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Incidence of *Salmonella* on Beef Carcasses Relating to the U.S. Meat and Poultry Inspection Regulations

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ABSTRACT

This article is part of a major study designed to collect baseline contamination data by sampling beef carcasses in seven slaughtering plants (four steer–heifer and three cow–bull plants) during both a dry season (November to January) and a wet season (May to June). Samples ($n = 30$) were excised from each of three carcass anatomical sites (brisket, flank, and rump) at each of three points in the slaughtering chain (pre-evisceration, following final carcass washing, after 24-h carcass chilling). A total of 3,780 samples (100 cm^2 each) were analyzed for presence of *Salmonella*; aerobic plate counts, total coliform counts, and *Escherichia coli* counts were also made. After 24-h chilling, average incidence (expressed as a percentage) of *Salmonella* in the brisket, flank, and rump samples, respectively, for steer–heifer carcasses was 0.8 ± 1.7, 0, and 2.5 ± 5.0 for the wet season and 0.8 ± 1.7, 0, and 0 for the dry season; the corresponding percentages for cow–bull carcasses were 4.4 ± 2.0, 2.2 ± 3.9, and 1.1 ± 1.9 for the wet season and 2.2 ± 3.9, 1.1 ± 1.9, and 0 for the dry season. Depending on plant and season, ranges of probabilities of chilled steer–heifer carcasses passing the U.S. regulatory requirements for *Salmonella* contamination were 0.24 to 1.0 for the brisket, 1.0 for the flank, and 0.002 to 1.0 for the rump; the corresponding ranges for the chilled cow–bull carcasses were 0.25 to 1.0, 0.25 to 1.0, and 0.70 to 1.0. When the number of positive brisket, flank, and rump samples were combined, the probabilities of passing the regulatory requirements were 0.242 to 1.0 and 0.772 to 1.0 for the wet and dry seasons, respectively, in steer–heifer plants and 0.368 to 0.974 and 0.865 to 1.0 in cow–bull plants. Correlation coefficients of aerobic plate counts, total coliform counts, and *E. coli* counts with *Salmonella* incidence were higher ($P \leq 0.05$) for cow–bull samples that had increased incidence of the pathogen when compared to steer–heifer samples.

The 1996 Meat and Poultry Inspection regulations, developed by the Food Safety and Inspection Service (FSIS) of the U.S. Department of Agriculture, established pathogen reduction performance standards for *Salmonella* *(4)*. These required standards were based on ''current prevalence of *Salmonella*'' as determined by FSIS baseline surveys *(2, 3)*. According to these surveys, the prevalence of *Salmonella* was 1.0% for steer–heifer carcasses and 2.7% for cow–bull carcasses. Based on these data, FSIS developed a two-class attributes sampling plan *(4, 9, 14)* with values of *c* (maximum number of positive samples) and *n* (total numbers of samples tested) set at 1 and 82, respectively, for steers–heifers, and at 2 and 58, respectively, for cows–bulls. These values were selected to provide 80% probability of passing the regulatory requirements *(4)* when an ''establishment was operating at the national baseline prevalence of *Salmonella* positive results'' *(2, 3)*. Enforcement of this requirement was assigned to FSIS, which collected and analyzed samples from different establishments. If an establishment failed to meet the *Salmonella* standard in three series of testing, FSIS would suspend inspection services until the establishment demonstrated its ability to meet the standard. According to FSIS, the probability of an establishment failing the FSIS pathogen reduction standard three consecutive times would be less than 1% when the establishment prevalence was at the limit of the standard *(4)*.

This study reports baseline data for *Salmonella* incidence (percentage of samples positive) on beef carcass samples (brisket, flank, and rump) collected prior to evisceration, after carcass washing, and after 24-h carcass chilling; samples were taken from seven slaughtering plants (four steer–heifer plants and three cow–bull plants) during a wet season (November to January) and a dry season (May to June). The data were also expressed as probabilities of passing the Performance Standards set in the United States Meat and Poultry Inspection regulations of 1996 *(4)*. In addition, simple correlation coefficients of various types of bacterial counts with incidence of *Salmonella* are reported.

