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Microbiological and Visual Effects of Trimming and/or Spray Washing for Removal of Fecal Material from Beef

BRENDA M. GORMAN, J. BRAD MORGAN, JOHN N. SOFOS,* and GARY C. SMITH

Center for Red Meat Safety, Department of Animal Sciences, Colorado State University, Fort Collins, Colorado 80523 USA

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ABSTRACT

Microbiological and visual evaluations were performed to compare the efficacy of hand trimming, spray washing, or a combination of treatments, in the removal of bacteria and fecal material from beef adipose tissue. Subcutaneous adipose samples with intact fascia from the surfaces of briskets (obtained within 15 min postmortem) were inoculated on different sizes of surface areas (0, 0.3125, 0.625, 1.25, 1.875, or 2.50 cm^2) with a bovine fecal paste containing a culture of streptomycin-resistant *Escherichia coli* ATCC 11370. The samples were then spray washed with water at 35°C in a specially designed automated spray washing cabinet at pressures of 2.76, 13.79, 20.68, or 27.58 bar and at chain speeds equivalent to 100, 200, or 300 carcasses per hour (exposure times of 36, 18, or 12 s). Total aerobic mesophilic plate counts, streptomycin-resistant bacterial plate counts and visual scores for fecal contamination were obtained. There was a reduction ($P < 0.05$) in microbiological counts on the treated samples compared with those on the unwashed and/or untrimmed inoculated (control) samples. The variation in removal of fecal material from, and in reduction of microbiological contamination on, different sizes of surface areas of fecal material contamination and with different chain-speeds was minor under the conditions of the study. Hand trimming followed by spray washing compared to spray washing alone were similiar in their effectiveness for reduction of microbiological contamination and slightly different in the extent of fecal material removal. Overall, however, higher spray washing pressures (20.68 or 27.58 bar) were more effective ($P < 0.05$) than the lower spray washing pressures (2.76 or 13.79 bar) in removing fecal material from and reducing bacterial numbers on adipose tissue samples.

Key words: Beef, fecal contamination, trimming, spray washing, bacterial reduction

The control of pathogenic microorganisms is, and always has been, an implicit goal of the United States federal meat and poultry inspection program. The major function of the Food Safety and Inspection Service (FSIS) of the United States Department of Agriculture (USDA) is to ensure the wholesomeness of the meat and poultry supply (*14*). Yet, due to the *Escherichia coli* O157:H7 outbreak which occurred in the Pacific Northwest during January and February of 1993, food safety has become a major concern for the food industry, consumers, and regulatory agencies (*6, 10, 20*). Because this outbreak was associated with consumption of undercooked ground beef patties, FSIS responded to this concern by implementing a "zero tolerance" system, which requires trimming all soil (fecal material, ingesta, and udder contents) from carcasses prior to washing, to ensure a clean product for the consumer (*12, 15*).

The presence of high numbers of microorganisms on animal carcasses is undesirable because it indicates poor sanitary practices, may lead to rapid and extensive product spoilage or failure of preservation treatments, and increases the likelihood of contamination with pathogens, especially those of fecal origin, which include *E. coli* O157:H7 (*21*). Thus, it is imperative that slaughtering practices follow sanitary guidelines and that programs are designed to minimize the physical, as well as microbiological, contamination of carcasses (*19*). The meat industry has taken steps to develop systems that reduce the incidence of contamination and is attempting to implement hazard analysis critical control point (HACCP) programs to ensure product safety (*18*).

Spray washing has been evaluated extensively as a method to clean meat-animal carcasses during slaughtering and dressing procedures. Numerous studies have confirmed the effectiveness of spray washing treatments in the reduction of microbial numbers on meat (1–5, 7–9, 11, 13). Anderson et al. (*5*) found a 42% reduction in visible foreign material, as well as a one-log-unit reduction in bacterial counts, using a commercial washer. It also has been reported that higher water pressures (24.13 bar) are more effective for reducing microbial numbers during spray washing of beef carcasses than are lower water pressures (4.12 bar) (*16*). Concern exists, however, that by increasing the water pressure during spray washing, bacteria may be physically driven into the surface tissue (*9*), especially when pressures exceed 20.7 bar *(2, 8)*.

