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Microbiological effects of carcass decontaminating treatments at four beef packing plants☆

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Abstract

The effects on the microbiological conditions of carcasses of decontaminating treatments at four beef packing plants were examined. Spraying with 2% lactic acid, vacuum-hot water cleaning and trimming were generally ineffective. Washing reduced numbers of bacteria on carcasses when numbers were relatively high but not when they were relatively low. Pasteurizing with steam or hot water was consistently effective. The results suggest that the maximum reduction of bacteria on carcasses may be obtained by washing and pasteurizing without the other decontaminating treatments that are currently applied to carcasses.

Keywords: Beef carcasses; Decontamination; Bacteria; *Escherichia coli*

1. Introduction

Concern about the contamination of beef with enteric pathogens has led to extensive investigation of treatments for reducing the numbers of bacteria on dressed beef carcasses. Treatments such as trimming, washing, vacuuming while treating the vacuumed area with hot water or steam, spraying with antimicrobial solutions and pasteurizing meat surfaces with steam or hot water have all been reported to be effective for removing bacteria from meat (Dorsa, 1997). Moreover, the application of several treatments to the same surface have been found to give greater reductions of bacterial numbers than any of the treatments alone (Dorsa, Cutter, Siragusa, & Koohmaraie, 1996; Graves Delmore, Sofos, Schmidt, & Smith, 1998). In view of such findings, most North American beef packing plants have supplemented the traditional treatments of trimming and washing with several others for the removal or destruction of bacteria on carcasses (Allen, 1999; Bacon et al., 2000).

Despite the efficacies in experimental circumstances of all treatments for decontaminating carcasses currently used at beef packing plants (Belk, 2001), and the reported efficacies of some in commercial practice (Dormedy, Brashears, Cutter, & Burson, 2000; Gill & Bryant, 2000; Nutsch et al., 1997), others have been reported to be ineffective when used routinely in commercial processes (Avens et al., 1996; Gill & Bryant, 1997). Moreover, the additive effects of multiple decontaminating treatments in commercial carcass dressing processes have not been demonstrated, while similar treatments may not be similarly effective at all plants, because the types of equipment or operating conditions for the same types of equipment may differ between plants. Thus, there must be uncertainty as to the extent that findings for decontaminating treatments in experimental circumstances can be assumed for treatments applied at packing plants. Therefore, the microbiological effects of the decontaminating treatments routinely applied during the dressing of beef carcasses at four beef packing plants were examined.

2. Materials and methods

2.1. Decontaminating treatments

The plants involved in the study process beef carcasses at rates that range from 100 to 280 carcasses/h (Table 1). Only beef cattle carcasses are processed at

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Table 1
Rates of processing and the types of carcasses processed at four beef packing plants

Plant	Rate of processing (carcasses/h)	Types of carcass	
		Beef cattle (%)	Culled cow (%)
A	280	100	–
B	250	90	10
C	100	40	60
D	180	80	20

Table 2
Types of decontaminating treatments applied to carcasses during the dressing processes at four beef packing plants

Treatment	Plant			
	A	B	C	D
Washing and spraying with 2% acid, before evisceration	+	+	+	−
Vacuum plus hot water cleaning	+	+	+	+
Trimming	+	+	+	+
Washing carcass sides	+	+	+	+
Spraying with 200 ppm peroxyacetic acid	+	−	−	−
Pasteurizing with steam	+	+	−	−
Pasteurizing with water	−	−	+	−
Spraying with 2% acid	−	+	+	+

plant A, but all the other plants process both beef cattle and culled cow carcasses.

Some types of decontaminating treatment are used at all the plants, but the set of decontaminating treatments is different at each (Table 2). The cabinets (model CAS-1000 Beef; CHAD Co, Lexana, KS, USA) for treating uneviserated carcasses at plants A, B and C are similar. In those cabinets, each carcass is washed for about 10 s with water at temperatures which range from 40 to 55 °C. The water is delivered at a nozzle pressure of about 20 kg/cm^2, from nozzles on oscillating manifolds, at a rate of about 240 l/min. As each carcass leaves a cabinet it passes through a spray of 2% w/v L+lactic acid, which is at the ambient air temperature (ca. 25 °C). The spray is delivered at a nozzle pressure of about 50 kg/cm^2, at a rate of about 35 l/min, from two vertical manifolds, one on each side of the exit from the cabinet.

