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MICROBIOLOGY INTERVENTION METHODS

Decontamination of Beef Carcasses by Commercial Steam-Vacuum

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Abstract

The use of a steam-vacuuming system (SV) for removal of feces from beef carcasses being processed has proven to be very effective. Post-treatment bacterial populations for SV, Hot Water Washes (W), or the combination of the two have not been observed to be statistically different ($P > 0.05$) from one another; however, the combination of SV+W consistently produces arithmetically greater reductions. These treatments using moist heat have been shown to produce comparable initial reductions up to 2.7 $\log_{10}$ CFU/cm^2 of APC, LAB and *L. innocua* when initial inoculation levels are about 5.5 $\log_{10}$. However, when beef is stored under refrigeration for 14 d after receiving these treatments, these bacteria have been shown to achieve levels of ≥ 7 $\log_{10}$ CFU/cm^2. *E. coli* O157:H7 has been shown to initially be reduced by as much as 3.4 $\log_{10}$ CFU/cm^2 and never grow to original inoculation levels when vacuum-packaged and stored under refrigeration for a period of 21 d. Vegetative cells of *C. sporogenes* have been shown to be initially reduced by as much as 3.4 $\log_{10}$ CFU/cm^2 and counts have been shown to continue to decline when vacuum-packaged and stored under refrigeration for a period of 21 d. When this technology is used in a slaughter facility, the producer, processor and consumer all benefit. The producer paid on a carcass yield basis benefits through higher per-animal carcass yield. The processor is able to produce generally safer carcasses and not reducing the profitable weight of the carcass through knife trimming, in effect, reduces labor-to-market product costs. The consumer benefits by receiving a safer product.

Key Words: Steam-vacuum, moist heat interventions, beef carcass decontamination

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†Portions of this manuscript have previously been published by Dorsa et al. Mention of a trade name, proprietary product or specific equipment is necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

Introduction

As part of an effort to reduce the occurrence of pathogenic microorganisms on beef products, the U.S. Department of Agriculture Food Safety and Inspection Service (FSIS) is proposing substantial changes in beef slaughter facility process requirements (CFR, 1995). However, the general hygiene of animal carcasses has long been a concern to the meat processing industry and recent fatal cases of disease caused by foodborne *Escherichia coli* O157:H7 have increased this concern. Consequently, red meat processors are actively looking for reasonable interventions that minimize the risk of bacterial pathogens on meat products from contaminated raw carcasses.

Thermal decontamination of carcasses is one type of intervention method being considered by the beef processing industry. To date, most methods of thermal decontamination of beef carcasses have concentrated on hot water washes (72° to 96°C) which have shown promise as effective interventions (Barkate et al., 1993; Davey and Smith, 1989; Dorsa et al., 1996a; Patterson, 1970; Smith and Graham, 1978). Hot water washes (>70°C) have been determined to be superior to ambient water washes for reducing general bacterial populations, *E. coli* and salmonellae from beef carcasses and do not permanently alter or affect carcass appearance.

A limited number of studies have been conducted to determine the efficacy of using steam interventions to reduce bacterial populations from beef carcass surfaces (Dorsa et al., 1996a; Nutsch et al., 1996; Phebus et al., 1996). Studies conducted at Roman L. Hruska U.S. Meat Animal Research Center, Clay Center NE (MARC; Dorsa et al., 1996a) compared a hot water wash (82.2°C) to steam delivered through

TABLE 1. Effect of Steam-Vacuum Sanitizing and Washing on Removing Bacterial Contamination Expressed as LSM + S.E.M. $\log_{10}$ CFU/cm^2 (APC) from Fecally-Contaminated Beef Carcass Short Plates (Study 3).

Treatment	N	Before	After	log Reduction
Steam-vac (V)	32	6.2±.14	3.2±.08	3.0±.14[a]
Wash[1] ($W_{72/30}$)	29	6.1±.14	3.4±.08	2.7±.14[a]
Steam-vac+Wash ($VW_{72/30}$)	30	6.1±.14	3.0±.08	3.1±.14[a]

[1]Washed with 72°C water @ 20 psi + 30°C water @ 125 psi reaching the carcass in a washer manufactured by Cary Engineering, Inc.
[a]Not statistically different P > 0.05.

TABLE 2. Effect of Steam-Vacuum Sanitizing and Washing on Removing Coliform Contamination Expressed as LSM + S.E.M. $\log_{10}$ CFU/cm^2 from Fecally-Contaminated Beef Carcass Short Plates (Study 3).

