Journal of Food Protection, Vol. 62, No. 2, 1999, Pages 140–145

Sources and Extent of Microbiological Contamination of Beef Carcasses in Seven United States Slaughtering Plants

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MS 98-180: Received 20 July 1998/Accepted 21 September 1998

ABSTRACT

This study determined microbiological loads of beef carcasses at different stages during the slaughtering to chilling process in seven (four steer/heifer and three cow/bull) plants. Potential sources of contamination (feces, air, lymph nodes) were also tested. Each facility was visited twice, once in November through January (wet season) and again in May through June (dry season). Carcasses were sampled by aseptic excision of surface tissue (100 cm^2) from the brisket, flank, and rump (30 samples each) after hide removal (pre-evisceration), after final carcass washing, and after 24-h carcass chilling. The samples were analyzed individually by standard procedures for aerobic plate counts (APC), total coliform counts (TCC), *Escherichia coli* biotype I counts (ECC), and presence of *Salmonella.* Incidence of *Salmonella* was higher on dry feces of older compared to younger animals, fresh feces of younger compared to older animals, and on cow/bull carcasses compared to steer/heifer carcasses. Most factors and their interactions had significant ($P \leq 0.05$) effects on the bacterial counts obtained. Depending on plant and season, APC, TCC, and ECC were $\leq 10^4$, $\leq 10^2$, and $\leq 10^1$ CFU/cm^2 in 46.7 to 93.3, 50.0 to 100.0, and 74.7 to 100.0% of the samples, respectively. TCC exceeded 10^3 CFU/cm^2 in 2.5% (wet season) and 1.5% (dry season) of the samples. ECC exceeded 10^2 CFU/cm^2 in 8.7%, 0.3%, and 1.5% of the pre-evisceration, final carcass-washing, and 24-h carcass-chilling samples, respectively, during the wet season; the corresponding numbers during the dry season were 3.5%, 2.2%, and 3.0%, respectively. These data should serve as a baseline for future comparisons in measuring the microbiological status of beef carcasses, as the new inspection requirements are implemented.

Increased consumer awareness and concern about microbial foodborne illness has led to establishment of new Meat and Poultry Inspection Regulations in the United States *(3).* These regulations require (i) establishment, by all meat and poultry processing plants, of sanitation standard operating procedures; (ii) operation under the principles of the hazard analysis critical control point (HACCP) system; and (iii) establishment of microbiological performance criteria for *Escherichia coli* and standards for *Salmonella* contamination. The microbiological performance criteria and standards were based on data obtained from national baseline carcass contamination studies conducted by the U.S. Department of Agriculture (USDA) Food Safety and Inspection Service (FSIS), which tested carcasses of steers and heifers in 1992 to 1993 *(1)* and carcasses of cows and bulls in 1993 to 1994 *(2).*

The study reported here was designed to evaluate the microbiological status of carcasses in the United States in 1995 to 1996, as the beef industry was preparing to operate under the HACCP system required by the new Meat and Poultry Inspection Regulations *(3).* Types of analyses included aerobic plate counts (APC), total coliform counts (TCC), and *E. coli* counts (ECC) on three carcass sites (brisket, flank, and rump), at three plant locations (pre-evisceration, after final carcass washing, and after 24-h carcass chilling), during the periods of November through January (''wet'' season) and May through June (''dry'' season) in each of seven slaughtering plants. In addition, fresh and dry fecal material and carcass samples were analyzed for the presence of *Salmonella,* and lymph node samples and air samples in several plant locations were analyzed for APC and TCC.

MATERIALS AND METHODS

Study design. The study was conducted in seven beef slaughtering/dressing plants across the United States. Of these seven plants, four were classified as primarily slaughtering fed steers/heifers and three were classified as primarily slaughtering nonfed cows/bulls. The plants were located in California, Nebraska, Pennsylvania, Texas (two plants), Washington, and Wisconsin. Characteristics of the plants in which samples were taken are shown in Table 1. Each facility was visited twice, once during the wet season (November through January) and once during the dry season (May through June) of 1995 to 1996. Following collection, all samples were refrigerated and placed in coolers with ice packs for shipment by overnight air express to a laboratory (Agri-West Laboratory, San Antonio, Tex.) for analysis.

