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Bacteria on Beef Briskets and Ground Beef: Correlation with Slaughter Volume and Antemortem Condemnation

ALLAN T. HOGUE*, DAVID W. DREESEN[1], STANLEY S. GREEN[2], ROBERT D. RAGLAND, WILLIAM O. JAMES, EDWARD A. BERGERON[3], L. VICTOR COOK[4], MARK D. PRATT[5], and DAVID R. MARTIN[6]

Food Safety and Inspection Service, Science and Technology, Slaughter Inspection Standards and Procedures Division, U.S. Department of Agriculture, Washington, DC 20250

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ABSTRACT

Aerobic plate counts of 3,455 brisket and 1,370 ground beef samples were examined for association with slaughter volume in 547 U.S. beef slaughter establishments. In general, high-volume beef slaughter establishments control total aerobic bacteria counts on briskets and ground beef more effectively than small volume establishments. The lower Aerobic plate counts at high slaughter volumes may have resulted from uniformity of cattle slaughtered, specialization of labor, measures taken to prevent contamination, and effective decontamination of carcasses in high-volume slaughter establishments. In this study the prevalence of *Salmonella* contamination was found to be more closely associated with the health of animals brought to slaughter than with certain conditions in the slaughter establishments. The prevalence of contamination of brisket and ground beef samples with *Salmonella* was highest in calf slaughter establishments. *Salmonella* contamination on brisket samples increased as antemortem condemnation increased in establishments that slaughter calves. No association was found between *Salmonella* contamination and slaughter volume.

The major function of the Food Safety and Inspection Service (FSIS) is to ensure the wholesomeness of meat and poultry in the United States. This has been accomplished through organoleptic inspection of animals, carcasses, and facilities in slaughter establishments. Organoleptic inspection involves the use of sight, touch, and smell to determine the wholesomeness of meat.

Since microbial hazards can exist in meat without organoleptically detectable changes, FSIS, in cooperation with the meat industry, is evaluating a Hazard Analysis Critical Control Point (HACCP) system to better control the microbial quality of meat. HACCP provides a more specific and critical approach to the control of microbiological hazards than that achievable by traditional organoleptically based inspection (*11*). HACCP principles are incorporated or being tested in several inspection systems in use by FSIS.

Risk of foodborne illness from beef may not be the same in meat produced in different size segments of the beef slaughter industry. Bryan et al. (*6*) state that increasing slaughter volume results in more finished product contamination by *Salmonella*. The relationship between establishment slaughter volume and cross-contamination is of special interest in light of recent changes in the cattle slaughter industry.

From 1986 to 1991, cattle slaughter in the United States consolidated into fewer establishments slaughtering higher numbers of cattle per establishment (Fig. 1). The total number of establishments slaughtering cattle declined each year over the 6-year period while the average number of cattle slaughtered per establishment increased each year except 1991 (from the Animal Disposition Reporting System Database, FSIS). During the same time period, total cattle slaughtered under the U.S. Department of Agriculture inspection decreased from 38 million to 29.6 million animals (*3*). In 1991, 73 establishments slaughtered 90% of the total U.S. annual slaughter of cattle while 977 establishments slaughtered the remaining 10%.

This study examined total aerobic bacteria counts on briskets and ground beef in U.S. cattle slaughter establishments to determine whether there was a relationship between aerobic bacteria counts and establishment slaughter volume. Also, *Salmonella* contamination of briskets and ground beef was examined for association with antemortem condemnation at the respective establishments.

Antemortem condemnation (number of animals condemned per 1,000 animals presented for slaughter) is a measure of some aspects of the animals' health detectable

[1]*Department of Medical Microbiology, College of Veterinary Medicine, University of Georgia, Athens, Georgia 30602.*
[2]*Food Safety and Inspection Service, Science and Technology, Microbiology Division, Microbiological Monitoring and Surveillance Branch, U.S. Department of Agriculture, Washington, DC 20250.*
[3]*Food Safety and Inspection Service, Science and Technology, Statistics and Data Sytstems Division, U.S. Department of Agriculture, Washington, DC 20250.*
[4]*Food Safety and Inspection Service, Science and Technology, Microbiology, Eastern Laboratory, U.S. Department of Agriculture, College Station Road, Athens, Georgia 30604.*
[5]*Food Safety and Inspection Service, Science and Technology, Microbiology, Midwestern Laboratory, U.S. Department of Agriculture, St. Louis, Missouri 63115.*
[6]*Food Safety and Inspection Service, Science and Technology, Microbiology, Western Laboratory, U.S. Department of Agriculture, Alameda, California 94501.*