Treatment	N	Before	After	log Reduction
Steam-vac (V)	31	5.0±.09	1.0±.13	4.0±.12[a]
Wash[1] ($W_{72/30}$)	29	5.0±.09	1.7±.14	3.4±.13[b]
Steam-vac+Wash ($VW_{72/30}$)	30	5.0±.09	0.8±.13	4.2±.13[a]

[1]Washed with 72°C water @ 20 psi + 30°C water @ 125 psi reaching the carcass in a washer manufactured by Cary Engineering, Inc.
[a,b]Statistically different P > 0.05.

a closed cabinet on lamb carcasses. The steam treatment consisted of a water wash (15.6°, 54.4°, or 82.2°C; 75 psi) followed by removal of surface water by an air blowing system, a closed cabinet steam treatment and a final cool water rinse (15.6°C). These researchers concluded that moist heat interventions were effective for reducing aerobic bacterial populations, *E. coli* and coliforms on carcasses, regardless of the application method. Subsequent studies using a recently developed, commercially available steam pasteurization chamber (Frigoscandia Food Processing Systems, Inc., Bellevue, WA and Cargill Inc., Minneapolis, MN) proved that this type of steam technology could be successfully used in a beef slaughter environment (Nutsch et al., 1996).

The original steam-vacuum was designed to take advantage of both hot water and steam, in combination with a physical removal of bacteria and contamination via vacuum. Studies conducted at MARC, using a commercially available steam-vacuuming system (Vac-San®, Kentmaster, Mfg., Monrovia, CA) have determined that hot water (88° to 94°C) delivered by the steam-vacuum sanitizing system effectively reduced fecal bacteria, non-specific strains of *E. coli* and *E. coli* O157:H7 from carcass surfaces (Dorsa et al., 1996a,b). Based on these results, FSIS allowed in-plant testing designed to collect additional data to determine its efficacy under industrial use. The in-plant testing determined that the steam-vacuuming system was capable of consistently reducing bacterial populations resulting from < 1 in. contaminated areas better than knife trimming. Consequently, the FSIS issued a notice announcing the approval of the steam-vacuuming technology for removal of fecal and ingesta contamination from beef carcasses in the April 4, 1996, Federal Register. Allowing use of the steam-vacuum technology on slaughter lines could potentially accomplish two things, the improved microbial safety of beef carcasses and a reduced amount of knife trimming required to meet the FSIS zero tolerance policy. Prior to the approval of the use of a steam-vacuuming system, the zero tolerance policy required removal of all visible feces by knife trimming.

Because of the time delay between carcass washing and beef consumption, it is important to determine the long term effects any intervention process will have on the microbial populations of beef. The effect of thermal inactivation of specific pathogens found in food and beef products is well documented (Fain et al., 1991; Line et al., 1991; Lund and Peck, 1994). However, the effects of thermal inactivation, followed by storage at refrigerated temperatures, has been investigated to a lesser extent (Farber and Brown, 1990). Consequently, the final studies with the steam-vacuum system conducted by Dorsa et al. (1996c) were designed to determine the effect of this type of moist heat intervention on several specific bacterial populations associated with beef carcass tissue handled and stored under normal industrial practices.

Description of the Steam-Vacuum

The Kentmaster steam-vacuum, trade name Vac-San®, uses a stainless steel vacuum head to remove bacterial and visible fecal contamination by delivering a continuous stream of 7 - 10 psi water at 88° - 94°C to a 1.5 x 6.5 cm area while simultaneously vacuuming the area around the stream of hot water. The water temperature being delivered to the carcass surface is continuously monitored using a thermocouple inserted into the water line inside the vacuum head. Static vacuum for the system is 7 in. of Hg and when contact is made with the meat surface, the vacuum is 10 in. of Hg. A stainless steel jacket surrounding the vacuum nozzle delivers steam at approximately 45 psi to continuously sanitize the equipment while in use.

Effectiveness of Steam-Vacuum followed by a Water Wash

Previous studies conducted at MARC with hot water washes (82.2°C) from a hand held sprayer and double water washes (72°C water followed by 30°C, W) delivered through a commercial carcass washer showed that moist heat delivered to a carcass surface is capable of reducing high levels of bacterial contamination (Dorsa et al., 1996a). However, since it is possible that washing large amounts of fecal bacterial contamination from beef carcasses might redistribute some of the contamination over additional areas of a carcass, it would be desirable to physically remove as much of the feces as possible prior to a wash treatment. The steam-vacuum system (SV) is designed to deliver >82.2°C water plus steam directly to the carcass surface, while physically

TABLE 3. Effect of Steam-Vacuum Sanitizing and Washing on Removing *E. coli* Contamination Expressed as LSM + S.E.M. $\log_{10}$ CFU/cm² from Fecally-Contaminated Beef Carcass Short Plates (Study 3).