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TABLE 1. *Characteristics of the seven beef slaughtering plants in which samples were collected for analysis*

Line speed (animals/hour)	90–216
Shifts per day	1
Pre-evisceration carcass washing (yes/no)	1/6
Carcass steam vacuuming (yes/no)	5/2
Final carcass-washing temperature (°C)	21–38
Final carcass-washing pressure (bar)	6.9–24.8
Final carcass-washing chemical	None
Final carcass rinsing (yes/no)	4/3
Final carcass-rinsing temperature (°C)	3–51
Final carcass-rinsing chemical (AA[a]/LA/none)	2/1/4
Carcass spray chilling (yes/no)	4/3

[a] AA, acetic acid; LA, lactic acid.

Feces, air, and lymph node sampling. Thirty animals were sampled postexsanguination, but prior to any hide opening, at each plant and during the 3-day period that university personnel were in the plant. A sample of approximately 30 g of feces was removed from the animal by palpation of the rectum with the person obtaining the sample wearing a clean, plastic palpation glove. Once the fecal sample was removed from the animal, it was placed in a sterile Whirl-Pak bag (Nasco, Modesto, Calif.).

A dunglock (dried feces/mud/hair) sample was removed from the outside of each of the same animals from which a feces sample was taken. Due to differences in environmental conditions in some areas from which slaughter cattle were obtained, there were no dunglocks present to retrieve from the animals; in those instances, the lower part of the tail, commonly referred to as the ''switch,'' was aseptically removed by use of scissors and placed in a Whirl-Pak bag. The scissors were rinsed with water and immersed into 82°C water for at least 5 s prior to removal/cutting of each sample. The person removing the fecal and dunglock samples wore latex gloves and changed them after each sampling.

Following removal of the fecal and dunglock samples, the animal was assigned a ''mud score.'' The mud scoring system was based on a scale of 0 to 3, where a 0 was indicative of cattle bearing no external mud/dunglocks; 1 indicated an animal whose lower legs had mud/dunglocks; 2 represented an animal with mud/dunglocks on its lower legs and belly; and 3 was indicative of an animal with mud/dunglocks that covered its entire body including the back or dorsal area. A total of 420 fecal and 420 dunglocks samples were obtained at the seven plants during the 14 visits (2 visits per plant).

The mandibular and parotid lymph nodes were aseptically removed with sterile forceps and scissors that had been immersed in 82°C water for at least 5 s prior to sample taking. The lymph nodes were removed from 20 animal heads per plant per season, immediately following USDA inspection. A total of 280 lymph nodes was collected during the 14 visits (seven plants; 2 visits per plant) to the packing plants.

Air sampling for microbiological evaluation was conducted by passive exposure of agar plates to air in each of five plant locations, twice (1 h after the shift started and 1 h before the shift ended), during each of 2 days, per season, in each of the seven plants. The air in the high rimming area of the slaughterhouse was sampled by exposure of agar plates to air for 5 min on the high bench, near the first leggers. The air at the hide puller area was also sampled for 5 min, behind the hide pullers. Air sampling at evisceration involved exposure of agar plates to air for 10 min immediately after FSIS inspection of the viscera. The air in the final carcass washing area was sampled for 10 min. Finally, the air in the carcass drip coolers, as carcasses were moved to the fabrication room was sampled for 15 min. In one of the plants the contamination of the air was determined with exposure to air of tryptic soy agar (TSA; Difco Laboratories, Detroit, Mich.) plates, violet red bile agar (VRBA; Difco) plates, aerobic count Petrifilm plates, and coliform count Petrifilm plates (3M Health Care Products, St. Paul, Minn.) that had been rehydrated 1 h before use. In the remaining six plants the air was sampled only with the Petrifilm plates.

Carcass sampling. The carcasses were sampled at three locations in the slaughtering/dressing sequence of each plant and at three different sites on the carcass. The plant locations were designated as pre-evisceration, postfinal carcass washing, and post-24-h carcass chilling. The sampling sites on the carcass were (i) brisket—anterior to the navel on the ventral midline, (ii) flank—posterior to the navel on the ventral mid-line, and (iii) rump—the cushion of the round. These sampling sites on the carcasses are equivalent to the brisket, flank, and rump areas, respectively, as described in the U.S. Meat and Poultry Inspection Regulation *(3)*. Carcass samples were taken over a period of 3 days (per season and plant) to obtain a representative sampling population from different lots of cattle.

Two (one for APC, TCC, and ECC, and a second for *Salmonella* analysis) 100-cm^2 portions (10 × 10 cm; 0.2 cm thick) of the adipose/muscle tissue surface were aseptically removed from each sampling site of the carcass at each location in the plant by use of a sterile rubber template, forceps, and scalpel, and these were placed in a sterile Whirl-Pak bag. At each sampling site on the carcass and at each location in the plant, samples were taken from 30 carcasses, but carcasses sampled at each plant location were different (i.e., carcasses were not followed through the entire production chain for sequential sampling). The overall total (all plants and both visiting periods) number of carcass samples taken for analysis was 3,780.