With increased concern about pathogens of fecal origin, such as *E. coli* O157:H7, the most effective manner of cleaning beef carcasses, without significantly altering the meat, needs to be found (*6, 20*). Therefore, research by our group has been designed to evaluate spray washing as a method of cleaning and decontaminating carcasses, and to compare its efficacy with that of hand trimming. The objective of this study was to compare the efficacy of spray washing and hand trimming treatments for removal of fecal and microbiological contamination from exterior adipose tissue surfaces

obtained from beef carcasses during the slaughtering and dressing process. Specific parameters to be evaluated included spray washing pressures, the size of surface area of fecal material contamination, and spray washing chain speed.

MATERIALS AND METHODS

Inoculum preparation

A pure culture of streptomycin-resistant *Escherichia coli* ATCC 11370 was prepared at a certified laboratory (Warren Analytical Laboratory, Greeley, CO) in nutrient broth containing 625 μg of dihydrostreptomycin per ml (Difco Laboratories, Detroit, MI). A portion (100 ml) of the culture, diluted to 10^8 colony-forming units (CFU) per ml, was mixed by hand massaging for 2 min in a sterile Stomacher bag (Nasco, Modesto, CA) with 300 g of fresh bovine feces randomly collected each day of experimentation from the holding pens of a large commercial beef slaughtering facility. The objective was to obtain a high level of inoculum in a fecal paste of repeatable consistency. This was controlled by addition of sterile water to achieve a ratio of 3 parts of total added liquid to 1 part of fecal material. The inoculum was then transported from the laboratory in coolers with ice packs to the commercial slaughtering facility (within a distance of one mile) for inoculation of samples and subsequent spray washing on the same day.

Trimming and washing treatments

Hot (<15 min postmortem) adipose tissue, cut from the brisket area of carcasses by plant personnel prior to any routine plant washing or trimming, was transported to a room adjacent to the slaughter floor using plastic trays cleaned before each use with a 90% alcohol spray. Each piece was aseptically cut with a sterile knife blade into a 10 by 10 square cm portion and inoculated by use of sterile plastic inoculating loops (Labcraft, Aurora, CO), which were immersed into the fecal paste. The inoculum was transferred to the center of each square of adipose tissue to achieve inoculum area sizes of 0.3125-, 0.625-, 1.25-, 1.875-, or 2.5-cm^2. The 0.3125-cm^2 area was achieved using a 0.3125 cm^2 inoculating loop, and the 0.625-, 1.25,- 1.875-, and 2.5-cm^2 areas were obtained using a 0.625-cm^2 inoculating loop and transferring inoculum to the adipose tissue for the appropriate number of times. For each replicate analytical unit (sample), three (10 by 10 square cm) pieces of adipose tissue from three different carcasses were inoculated, held for 15 min at room temperature (20°C) to allow for attachment of fecal material and bacteria, and then treated by hand trimming with a sterile knife or by spray washing under specified conditions. Spray washing was done in a specially constructed test-size conveyorized model spray washing cabinet with one 0.3125-cm (MEG 2150) diameter oscillating nozzle and with the nozzle oscillation set at 80 rpm, covering the entire length of the piece of fat being washed (CHAD Co., Lenexa, KS). The cabinet was custom-made for these studies and designed to simulate slaughter production speeds as well as wash action of a final-carcass spray washing cabinet. Variables studied, in addition to the size of the contaminated area, included slaughter chain speed (100, 200, or 300 carcasses per hour, corresponding to exposure times of 36, 18 and 12 sec., respectively) and spray washing pressure (2.76, 13.79, 20.68, or 27.58 bar) . The water temperature was maintained at 35 ± 5°C. Trimming was done using a sterile knife and forceps, cutting vertically to remove all visible fecal contamination. The knife and forceps were sterilized using 90% alcohol and flaming between samples. For the combination treatment of trimming followed by washing, the trimmed samples were immediately placed on the spray washer for subsequent washing.

Visual evaluation

After treatment, the three beef brisket adipose samples were immediately removed from the spray washer or trimming table and evaluated visually for any remaining fecal contamination by trained Colorado State University personnel. The two or three evaluators were trained by USDA FSIS beef-slaughter inspectors and by plant quality-control personnel to assign scores as they are applied in administering the current zero tolerance and clean meat program policies of USDA FSIS (*12, 15*). Visual scores were based on a 5-point scale in which 0 indicated no visible fecal material contamination; 1, sparse evidence of fecal material; 3, presence of fecal material; and 5, obvious fecal contamination (typical of that detected on the unwashed inoculated samples). The samples were evaluated visually both before and after spray washing or hand trimming.