Treatment	N	Before	After	log Reduction
Steam-vac (V)	31	4.8±.08	0.8±.12	4.0±.12[a]
Wash[1] ($W_{72/30}$)	29	4.9±.08	1.5±.12	3.4±.12[b]
Steam-vac+Wash ($VW_{72/30}$)	30	4.9±.08	0.6±.12	4.3±.12[a]

[1]*Washed with 72°C water @ 20 psi + 30°C water @ 125 psi reaching the carcass in a washer manufactured by Cary Engineering, Inc.*
[a,b]*Statistically different P > 0.05.*

TABLE 4. Effectiveness of the Vac-San® System for Removing Bacteria of Fecal Origin and *E. coli* O157:H7 in Feces from Beef Carcass Short Plates.

Innoculation Type	N	$\log_{10}$ CFU/cm² Before Steam-Vac	After Steam-Vac	log Reduction
Feces	10	5.5±0.09	3.0±0.21	2.5±0.25[a]
E. coli O157:H7	10	7.6±0.09	2.1±0.21	5.5±0.25[b]

removing the contamination through a vacuum. Consequently, a study was designed to evaluate the ability of this system to reduce aerobic bacteria from beef carcasses and determine if an additive effect would be realized when used in combination with a wash treatment.

For reduction of aerobic bacteria from fecally inoculated beef short plates, the steam-vacuum plus wash combination sequence (SV+W) produced 0.4 $\log_{10}$ CFU/cm² greater reductions than the W wash treatment alone (Table 1). While the reductions indicated no significant difference between treatments, the range of residual APCs indicate that the steam-vacuum treatments are more consistently effective than water washes alone. The range of residual APCs for the SV and SV+W were 2.3 - 4.0 and 2.4 - 3.6 $\log_{10}$ CFU/cm², respectively. The range for residual APCs of W was much higher, 2.6 - 5.1 $\log_{10}$ CFU/cm². All but one of the short plates inoculated and treated with the steam-vacuum treatments were reduced to 3.6 $\log_{10}$ CFU/cm² or below, while 21% of the short plates treated with W were above 3.6 $\log_{10}$ CFU/cm².

When the intervention SV+W was used, coliform and *E. coli* population reductions of 4.2 and 4.3 $\log_{10}$ CFU/cm² yielded additional indications that both treatment combinations with the steam-vacuum were significantly more effective than the W combination wash (Table 2 and 3). While no attempt was made to isolate *E. coli* O157:H7 during the study, these results indicated that SV+W or SV treatments administered to beef carcasses in a slaughter facility, prior to entering the chill coolers, had the potential to reduce the risk of *E. coli* O157:H7 contamination. Observations by Phebus et al. (1996) further substantiate the finding of Dorsa et al. (1996a). Using a steam-vacuum system on beef surface tissue, they observed reductions of 3.5 $\log_{10}$ CFU/cm² for *E. coli* O157:H7 fecal inoculums with initial levels of 5.3 $\log_{10}$ CFU/cm². They noted that the steam-vacuum system tended to have more variable reduction levels than other moist heat interventions they tested. They attributed this variation to repeated passes of the nozzle over the sampled beef contaminated area (25 cm x 12 cm), embedding bacteria and making them more difficult to remove by the steam-vacuuming system. Since the size of the inoculated area exceeded the width of the nozzle head during this study, their assertions seem plausible. They noted that the < 2.54-cm diameter area on which FSIS will allow the system to be used would probably reduce the negative embedding effect they observed when attempting to use the system on a much larger area.