At all four plants, after carcasses are eviscerated and split, the rump, brisket and fore leg of each side are cleaned using the same type of vacuum plus hot water cleaning equipment (Kentmaster Manufacturing Co, Monrovia, CA, USA), with a different cleaner being used for each site on the sides. After cleaning, sides at all four plants are trimmed to remove any remaining, visible contamination.

After trimming, sides at all four plants are washed in cabinets (CHAD) with water delivered from nozzles on oscillating manifolds, at rates that range from 600 to 900 l/min, at nozzle pressures of about 20 kg/cm^2. The temperature of the water at the nozzles is 40 °C at plant A, but variable between 5 and 10 °C at the other plants; and the treatment time is 12 s at plant A, but 25–30 s at the other plants.

At plant A, the sides enter a cabinet (CHAD) in which they are sprayed with a solution of peroxyacetic acid (Inspexx; Ecolab Inc., St. Paul, MN, USA) at a concentration of 200 ppm, delivered at a nozzle pressure of about 50 kg/cm^2, at a rate of 50 l/min. The sprayed sides at plant A and the washed sides at plant B pass between two vertical manifolds (Frigoscandia, Bellevue, WA, USA), each with several nozzles from which filtered air is blown onto the sides to remove water. Then, each side passes for 12 s through a chamber in which a steam atmosphere with a temperature between 88 and 94 °C is maintained, with fresh steam entering at the base of the chamber and spent steam leaving at the top (Frigoscandia). The sides at plant B pass through a spray of 2% lactic acid, delivered at a nozzle pressure of about 50 kg/cm^2, at a rate of about 35 l/min, as they leave the pasteurizer.

At plant C, the washed sides pass to a cabinet (CHAD) where first they are treated for 10 s with water of 85 °C delivered from nozzles on oscillating manifolds at a nozzle pressure of about 20 kg/cm^2, at a rate of 700 l/min. Then, in the same cabinet, the sides are sprayed for 5 s with 2% lactic acid delivered at the ambient air temperature of about 25 °C at a nozzle pressure of about 50 kg/cm^2, at a rate of 35 l/min. Finally the sides enter another cabinet (CHAD), where they are washed with water at a temperature <2 °C delivered at a nozzle pressure of about 10 kg/cm^2, at a rate of about 100 l/min. At plant D, washed sides are not pasteurized, but they are treated with 2% lactic acid as at plant C.

2.2. Sample collection

At plant A on each of 5 days, samples were collected from five carcasses selected at random at each of five stages of processing, which were after skinning, after washing and spraying lactic acid on uneviscerated carcasses, before washing of dressed sides, after washing sides, and after pasteurizing. Samples were collected similarly at plant B. At plant C, samples were collected on each of 5 days from five carcasses at each of six stages of processing. The first four stages of processing were as at plant A. The fifth stage of processing was after pasteurizing with water and spraying with lactic acid. The sixth stage was after the spraying with water at <2 °C. At plant D, samples were collected on each of 5 days from five carcasses at four stages of processing, which were after skinning, before washing sides, after washing sides, and after spraying with lactic acid.

A single sample was collected from a randomly selected site on each carcass. Sites were selected by reference to a

grid which specifies 126 areas on the distal surface of a beef carcass side (Gill, Badoni, & Jones, 1996). Each sample was obtained by swabbing an undelimited area of approximately 100 cm^2 with a sterile gauze swab (Curity gauze sponge; Kendall Canada, Peterborough, ON, Canada) which had been moistened with 0.1% w/v peptone water (Difco Laboratories, Detroit, MI, USA). Each swab was placed in a separate stomacher bag (Baxter Diagnostic Corp., Edmonton, AB, Canada) which was immersed in slush ice. Samples were processed within 3 h of being collected.