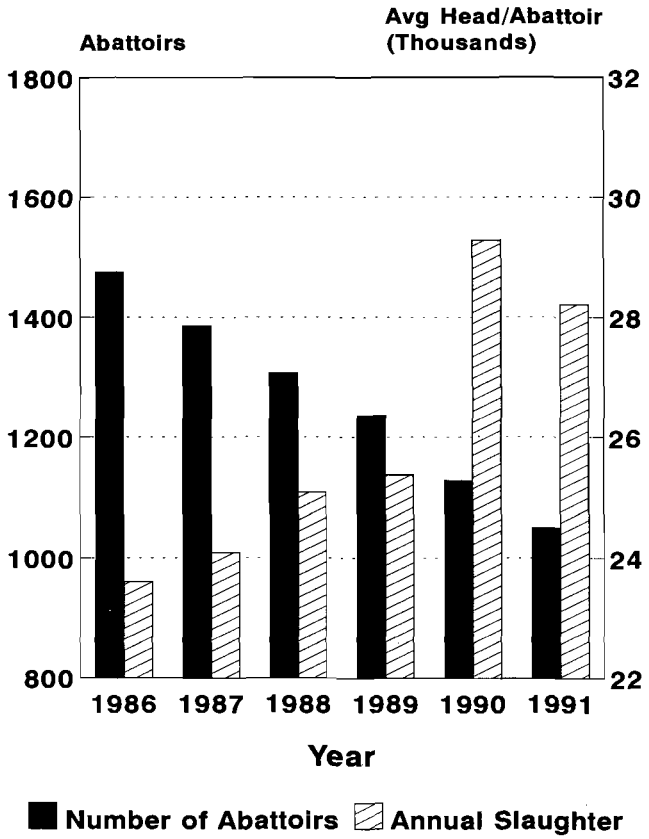

Figure 1. *Cattle abattoirs under USDA inspection - number and average annual volume (1986-1991).*

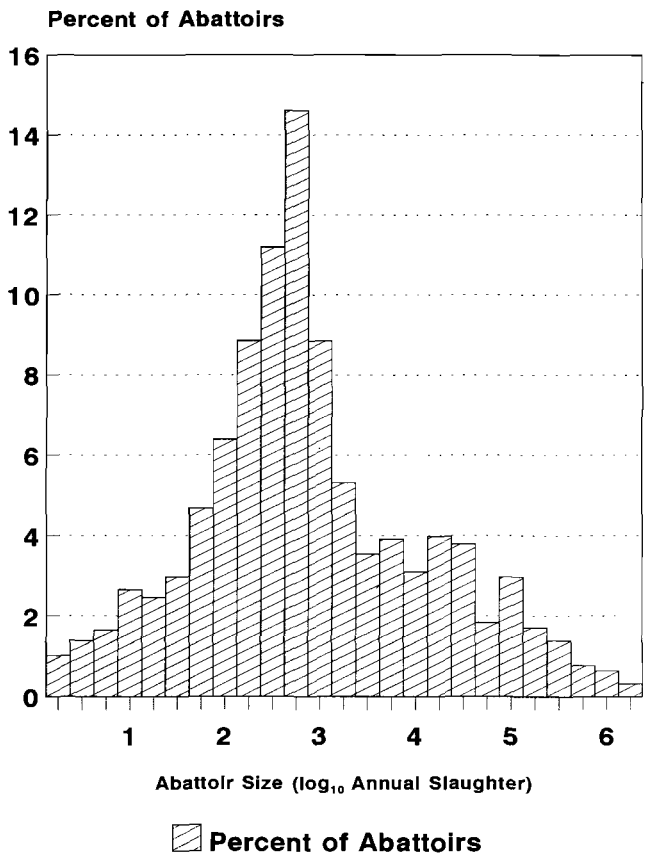

Figure 2. *Slaughter volume of U.S. cattle slaughter abattoirs.*

on physical examination. Animals are condemned on antemortem inspection by FSIS veterinarians when obviously unfit for human food because of systemic diseases or abnormalities, when symptoms indicate diseases or conditions difficult to detect on postmortem inspection (central nervous system disorders, chemical poisoning), and when symptoms indicate a zoonotic disease (*1*).