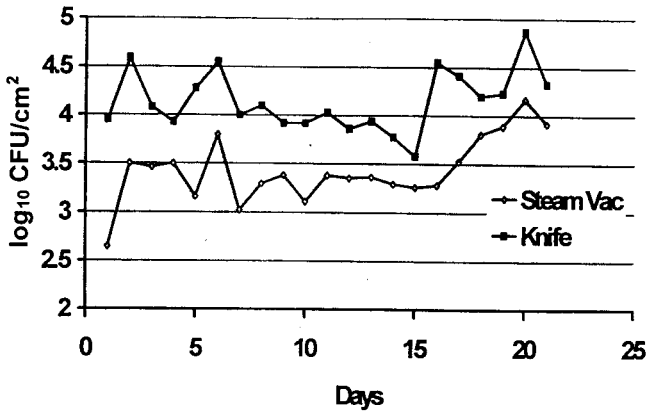
During all the studies conducted at MARC (Dorsa et al., 1996a,b,c), some bleaching of the carcass surface was noticeable immediately post-treatment. However, after 24 h in the chill cooler, no color difference was noticeable when untreated and treated carcasses were visually compared. Also, an additional study conducted using the protocols described for the present study (n = 10), but using short plates with distinctive lean and adipose areas, demonstrated no significant difference of treatment (SV+W or SV) effectiveness between the two tissue types.

From these studies, it can be concluded that a hot water (72°C) wash at low pressure (20 psi) used in combination with a high pressure (125 psi) warm water (30°C) wash, administered through a commercial carcass washer, would be very effective for reducing bacterial populations from fecally contaminated beef carcass surfaces. However, residual bacteria as high as 5.1 $\log_{10}$ CFU/cm² on carcass surfaces after wash treatments indicate that washing alone would not be adequate for the complete removal of fecal contamination. When a commercially available steam-vacuum was added to the best wash treatment, greater bacterial reductions were obtained. Implementation of these interventions could reduce the amount of trimming needed on carcass processing lines and would increase the microbial safety of beef carcasses.

Steam-Vacuum Effectiveness on *E. coli* O157:H7

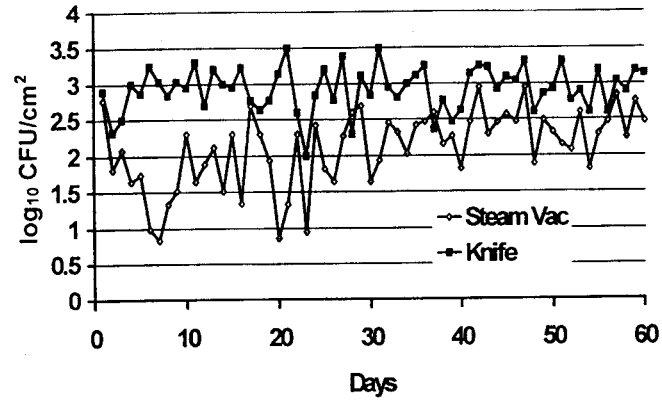
Since it had been determined that the Vac-San® system was very effective for removing bacterial contamination on beef carcass short plates inoculated with feces, another study was designed to determine its effectiveness on *E. coli* O157:H7 (Dorsa et al., 1996b). During this study, the Vac-San® system reduced aerobic plate counts from inoculation levels of 5.5 $\log_{10}$ CFU/cm² to levels close to that of the bacterial levels normally found on beef carcasses being processed in a commercial plant (2.7 $\log_{10}$ CFU/cm²; Anonymous, 1994). Results of the Vac-San® system's ability to reduce high levels of *E. coli* O157:H7 in bovine feces from

FIGURE 1.



The residual aerobic bacteria resulting from removal of contamination from beef carcasses by steam-vacuum (Vac-San®, Kentmaster Mfg., Monrovia, CA) and knife-trimming at a 2,000 head-per-day slaughter facility.

FIGURE 2.



The residual aerobic bacteria resulting from removal of contamination from beef carcasses by steam-vacuum (Jarvis Prod. Corp., Middletown, CT) and knife-trimming at a 2,400 head-per-day slaughter facility.

beef short plates are given in Table 4. High initial inoculation levels of 7.6 $\log_{10}$ CFU/cm^2 experienced large $\log_{10}$ reductions of *E. coli* O157:H7.

When Cray and Moon (1995) experimentally infected adult cattle with *E. coli* O157:H7 at 1010, 107 and 104 CFU/g, they observed fecal shedding of the bacterium at levels of < 6.9 $\log_{10}$, < 5.0 x 101 and 0 CFU/g, respectively. In a different study, Hancock et al. (1994) did presumptive *E. coli* O157:H7 colony screenings from sorbitol non-fermenting bacteria of rectal swabs from breeding, fatting and dairy cattle, on sorbitol MacConkey agar. They observed average numbers of only 1.6 and 6.6 colonies per fecal sample, depending on the season. Apparently *E. coli* O157:H7 is shed in cattle feces at much lower levels than were used for the inoculations in the present study; however, it was the intent of this study to observe the Vac-SanÆ system's ability to remove inoculated *E. coli* O157:H7 in a worst-case scenario.