MATERIALS AND METHODS

Experimental design. The study was performed in seven slaughtering–dressing facilities across the United States *(12)*. Of these seven plants, four were classified as primarily slaughtering fed steers–heifers and three were classified as primarily slaugh-

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TABLE 1. *Averages and ranges of percentages of beef carcass samples 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, at three plant locations (pre-evisceration, after final carcass washing, after 24-h carcass chilling), and on three carcass sites (brisket, flank, and rump)*[a]

Plant type	Plant location	Carcass site	Season: Wet	Season: Dry
Steer–heifer	Pre-evisceration	Brisket	3.3 (0–6.7)	4.2 (0–16.7)
		Flank	0.8 (0–3.3)	1.7 (0–6.7)
		Rump	3.3 (0–10.0)	5.0 (0–16.7)
	Final carcass washing	Brisket	0	0.8 (0–3.3)
		Flank	0	0.8 (0–3.3)
		Rump	1.7 (0–6.7)	0.8 (0–3.3)
	24-h carcass chilling	Brisket	0.8 (0–3.3)	0.8 (0–3.3)
		Flank	0	0
		Rump	2.5 (0–10.0)	0
Cow–bull	Pre-evisceration	Brisket	15.5 (3.3–30.0)	5.5 (3.3–10.0)
		Flank	5.5 (0–13.3)	2.1 (0–3.3)
		Rump	4.4 (0–10.0)	7.8 (0–20.0)
	Final carcass washing	Brisket	6.7 (0–16.7)	3.3 (0–6.7)
		Flank	1.1 (0–3.3)	1.1 (0–3.3)
		Rump	1.1 (0–3.3)	1.1 (0–3.3)
	24-h carcass chilling	Brisket	4.4 (3.3–6.7)	2.2 (0–6.7)
		Flank	2.2 (0–6.7)	1.1 (0–3.3)
		Rump	1.1 (0–3.3)	0

[a] Each mean is derived from 30 samples analyzed from each of four steer–heifer or three cow–bull slaughtering plants.

tering nonfed cows–bulls. Each facility was visited twice, once during the wet season and once during the dry season of 1995–1996. 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.

Sampling and analysis. Carcass sampling was performed at three different points in the slaughtering chain of each plant and at three different anatomical sites on the carcass. The points in the slaughtering chain were designated as pre-evisceration, after final carcass washing, and after 24-h carcass chilling. The sampling sites on the carcass were brisket (anterior to the navel on the ventral midline), flank (posterior to the navel on the ventral midline), and rump (the cushion of the round). These sampling sites on the carcasses are equivalent to the brisket, flank, and rump areas, respectively, as listed in FSIS's final rule regarding pathogen reduction *(4)*. Carcass samples were taken over a period of 3 days (per visit, season, and plant) to obtain a representative sampling population from different lots of cattle.

A 100-cm^2 portion (10 $\times$ 10 $\times$ 0.2 cm) of the adipose–muscle tissue surface was aseptically removed from each sampling area of the carcass at each location in the plant by use of a sterile rubber template, forceps, and a scalpel. The sample from a single carcass was placed in a sterile Whirl-Pak bag (Nasco). For each sampling site on the carcass and at each point in plant production,

TABLE 2. *Averages and ranges of percentages of beef carcass samples 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, at three plant locations (pre-evisceration, final carcass washing, 24-h carcass chilling) for the three carcass sites (brisket, flank, and rump) analyzed together*[a]

Plant type	Plant location	Season: Wet	Season: Dry
Steer–heifer	Pre-evisceration	2.5 (0–5.6)	3.6 (0–13.3)
	Final carcass washing	0.6 (0–2.2)	0.8 (0–3.3)
	24-h carcass chilling	1.1 (0–3.3)	0.3 (0–1.1)
Cow–bull	Pre-evisceration	8.5 (1.1–15.6)	5.2 (1.1–8.9)
	Final carcass washing	3.0 (1.1–6.7)	1.8 (0–4.4)
	24-h carcass chilling	2.6 (1.1–5.6)	1.1 (0–2.2)

[a] Each mean is derived from 90 samples analyzed from each of four steer–heifer or three cow–bull slaughtering plants.

TABLE 3. *Ranges of probabilities of beef carcass samples passing the U.S. regulatory performance standards for* Salmonella *expressed by carcass sampling site at different locations in four steer–heifer and three cow–bull slaughtering plants during the wet (November to January) and dry (May to June) season of the year*

Plant type	Plant location	Carcass site	Season	
			Wet	Dry
Steer–heifer	Pre-evisceration	Brisket	0.02–1.0	0.00–1.0
		Flank	0.24–1.0	0.02–1.0
		Rump	0.002–1.0	0.00–1.0
	Final carcass washing	Brisket	1.0	0.24–1.0
		Flank	1.0	0.24–1.0
		Rump	0.02–1.0	0.24–1.0
	24-h carcass chilling	Brisket	0.24–1.0	0.24–1.0
		Flank	1.0	1.0
		Rump	0.002–1.0	1.0
Cow–bull	Pre-evisceration	Brisket	0.00–0.70	0.06–0.70
		Flank	0.06–1.0	0.70–1.0
		Rump	0.06–1.0	0.00–1.0
	Final carcass washing	Brisket	0.002–1.0	0.25–1.0
		Flank	0.70–1.0	0.70–1.0
		Rump	0.70–1.0	0.70–1.0
	24-h carcass chilling	Brisket	0.25–0.70	0.25–1.0
		Flank	0.25–1.0	0.70–1.0
		Rump	0.70–1.0	1.0