MATERIALS AND METHODS

Between 1987 and 1990, FSIS inspectors collected 3,455 beef brisket and 1,370 ground beef samples for microbial analysis. Brisket was chosen because the brisket is the site most likely to be contaminated when contamination occurs during slaughter. Each brisket sample was collected from a carcass 18-24 h after slaughter. Ground beef provides a measure of sanitary meat handling procedures at an establishment. Ground beef samples were collected from the previous day's production. The samples were frozen for 12-24 h at temperatures from -10 to -20°C and then mailed to one of three FSIS laboratories: Alameda, CA; St. Louis, MO; or Athens, GA. Samples were analyzed only if they arrived at the laboratory in a frozen condition.

The samples were tempered at 4°C; 25 g was removed. Alternatively, a 25-g portion was cut from the frozen sample. The 25-g samples were stomached with 225 ml phosphate-buffered diluent for 2 min. Serial dilutions were made in 90 ml phosphate buffer, and 1 ml of each dilution was added to plates containing molten plate count agar at 46-48°C. Total aerobic plate counts (APC) were quantified after 48 h incubation at 35°C (*2*).

Salmonella isolation and identification were done on two portions from each sample; one consisting of 100 g and the other, 25 g. The culture process included: i) addition of sufficient lactose broth containing 0.6% tergitol to result in an 1:10 dilution for each portion (900 and 225 ml, respectively); ii) stomaching for 2 min; iii) incubation for 18-24 h at 35°C; iv) transfer of 0.5 to 10 ml of a new tetrathionate broth (*7*); v) incubation at 42°C for 18-24 h; vi) streaking on brilliant green sulfa and modified LIA (*4*) agar and incubation at 35°C; and vii) selection of three to five suspect colonies for identification and serotyping (*2*). *Salmonella* was recorded as a 0/1 variable, where 0 indicates a negative finding and 1 a positive culture.

Results of the microbial analyses were entered into the Microbiological and Residue Computer Information System (MARCIS) database. Edit checks were run against the data and discrepancies reconciled with the submitted forms. MARCIS data were combined with other establishment information in the Animal Disposition Reporting System (ADRS). The ADRS database contains information on abattoir slaughter volume and condemnation rates used in the analysis.

All market classes of cattle were sampled. Cows, bulls, and calves were somewhat overrepresented and steers and heifers somewhat underrepresented in the sample population. Approximately one-third (547 of 1,581) of the establishments that slaughtered cattle during the period of the study were sampled. High-volume establishments were overrepresented and low-volume establishments were underrepresented in the data for both ground beef and brisket samples. The information presented in this study applies to cattle slaughter establishments and not total U.S. beef produced because the largest 10% of cattle slaughter establishments produce over 90% of U.S. beef.

Yearly slaughter volume for U.S. beef slaughter establishments is log normally distributed (skewness, 0.38; kurtosis, 0.04) (Fig. 2). Standard statistics in the results section that follows are shown in log_{10} of slaughter volume.

Calculations for the correlation between *Salmonella* and antemortem condemnation were based on sample record groupings because *Salmonella* is a 0/1 variable. Sample records were grouped by seven from lowest to highest antemortem condemnation rate. The percentage of 25-g *Salmonella*-positive samples

were correlated with average antemortem condemnation for the groups. Data were analyzed with Statistical Analysis System (SAS) 6.04 on a personal computer.

RESULTS

Aerobic plate counts varied inversely ($p < 0.01$) with the slaughter volume at the respective establishments. The APC for briskets at the smallest and largest beef slaughter establishments predicted by the regression formula ($y = 4.64 - 0.23x$) were 4.2 $\log_{10}$ (15,500 organisms per g) and 3.2 $\log_{10}$ (1,600 organisms per g), respectively (Fig. 3). In ground beef the APC at the smallest and largest establishments predicted by the regression formula ($y = 6.84 - 0.49x$) were 5.9 $\log_{10}$ (780,000 organisms per g) and 3.8 $\log_{10}$ (6,600 organisms per g), respectively (Fig. 4). The coefficient of determination (r^2) indicates that only 5% of the variability in APC in brisket samples and 24% in ground beef samples can be predicted from slaughter volume.

