food-processing environment.

MATERIALS AND METHODS

Processing facility. A large (more than 500 employees) beef slaughter facility in Nebraska was chosen for this study. In this facility, 350 to 400 beef animals are slaughtered per hour, and carcasses are chilled at 4°C for 24 h. Immediately following chilling, carcasses are fabricated into subprimal cuts and 2,000-pound “combos” of beef trim. Combos are plastic-lined cardboard containers of cut beef pieces supported by a wooden pallet. "Combos" of beef trim. Combos are plastic-lined cardboard containers of cut beef pieces supported by a wooden pallet (11). The primal cuts are vacuumed packaged and stored up to 2 days at 4°C. The combo bins are taken to the beef grinder as they are filled. Food safety and meat-processing extension specialists at the University of Nebraska–Lincoln assisted the HACCP team in writing the HACCP plan for the facility and in training plant management in the HACCP principles. CCPs in the HACCP plan included carcass trimming (zero fecal contamination limit), acid rinsing of carcasses (2% lactic acid), and carcass chilling.

Microbiological sampling. Previously, scientists have collected sets of 25 random samples from each point in a process being investigated and enumerated total aerobic counts (reported in 1 CFU/cm²) and coliform and generic E. coli (reported in 1 CFU/100 cm²) in each sample. From these, the mean log numbers of each group of organisms were calculated. Aerobic counts and coliforms that were not E. coli were the accepted indicators of general processing hygiene, and E. coli was the accepted indicator for contamination with fecal organisms (13).

In this study we used this previously published information as a guideline for the number of samples needed to collect a statistically sound data set. Additionally, we collected 10 sets of preliminary data to determine the variability of the microbial populations on the carcasses, primal cuts, and in the ground beef. We decided to collect enough data for the study to detect statistical differences at the α = 0.05 level of confidence. The equations used for these calculations are similar to those found in Hicks (16). From these calculations we determined that 27 samples would be sufficient to detect differences. However, we collected 30 samples to increase the level of statistical soundness.

To establish a carcass microbial profile, carcasses were sampled using the U.S. Department of Agriculture (USDA)/Food Safety and Inspection Service sponge method (24). The Final Rule describes the techniques in great detail (23). Briefly, sterile sponge-

...ERAS AND METHODS

Processing facility. A large (more than 500 employees) beef slaughter facility in Nebraska was chosen for this study. In this facility, 350 to 400 beef animals are slaughtered per hour, and carcasses are chilled at 4°C for 24 h. Immediately following chilling, carcasses are fabricated into subprimal cuts and 2,000-pound “combos” of beef trim. Combos are plastic-lined cardboard containers of cut beef pieces supported by a wooden pallet (11). The primal cuts are vacuumed packaged and stored up to 2 days at 4°C. The combo bins are taken to the beef grinder as they are filled. Food safety and meat-processing extension specialists at the University of Nebraska–Lincoln assisted the HACCP team in writing the HACCP plan for the facility and in training plant management in the HACCP principles. CCPs in the HACCP plan included carcass trimming (zero fecal contamination limit), acid rinsing of carcasses (2% lactic acid), and carcass chilling.

Microbiological sampling. Previously, scientists have collected sets of 25 random samples from each point in a process being investigated and enumerated total aerobic counts (reported in 1 CFU/cm²) and coliform and generic E. coli (reported in 1 CFU/100 cm²) in each sample. From these, the mean log numbers of each group of organisms were calculated. Aerobic counts and coliforms that were not E. coli were the accepted indicators of general processing hygiene, and E. coli was the accepted indicator for contamination with fecal organisms (13).

In this study we used this previously published information as a guideline for the number of samples needed to collect a statistically sound data set. Additionally, we collected 10 sets of preliminary data to determine the variability of the microbial populations on the carcasses, primal cuts, and in the ground beef. We decided to collect enough data for the study to detect statistical differences at the α = 0.05 level of confidence. The equations used for these calculations are similar to those found in Hicks (16). From these calculations we determined that 27 samples would be sufficient to detect differences. However, we collected 30 samples to increase the level of statistical soundness.