Microbiological analyses. Samples of fresh feces, dunglocks, and one of the two 100-cm^2 carcass tissue samples were analyzed for *Salmonella* spp. Enrichment technique, isolation, and identification of *Salmonella* were performed following standard FSIS/USDA procedures *(4, 6)*. Lymph node samples were analyzed for APC and TCC (as described below) and for the presence of *Salmonella* spp. in the manner described above. The Petrifilm used for air sampling (APC and TCC) were incubated for 48 ± 2 h at 35°C, and colonies were enumerated as described by the manufacturer.

The second 100-cm^2 carcass tissue sample was analyzed for APC, TCC, and ECC. In the Whirl-Pak bag containing the carcass tissue sample, 100 ml of sterile phosphate buffer was added (Difco). The sample was agitated for 1 min using a Stomacher-3500 (Tekmar, Cincinnati, Ohio), and appropriate dilutions were prepared for plating on Petrifilm aerobic count plates and *E. coli* count plates (3M). Both types of Petrifilm were incubated at 35°C for 48 ± 2 h. After incubation, colonies on Petrifilm were enumerated as instructed by the manufacturer.

Statistical analysis. The quantitative carcass data were expressed as log CFU/cm^2. The quantitative data for lymph node samples were expressed as log CFU/g and those for air samples as log CFU per total time of agar exposure to the air. In order to determine the influence of the parameters tested (i.e., plant, season, plant location, carcass site) and their interactions on the extent of microbiological contamination, the data were analyzed by analysis of variance using the General Linear Model Procedure of

TABLE 2. *Averages (minimum–maximum) of percentages of samples of fresh feces, dry feces (dunglocks), and carcass tissue (brisket, flank, and rump tested at pre-evisceration, after final carcass washing and after 24 h of carcass chilling) that were positive for* Salmonella *in four steer/heifer and three cow/bull slaughtering plants during two seasons (wet, November to January; dry, May to June) of the year*

Plant type	Season	Sample type		
		Fresh feces[a]	Dunglocks[a]	Carcass tissue[b]
Steer/heifer	Wet	14.2 (0–50.0)	7.5 (0–16.7)	1.4 (0–3.0)
	Dry	8.3 (0–30.0)	0.8 (0–3.3)	1.6 (0–5.9)
Cow/bull	Wet	10.0 (0–20.0)	7.8 (0–20.0)	4.7 (1.1–7.0)
	Dry	4.4 (0–10.0)	12.2 (3.3–16.7)	2.7 (0.7–4.8)

[a] Thirty samples per plant and season.
[b] Two hundred seventy samples per plant and season.

SAS *(7)* and means were separated by the least significant difference procedure.

RESULTS AND DISCUSSION

Incidence of *Salmonella* varied greatly among fresh feces, dunglocks, and carcass tissue samples; among plants; and between seasons (Table 2). In fresh feces, the average incidence of *Salmonella* was greater during the wet season compared to the dry season for both steer/heifer and cow/bull plants. In dunglocks, however, the cows/bulls had a higher incidence during the dry than during the wet season, whereas the opposite was true for steers/heifers. Cows/bulls had a higher overall incidence of *Salmonella* in the dunglocks than in fresh feces, whereas steers/heifers had a higher overall incidence in fresh feces than in dunglocks (Table 2). Overall, incidence of *Salmonella* on carcasses of both steers/heifers and cows/bulls was lower than in feces or dunglocks, and incidence of *Salmonella* was higher on cow/bull (2.7 to 4.7%) carcasses than that on steer/heifer (1.4 to 1.6%) carcasses (Table 2). The higher incidence of *Salmonella* on cow/bull carcasses is in agreement with the findings of the USDA/FSIS baseline studies *(1, 2)*. Incidence of *Salmonella* on steer/heifer carcasses was higher during the dry season than during the wet season, while incidence of the pathogen in feces and dunglocks was higher during the wet season than during the dry season (Table 2), which may be indicative of the importance of plant processes on transfer of contamination from the environment onto carcasses. Van Donkersgoed et al. *(8)* reported that there was no consistent association between tag (dunglock) scores on beef cattle hides and bacterial contamination of carcasses, with differences generally being <0.5 log/cm^2.