2.3. Enumeration of bacteria

Ten mililiters of 0.1% peptone water was added to each swab sample, which was then stomached for 2 min. Bacteria were enumerated by hydrophobic grid membrane filtration techniques, with detection of total aerobes at a level of 1 cfu/10 cm^2 and detection of coliforms and *Escherichia coli* at a level of 1 cfu/100 cm^2, as previously described (Gill & Jones, 2000).

2.4. Analysis of microbiological data

The counts of each type from 25 samples obtained at each stage of processing at each plant were each regarded as a set. All counts were transformed to log values. When bacteria were recovered from 20 or more of 25 samples, values for the mean log ($\overline{x}$) and standard deviation (s) of the set were calculated on the assumption of the log normal distribution of the counts (Brown & Baird-Parker, 1982); with the assignment of a log value of -1.5/cm^2 for samples from which aerobes were not recovered, or -0.5/100 cm^2 for samples from which coliforms or *E. coli* were not recovered. When values for $\overline{x}$ and s were calculated for a set of counts, a value for the log mean (log A) was also calculated from the formula $\log A = \overline{x} + \log_e 10 . s^2/2$ (Kilsby & Pugh, 1981). A value for the log total number of bacteria recovered (N) was calculated for each set by summing the counts and obtaining the log of the sum. Those calculations were performed with Microsoft Excel version 4 (Microsoft Corp., Redmond, WA, USA).

In addition, the Statistical Analysis Systems, version 6 (SAS Institute, Cary, NC, USA) was used to apply a Shapiro–Wilk test for normal distribution to each set of log counts for which a log A value was calculated; and to separate mean log values for sets of counts of the same type obtained from samples from the same plant, using the Tukey option of the general linear model procedure.

3. Results

The microbiological conditions of carcasses at different stages of processing can be compared by reference to values for log A and/or N. These statistics for sets of bacterial counts obtained from carcasses at plant A showed that after pre-evisceration washing and spraying with lactic acid, the numbers of aerobes recovered from carcasses were >1 log unit less than the numbers from untreated carcasses, but that the numbers of coliforms and *E. coli* were <0.5 log unit less on treated than on untreated carcasses (Table 3). Numbers of each of the three types of bacteria recovered from carcasses before and after vacuum plus hot water cleaning and trimming, and after washing differed by <0.5 log unit. Consequently, the numbers of aerobes, coliforms and *E. coli* recovered after the washing of sides were, respectively, about 1.5, <1.0 and <0.5 log unit less than the numbers recovered from unwashed, uneviscerated carcasses. After treating with peroxyacetic acid and pasteurizing the number of aerobes recovered were >1 log unit less, and the numbers of coliforms and *E. coli* were >2 log units less than before the treatments.

At plant B, the number of aerobes recovered from uneviscerated, unwashed carcasses were >2 log units

Table 3
Statistics for sets of 25 total aerobic counts (cfu/cm^2), coliform counts (cfu/100 cm^2) or *Escherichia coli* counts (cfu/100 cm^2) recovered from carcasses at plant A (1) after skinning; (2) before evisceration, after washing then spraying with 2% lactic acid; (3) before washing carcass sides; (4) after washing carcass sides; and (5) after spraying with 200 ppm peroxyacetic acid solution then pasteurizing with steam

Count	Stage of processing	Statistics				
		$\overline{x}$[a]	s[b]	No[c]	log A[d]	N[e]
Aerobes	1	3.07a	1.07	0	4.40[f]	5.84
	2	2.60ab	0.61	0	3.02[f]	4.48
	3	2.19b	0.77	0	2.87[f]	4.17
	4	2.28b	0.74	0	2.90[f]	4.28
	5	1.25c	0.58	0	1.63	2.97
Coliforms	1	–[g]	–	10	–	3.25
	2	–	–	11	–	2.92
	3	–	–	8	–	2.71
	4	–	–	10	–	2.53
	5	–	–	23	–	0.48
E. coli	1	–	–	10	–	2.97
	2	–	–	11	–	2.76
	3	–	–	12	–	2.63
	4	–	–	12	–	2.51
	5	–	–	25	–	n.d.[h]

Mean logs for sets of counts of the same type with the same letter are not significantly different ($P>0.05$).