samples were taken from 30 carcasses. Samples taken from different stages in plant production were from different carcasses (i.e., individual carcasses were not followed through the entire production chain for subsequent sampling). The overall total of carcass samples taken for analysis (for all plants and both visiting periods) was 3,780. Sample enrichment, isolation, and identification of *Salmonella* were performed according to procedures described by FSIS *(8, 11)*. Additional samples were analyzed for aerobic plate counts (APC), total coliform counts (TCC), and *Escherichia coli* counts (ECC), and the results are reported by Sofos et al. *(12)*.

Statistical analysis. The *Salmonella* analysis data were reported as percentage of samples testing positive for the pathogen. In addition, probabilities of passing the regulatory requirements *(4)* were calculated, and simple correlation coefficients between *Salmonella* incidence and APC, TCC, and ECC were determined with a statistical analysis system (SAS Inc., Cary, N.C.).

RESULTS AND DISCUSSION

The results indicated that the overall percentage of *Salmonella*-positive carcass samples was higher for pre-evisceration samples and decreased following application of carcass decontamination procedures *(1, 5, 10, 13)* during both seasons of the year and in both steer–heifer and cow–bull slaughtering plants (Tables 1 and 2). Characteristics of the plants and conditions of carcass decontamination interventions applied in these seven plants are re-

TABLE 4. *Ranges of probabilities of beef carcass samples passing the U.S. regulatory performance standards 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, at three plant locations (pre-evisceration, final carcass washing, 24-h carcass chilling) for the three carcass sites (brisket, flank, and rump) analyzed together*

Plant type	Plant location	Season	
		Wet	Dry
Steer–heifer	Pre-evisceration	0.052–1.0	0–1.0
	Final carcass washing	0.459–1.0	0.242–1.0
	24-h carcass chilling	0.242–1.0	0.772–1.0
Cow–bull	Pre-evisceration	0.004–0.974	0.101–0.974
	Final carcass washing	0.245–0.974	0.528–1.0
	24-h carcass chilling	0.368–0.974	0.865–1.0

TABLE 5. *Simple correlation coefficients between the log CFU/cm² of aerobic plate counts (APC), total coliform counts (TCC),* E. coli *biotype I counts (ECC), and the percentage of positive samples for* Salmonella *(SAL), grouped by plant location and carcass site, for four steer–heifer plants*

Carcass site	Analyses correlated	Plant location: Pre-evisceration	Final carcass washing	24-h carcass chilling	All locations
Brisket	APC vs. TCC	0.80*[a]	0.42	0.81*	0.75*
	APC vs. ECC	0.84*	0.65	0.88*	0.83*
	APC vs. SAL	0.43	0.17	0.11	0.42*
	TCC vs. ECC	0.96*	0.91*	0.93*	0.92*
	TCC vs. SAL	0.29	0.19	−0.05	0.29
	ECC vs. SAL	0.24	−0.07	−0.07	0.33
Flank	APC vs. TCC	0.34	0.87*	0.53	0.59*
	APC vs. ECC	0.36	0.69	0.44	0.54*
	APC vs. SAL	0.16	0.12	—[b]	0.19
	TCC vs. ECC	0.99*	0.91*	0.97*	0.96*
	TCC vs. SAL	−0.33	0.01	—	−0.09
	ECC vs. SAL	−0.40	−0.25	—	−0.12
Rump	APC vs. TCC	0.79*	0.38	0.56	0.67*
	APC vs. ECC	0.75*	0.64	0.54	0.67*
	APC vs. SAL	0.18	−0.19	−0.22	0.13
	TCC vs. ECC	0.99*	0.87*	0.96*	0.99*
	TCC vs. SAL	0.01	−0.55	−0.10	0.14
	ECC vs. SAL	0.03	−0.57	−0.04	0.17
All sites	APC vs. TCC	0.58*	0.54*	0.69*	0.66*
	APC vs. ECC	0.55*	0.62*	0.68*	0.64*
	APC vs. SAL	0.27	−0.02	−0.12	0.23*
	TCC vs. ECC	0.98*	0.87*	0.94*	0.95*
	TCC vs. SAL	0.05	−0.15	−0.10	0.14
	ECC vs. SAL	0.02	−0.28	−0.08	0.16