To establish a carcass microbial profile, carcasses were sampled using the U.S. Department of Agriculture (USDA)/Food Safety and Inspection Service sponge method (24). The Final Rule describes the techniques in great detail (23). Briefly, sterile sponge-

...es (Specisponge; Nasco, Fort Atkinson, Wis.) were hydrated with 25 ml of buffered peptone water (Difco Laboratories, Detroit, Mich.). Residual moisture was expelled from the sponge inside a Whirlpak bag (Nasco), and the sponge was removed from the bag with sterile gloved hands. Using a sterile template, each of the three 100-cm² areas was rubbed with the sponge 10 times in each horizontal and vertical direction. Each sampling area was sampled with a clean area on the sponge. Samples were collected from randomly selected carcasses before and after carcass acid wash treatment as well as after a 24-h chill.

In addition to carcasses, the sponge method was also used to sample fabricated meat samples and beef combos, as described above. Using a sterile template, each of three 100-cm² areas of the samples was rubbed with the sponge 10 times in each horizontal and vertical direction. Each sampling area was sampled with a clean area on the sponge. Ground beef samples were collected using the sampling procedures outlined in the Food and Drug Administration’s “Bacteriological analytical manual” (28) and the USDA/Food Safety and Inspection Service “Microbiological lab manual” (27). All samples were transported to the laboratory in coolers maintained at 4°C with ice packs and processed the same day. Samples were held at 4°C until plated. All samples were taken from the same processing facility.

Microbiological analysis. Sponge samples were stomached for 2 min in a Stomacher Lab Blender 400 (Tekmar, Inc., Cincinnati, Ohio) and serially diluted in buffered peptone water. After plating for enumeration, all samples were incubated at 35°C for 18 to 24 h to enrich for Salmonella spp. detection. At the request of the plant and because this type of testing was already done in the facility by the Food Safety and Inspection Service, Salmonella spp. was the only pathogen tested in this study.

Enumeration of bacterial populations included mesophilic aerobic bacteria, psychrotrophic aerobic bacteria, coliforms, generic E. coli, acid-tolerant bacteria, lactic acid bacteria (LAB), and pseudomonads. For determination of an aerobic plate count (APC), appropriate dilutions were plated in duplicate on 3M Petrifilm Aerobic Plate Count Plates (3M Inc., St. Paul, Minn.). For enumeration of total coliforms and generic E. coli populations, 3M Petrifilm Coliform/E. coli Count Plates were used. All plates were incubated at 37°C and enumerated according to the manufacturers’ directions, except for the psychrotrophic aerobic plates that were incubated at 20°C. The mesophilic APC and coliform counts were enumerated after 24 h of incubation, the E. coli counts were taken after 48 h, and the psychrotrophic APC counts were taken at 3 days.

For enumeration of pseudomonads, appropriate dilutions were plated in duplicate on Pseudomonas isolation agar and incubated at 37°C for 48 h. For enumeration of LAB, appropriate dilutions were plated in duplicate on de Mann, Rogosa, Sharpe agar and incubated in 5% CO₂ at 37°C for 48 h. For enumeration of acid-tolerant bacteria, appropriate dilutions were plated in duplicate on perchloric acid adjusted to pH 4.2 and incubated at 37°C for 48 h. In addition, a qualitative screening for Salmonella spp. was conducted following enrichment methods as described earlier. Following pre-enrichment of the samples, samples were screened for the qualitative presence of Salmonella spp. using Tecra UNIQUE Salmonella (Tecra Diagnostics, Roseville, New South Wales, Australia) according to manufacturer directions. Presumptive positive results obtained with Tecra UNIQUE were confirmed by streaking the suspect sample on xylose lysine deoxycholate agar (Difco) and incubating at 37°C for 18 to 24 h. Confirmation tests were performed on suspect colonies including catalase, cytochrome oxidase, and API 20E (BioMerieux Vitek,
Hazelwood, Mo.) as outlined in the U.S. Food and Drug Administration’s “Bacteriological analytical manual” (28).

Statistical analysis. The means of duplicate plate counts were converted to log_{10} CFU/cm^2 for carcass, primal, and trim samples and analyzed using the general linear models procedure of the Statistical Analysis System (SAS Institute, Inc., Cary, N.C.) with a statistical significance level of P < 0.05. When significant differences were observed, separation of means was accomplished by using Duncan’s multiple range test (SAS). Means from other sets of data were compared by Student’s t test.