Sampling and microbiological analyses

Tissue samples were taken aseptically from each piece of adipose tissue that was hand trimmed and/or spray washed or a control, using sterile cork borers (samples of 3.175 cm diameter and approximately 0.5 cm thickness), a sterile scalpel, and forceps. The samples were taken from the center of all three pieces of adipose tissue and placed into one sterile stomacher bag (Nasco, Modesto, CA). This sample bag was designated as sample A. In addition, similar core samples were taken aseptically from positions immediately above and below the A sample. These six B samples were placed into another single sterile stomacher bag for subsequent microbial analysis. The B tissue samples were taken to determine the potential of spray washing for causing translocation of microorganisms (from the central site to surrounding sites) through splashing or runoff and contamination of areas adjacent to the inoculation site. The A and B samples were then placed in coolers with ice packs for transportation to the laboratory for subsequent microbiological analyses within 2 h of hand trimming or spray washing.

Samples were diluted (10^{-1}) with sterile phosphate buffer (KH_2PO_4, pH 7.0, Difco) and then macerated using a model 400 stomacher (Tekmar Company, Cincinnati, OH) for 2 min. Plating was done on nutrient agar with or without 625 μg of dihydrostreptomycin per ml with a spiral plating system (model D, Spiral System Instruments, Bethesda, MD). The inoculated plates were incubated at 37°C for 48 h and then colonies were counted using a model 800 processor with a model 500 laser colony counter (Tekmar Company, Cincinnati, OH). The results were expressed and recorded as CFU/cm^2 of surface adipose tissue. No attempt was made to culture anaerobic bacteria, because such analysis was beyond the scope of this study.

Statistical analysis

A randomized incomplete block design was used, with day of test treated as a block, to analyze the data. There were 39 treatments for each spray washing chain speed in this study (Table 1). The set of treatments was replicated six times on different days. Least-square means (LSM) were calculated from the six replications (*17*). The model included treatment, chain speed, water pressure, and interactions. Since no interactions were significant, only the main effects of water pressure, chain speed, and size of fecal contamination surface area are discussed in this paper. The LSM were separated using the least-significant difference (LSD) procedure. The α level was set at 0.05 throughout the study.

RESULTS AND DISCUSSION

Effect of spray washing and hand trimming on microbiological counts

The initial natural contamination level of uninoculated brisket fat was 5.42 and 5.00 log CFU/cm^2 for total plate and streptomycin-resistant bacteria counts, respectively (Table 2). Inoculation with fecal material containing *E. coli* ATCC 11370 increased the total plate and streptomycin-resistant bacterial counts to 7.09 and 6.86 log CFU/cm^2, respectively. Hand trimming inoculated samples reduced ($P < 0.05$) the total plate and streptomycin-resistant bacteria counts by 1.96 and 2.19 log CFU/cm^2, respectively. The spray washing (no hand trimming) treatments with pressures in the range of 2.76 to 27.58 bar achieved reductions of 1.70 to 2.18 and 1.81 to 2.34 log CFU/cm^2 in total plate and streptomycin-resistant bacteria counts, respectively (Table 2). In general, the spray washing treatments were as effective as hand trimming (no washing) in reducing total plate and streptomycin-resistant bacteria counts on pieces of beef brisket adipose tissue. These results agree with findings of previous studies (*9, 16*) which have reported that higher washing pressures were more effective than lower washing pressures in reducing microbial numbers on carcasses.

Effect of surface area size of fecal material inoculation

As the surface area of the spot of fecal material inoculated onto the beef brisket adipose tissue sample increased, the total plate and streptomycin-resistant bacteria counts increased across all treatments for both the A and B sampling sites (Table 3). However, the effect of the surface size of the area of the spot of fecal material on bacterial count reductions achieved by spray washing was not significant ($P > 0.05$). Reductions achieved in total plate and streptomycin-resistant bacteria counts were in the range of 1.37 to 2.25 and 1.42 to 2.56 log CFU/cm^2, respectively (Table 3). The reductions of less than 2 log CFU/cm^2 were associated with the smallest fecal material contamination surface area (0.3125 cm^2). Therefore, under the conditions of this pilot study, the effect of fecal contamination surface area size on the efficacy of decontamination by spray washing was only minor.

Effect of slaughter chain speed

Sample washing chain speed (100, 200, or 300 carcasses per hour) had no significant effect ($P > 0.05$) on the extent of bacterial reduction achieved by spray washing. Reductions in total plate and streptomycin-resistant bacteria counts were in the range of 1.93 to 2.19 and 2.00 to 2.30 log CFU/cm^2, respectively (Table 4).