[a] *, Correlation coefficients are significant to the 0.05 level.
[b] Values denote undefined correlation due to zero variance in the SAL variable.

ported by Sofos et al. *(12)*. Pre-evisceration carcasses in steer–heifer plants had more *Salmonella*-positive samples during the dry season, while with 24-h chilling, there were more *Salmonella*-positive samples during the wet season. Carcasses in cow–bull plants had more *Salmonella*-positive samples at all stages of slaughter during the wet season. There was high variation among plants for incidence of *Salmonella*, especially at the stage of pre-evisceration (Tables 1 and 2). Overall incidence of *Salmonella*-positive samples was higher (1.1 to 8.5%) for carcasses in cow–bull plants than for carcasses (0.3 to 3.6%) in steer–heifer plants (Table 2).

Incidence of *Salmonella*-positive samples in individual carcass anatomical sampling sites varied with type of plant and location within each plant. At 24-h carcass chilling, the percentage of *Salmonella*-positive samples for the brisket, flank, and rump, respectively, were 0 to 3.3, 0, and 0 to 10.0 for the steer–heifer plants, and 0 to 6.7, 0 to 6.7, and 0 to 3.3 for the cow–bull plants (Table 1). When the data of the three carcass sites were combined, as required by regulation *(4)*, the average percentages of positive samples for the wet and dry seasons, respectively, at 24-h carcass chilling were 1.1 and 0.3 for the steer–heifer plants and 2.6 and 1.1 for the cow–bull plants (Table 2); these percentages are in agreement with the results of the FSIS baseline studies *(2, 3)*.

Probabilities of plants meeting the U.S. Meat and Poultry Inspection regulatory performance standards for *Salmonella* contamination *(4)* were also variable (Tables 3 and 4). In steer–heifer plants, the probabilities of passing the standards at 24-h carcass chilling were 0.24 to 1.0, 1.0, and 0.002 to 1.0 for the brisket, flank, and rump, respectively (Table 3); the corresponding probabilities for the cow–bull plants were 0.25 to1.0, 0.25 to 1.0, and 0.70 to 1.0. When the data of the three carcass sites were analyzed together, the probabilities of passing the regulatory standards were 0.242 to 1.0 and 0.772 to 1.0 for the steer–heifer plants during the wet season and dry season, respectively (Table 4); for the cow–bull plants, the corresponding probabilities were 0.368 to 0.974 and 0.865 to 1.0. It is clear that certain plants will have to make adjustments to processes and may need to introduce decontamination procedures *(1, 5, 10, 13)* in their facilities in order to reduce potential contamination and meet the regulatory requirements.

TABLE 6. *Simple correlation coefficients between the log CFU/cm² of aerobic plate counts (APC), total coliform counts (TCC),* E. coli *biotype I counts (ECC) and the percentage of positive samples for* Salmonella *(SAL), grouped by plant location and carcass site, for three cow–bull plants*

		Plant location			
Carcass site	Analyses correlated	Pre-evisceration	Final carcass washing	24-h carcass chilling	All locations
Brisket	APC vs. TCC	0.87*[a]	0.58	0.53	0.81*
	APC vs. ECC	0.88*	0.63	−0.46	0.77*
	APC vs. SAL	0.52	0.24	0.32	0.50*
	TCC vs. ECC	1.00*	0.89*	0.20	0.94*
	TCC vs. SAL	0.42	0.44	0.57	0.54*
	ECC vs. SAL	0.42	0.32	0.13	0.53*
Flank	APC vs. TCC	0.57	0.42	0.85*	0.66*
	APC vs. ECC	0.71	0.64	0.89*	0.78*
	APC vs. SAL	0.68	0.39	0.90*	0.70*
	TCC vs. ECC	0.95*	0.89*	0.99*	0.93*
	TCC vs. SAL	0.35	−0.38	0.93*	0.44
	ECC vs. SAL	0.42	−0.23	0.97*	0.51*
Rump	APC vs. TCC	0.83*	0.43	0.80	0.77*
	APC vs. ECC	0.82*	0.52	0.80	0.72*
	APC vs. SAL	0.49	0.52	0.80	0.52*
	TCC vs. ECC	1.00*	0.92*	1.00*	0.95*
	TCC vs. SAL	0.28	0.00	1.00*	0.40
	ECC vs. SAL	0.26	−0.14	1.00*	0.42
All sites	APC vs. TCC	0.81*	0.47*	0.73*	0.76*
	APC vs. ECC	0.81*	0.57*	0.66*	0.73*
	APC vs. SAL	0.59*	0.22	0.62*	0.56*
	TCC vs. ECC	1.00*	0.89*	0.91*	0.94*
	TCC vs. SAL	0.43	0.08	0.63*	0.47*
	ECC vs. SAL	0.42	0.00	0.50*	0.48*

[a] *, Correlation coefficients are significant to the 0.05 level.