RESULTS

Figures 1 and 2 and Table 1 depict the microbial profiles of pre-acid-washed carcasses, post-acid-washed carcasses, acid-washed carcasses subjected to a 24-h chill, and subprimal fabrication samples from acid-washed carcasses.

Figure 1 represents the total mesophilic bacteria and psychrotrophic bacteria detected. There were significant declines (P < 0.05) in the mesophilic counts and the psychrotrophic counts after the acid wash. The reduction was sustained after a 24-h chill and after fabrication. Although there was a slight increase in psychrotrophic bacteria, the increase was not significant (P > 0.05).

Table 1 illustrates the pseudomonad counts on the sample areas. Acid washing did not significantly (P > 0.05) reduce the numbers of pseudomonads, but numbers were very low prior to acid washing. Numbers remained low after 24 h of chilling and did not significantly increase after fabrication of the carcass.

LAB were also significantly (P < 0.05) reduced after acid wash (Table 1). There were additional significant (P < 0.05) declines in the LAB counts after 24 h of chilling. While there was a slight increase in numbers after fabrication into primal cuts, the increase was not significant (P > 0.05).

The number of acid-tolerant organisms followed a similar trend as the other microorganisms (Table 1). Acid washing significantly reduced the numbers (P > 0.05) and they were further reduced after chilling. There was a slight increase in the number of acid-tolerant microorganisms after fabrication, but the numbers were less than on pre-acid-washed carcasses.

Numbers of coliforms and generic E. coli are illustrated in Figure 2 as log_{10} CFU/100 cm^2. Acid washes in the processing facility significantly reduced these indicator organisms. Both indicators remained significantly low throughout the entire process. Numbers of generic E. coli did increase on fabricated samples, but stayed equivalent to the counts found on post-acid-washed and chilled samples.

Ground beef made from the beef carcasses was subjected to the same microbial analyses as the other samples. We determined the CFU/g in ground beef so the numbers cannot be compared side by side to the numbers found on the surface of the carcasses. Figure 3 illustrates that all counts were less than 3 log_{10} CFU/g. Psychrotrophic counts were the highest in the ground beef followed by the mesophilic counts. Generic E. coli and coliform counts remained low in the ground beef products. The USDA Baseline study indicated that the estimated APC of ground beef was 3.90 log_{10} CFU/g of ground beef (26). In this facility the APC (mesophilic) was 2.33 log_{10} CFU/g of ground beef, more than 1 log cycle less than the reported USDA average. Additionally the total coliforms found in the ground beef made from acid-washed carcasses were 0.27 log_{10} CFU/g and the E. coli counts were 0.22 log_{10} CFU/g.

| TABLE 1. Pseudomonads, Lactic bacteria, and acid-tolerant bacteria detected on beef carcasses after a 2% lactic acid wash of the beef carcasses |
|----------------|------------|----------------|
|                | Pseudomonads | Lactic acid   | Acid-tolerant |
|                |             | bacteria      | bacteria      |
| Pre-acid wash  | 0.62 A      | 2.14 A        | 1.62 A        |
| Post-acid wash | 0.37 A      | 1.34 B        | 0.74 B        |
| 24 h chill     | 0.31 A      | 0.81 C        | 0.25 C        |
| Fabrication    | 0.79 A      | 1.01 C        | 0.54 BC       |

*Each value is the mean from three trials and reported as log_{10} CFU/ml; means having the same letter in common within data in each column are not significantly different (P > 0.05).*
FIGURE 3. Microbial profile of ground beef produced from acid-washed beef carcasses.

Log cfu/g for coliforms and 1.73 log_{10} CFU/g for E. coli. Salmonella was not detected in any of the 150 samples tested.