Percentage of *Salmonella*-positive steer/heifer dunglock samples increased with higher presence of mud on live animal hides, while no such trend was observed with *Salmonella* incidence in dunglocks from cows/bulls (Table 3). This finding may indicate that cleanliness can reduce pathogen presence, but in older animals greater accumulation of pathogens on the hide may be a function of time.

Bacterial counts detected in air samples were influenced ($P \leq 0.05$) by plant (P), season (S), plant location (L), and the interactions of P $\times$ S, P $\times$ L, and S $\times$ L.

TABLE 3. *Percentages of dry feces (dunglock) samples positive for* Salmonella*, taken from animals waiting to be slaughtered in four steer/heifer and three cow/bull plants, as related to mud scores on animal hides*

Mud score[a]	Percent *Salmonella* positive	
	Steer/heifer[b]	Cow/bull[c]
0	1.0	8.9
1	4.0	12.3
2	8.5	7.4
3	11.1	13.3

[a] 0, No mud present on the animal; 1, mud present on lower legs; 2, mud present on lower legs and belly of animal; and 3, mud present on lower legs, belly, and back of animal.
[b] Two hundred twenty-seven samples.
[c] One hundred seventy-eight samples.

Overall, there was a trend of decreasing airborne contamination between the high rimming area on the slaughtering/dressing floor and the carcass fabrication room (Table 4). However, there was major variation, considering differences existing among packing plant designs. These results agree with findings reported by Worfel et al. *(9)*, who documented the importance of airflow patterns and pressures in decreasing contamination on beef slaughtering/dressing floors in packing plants.

Lymph nodes were found contaminated with average APC in the range of 1 to >1,000 CFU/g and with average TCC in the range of 1 to 100 CFU/g (Table 5). However, bacterial populations in lymph nodes were variable among animals as indicated by the large variation in percentage of samples with counts in the selected ranges. Percentages of lymph node samples with APC >1,000 CFU/g were 27.9 and 24.3 during the wet and dry seasons, respectively. No *Salmonella* was detected in any of the lymph node samples analyzed.

When the data from carcass samples from the seven plants were analyzed as a combined group or as separate groups of steer/heifer versus cow/bull plants, most factors

TABLE 4. *Means (standard deviations) of aerobic plate counts (APC) and total coliform counts (TCC) of air samples taken from five plant locations at two times (a.m. and p.m.), on each of 2 consecutive days, from each of seven beef slaughtering plants (four steer/heifer, three cow/bull) during two seasons (wet, November to January; dry, May to June) of the year with seasons combined*

Plant location	Agar plate exposure time (min)	APC[a]	TCC[a]
High rimming	5	2.0 A (0.5)	0.3 A (0.4)
Hide puller	5	—[b]	—[b]
Evisceration	10	—[b]	—[b]
Post-final wash	10	1.7 B (0.7)	0.1 B (0.2)
Fabrication room	15	0.8 C (0.7)	0.1 B (0.3)

[a] Means in the same column with different letters are significantly ($P \leq 0.05$) different.
[b] Not detected during the agar exposure time allowed.

TABLE 5. *Averages (minimum–maximum) of percentages of cattle lymph node samples collected from four steer/heifer and three cow/bull plants, with plants combined, with aerobic plate counts (APC) and total coliform counts (TCC) in several ranges during two seasons (wet, November to January; dry, May to June) of the year*[a]

Bacterial type	Range of counts (CFU/g)	Season	
		Wet	Dry
APC	1–10	4.3 (0–20.0)	12.1 (0–25.0)
	11–100	22.1 (0–40.0)	23.6 (5.0–35.0)
	101–1,000	45.7 (20.0–65.0)	40.0 (30.0–60.0)
	>1,000	27.9 (5.0–80.0)	24.3 (10.0–60.0)
TCC	1–10	82.9 (0–100)	97.1 (90.0–100)
	11–100	17.1 (0–100)	2.9 (0–10.0)

[a] Twenty samples per plant and season (280 samples total).

(plant—P, season—S, plant location—L, carcass site—C) and most of their interactions had a significant ($P \leq 0.05$) effect on the APC, TCC, and ECC (Tables 6 to 8). When the seven plants were analyzed as one group (Table 6), the only exceptions to all factors having significant effects on APC, TCC, and ECC were that S had no significant ($P > 0.05$) effect on ECC, S × C had no significant effect on APC, and S × L × C had no significant effect on TCC and ECC. Generally, though, bacterial counts were affected significantly ($P \leq 0.05$) by P, S, and C and their interactions.