Results from the present study indicated that the Vac-San® system had the ability to reduce high levels of *E. coli* O157:H7 in a fecal menstruum on beef cattle carcass short plates by 5.5 $\log_{10}$ CFU/cm^2. A subsequent study conducted by Phebus et al. (1996) observed similar reductions when using the Vac-San® system to remove *E. coli* O157:H7 in a fecal inoculum on beef carcass tissue. In their study, a fecal inoculum containing about 2 $\log_{10}$ less *E. coli* O157:H7 than the Dorsa et al. (1996) study was reduced by 3.5 $\log_{10}$, resulting in a residual population of 1.8 $\log_{10}$. Based on these findings, it was determined that a steam-vacuuming sanitizer system should be effective for the removal of normal levels of *E. coli* O157:H7 resulting from visible fecal contamination on beef carcass surfaces in processing facilities.

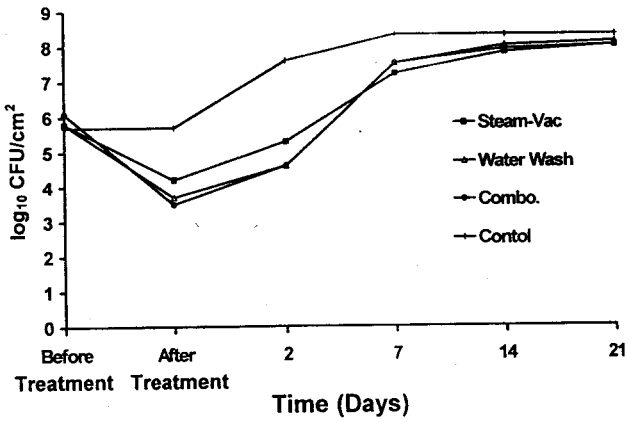
In-Plant Effectiveness of Steam-Vacuum

Prior to FSIS final approval for the use of a steam-vacuum system in a slaughter facility, all plants wishing to use a system were required to conduct in-plant testing. This involved taking samples from normally-occurring contaminated areas that had been knife-trimmed and taking additional samples from similar normally-occurring contaminated areas that had received a steam-vacuum treatment. Initial in-plant studies required plant personnel to take a total of 12 samples per day, six knife-trimmed and six steam-vacuumed, for 10 days. The second part of the study required plant personnel to sample one knife-trimmed and 1 steam-vacuumed sample per day for 60 days. These data sets were used by FSIS to help assess the steam-vacuum's ability to perform in a slaughter plant environment. In general, data indicated that steam-vacuuming removed aerobic bacteria more effectively than knife-trimming. Data from two separate commercial fed beef slaughter facilities are presented in Figures 1 and 2. The data from these two slaughter plants (~ 2,500 head/day) was typical of that seen by other facilities. From these two plants, contaminated areas of beef carcasses decontaminated using the steam-vacuuming systems averaged 0.82 and 0.72 $\log_{10}$ CFU/cm^2 fewer residual aerobic bacteria than those decontaminated by knife-trimming. The in-plant studies demonstrated that a commercial steam-vacuum system could consistently outperform knife-trimming for the removal of bacterial contamination of defined areas on beef carcasses being processed in commercial facilities.

Microbial Ecology Resulting from Steam-Vacuum Treatments

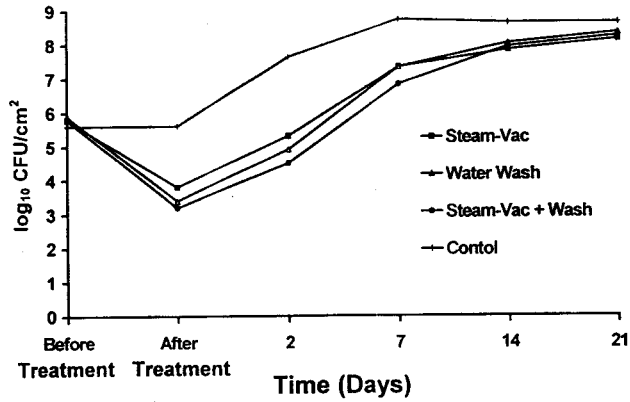
Since beef is not consumed until some time after the use of steam-vacuum technology or other moist-heat interventions, a study was designed to determine these interventions' long-range effectiveness. In this study, the ability of a steam-vacuum system to control specific pathogens on beef during simulated commercial storage for up to 21 days was compared to hot and ambient water washes. It was determined that all treatment interventions were effective for re-

FIGURE 3.