Analysis of the same data by market class indicated a statistically significant inverse correlation ($p < 0.01$) between slaughter volume and APC in all market classes except calves (Table 1). In briskets, the inverse correlation between APC and slaughter volume was stronger for steers and heifers ($r = -0.28$, $p < 0.01$), weaker for cows and bulls ($r = -0.13$, $p < 0.01$), and not significant in calves ($r = -0.12$, $p = 0.02$). Ground beef showed a similar pattern with a significant correlation ($p < 0.01$) in all market classes except calves (Table 1).

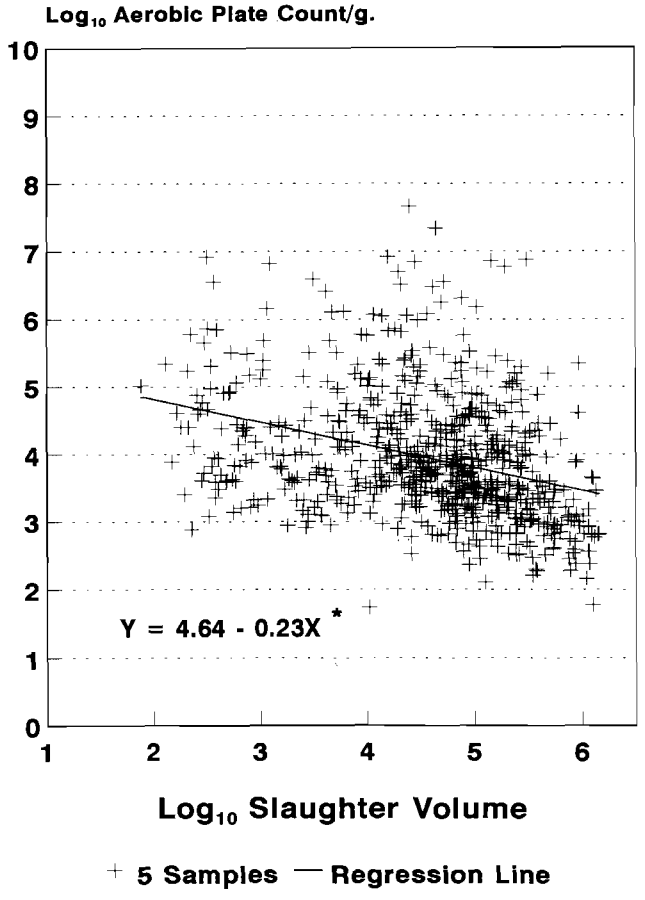

Figure 3. *Log_{10} aerobic plate counts from briskets by log_{10} abattoir volume (1987-1990).*

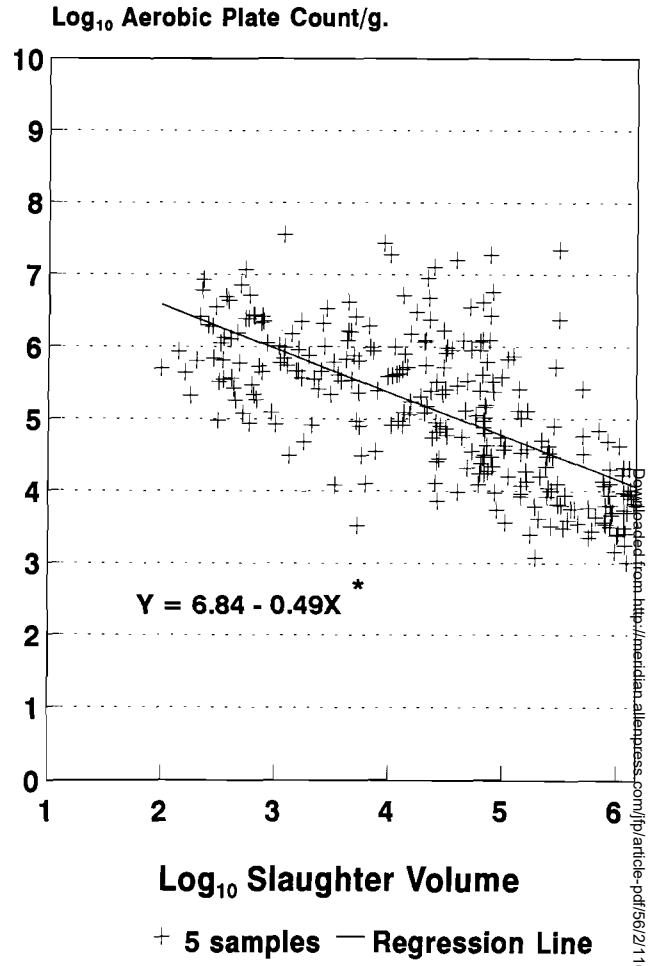

Figure 4. *Log_{10} aerobic plate counts from ground beef by log abattoir volume (1987-1990).*

Establishments were grouped by slaughter volume, and the mean APC of the groups were compared using Tukey's studentized range test (*8*). Mean APC of brisket samples decreased as slaughter volume increased in all market classes (Table 2). Mean APC for ground beef also decreased as slaughter volume increased in all market classes with two exceptions, both involving sample sizes of 30 or less (Table 3).