Effect of spray washing on spreading of contamination

Two concerns with spray washing treatments to remove contaminants from carcasses include whether the treatment either physically drives the microorganisms into the meat or spreads them across the surface of the carcass, thereby increasing the contamination of adjacent areas. The samples

TABLE 1. *Treatment combinations used to evaluate the efficacy of hand trimming and spray washing on removal of fecal material and reduction of microbiological counts from pieces of beef brisket fat (all treatments were repeated for spray washing chain speeds of 100, 200, or 300 carcasses per hour)*

Hand trimming	Spray washing	Spray washing pressure (bar)	Surface area (cm^2) of fecal paste inoculum placed in the center of each piece of adipose tissue					
			0	0.3125	0.625	1.25	1.875	2.5
No	No	—	I	2	3	4	5	6
No	Yes	2.76	7	8	9	10	11	12
No	Yes	13.79	13	14	15	16	17	18
No	Yes	20.68	19	20	21	22	23	24
No	Yes	27.58	25	26	27	28	29	30
Yes	No	—	N/T[a]	31	32	33	34	35
Yes	Yes	2.76	N/T	N/T	N/T	36	N/T	N/T
Yes	Yes	13.79	N/T	N/T	N/T	37	N/T	N/T
Yes	Yes	20.68	N/T	N/T	N/T	38	N/T	N/T
Yes	Yes	27.58	N/T	N/T	N/T	39	N/T	N/T

[a]N/T; not tested.

TABLE 2. *Mean visual scores for the presence of fecal material, total plate counts of bacteria, and streptomycin-resistant counts of bacteria on beef brisket adipose tissue samples inoculated with fecal material (0.3125, 0.625, 1.25, 1.875, or 2.5 cm^2) and hand trimmed or spray washed at rates equivalent to 100, 200, or 300 carcasses per hour*[a]

Treatments	Total plate counts (log CFU/cm^2)		Streptomycin-resistant counts (log CFU/cm^2)		Visual scores[b]	
Spray washing pressures	A[g]	B	A	B	before treatment	after treatment
Uninoculated	5.42[d]	4.97[c]	5.00[d]	4.64[d]	1.17[d]	1.17[d]
Inoculated	7.09[c]	5.02[c]	6.86[c]	4.73[c]	5.00[c]	5.00[c]

continues

TABLE 2. *Continued*

Treatments	Total plate counts (log CFU/cm^2)		Streptomycin-resistant counts (log CFU/cm^2)		Visual scores[b]	
Spray washing pressures	A[g]	B	A	B	before treatment	after treatment
Hand trimming, no washing	5.13^e	5.01^c	4.67^d	4.70^c	5.00^d	1.22^d
No hand trimming, washing at 2.76 bar	5.39^d	4.72^d	5.05^d	4.33^d	5.00^c	1.13^d
No hand trimming, washing at 13.79 bar	5.17^e	4.47^e	4.87^{de}	4.17^{de}	5.00^c	0.86^e
No hand trimming, washing at 20.68 bar	5.02^{ef}	4.34^{ef}	4.76^e	4.13^e	5.00^c	0.57^f
No hand trimming, washing at 27.58 bar	4.91^f	4.27^f	4.52^f	4.00^e	5.00^c	0.38^f

[a] Data averaged over surface area of fecal material inoculation and chain speeds.
[b] Score of 0, no visible fecal material contamination; 1, sparse evidence of fecal material; 3, presence of fecal material; 5, obvious fecal contamination.
[c-f] Means within a column with different superscript letters differ ($P < 0.05$).
[g] Sampling locations: A, contamination spot; B, adjacent areas.