Effects of moist-heat interventions on the initial levels and subsequent outgrowth of mesophilic aerobic bacterial populations (least squares means $\log_{10}$ CFU/cm²) during a combination of aerobic and vacuum storage at 5°C for 21 d.

FIGURE 4.



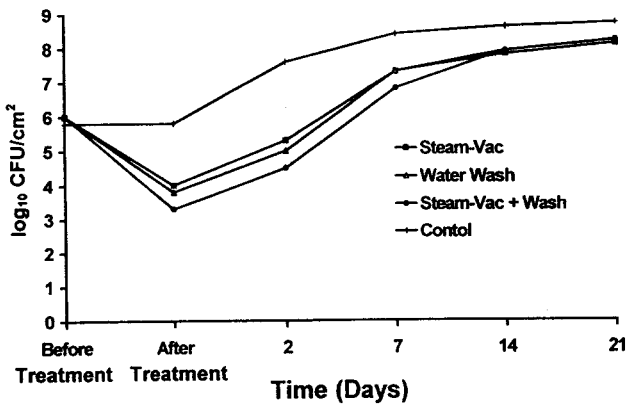
Effects of moist-heat interventions on the initial levels and subsequent outgrowth of Listeria innocua *populations (least squares means $\log_{10}$ CFU/cm²) during a combination of aerobic and vacuum storage at 5°C for 21 d.*

ducing both APC and specific target bacteria, except in the case of pseudomonads which started at a low level and remained that way after treatments (Fig. 3-8). Immediate reductions were expected and the efficacy of using these intervention strategies, in particular steam-vacuum plus a water wash (SV+W), for the reduction of APC as well as *E. coli* and coliforms has been discussed above.

The initial reductions for APCs of 1.6, 2.1 and 2.6 $\log_{10}$ CFU/cm² for steam-vacuum (SV), water wash (W) and SV+W, respectively, were slightly lower than the APC reductions observed in the previous study using these parameters (Dorsa et al., 1996a). However, in both studies, initial reductions were significant ($P < 0.05$), regardless of the moist-heat intervention used. Initial reductions of 2.0, 2.5 and 2.6 $\log_{10}$ CFU/cm² for *L. innocua* MARC1-S and 2.0, 2.2 and 2.7 $\log_{10}$ CFU/cm² for LAB, were observed after treatments of SV, W and SV+W, respectively.

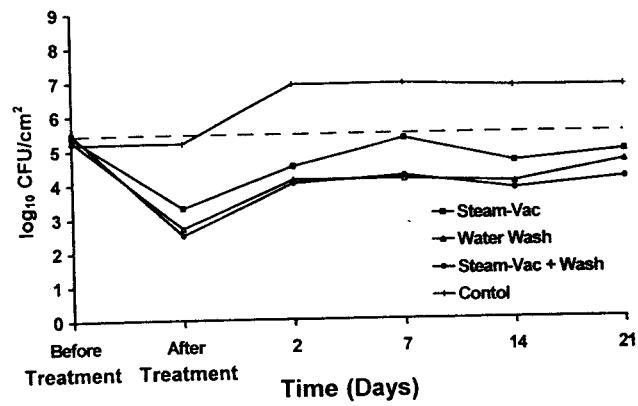
Population growth curves for APC, *L. innocua* MARC1-S and LAB are presented in Figures 3-5. For all three bacterial groups, growth began within 2 d of all treatments and had reached 7 $\log_{10}$ CFU/cm² by 7 d. Growth continued for the duration of the study and was equivalent to the untreated control by day 21. As in other studies (Barkate et al., 1993; Davey and Smith, 1989; Smith and Graham, 1978), the reductions in total APC immediately after moist-heat treatments to beef carcasses indicate efficacy as an effective antimicrobial treatment. However, when the carcass tissue is allowed to chill at 5°C for 48 h, then is cut and vacuum-packaged for 21 d storage at 5°C, as would occur to a beef carcass in a slaughter/fabrication facility, APCs from the present study indicate that hot water as a comprehensive antimicrobial treatment would be of little value when compared to untreated beef tissue. The growth rate of *L. innocua* (Figure 4) observed in the present study might also suggest that the use

FIGURE 5.