The relationship between APC and slaughter volume was not linear. The slope of the line that defines the relationship between APC and slaughter volume steepened as slaughter volume increased in several cases. In brisket samples, the differences between mean APC increased as slaughter volume increased for every market class except calves (Table 2). In ground beef samples, the differences between mean APC increased as slaughter volume increased for establishments slaughtering cows and bulls (Table 3).

In calf establishments, the *Salmonella* contamination of brisket samples increased with the proportion (per 1,000 animals slaughtered) of animals condemned on antemortem ($r = 0.65$, $p < 0.01$). A very weak correlation was seen for

TABLE 1. *Correlation of log_{10} APC with log_{10} slaughter volume for brisket and ground beef samples.*

Market class	Brisket		Ground beef	
	n	r	n	r
Steers and heifers	1833	-0.28*	932	-0.54*
Cows and bulls	1236	-0.13*	407	-0.31*
Calves	386	-0.12	31	-0.43
All classes	3455	-0.25*	1370	-0.49*

*Significant at $p < 0.01$.
n = Number of samples.

TABLE 2. *Mean log_{10} APC per g of brisket samples from cattle slaughter establishments grouped by slaughter volume.*

Slaughter volume (Animals/year)	Steers and heifers	Cows and bulls	Calves	All market classes
1 - 10K	3.6[a](535)	3.3[a] (192)	3.8[a] (53)	3.5[a] (780)
10K- 100K	3.4[a](517)	3.2[a](663)	3.6[a](281)	3.4[b](1,461)
100K- 1M	2.9[b](696)	3.0[a] (379)	3.4[a] (52)	2.9[c](1,127)
1M - 1.5M	2.2[c](85)	2.3[a](2)	- (0)	2.2[d](87)
All volumes	3.2(1,833)	3.2 (1,236)	3.6 (386)	3.2 (3,455)

Statistical comparisons of means apply to vertical columns only. Superscript letters indicate significant differences within the same market class ($p < 0.01$). Number of samples (n) is shown in parentheses.

TABLE 3. *Mean log_{10} APC per g of ground beef samples from cattle slaughter establishments grouped by slaughter volume.*

Establishment volume	Steers and heifers	Cows and bulls	Calves	All market classes
1 - 10K	5.2[a](373)	5.0[a] (105)	5.2[a] (1)	5.2[a](479)
10K- 100K	4.9[b](231)	4.6[b] (194)	7.5[a](30)	4.8[b](455)
100K -1M	3.8[c](232)	4.0[c] (106)	- (0)	3.9[c](338)
1M - 1.5M	3.5[d] (96)	4.1[abc] (2)	- (0)	3.5[d] (98)
All volumes	4.6(932)	4.5 (407)	4.8(31)	4.6(1,370)

Statistical comparisons of means apply to vertical columns only. Superscript letters indicate significant differences within the same market class ($p < 0.01$). Number of samples (n) is shown in parentheses.

steers and heifers ($r = 0.10$, $p < 0.01$). No significant association was found for cows and bulls (Table 4). In ground beef samples, the only statistically significant correlation was observed between *Salmonella* and antemortem condemnation in establishments slaughtering steers and heifers (Table 4).

The proportion of briskets contaminated with *Salmonella* was higher in calves than other market classes for 25- and 100-g samples (Table 5). In ground beef, 3.4% of 25-g portions and 5.4% of 100-g portions were culture positive for *Salmonella*.

No correlation between *Salmonella* contamination and slaughter volume was found for ground beef and brisket samples in any market class.

TABLE 4. *Correlation of antemortem condemnation with* Salmonella**.

	Brisket		Ground beef	
	n	r	n	r
Steers and heifers	305	0.10*	155	0.23*
Cows and bulls	206	-0.03	67	-0.01
Calves	65	0.65*	5	-0.23
All market classes	577	0.43*	228	0.10

*Significant at $p < 0.01$.
**Percentage of *Salmonella* positive 25-g samples in groups of seven samples.
n = Number of samples.