TABLE 3. *The effect of the surface area of fecal contamination on total plate counts, streptomycin-resistant counts of bacteria, and visual fecal-contamination scores of beef brisket adipose tissue samples (numbers in parantheses are standard deviations)*[a]

Fecal contamination surface area(cm^2)	Total plate counts (log CFU/cm^2)				Streptomycin-resistant counts (log CFU/cm^2)				Visual scores[b]	
	A		B		A		B			
	unwashed	washed	unwashed	washed	unwashed	washed	unwashed	washed	unwashed	washed
Uninoculated	5.42(0.43)^f	4.77(0 75)^e	4 97(0.33)^{cd}	4.42(0.71)^{cd}	5.00(0.60)^f	4.38(0.72)^d	4.64(0.43)^{cd}	4.22(0.72)^{cd}	1.17(0.87)^d	0.19(0.44)^f
0.3125	6.36(0.79)^e	4.99(0.80)^{de}	4.96(0.67)^{cd}	4.35(0.72)^d	6.10(0.92)^e	4.68(0.78)^c	4.66(0.54)^{cd}	3.99(0.69)^d	5.00(0.00)^c	0.51(0.59)^e
0.6250	7.08(0.60)^d	5.01(0.76)^{de}	4.78(0.63)^d	4.38(0.63)^d	6 77(0.77)^d	4.73(0.78)^c	4.49(0.58)^{cd}	4.11(0.69)^{cd}	5.00(0.00)^c	0.52(0.62)^e
1.25	7.28(0 40)^{cd}	5.15(0 70)^{cd}	5.15(0 78)^{cd}	4.50(0 66)^{cd}	7 16(0.45)^{cd}	4.83(0.76)^c	4.82(0.92)^{cd}	4.25(0.82)^c	5.00(0.00)^c	0.62(0.78)^{de}
1.875	7.18(0.12)^d	5.16(0.63)^{cd}	4.85(0.77)^d	4.42(0.58)^{cd}	6.85(0.55)^d	4.88(0.63)^c	4.61(0.74)^{cd}	4.12(0.67)^{cd}	5.00(0.00)^c	0.86(0.90)^d
2.50	7.56(0.50)^c	5.31(0.71)^c	5.34(0.78)^c	4.60(0.60)^c	7 44(0.52)^c	4.88(0.78)^c	5.08(0.41)^c	4.31(0.61)^c	5.00(0.00)^c	1.15(0.98)^c

[a] Data averaged over spraying pressures and chain speeds.
[b] Score of 0, no visible fecal material contamination; 1, sparse evidence of fecal material; 3, presence of fecal material; 5, obvious fecal contamination.
[c-f] Means within a column with different superscript letters differ ($P < 0.05$).
[g] Sampling locations: A, contamination spot; B, adjacent areas.

analyzed for microbiological contamination in this study were excised cores (not surface swabs) which were then macerated to release bacterial cells before plating for enumeration on agar media. The fact that bacterial counts detected in macerated samples after all spray washing treatments were lower than counts present in macerated and not spray-washed control samples indicates that no embedding of bacterial cells occurred due to the spray washing process (Tables 2, 3, and 4). Studies with blue lake dye have recommended use of pressures of less than 20.7 bar to avoid embedding bacteria in carcass surfaces (*2, 8*).

Results presented in Tables 2, 3, and 5 demonstrate that the spray washing treatments employed in this study did not translocate or spread the bacteria onto areas adjacent to the spot of artificial contamination with inoculated fecal material. The microbiological counts recovered from the B locations were generally lower, both before and after spray washing, than counts at the inoculation sites (A). However, trimming of samples did seem to slightly spread the contamination as indicated by greater ($P<0.05$) bacterial counts for the trimmed B samples compared to the spray-washed-only B samples (Tables 2 and 5).

Visual evaluation scores

The adipose tissue samples were evaluated visually for detection of fecal material both before and after treatment to assess the cleanliness of the pieces of fat. All unwashed and untrimmed samples soiled with inoculated fecal material had scores of 5 before treatment, whereas samples that were washed (combining results at all pressures and speeds) had scores below 1.13 after treatment (Table 2). Thus, spray washing (score 1.13) and hand trimming (score 1.22) were both effective in visibly cleaning the samples, as fecal contamination scores for all samples decreased significantly ($P < 0.05$) when compared to the inoculated, nonwashed samples (Tables 2 to 4). This finding agrees with the conclusion of

TABLE 4. *The effect of carcass washing chain speed on total plate count, streptomycin-resistant bacteria counts, and visual fecal contamination scores of beef brisket adipose tissue samples (numbers in parentheses are standard deviations)*[a]