DISCUSSION

Gorman et al. reported that organic acid is more effective at decontamination than many other techniques or compounds (14). In beef-processing facilities, both lactic acid and acetic acids are extensively used as a part of meat decontamination procedures. Dorsa et al. showed that these acids suppressed growth on beef surfaces of Listeria innocua, Salmonella Typhimurium, E. coli O157:H7, Clostridium sporogenes, other aerobic bacteria, as well as LAB and pseudomonads (10). Many studies have shown that acids, because they suppress growth better during subsequent storage, are more effective for meat decontamination than trisodium phosphate, hydrogen peroxide, sodium hypochlorite, and hot water washes (5, 8, 9, 14, 17). Quattara reported that acetic and lactic acids offer the best combination of solubility, and inhibition of spoilage bacteria like Brochothrix thermosphacta, Carnobacterium piscicola, Lactobacillus curvatus, Lactobacillus sake, Pseudomonas fluorescens, and Serratia liquefaciens (20).

For most of the enumerated bacterial groups in this study, the overall populations decreased significantly after the acid wash application, and the numbers remained low during further processing. In general, the numbers of bacteria increased slightly, some significantly and some not significantly, during fabrication. There could be several contributing factors for this immediate drop and then slow increase in numbers. First, the injured cells could simply be displaying a longer lag phase while recovering from the acid wash, followed by a normal log phase of growth. Second, the process could be systemically adding bacteria to the meat product through contamination from equipment, employees, and further handling. The data also show that the acid did not continue to destroy microorganisms after the initial application. This correlates to the many laboratory studies in which the pH of acid-washed meat has been observed to return to initial values as soon as 5 h (29, 31, 32). However, groups of organisms expected to survive the acid treatment, acid-tolerant organisms and LAB, were further reduced after chilling. Therefore, acid washes did significantly reduce the initial numbers of bacteria on the carcass in this processing facility, thus making it an effective CCP. In fresh meat HACCP plans, we can only reduce or control, not eliminate, microbial growth. Based on these findings, it appears that acid washes are effective in achieving this goal.

In this study we did not detect any Salmonella spp. in any of the samples. This observation is similar to the USDA baseline of 1% incidence on steer and heifer carcasses in beef slaughter facilities (25). The USDA reports a baseline of 7.5% in ground beef in processing facilities (26). The numbers reported by the USDA are averages from many processing facilities and do not directly compare to individual plants. Microbial profiles found in this processing facility could vary from the USDA baselines for a number of reasons. The animals coming into this facility may have been infected with a lower percentage of pathogens than average. Additionally, the practices in food-processing facilities vary tremendously. The practices in this plant could be sufficient to prevent contamination of the carcasses.

Another important consideration in an HACCP system is the methods used for monitoring, the critical limits, and the corrective actions. In this particular processing facility, the critical limit had several parameters. Each hour, the titratable acidity of the lactic acid was monitored and the critical limit was 2.0% lactic acid. Additionally, the water pressure must be at least 15 psi, and all nozzles in the spray cabinet had to be functioning. If any of the parameters were not met as described by the critical limits, all carcasses since the last monitoring interval (about 300 carcasses) were tagged and held. The carcasses were either rerouted back through the acid cabinet at the end of the production day, or acid was manually applied to all carcasses using a hand pump device. Eventually, the facility installed two acid cabinets to facilitate better a corrective action. Other corrective actions taken included notification of the HACCP coordinator and supervisors, a check of the system by maintenance to determine why the water was not hot and/or why the psi was not adequate. Additionally, the quality assurance department was notified to correct improper concentrations of lactic acid in the rinse. It is important to note that this is only one example of how an acid wash may be used as a CCP in a beef slaughter facility. The exact critical limits and corrective actions will vary depending on the needs of the processing facility.

Although the use of organic acid washes does not offer a “magic bullet” for the meat industry in eliminating pathogenic hazards, acid washes are effective in reducing the initial microbial load on the carcass. This reduction makes acid washing an effective CCP in reducing microorganisms on the carcass. In addition, this intervention method is not a substitute for a strict sanitation program and good man-
ufacturing practices. However, acid rinses have been dem-
strated to be an effective means of controlling pathogenic
hazards when used in combination with other processing
methods as part of a successful HACCP program. The use
of organic acids offers a safe, inexpensive, and efficient
decontamination system, with minimum adverse effects to
the product. The system is predictable, consistent, and
is affordable to small and very small processors.