TABLE 6. *Mean square values of aerobic plate counts (APC), total coliform counts (TCC), and* E. coli *biotype I counts (ECC) of excised carcass samples (*n *= 30) taken from each of three carcass sites (brisket, flank, rump), at three plant locations (pre-evisceration, final carcass washing, 24-h carcass chilling), from each of seven beef slaughtering plants (four steer/heifer, three cow/bull), during two seasons (wet, November to January; dry, May to June) of the year*

Variable	Degrees of freedom	Mean square[a]		
		APC	TCC	ECC
Plant (P)	6	69.2**	16.9**	7.2**
Season (S)	1	32.9**	1.6*	0.8
Plant location (L)	2	168.6**	47.3**	56.5**
Carcass site (C)	2	30.8**	1.7*	1.0*
P × S	6	70.6**	33.8**	14.7**
P × L	12	8.7**	6.0**	4.8**
S × L	2	12.6**	8.7**	10.1**
P × C	12	6.6**	2.7**	2.4**
S × C	2	2.8	2.2*	1.1*
L × C	4	10.5**	4.0**	3.1**
P × S × L	12	9.2**	4.5**	4.4**
P × S × C	12	3.6**	1.3**	1.1**
P × L × C	24	3.2**	2.7**	2.6**
S × L × C	4	5.2*	0.4	0.4
P × S × L × C	24	1.7*	1.1**	1.1**
Residual (error)	3,652	1.0	0.4	0.3

[a] * $P \leq 0.05$; ** $P \leq 0.01$.

TABLE 7. *Mean square values of aerobic plate counts (APC), total coliform counts (TCC), and* E. coli *biotype I counts (ECC) of excised carcass samples (*n *= 30) taken from each of three carcass sites (brisket, flank, rump), at three plant locations (pre-evisceration, final carcass washing, 24-h carcass chilling), from each of four steer/heifer slaughtering plants during two seasons (wet, November to January; dry, May to June) of the year*

Variable	Degrees of freedom	Mean square[a]		
		APC	TCC	ECC
Plant (P)	3	10.3**	4.2**	2.5**
Season (S)	1	33.2**	13.1**	3.1*
Plant location (L)	2	72.7**	18.8**	21.7**
Carcass site (C)	2	12.2**	0.1	0.2
P × S	3	110.8**	7.4**	4.6**
P × L	6	4.5**	5.5**	4.5**
S × L	2	3.0*	6.4**	4.7**
P × C	6	8.5**	2.5**	2.1**
S × C	2	2.1	1.7*	0.6
L × C	4	3.8*	1.6*	0.7*
P × S × L	6	6.6**	1.5*	1.0**
P × S × C	6	3.6*	0.4	0.2
P × L × C	12	2.7**	1.7**	1.4**
S × L × C	4	4.0*	0.7	0.7*
P × S × L × C	12	1.6*	0.5	0.3
Residual (error)	2,086	0.8	0.3	0.2

[a] * $P \leq 0.05$; ** $P \leq 0.01$.

TABLE 8. *Mean square values of aerobic plate counts (APC), total coliform counts (TCC), and* E. coli *biotype I counts (ECC) of excised carcass samples (*n *= 30) taken from each of three carcass sites (brisket, flank, rump), at three plant locations (pre-evisceration, final carcass washing, 24-h carcass chilling), from each of three cow/bull slaughtering plants during two seasons (wet, November to January; dry, May to June) of the year*

Variable	Degrees of freedom	Mean square[a]		
		APC	TCC	ECC
Plant (P)	2	185.0**	41.4*	16.7**
Season (S)	1	4.4	37.0*	11.6**
Plant location (L)	2	100.3**	30.2**	37.6**
Carcass site (C)	2	20.5**	3.7*	3.5**
P × S	2	43.2**	66.3**	30.3**
P × L	4	17.2**	8.9**	6.2**
S × L	2	12.8**	9.6**	9.7**
P × C	4	6.0*	3.2**	2.6**
S × C	2	2.8	2.3*	1.7*
L × C	4	11.1**	8.2**	7.7*
P × S × L	4	16.2**	7.6**	9.6**
P × S × C	4	4.5*	2.4*	2.5**
P × L × C	8	3.3*	2.8**	3.1**
S × L × C	4	3.5*	0.9**	1.2*
P × S × L × C	8	1.6	2.0**	2.3**
Residual (error)	1,566	1.3	0.5	0.4

[a] * $P \leq 0.05$; ** $P \leq 0.01$.