TABLE 5. *Brisket contamination with* Salmonella.

		Steers and Heifers	Cows and Bulls	Calves	All classes
25-g	Positive	17	14	20	51
	Samples	1,836	1,239	397	3,472
	% Positive	0.9	1.1	5.0	1.5
100-g	Positive	20	35	29	84
	Samples	1,607	1,181	366	3,154
	% Positive	1.2	3.0	7.9	2.7

DISCUSSION

In general, high-volume beef slaughter establishments control total aerobic bacteria counts on briskets and ground beef more effectively than low-volume establishments. The reductions in APC observed may have been achieved by reducing contamination of carcasses during slaughter, improving methods of contamination removal, slaughtering cattle of uniform size and weight, specializing the slaughter process, and/or chilling carcasses more efficiently in the 18-24 h after slaughter.

One or more of the factors above may be responsible for lower APC in high-volume establishments. Quality control programs identify sources and prevent contamination on the slaughter line. Carcass sprays remove some contamination as a last step in the dressing procedure before carcasses are moved to the cooler. High-volume establishments usually slaughter only steers and heifers of uniform size and weight and purchase cattle from a few feedlots that can supply large numbers of animals. The slaughter process used generally involves more specialization of labor with more workers making fewer types of cuts per worker resulting in better control of contamination during the slaughter process.

Calf slaughter establishments had a higher prevalence of brisket contamination with *Salmonella* probably due to a higher prevalence of *Salmonella* infection in calves because of the lack of acquired immunity. Calf slaughter establishments also showed a stronger association between antemortem condemnation and *Salmonella* contamination than establishments slaughtering other market classes. A correlation between antemortem condemnation and *Salmonella* contamination in establishments that slaughter other

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5. Entis, P. 1986. Hydrophobic grid membrane filter method for aerobic plate count in foods: Collaborative study. J. Assoc. Off. Anal. Chem. 69:671-676.
6. Entis, P., and P. Boleszczuk. 1986. Use of Fast Green FCF with tryptic soy agar for aerobic plate count by the hydrophobic grid membrane filter. J. Food Prot. 49:278-279.
7. Hippe, C. L., R. A. Field, and W. C. Russell. 1991. Effect of spray-chilling on quality of beef from lean and fatter carcasses. J. Anim. Sci. 69:178-183.
8. Ingram, M., and T. A. Roberts. 1976. The microbiology of the red meat carcass and the slaughterhouse. Roy. Soc. Health. J. 96:270-276.
9. Kriaa, H., J. F. Arthaud, and J. Fournaud. 1985. Contamination and bacterial retention capacity of carcasses at the abattoir. J. Appl. Bacteriol. 59:23-28.
10. Lasta, J., and R. Fonrouge. 1988. Significance of sample taken for bacterial counts from reduced areas of bovine carcasses. J. Food Prot. 51:214-217.
11. Lazarus, C. R., A. Abu-Bakar, R. L. West, and J. L. Oblinger. 1977. Comparison of microbial counts on beef carcasses by using the moist-swab contact method and secondary tissue removal technique. Appl. Environ. Microbiol. 33:217-218.
12. McNab, W. B., C. M. Forsberg, and R. C. Clarke. 1991. Application of an automated Hydrophobic grid membrane filter interpreter system at a poultry plant. J. Food Prot. 54:619-622.
13. Milliken, G. W., and D. E. Johnson. 1984. Analysis of messy data, vol. 1. Van Nostrand Reinhold Company, New York.
14. Roberts, T. A., H. J. H. MacFie, and W. R. Hudson. 1980. The effect of incubation temperature and site of sampling on assessment of the numbers of bacteria on red meat carcasses at commercial abattoirs. J. Hyg. Camb. 85:371-380.
15. Roberts, T. A., W. R. Hudson, O. P. Whelehan, et al. 1984. Number and distribution of bacteria on some beef carcasses at selected abattoirs in some member states of the European communities. Meat Sci. 11:191-205.
16. Roberts, T. A., and W. R. Hudson. 1987. Contamination in the meat plant - standpoint of an importing country. *In* F. J. M. Smulders (ed.) Elimination of pathogenic organisms from meat and poultry. Elsevier Science Publishers (BV) (Biomedical Division), Amsterdam.
17. SAS Institute, Inc. 1989. SAS/Stat^R user's guide. Version 6, 4th ed., vol. 1. SAS Institute, Inc., Cary, NC.
18. Sharpe, A. N., and P. I. Peterkin. 1988. Membrane filter food microbiology. John Wiley & Sons, Inc., Toronto.
19. Snedecor, G. W., and W. G. Cochran. 1980. Statistical methods, 7th ed. Iowa State University Press, Ames.
20. Stolle, F. A. 1988. Establishing microbiological surveillance programmes at slaughterlines--A new concept of meat hygiene. Meat Sci. 22:203-211.