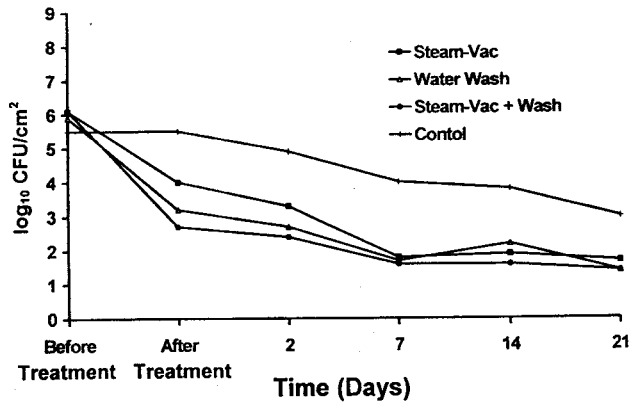
Effects of moist-heat interventions on the initial levels and subsequent outgrowth of lactic acid bacteria populations (least squares means $\log_{10}$ CFU/cm²) during a combination of aerobic and vacuum storage at 5°C for 21 d.

FIGURE 6.



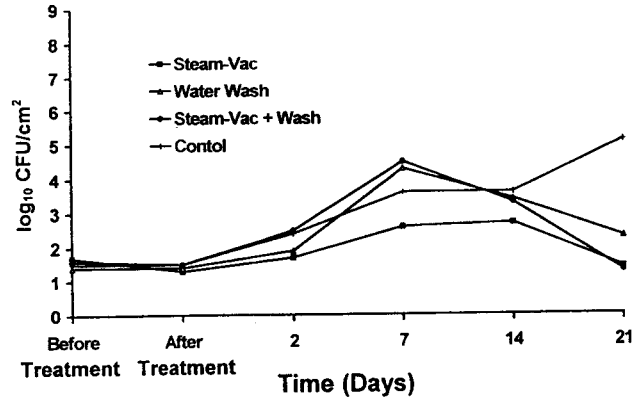
Effects of moist-heat interventions on the initial levels and subsequent outgrowth/survival of Escherichia coli *O157:H7 populations (least squares means $\log_{10}$ CFU/cm²) during a combination of aerobic and vacuum storage at 5°C for 21 d.*

FIGURE 7.



Effects of moist-heat interventions on the initial levels and subsequent survival of Clostridium sporogenes *populations (least squares means $\log_{10}$ CFU/cm²) during a combination of aerobic and vacuum storage at 5°C for 21 d.*

FIGURE 8.



Effects of moist-heat interventions on the initial levels and subsequent growth/survival of pseudomonas *populations (least squares means $\log_{10}$ CFU/cm²) during a combination of aerobic and vacuum storage at 5°C for 21 d.*

of hot water sprays to eliminate other Listeria spp. such as L. monocytogenes would not be effective.

Reductions of 2.1, 2.6 and 3.0 $\log_{10}$ CFU/cm² for *E. coli* MARC1-S were initially obtained after application of the SV, W and SV+W, respectively. These reductions are comparable to the $\log_{10}$ reductions for *E. coli* observed by Smith and Graham (1978) when they applied 80°C water for 10 sec on sheep carcasses. Hot-water treatments of beef carcass tissue previously reported (Davey and Smith, 1989; Dorsa et al., 1996a) also reduced *E. coli* to levels similar to those in the present study, of 3.0 and 3.4 $\log_{10}$ CFU/cm².

The population curves observed for *E. coli* O157:H7 were very different than for other bacterial groups observed in the present study (Figure 6). The growth increases of *E. coli* MARC1-S treated with SV, W and SV+W were 1.2, 1.4 and 1.5 $\log_{10}$ CFU/cm², respectively, after 2 d of aerobic 5°C storage. While no growth of the bacterium was expected at 5°C, Ingraham (1987) observed that *E. coli* held at a minimal growth temperature of 10°C, then shifted to the non-growth temperature of 7°C, continued to grow for a period of one day, during which time the growth rate gradually declined. As expected, after the initial 2-d period, no significant growth was observed between sampling days 2 through 21. The 21-d levels of 4.9, 4.6 and 4.1 $\log_{10}$ CFU/cm² for SV, W and SV+W, respectively, were as much as 1.4 $\log_{10}$ CFU/cm² lower than the original inoculated level, 5.4+0.1 $\log_{10}$ CFU/cm². The difference between the untreated populations and populations following SV, W and SV+W at 21 d were 1.4, 2.2 and 2.7 $\log_{10}$ CFU/cm², respectively. These results indicate that any of these treatments would offer an additional long-term degree of safety to beef that might be contaminated with *E. coli* O157:H7 via feces during carcass processing.