Spray washing chain speeds (carcasses per hour)	Total plate counts (log CFU/cm^2)		Streptomycin-resistant counts (log CFU/cm^2)		Visual scores[a]	
	A	B	A	B	before	after
Uninoculated	5.42(0.46)^e	4.97(0.35)^d	5.00(0.64)^e	4.64(0.46)^d	1.17(0.93)^f	1.17(0.93)^e
Inoculated[c]	7.09(0.66)^d	5.02(0.75)^d	6.86(0.80)^d	4.73(0.69)^d	5.00(0.00)^d	5.00(0.00)^d
100	4.90(0.77)^f	4.31(0.61)^f	4.56(0.73)^f	14.11(0.66)^e	4.33(1.53)^e	0.59(0.77)^f
200	5.13(0.72)^e	4.47(070)^e	4.77(0.74)^e	4.15(0.76)^e	4.39(1.45)^e	0.64(0.76)^f
300	5.16(0.72)^e	4.56(0.63)^e	4.86(0.76)^e	4.25(0.69)^e	4.36(1.47)^e	0.70(0.86)^f

[a] Data averaged over spraying pressures and surface area of fecal material inoculation and chain speed.
[b] Score of 0, no visible fecal material contamination; 1, sparse evidence of fecal material; 3, presence of fecal material; 5, obvious fecal contamination.
[d-f] Means within a column with different superscript letters differ ($P < 0.05$).
[g] Sampling locations: A, contamination spot; B, adjacent areas.

TABLE 5. *Mean visual scores for the presence of fecal material, total plate counts of bacteria, and streptomycin-resistant counts of bacteria on beef brisket adipose tissue samples inoculated with 1.25 cm^2 fecal material then spray washed at 2.76, 13.79, 20.68, or 27.58 bar and at rates equivalent to 100, 200, or 300 carcasses per hour with or without previous hand trimming of fecal contamination.*

Treatments	Total plate counts (log CFU/cm^2)		Streptomycin-resistant counts (log CFU/cm^2)		Visual scores[a]	
	A	B	A	B	before treatment	after treatment
Hand trimmed, spray washed	5.28^b	4.97^b	4.92^b	4.47^b	4.45^b	1.12^c
Not hand trimmed, spray washed	5.49^b	4.70^c	5.13^b	4.44^b	4.45^b	1.40^b

[a] Score of 0, no visible fecal material contamination; 1, sparse evidence of fecal material; 3, presence of fecal material; 5, obvious fecal contamination.
[b-c] Means within a column with different superscript letters differ ($P < 0.05$).
[a] Sampling locations: A, contamination spot; B, adjacent areas.

Anderson et al. (*5*) that washing beef carcasses reduces the amount of foreign material on carcass surfaces. Among the treatments, those resulting in the lowest visual scores for fecal material contamination were washing with water pressures of 20.68 or 27.58 bar (Table 2). The treatment with the largest surface area of fecal contamination (2.5 cm^2) had a visual score of 1.15 after spray washing (Table 3). However, the combination of hand trimming and spray washing resulted in lower ($P < 0.05$) visual scores than did spray washing alone, regardless of water pressures (Table 5). None of the treatments achieved the ideal visual score of zero, even under the controlled conditions of this study or even when a sterile knife was used for trimming for removal of fecal material. In some instances, certain spray washing treatments (Table 2) at higher pressures (13.79 to 27.58 bar) improved visual scores more than trimming and spray washing (2.76 to 27.58 bar).

CONCLUSIONS

The present studies have shown that the most important factor in spray washing with water to decontaminate artificially contamintated beef adipose tissue was spraying pressure (2.76, 13.79, 20.68, or 27.58 bar). The influence of chain speed (100, 200, or 300 carcasses per hour) and size of surface area of fecal material contamination (0.3125, 0.625, 1.25, 1.875, or 2.5 cm^2) was less important than spray washing pressure, under the conditions of this study. Pressures above 13.79 bar were more effective than lower pressures in reducing microbiological contamination and in cleaning the samples to remove visible fecal contaminants. Reductions in microbiological contamination achieved by spray washing were in the range of 1 to 2 log CFU/cm^2. It should be noted, however, that the samples tested were soiled with a fecal paste inoculated with *E. coli* in order to provide consistently high levels of contamination before trimming and/or spray washing. Effective spray washing treatments were similiar to hand trimming in reducing microbiological counts and in removing visual fecal contaminants. Additionally, there was no significant difference ($P > 0.05$) in microbiological counts between samples that were hand-trimmed and then spray-washed compared to samples that were spray-washed only (Table 5). Therefore, spray washing without trimming was found to be an effective measure for removing fecal material and microbiological contamination from beef adipose tissue samples. On the basis of these results and a previous study (*8*), we recommend a maximum pressure of 20.70 bar for spray washing applications to remove fecal contaminants from beef carcasses.

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