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market classes may not have been detected because of the low prevalence of contamination. This conclusion is supported by the work of Spika et al. (*10*) who demonstrated a relationship between antemortem condemnation and *Salmonella* prevalence in pelvic fat samples from cows. That study involved fewer establishments and a higher prevalence of *Salmonella* contamination.

The carcass processing methods employed by high-volume establishments, although effective in reducing counts of microorganisms, had no measurable effect on the contamination of briskets or ground beef with *Salmonella* in this survey. *Salmonella* contamination may be more dependent on the animals brought to slaughter than on existing conditions in abattoirs. Previous studies (*5,9*) indicate that the prime source of *Salmonella* in slaughter establishments is the animals themselves.

The microbial contamination of cattle carcasses during slaughter is controllable to some extent by slaughter procedures. Some companies do so more effectively than others by the prevention of contamination during the dressing process and/or by the effective use of decontamination measures. More specific studies would be required to determine which measures were most effective in reducing total aerobic plate counts.

This study did not support the contention of Bryan et al. (*6*) that increased slaughter volume results in more finished product contamination by *Salmonella*. The prevalence of *Salmonella* contamination was found to be more closely associated with the health of animals brought to slaughter than on certain conditions in the slaughter establishments.

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REFERENCES

1. Anonymous. Meat and poultry inspection manual, U.S. Department of Agriculture, Food Safety and Inspection Service. U.S. Government Printing Office, Washington, DC.
2. Anonymous. 1974. Microbiological laboratory guidebook, U.S. Department of Agriculture, Food Safety and Inspection Service. U.S. Government Printing Office, Washington, DC.
3. Anonymous. 1986-1991. Statistical summary, Federal meat and poultry inspection for fiscal year 1986-1991. U.S. Department of Agriculture, Food Safety and Inspection Service. U.S. Government Printing Office, Washington, DC.
4. Bailey, J. S., J. Y. Chiu, N. A. Cox, and R. W. Johnston. 1988. Improved selective procedure for detection of salmonellae from poultry and sausage products. J. Food Prot. 51:391-396.
5. Brown, M. H., and A. C. Baird-Parker. 1982. The microbiological examination of meat. pp. 423-528. *In* M. H. Brown (ed.), Meat microbiology. Applied Science Publishers. London, New York.
6. Bryan, F. L., M. J. Fanelli, and H. Riemann. 1979. *Salmonella* Infections. pp. 73-130. *In* H. Riemann, and F. S. Bryan (ed.), Food-borne infections and intoxications. Academic Press, New York.
7. Hajna, A. A., and S. R. Damon. 1956. New enrichment and plating media for the isolation of *Salmonella* and *Shigella* organisms. Appl. Microbiol. 4:341-345.
8. Ott, L. 1984. An introduction to statistical methods. PWS Publishers. Boston.
9. Smeltzer, T. I. 1985. *Salmonella* contamination of beef in the abattoir environment. pp 262-270. *In* G. H. Snoyenbos (ed.), Proceedings of the International Symposium on *Salmonella* in New Orleans, 1984. American Association of Avian Pathologists. Univ of Penn, Kennett Square, PA.
10. Spika, J. S., S. H. Waterman, G. W. Soo Hoo, M. E. St. Louis, R. E. Pacer, S. M. James, M. L. Bissett, L. W. Mayer, J. Y. Chiu, B. Hall, K. Greene, M. E. Potter, M. L. Cohen, and P. A. Blake. 1987. Chloramphenicol-resistant *Salmonella newport* traced through hamburger to dairy Farms. N. Engl. J. Med. 316:565-570.
11. Subcommittee on Microbiological Criteria, Committee on Food Protection, Food and Nutrition Board, National Research Council. 1985. An evaluation of the role of microbiological criteria for foods and food ingredients. National Academy Press, Washington, DC.