It is often debated whether testing for indicator microorganisms can be useful in predicting potential presence of pathogens in the samples analyzed. Actually, the U.S. Meat and Poultry Inspection regulations *(4)* require routine determination of *E. coli* counts as a performance criterion for process control and operation under hazard analysis and critical control point systems. However, numerous studies have failed to find strong relationships between total plate counts, coliforms, *Enterobacteriaceae*, or *E. coli* and pathogens such as *Salmonella* in meat and poultry products *(6, 7, 9, 15)*. For these reasons, the *Salmonella* incidence data reported here were analyzed for correlation with APC, TCC, and ECC data derived from the same study and reported by Sofos et al. *(12)*. Data in Tables 5 through 7 are simple correlation coefficients between log CFU/cm² of APC, TCC, and ECC and the percentage of *Salmonella*-positive samples grouped by plant type. Correlation coefficients varied with plant type, plant location, and carcass site. As expected, TCC and ECC were correlated highly with each other. Correlation of *Salmonella* incidence with bacterial counts increased with the number of *Salmonella*-positive samples (Tables 5 through 7). These findings support the conclusion that it is not advisable or valid to predict the safety of meat or poultry products based on indicator counts such as total bacterial plate counts, coliform counts, or *E. coli* counts *(6, 7, 9, 15)*. High incidence of such counts, however, may be an indicator of increased probability for presence of pathogens.

In summary, there was major variation among plants for presence of *Salmonella* in various carcass sampling sites. Samples taken from cow–bull plants after 24-h carcass chilling carried more *Salmonella* contamination than corresponding samples taken from steer–heifer plants and thus agreed with the results of USDA/FSIS baseline studies *(2, 3)* that were used in calculating the performance standards set in meat and poultry inspection regulation *(4)*. It appears that certain plants may have difficulties in meeting the standards of the new regulation, but it is unknown what the extent of this failure will be on a national basis. It should be interesting to compare the results of this study with those of future studies in order to evaluate the impact of the new inspection regulations *(4)* on the incidence of *Salmonella* in beef carcasses.

TABLE 7. *Simple correlation coefficients between the log CFU/cm² of aerobic plate counts (APC), total coliform counts (TCC),* E. coli *biotype I counts (ECC) and the percentage positive samples for* Salmonella *(SAL), grouped by plant location and carcass site, for all seven plants*

Carcass site	Analyses correlated	Plant location			
		Pre-evisceration	Final carcass washing	24-h carcass chilling	All locations
Brisket	APC vs. TCC	0.82*[a]	0.49	0.65*	0.76*
	APC vs. ECC	0.82*	0.62*	0.52	0.75*
	APC vs. SAL	0.55*	0.09	0.29	0.47*
	TCC vs. ECC	0.99*	0.88*	0.67*	0.94*
	TCC vs. SAL	0.49	0.25	0.22	0.50*
	ECC vs. SAL	0.49	0.23	−0.20	0.51*
Flank	APC vs. TCC	0.41	0.68*	0.75*	0.62*
	APC vs. ECC	0.44	0.65*	0.73*	0.62*
	APC vs. SAL	0.43	0.28	0.68*	0.48*
	TCC vs. ECC	0.98*	0.89*	0.97*	0.93*
	TCC vs. SAL	−0.08	−0.13	0.74*	0.23
	ECC vs. SAL	−0.13	−0.19	0.67*	0.17
Rump	APC vs. TCC	0.81*	0.40	0.73*	0.73*
	APC vs. ECC	0.79*	0.54*	0.74*	0.70*
	APC vs. SAL	0.37	0.07	0.09	0.35*
	TCC vs. ECC	1.00*	0.90*	0.98*	0.96*
	TCC vs. SAL	0.19	−0.28	0.25	0.30
	ECC vs. SAL	0.18	−0.31	0.25	0.32*
All sites	APC vs. TCC	0.73*	0.50*	0.71*	0.72*
	APC vs. ECC	0.72*	0.57*	0.65*	0.69*
	APC vs. SAL	0.49*	0.12	0.31*	0.44*
	TCC vs. ECC	0.99*	0.87*	0.89*	0.94*
	TCC vs. SAL	0.34*	0.03	0.36*	0.38*
	ECC vs. SAL	0.33*	−0.04	0.21	0.39*

[a] *, Correlation coefficients are significant to the 0.05 level.

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