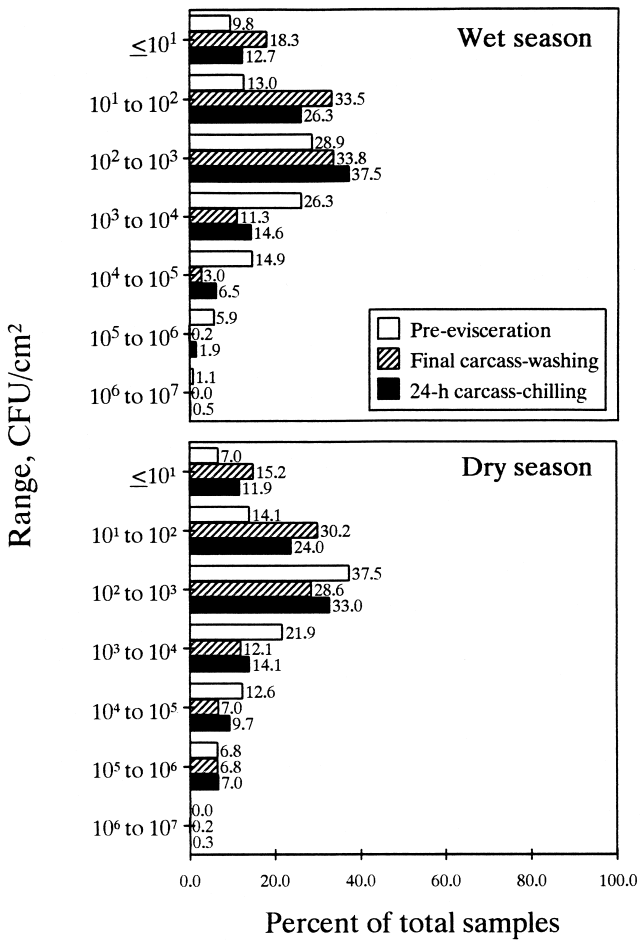

FIGURE 1. *Distribution (percentage of samples) of aerobic plate counts on carcass samples during the wet and dry seasons, at pre-evisceration, final carcass-washing, and 24-h carcass-chilling plant locations (samples of all carcass sites combined).*

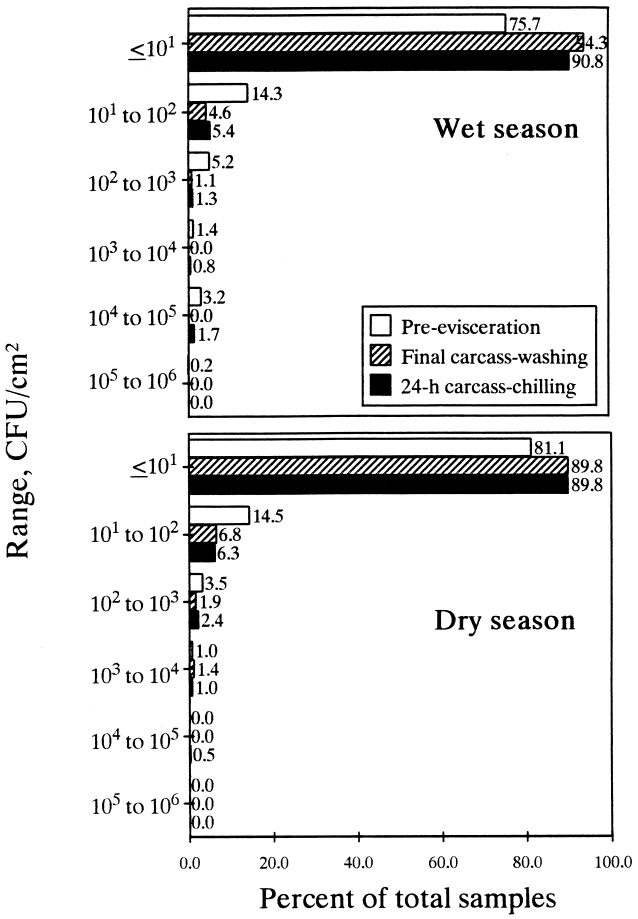

FIGURE 2. *Distribution of total coliform counts on carcass samples during the wet and dry seasons, at pre-evisceration, final carcass-washing, and 24-h carcass-chilling plant locations (samples of all carcass sites combined).*