[a] Mean of log counts.

[b] Standard deviation of log counts.

[c] Number of samples from which bacteria of a type were not recovered.

[d] Log of the arithmetic mean.

[e] Log of the total number recovered from 25 samples.

[f] Set of log counts is normally distributed ($P>0.05$).

[g] Insufficient data for calculation of the statistic.

[h] None detected.

less, but the numbers of coliforms and *E. coli* were each <1 log unit less than the numbers recovered from the corresponding carcasses at plant A (Table 4). Decontaminating treatments up to and including washing carcass sides had little effect on the numbers of aerobes recovered, but the numbers recovered from sides that had been pasteurized and sprayed with acid were 1 log unit less than the numbers recovered from untreated sides. Numbers of coliforms and *E. coli* recovered from uneviscerated carcasses before and after washing and spraying with lactic acid also differed little. However, numbers of coliforms and *E. coli* recovered from unwashed sides were, respectively, about 2 and about 1.5 log units more than the numbers recovered from washed, uneviscerated carcasses. After washing, the numbers of coliforms and *E. coli* recovered from sides were, respectively, about 1 and <0.5 log unit less than the numbers recovered from unwashed sides; and the numbers recovered from sides after pasteurizing and treating with lactic acid were each >3 log units less than the numbers recovered from sides before those treatments.

Table 4
Statistics for sets of 25 total aerobic counts (cfu/cm^2), coliform counts (cfu/100 cm^2) or *Escherichia coli* counts (cfu/100 cm^2) recovered from carcasses at plant B (1) after skinning, (2) before evisceration, after washing then spraying with 2% lactic acid; (3) before washing carcass sides; (4) after washing carcass sides, and (5) after pasteurizing with steam and spraying with 2% lactic acid

Count	Stage of processing	Statistics				
		$\overline{x}$[a]	s[b]	No.[c]	log A[d]	N[e]
Aerobes	1	1.56a	0.84	0	2.37[f]	3.52
	2	1.18a	0.78	0	1.88[f]	3.25
	3	1.59a	0.66	0	2.09[f]	3.40
	4	1.44a	0.71	0	2.02[f]	3.28
	5	−0.14b	0.87	2	0.73	2.28
Coliforms	1	–[g]	–	16	–	2.34
	2	–	–	8	–	2.28
	3	1.82a	1.27	2	3.67[f]	4.41
	4	1.33b	1.03	3	2.56[f]	3.49
	5	–	–	24	–	0.00
E. coli	1	–	–	20	–	2.20
	2	–	–	12	–	2.04
	3	1.33a	1.13	2	2.80	3.56
	4	0.99b	0.96	2	2.04[f]	3.19
	5	–	–	25	–	n.d.[h]

Mean logs for sets of counts of the same type with the same letter are not significantly different ($P>0.05$).
[a] Mean of log counts.
[b] Standard deviation of log counts.
[c] Number of samples from which bacteria of a type were not recovered.
[d] Log of the arithmetic mean.
[e] Log of the total number recovered from 25 samples.
[f] Set of log counts is normally distributed ($P>0.05$).
[g] Insufficient data for calculation of the statistic.
[h] None detected.