This research demonstrates that more goes into estab-
lishing a successful HACCP plan than common sense and
use of generic plans. HACCP requires a detailed microbi-
ological study of each stage of meat handling and process-
ing. If HACCP is to be successful in achieving the goal of
eliminating pathogens from our meat supply, then it must
be based upon the best current microbiological data. More
effort must be devoted to improving our base of knowledge
on how processing procedures affect the microbiological
state of the meat we are producing.

ACKNOWLEDGMENT

The authors thank the University of Nebraska–Lincoln, Research
Council Office for support of this project.

REFERENCES

vival and growth of Escherichia coli O157:H7 in ground, roasted
beef as affected by pH, acidulants, and temperature. Appl. Environ.
Food Prot. 53:804–817.
A. Krolath, M. N. Lobato, S. M. Strand, K. A. Casale, and M. T.
associated with consumption of precooked meat patties. J. Infect.
mann. 1983. Effects of washing and sanitizing on the bacterial flora
erichia coli O157:H7 under acidic conditions. Appl. Environ. Mi-
crobiol. 61:382–385.
against Escherichia coli O157:H7 attached to beef carcass tissue
using a pilot scale model carcass washer. J. Food Prot. 57:97–103.
and hydrogen peroxide application during defeathering on the mi-
icrobiological quality of broiler carcasses prior to evisceration. Poul-
try Sci. 76:657–660.
acid, lactic acid and trisodium phosphate on the microflora of re-
frigerated beef carcass surface tissue inoculated with Escherichia
coli O157:H7, Listeria innocua, and Clostridium sporogenes. J. Food
Prot. 60:619–624.
effect of alkaline, acid, or hot water washes on the microbial profile
of refrigerated beef contaminated with bacterial pathogens after
washing. J. Food Prot. 61:300–306.
sampling method for large commercial containers of raw beef based
on purge. J. Food Prot. 61:162–165.
6:28–32.
Schmidt, and C. Smith. 1997. Changes on beef adipose tissue fol-
lowing decontamination with chemical solutions or water at 35°C or
15. Griffin, P. M., S. M. Ostroff, R. V. Tauxe, K. D. Greene, J. G. Wells,
J. H. Lewis, and A. Blake. 1988. Illnesses associated with Escher-
16. Hicks, C. R. 1993. Fundamental concepts in the design of experi-
of selected lactic acid bacteria on storage life of beef stored under
Comparative analysis of extreme acid survival in Salmonella typhi-
murium, Shigella flexneri, and Escherichia coli. J. Bacteriol. 177:
4097–4104.
20. Quattara, B., R. E. Simard, R. A. Holley, G. J. P. Piette, and A.
Begin. 1997. Inhibitory effect of organic acids upon meat spoilage
Fate of Escherichia coli O157:H7 and other coliforms in commercial
mayonnaise and refrigerated salad dressing. J. Food Prot. 58:13–18.
22. Riley, L. W. 1987. The epidemiologic, clinical, and microbiologic
analysis critical control point (HACCP) systems—generic HACCP
1996. Pathogen reduction; hazard analysis and critical control point
1996. Nationwide beef microbiological baseline data collection pro-
Department of Agriculture, Washington, D.C.
1996. Nationwide federal plant raw ground beef microbiological sur-
vey, August 1993–March 1994. U.S. Department of Agriculture,
Washington, D.C.
27. U.S. Department of Agriculture Food Safety and Inspection Service.
1998. Microbiological lab manual. U.S. Department of Agriculture,
Washington, D.C.
methods. 8th ed. AOAC International, Gaithersburg, Md.
29. Van de Mare, G. M., J. G. van Logtestijn, and D. A. A. Mossel.
1988. Bacteriological quality of broiler carcasses as affected by in-
Greene, D. N. Cameron, F. P. Downes, M. L. Martin, P. M. Griffin,
Isolation of Escherichia coli O157:H7 and other shiga-like-toxin-
producing Escherichia coli from dairy cattle. J. Clin. Microbiol. 29:
985–989.
Kruifj, and J. M. Smulders. 1984. Microbial decontamination of por-
cine liver with lactic acid and hot water. J. Food Prot. 47:220–226.
tamination of calf carcasses by lactic acid sprays. J. Food Prot. 48:
832–837.