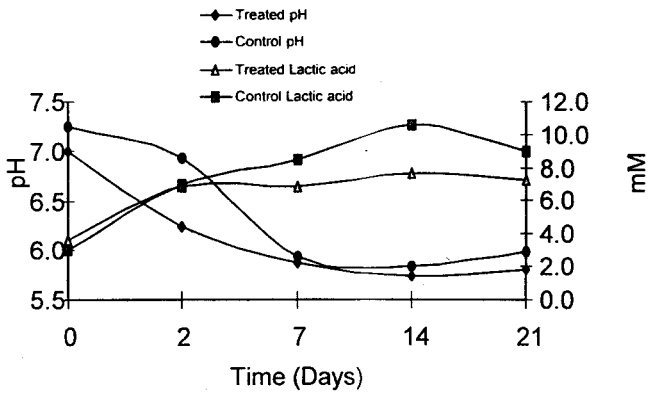
Vegetative cells of *C. sporogenes* MARC1-N were initially reduced on beef carcass tissue by 2.1, 2.7 and 3.4 $\log_{10}$ CFU/cm² when treated with SV, W and SV+W, respectively. *C. sporogenes* populations continued to be reduced over time and were 4.4, 4.5 and 4.7 $\log_{10}$ CFU/cm² lower after 21 d than the original level of ~6.0 $\log_{10}$ CFU/cm² (Fig. 5). Li et al. (1993) observed a similar behavior over a 14-d period for *C. sporogenes* spores in heat-treated deboned turkey meat stored at 4°C.

Initial reductions were a result of heat and physical removal. The remaining *C. sporogenes* population would be comprised of spores and of undamaged and sublethally-damaged vegetative cells. The initial 2-d storage period was aerobic, thus not conducive to the outgrowth of any sublethally damaged vegetative cells. During the initial 2-d storage period, the beef surface allowed exponential growth of lactic acid producing bacteria (Fig. 3), concomitant with a drop in surface pH and an increase in lactic acid (Figure 9). Lower pH and higher lactic acid concentrations of samples after vacuum-packaging probably affected the survival of remaining *C. sporogenes* vegetative cells (Thylin et al., 1995) and by day seven surviving cell populations remained constant for the duration of the study.

As has been shown by previous investigators, hot-water washes and steam-vacuum treatments were effective for reducing aerobic and *E. coli* populations on beef carcass surfaces. This study demonstrated that these treatments would also result in significant initial reductions of *L. innocua*, *C. sporogenes* and LAB.

It has been suggested that the beef industry is producing such a microbially clean carcass that, due to the lack of competitive inhibition, pathogens are posing greater safety or health risks (Jay, 1995). While *L. innocua* did reach the level of the untreated tissue by day 21 in the present study, it at no time exceeded the level of the untreated tissue. The data from this study suggest that the microbial progression was similar for APC and LAB and that no competitive advantage was afforded *E. coli* O157:H7 or *C. sporogenes* when compared to the untreated controls. *E. coli* O157:H7 or *C.*

FIGURE 9.



Average surface pH (n = 18) from beef tissue and lactic acid content (mM; n = 18) of sample stomachate from beef tissue of all moist-heat interventions immediately after treatment and over time.

sporogenes were never able to recover to initial inoculation levels. These observations indicate that regardless of the application method, the use of moist-heat interventions on beef carcass tissue surfaces during processing does not increase the outgrowth potential of selected pathogens in the presence of lower numbers of non-pathogenic bacteria. However, post-processing contamination of moist-heat treated carcasses must be determined.

While moist-heat interventions would appear to have no long-range benefit for beef products contaminated with *Listeria* spp., these interventions did not create an environment that presented a growth advantage to *Listeria* spp. However, moist-heat interventions did appear to add a degree of safety to beef products when *Escherichia* spp. and vegetative *Clostridium* spp. were present on the carcass surface.

Summary

The use of a steam-vacuuming system for removal of feces from beef carcasses being processed has proven to be very effective. When this technology is used in a slaughter facility, the producers, processor and consumers all benefit. The producer paid on a carcass yield basis benefits through higher per-animal gross profit. The removal of fecal contamination by knife-trimming costs the producer money through carcass yield loss, whereas the removal of this same fecal contamination by a steam-vacuum system does not. The steam-vacuum system allows the processor two distinct advantages. First, the processor is able to produce generally safer carcasses. Second, by not reducing the profitable weight of the carcass through knife-trimming, the processor has, in effect, reduced labor-to-market product costs.

The consumer benefits by receiving a safer product when the steam-vacuum is used to remove fecal contamination from beef carcasses during processing.

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