Numbers of aerobes recovered from uneviscerated, unwashed carcasses at plant C were similar to the numbers recovered from the corresponding carcasses at plant B, but numbers of coliforms and *E. coli* recovered from the former carcasses were about 1.5 log units more than the numbers recovered from the latter carcasses (Table 5). Washing and spraying with lactic acid had no effect on the numbers of aerobes recovered from uneviscerated carcasses, but the numbers of coliforms and *E. coli* recovered from treated carcasses were both >1 log unit less than the numbers recovered from untreated carcasses. Numbers of aerobes recovered from unwashed sides were >0.5 log unit less than the numbers recovered from uneviscerated, washed carcasses; but the numbers of coliforms and *E. coli* recovered from both types of carcass were similar. Numbers of all three types of bacteria recovered from unwashed and washed sides

Table 5
Statistics for sets of 25 total aerobic counts (cfu/cm^2), coliform counts (cfu/100 cm^2) or *Escherichia coli* counts (cfu/100 cm^2) recovered from carcasses at plant C (1) after skinning; (2) before evisceration, after washing then spraying with 2% lactic acid; (3) before washing carcass sides; (4) after washing carcass sides, before pasteurizing; (5) after pasteurizing, and spraying with 2% lactic acid; and (6) after spraying with cold water

Count	Stage of processing	Statistics				
		$\overline{x}$[a]	s[b]	No.[c]	log A[d]	N[e]
Aerobes	1	1.91a	0.83	0	2.71[f]	3.88
	2	1.98a	0.80	0	2.72[f]	3.84
	3	1.14b	0.69	0	1.68[f]	3.00
	4	1.35b	0.69	0	1.90[f]	3.30
	5	–[g]	–	7	–	1.58
	6	0.55c	0.50	1	0.84[f]	2.28
Coliforms	1	–	–	12	–	4.00
	2	–	–	10	–	2.76
	3	–	–	8	–	2.96
	4	–	–	14	–	2.57
	5	–	–	25	–	n.d.[h]
	6	–	–	18	–	1.20
E. coli	1	–	–	13	–	3.99
	2	–	–	10	–	2.74
	3	–	–	10	–	2.78
	4	–	–	17	–	2.45
	5	–	–	25	–	n.d.
	6	–	–	22	–	1.08

Mean logs for sets of counts of the same type with the same letter are not significantly different ($P>0.05$).
[a] Mean of log counts.
[b] Standard deviation of log counts.
[c] Number of samples from which bacteria of a type were not recovered.
[d] Log of the arithmetic mean.
[e] Log of the total number recovered from 25 samples.
[f] Set of log counts is normally distributed ($P>0.05$).
[g] Insufficient data for calculation of the statistic.
[h] None detected.

each differed by <0.5 log unit. For pasteurized and acid sprayed sides the numbers of aerobes recovered from sides were 1.5 log unit less, and the numbers of coliforms and *E. coli* were each 2.5 log units less than the numbers recovered from untreated sides. The numbers of all three types of bacteria recovered from sides washed with cold water were more than the numbers recovered from sides before they were washed.

The number of aerobes recovered from uneviscerated, unwashed carcasses at plant D were similar to the numbers recovered from the corresponding carcasses at plant A, but numbers of coliforms and *E. coli* were similar to the numbers recovered from the corresponding carcasses at plant C (Table 6). Numbers of all three types of bacteria recovered from unwashed sides were each similar to the numbers recovered from uneviscerated carcasses. After washing, the numbers of aerobes recovered from sides were 0.5 log unit less, and the numbers of both coliforms and *E. coli* were 1 log unit less than the numbers recovered from unwashed sides. The numbers of aerobes recovered from sides sprayed with lactic acid were about 1 log unit more than the numbers recovered from untreated sides; but the numbers of coliforms and *E. coli* recovered from treated and untreated sides were similar.

Table 6
Statistics for sets of 25 total aerobic counts (cfu/cm^2), coliform counts (cfu/100 cm^2) or *Escherichia coli* counts (cfu/100 cm^2) recovered from carcasses at plant D (1) after skinning; (2) before washing carcass sides; (3) after washing carcass sides; (4) after spraying with 2% lactic acid

Count	Stage of processing	Statistics				
		$\bar{x}$[a]	s[b]	No.[c]	log A[d]	N[e]
Aerobes	1	2.93a	0.89	0	4.03[f]	4.98
	2	2.47a	1.08	0	3.81[f]	4.86
	3	1.77b	1.05	0	3.04[f]	4.32
	4	1.70b	1.66	0	4.87	5.16
Coliforms	1	–[g]	–	7	–	4.18
	2	1.59	1.46	4	4.03[f]	4.46
	3	–	–	8	–	3.44
	4	–	–	14	–	3.52
E. coli	1	–	–	9	–	4.01
	2	–	–	8	–	4.16
	3	–	–	10	–	3.16
	4	–	–	17	–	2.93

Mean logs for sets of counts of the same type with the same letter are not significantly different ($P>0.05$).