Most of the carcass samples had APC in the range of 10^1 to 10^4 CFU/cm^2 during both wet and dry seasons, but samples with fewer than 10^1 CFU/cm^2 and as high as 10^7 CFU/cm^2 were also found (Fig. 1). Most of the carcass samples had TCC and ECC of $\leq 10^1$ CFU/cm^2, but samples with TCC and ECC levels as high as 10^4 to 10^6 CFU/cm^2 were detected (Figs. 2 and 3). Based on results of the USDA/FSIS baseline study of 1992 to 1993 involving 2,100 chilled steer/heifer carcasses, 93.1% of the samples had APC of up to 10^4 CFU/cm^2 96.4% had TCC of up to 10^2 CFU/cm^2, and 95.9% had ECC of up to 10^1 CFU/cm^2 *(1)*; corresponding percentages of samples from the 1993 to 1994 USDA/FSIS cow/bull baseline study were 84.7, 92.2, and 84.9 *(2)*. Both sets of USDA/FSIS microbiological baseline results are in general agreement with levels of contamination reported by a committee of the National Academy of Sciences in 1985 *(5)*. The data for chilled carcasses of the present study indicated that APC of up to 10^4 CFU/cm^2 were present in 91.1% and 83.0% of the samples during the wet and dry season, respectively; corresponding percentages for TCC of up to 10^2 CFU/cm^2 were 96.2 and 96.1, and for ECC of up to 10^1 CFU/cm^2 were 97.0 and 93.5. Thus, in this study, a larger number of samples had higher APC and ECC during the dry, compared to the wet, season.

Carcass contamination levels (APC, TCC, ECC) were generally higher at pre-evisceration, compared to the levels detected following final carcass washing and after 24-h carcass chilling, which were similar in extent of contamination (Figs. 1 to 3). At pre-evisceration, >75% of the samples had TCC $\leq 10^1$ CFU/cm^2, while at carcass washing and 24-h chilling $\geq$90% of the samples had contamination of $\leq 10^1$ CFU/cm^2 (Fig. 2). As indicated, however, samples with coliform contamination (TCC) as high as 10^5 CFU/cm^2 were detected. Sample distribution for *E. coli* biotype I contamination (ECC) was similar to that for TCC; however, at final washing and 24-h chilling, 94.9 to 98.0% and 93.5 to 97.0% of the samples, respectively, had counts $\leq 10^1$ CFU/cm^2 (Fig. 3).

Overall, means and standard deviations of carcass bacterial counts by plant, season of the year, plant location, and carcass site indicated high variation for means in each group, while overall means in each category were similar. Overall APC means in the seven plants ranged between 2.0 log CFU/cm^2 and 3.2 log CFU/cm^2 while TCC and ECC ranged between 0.13 and 0.68 log CFU/cm^2 and 0.09 and 0.44 log CFU/cm^2, respectively (data not shown). Although season of the year appeared to have a significant effect on APC, overall (all plants, locations, carcass sites combined)

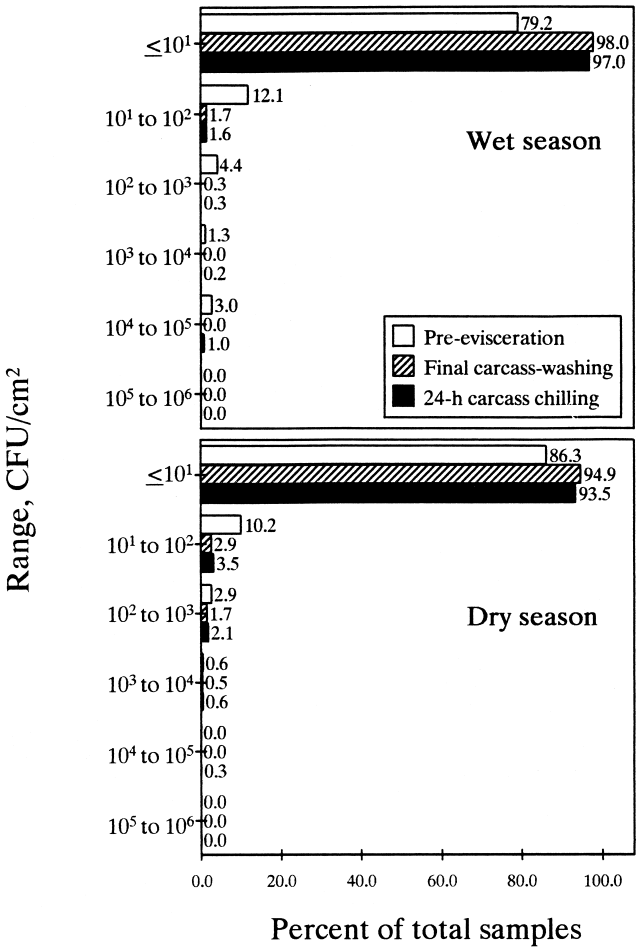

FIGURE 3. *Distribution of* Escherichia coli *counts on carcass samples during the wet and dry seasons, at pre-evisceration, final carcass-washing, and 24-h carcass-chilling plant locations (samples of all carcass sites combined).*

mean counts for the two seasons were similar (APC 2.43 to 2.73; TCC, 0.24 to 0.55; ECC, 0.18 to 0.35 log CFU/cm^2), but standard deviations were high (APC, 0.9 to 1.4; TCC, 0.5 to 1.1; ECC, 0.5 to 0.9). All three carcass sites sampled had similar overall loads of APC, TCC, and ECC (2.43 to 2.90, 0.30 to 0.48, and 0.18 to 0.33 log CFU/cm^2, respectively).

This study involved analyses of 3,780 samples and presents a generalized picture of contamination levels on beef carcasses in the U.S. meat industry at the time these samples were collected. The results indicated major variation in extent of carcass contamination that was influenced by season, plant, location within plant, and to some extent by carcass site sampled, even though overall mean levels of contamination were not different in all comparisons. Carcass washing before chilling had an impact in reducing contamination. Although overall means of bacterial counts were similar among plants and carcass sites, as well as between seasons of the year, individual levels of contamination varied greatly. Overall, levels of contamination among plants on carcasses after 24 h of chilling were 2.55, 0.27, and 0.12 log CFU/cm^2 for APC, TCC, and ECC, respectively. Overall, more than 90% of the samples had TCC of less than 10^1 CFU/cm^2; however, coliform counts and *E. coli* counts as high as 10^5 CFU/cm^2 were detected, even on chilled carcasses.

The findings of this study indicate that individual plants will need to assess their operations and determine procedures that will help them consistently slaughter and dress carcasses of low microbiological contamination. As beef slaughtering operations operate under the new meat and poultry inspection regulations, they will undoubtedly need to establish their own baselines for microbiological contamination of carcasses in order to assure that operation under HACCP improves the microbiological status of their products.

ACKNOWLEDGMENTS

This study was supported by the National Cattlemen's Beef Association. We thank personnel in the cooperating plants for allowing us to collect samples and all of the students who helped in sample collection and data analysis.

REFERENCES

1. Food Safety and Inspection Service (FSIS). 1994. Nationwide beef microbiological baseline data collection program: steers and heifers, October 1992–September, 1993. United States Department of Agriculture, FSIS, Science and Technology, Microbiology Division, Washington, D.C.
2. Food Safety and Inspection Service (FSIS). 1996. Nationwide beef microbiological baseline data collection program: cows and bulls, December 1993–November 1994. United States Department of Agriculture, FSIS, Science and Technology, Microbiology Division, Washington, D.C.
3. Food Safety and Inspection Service (FSIS). 1996. Pathogen reduction; hazard analysis and critical control point (HACCP) systems; final rule. Fed. Register 61:38806–38989.
4. Moran, A. B. 1974. USDA/FSIS procedure for isolation and identification of *Salmonella* from food. Microbiology laboratory guidebook. United States Department of Agriculture, FSIS, Washington, D.C.
5. National Academy of Sciences (NAS). 1985. An evaluation of the role of microbiological criteria for foods and food ingredients. National Research Council, Committee on Food Protection, Food and Nutrition Board, Subcommittee on Microbiological Criteria. National Academy Press, Washington, D.C.
6. Rose, B. E. 1993. Rationale and procedures for the use of buffered peptone water as a pre-enrichment broth for the recovery of *Salmonella* from meat and poultry products. USDA, FSIS, Food Microbiology Branch, Washington, D.C.
7. SAS. 1990. Statistical analysis system: user's guide, vol. 2, 4th ed. SAS Institute Inc., Cary, N.C.
8. Van Donkersgoed, J., K. W. F. Jericho, H. Grogan, and B. Thorlakson. 1997. Preslaughter hide status of cattle and the microbiology of carcasses. J. Food Prot. 60:1502–1508.
9. Worfel, R. C., J. N. Sofos, G. C. Smith, and G. R. Schmidt. 1996. Airborne bacterial contamination in beef slaughtering–dressing plants with different layouts. Dairy, Food Environ. Sanit. 16:440–443.