[a] Mean of log counts.

[b] Standard deviation of log counts.

[c] Number of samples from which bacteria of a type were not recovered.

[d] Log of the arithmetic mean.

[e] Log of the total number recovered from 25 samples.

[f] Set of log counts is normally distributed ($P>0.05$).

[g] Insufficient data for calculation of the statistic.

4. Discussion

It is generally recognized that bacterial counts which differ by <0.5 log unit are not substantially different (Jarvis, 1989). Thus, the microbiological effects of decontaminating treatments must be regarded as trivial when the numbers of bacteria recovered before and after a treatment do not differ by at least 0.5 log unit.

The effects of the various decontaminating treatments on the microbiological conditions of carcasses would preferably have been determined by sampling carcasses before and after each treatment. However, that was not possible where treatments were combined, as in the treatment of uneviscerated carcasses by washing and spraying with lactic acid; or where access to the whole carcass was not practicable, as after vacuum plus hot water cleaning treatments but before trimming. Therefore, for some types of treatment, the general effects must be deduced by consideration of the various effects of the similar treatments at all four plants.

With regard to the effects of spraying with antimicrobial solutions, it is apparent that 2% lactic acid was ineffective when applied to washed, uneviscerated carcasses at plant B and washed sides at plant D. Indeed, at plant D the numbers of aerobes on carcasses were higher after than before the lactic acid treatment, probably because the washed sides contacted contaminated equipment. Moreover, the different effects of the pre-evisceration washing plus lactic acid treatments at plants A and C, with the numbers of aerobes but not those of coliforms and *E. coli* being reduced at plant A, but with coliforms and *E. coli* but not aerobes being reduced at plant C are difficult to explain as effects of the acid treatments. Thus, it seems likely that spraying with 2% lactic acid is an ineffective treatment wherever it is applied at all of the plants. The spraying of sides with peroxyacetic acid before they are pasteurized at plant A may also be ineffective, as the reductions obtained by those treatments were no more than the reductions obtained by pasteurizing and treating with 2% lactic acid at plant B.

The apparent failure of the lactic acid spray treatments to produce substantial microbiological effects may be due to the sprays giving poor coverage of the carcasses or sides, and/or by the solutions being diluted by water present on carcasses from washing or condensation of steam, rather than from the resistance of bacteria to the antibacterial effects of lactic acid, which are well established (Smulders & Greer, 1998). Certainly, poor distribution of the lactic acid solution appeared to have occurred during the final treatment at plant D, as numbers of aerobes recovered from some sites were very few, which gave a set of log counts with a non-normal distribution and a high standard deviation, while the incidences of coliforms and *E. coli* positive samples were greater before than after the treatment.

Those findings indicate that the lactic acid solution had been effectively applied to some sites, which were decontaminated, but the overall effect was trivial because many other sites remained unaffected.

If the lactic acid spray treatments were indeed all ineffective, then the effects of the treatments of uneviscerated carcasses can be ascribed to washing alone. Then it appears that washing uneviscerated carcasses was effective for reducing the relatively large numbers of aerobes on carcasses at plant A, and the relatively large numbers of coliforms and *E. coli* on carcasses at plant C; but washing was ineffective for reducing the relatively small numbers of aerobes on carcasses at plants B and C, and the relatively small numbers coliforms and *E. coli* on carcasses at plants A and B. Similarly, washing of sides was effective for reducing the relatively large numbers of coliforms and *E. coli* on sides at plant B, and the relatively large numbers of all three types of bacteria on sides at plant D; but washing was ineffective for reducing the relatively small numbers of all three types of bacteria on sides at plants A and C. The recovery of higher numbers from sides after than before the final, cold water wash at plant C was probably a result of bacteria being redistributed by the treatment, as aerobes were log normally distributed after but not before washing.

Studies of the effects of washing beef carcasses in both experimental and commercial circumstances have shown that, generally, few bacteria are removed by washing, although they may be redistributed from specific, heavily contaminated sites to other parts of the carcass (Bolton, Doherty, & Sheridan, 2001). Nonetheless, in a recent study, substantial reductions in bacterial numbers as a result of washing beef sides at one plant, although not at two others, were observed (Gill, Bryant, & McGinnis, 2001). From consideration of findings with experimentally contaminated carcasses (Dorsa et al., 1996; Graves, Delmore et al., 1998) it was suggested that the different effects could be accounted for by differences in the washing treatments. However, the findings of this study suggest otherwise, as the data indicate that washing was effective when initial numbers were relatively high, but ineffective when numbers were relatively low. That may occur because when numbers are relatively high many of the bacteria are probably associated with particles, which are washed from the meat by the large volumes of water applied to carcasses in automatic washing operations. When numbers are relatively low most of the bacteria are probably directly associated with the tissues, and so may be refractory to physical removal by washing (Li & McLandsborough, 1999).

Both vacuum plus hot water cleaning and trimming have been found highly effective for removing bacteria from experimentally contaminated sites on carcasses (Kochevar, Sofos, Bolin, Regan, & Smith, 1997; Regan et al., 1996). It might then be expected that sides which have been cleaned and trimmed after evisceration and splitting of carcasses would carry fewer bacteria than uneviscerated carcasses. Instead, only at plant C, and then only aerobes were substantially fewer on unwashed sides than on uneviscerated carcasses. The numbers of coliforms and *E. coli* on unwashed sides at plant B were substantially higher than the numbers on uneviscerated carcasses. That may have been due to the carcasses being contaminated from persisting detritus in equipment, as *E. coli* were only 10% of the coliform population. If the contaminants were derived from faecal material, then the coliforms would have been largely *E. coli* (Gill, Deslandes, Rahn, Houde, & Bryant, 1998). Thus, the data suggest that eviscerating and splitting operations generally added few bacteria to carcasses, and vacuum plus hot water cleaning and trimming operations did not remove many. That would be agreeable with previous findings of bacteria being deposited on commercial carcasses mainly during skinning operations (Bell, 1997) and cleaning and trimming operations being without substantial effects on the microbiological conditions of carcasses (Gill et al., 1996; Gill & Bryant, 1997). The reduction in the numbers of aerobes on sides at plant C may be the result of unusually extensive trimming, but more detailed study of the process would be needed to decide that matter.

Of all the decontaminating treatments only pasteurizing with steam or hot water appeared in all cases to be effective for substantially reducing the numbers of bacteria on carcasses, in agreement with previous reports on the effects of such treatments in commercial practice (Gill & Bryant, 2000; Nutsch et al., 1997). Even so, the reductions in numbers might not always be as great as the numbers recovered before and after pasteurizing suggest, because reductions in numbers are apparently not uniform over the whole of each side. Indeed, the apparent increases in numbers after washing of pasteurized sides at plant C were likely due to bacteria being redistributed from sites less affected to those more affected by the pasteurizing treatment.

The indications that most supposed decontaminating treatments had little effect are contrary to the view that multiple decontaminating treatments applied sequentially will each incrementally improve the microbiological conditions of commercial carcasses. Instead, the data suggest that washing at the end of the dressing process, to reduce high levels of contamination, followed by an effective pasteurizing treatment may give the maximum possible reduction of the bacteria deposited on carcasses during any dressing process. However, further examination of commercial processes will be necessary to determine if those treatments alone could in fact yield beef carcasses of the best microbiological condition.

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