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Microbial contamination of meat during the skinning of beef carcass hindquarters at three slaughtering plants

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Abstract

The microbiological effects on the product of the series of operations for skinning the hindquarters of beef carcasses at three packing plants were assessed. Samples were obtained at each plant from randomly selected carcasses, by swabbing specified sites related to opening cuts, rump skinning or flank skinning operations, randomly selected sites along the lines of the opening cuts, or randomly selected sites on the skinned hindquarters of carcasses. A set of 25 samples of each type was collected at each plant, with the collection of a single sample from each selected carcass. Aerobic counts, coliforms and *Escherichia coli* were enumerated in each sample, and a log mean value was estimated for each set of 25 counts on the assumption of a log normal distribution of the counts. The data indicated that the hindquarters skinning operations at plant A were hygienically inferior to those at the other two plants, with mean numbers of coliforms and *E. coli* being about two orders of magnitude greater, and aerobic counts being an order of magnitude greater on the skinned hindquarters of carcasses from plant A than on those from plants B or C. The data further indicated that the operation for cutting open the skin at plant C was hygienically superior to the equivalent operation at plant B, but that the operations for skinning the rump and flank at plant B were hygienically superior to the equivalent operations at plant C. The findings suggest that objective assessment of the microbiological effects on carcasses of beef carcass dressing processes will be required to ensure that Hazard Analysis: Critical Control Point and Quality Management Systems are operated to control the microbiological condition of carcasses.

Keywords: Beef; Carcasses; *Escherichia coli*; HACCP

1. Introduction

Throughout the world, meat inspecting authorities are encouraging or requiring meat packing plants to implement Hazard Analysis: Critical Control Point (HACCP) systems for their processes, with particular emphasis on the development of such systems for the control of the numbers of pathogenic bacteria deposited on carcasses during carcass dressing (Hudson et al., 1996; USDA, 1996). Concurrently, meat packing plant managements may be developing Quality Management (QM) systems which include control of the contamination of product with spoilage

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bacteria (MFSC, 1992). For both types of system, the operations with large effects on the microbiological condition of the product must be identified as Critical Control Points (CCPs) and/or Quality Control Points (QCPs), and managed to minimize the contamination of meat with pathogenic and/or spoilage bacteria (Webb and Marsden, 1995).

Currently, it is recommended that Critical or Quality Control Points in carcass dressing processes be identified by subjective judgment (Fulks, 1991; NAC, 1992). That is obviously unsatisfactory, as misidentification of control points and implementation of ineffective controlling measures are both distinctly possible when data directly relating to the microbiological effects of individual operations in a process are wholely lacking (Gill, 1995). A procedure for objectively identifying Critical and Quality Control Points in carcass dressing processes has therefore been proposed (Gill et al., 1996a).

The procedure involves the collection of swab samples from a site associated with each suspected contaminating operation, from randomly selected carcasses, before and/or after each operation. Aerobic counts, coliforms and *Escherichia coli* recovered from the samples are enumerated, and the log mean numbers of those bacteria at each site before or after an operation are estimated from sets of 25 counts. Thus, the numbers of bacteria deposited on carcasses by an operation can be assessed. Relatively heavy contamination with *E. coli* as the result of an operation is assumed to indicate a CCP, while heavy contamination with total aerobes indicates a QCP (Gill and Jones, 1997). The coliform count can assist in identifying the source of contamination, as faecal sources will usually yield coliforms which are largely *E. coli*, while *E. coli* from other sources will commonly be a minority of the coliforms recovered (Gill et al., 1996c).

The procedure has been applied for the assessment of a process for dressing pasteurized pig carcasses (Gill and Jones, 1997). In that process, the Critical and Quality Control Points were few, a sampled site of 100 cm^2 was often a large part of the portion of the carcass surface affected by an individual operation, and the changes likely to improve the process were obvious. However, such a situation cannot be assumed for beef carcass dressing processes, where each of a dozen or more skinning operations, and several eviscerating operations, some of which involve large areas of carcass surface, are likely to result in bacteria being deposited on carcasses in numbers which may not be readily controlled (Gill et al., 1996b).

The examination of all possibly critical operations in a beef carcass dressing process would therefore be arduous. Moreover, some comparison of the hygienic performances of similar operations in different processes is required as a basis for assessing the adequacy of the hygienic performance of any one of those operations. Therefore, as an initial study of the microbiological effects of individual beef carcass dressing operations, the hindquarters skinning operations in three beef carcass dressing processes were examined, to estimate the numbers of bacteria deposited on carcasses by the operations, to decide whether or not the contamination resulting from each operation could be assessed by the sampling of a single site on carcasses, and to obtain some indication of the extent to which contamination of meat by those operations might be controlled.

2. Materials and methods.

2.1. Carcass dressing processes

The carcass dressing processes at three beef slaughtering plants were examined. Plants A and B are commercial facilities in which approximately 1500 and 2000 cattle are slaughtered, respectively, during an eight hour working shift. Plant C is an experimental facility in which between 10 and 20 cattle are slaughtered during a working day. All three facilities are subject to inspection by the Canadian Food Inspection Agency (CFIA), and all three have HACCP systems for their carcass dressing processes, with documentation and monitoring procedures which meet with CFIA recommendations (CFIA, 1994).

At each plant, the hindquarters skinning operations in the dressing process were observed during periods of at least 2 h on five or more days. On each occasion, notes were made on the personnel involved in and the actions performed during each operation. In addition, the descriptions of the operations in the HACCP manuals were examined, and individual workers were asked to describe their usual working practices in relation to the operations which were

studied. For each process, the information from those sources were combined to obtain a detailed description of the hindquarters skinning operations.

2.2. Sampling of carcasses

Carcasses to be sampled were selected at random from those passing through the dressing processes during normal processing. A single sample was collected from each selected carcass. For each set of data, samples were collected from 25 carcasses, with five samples being collected on each of five days.

Sites to be sampled were selected by reference to a grid which specified 126 areas on one side of a carcass (Fig. 1), or by reference to a grid which specified ten areas along the lines of the opening cuts in the skin (Fig. 2). For each process, sets of 25 samples were collected from randomly selected sites C1 to C10 along the lines of the opening cuts, immediately after the operation for skinning the medial surface of the first leg to be skinned; from site 61, immediately after the operation for skinning the medial surface of the first leg to be skinned; from site 42, immediately after the operation for skinning the first rump to be skinned; from site 45, immediately after completion of the hindquarters skinning operations; and from sites randomly selected from the sites 1 to 6, 21 to 26, 41 to 46, 81 to 86 inclusive, and 101, immediately after the completion of the hindquarter skinning operations

Each sample was obtained by swabbing an non-delimited site of approximately 100 cm^2 within the selected grid area with a sterile gauze swab (5×5 cm, eight ply, Curity gauze sponge: Kendall Canada, Peterborough, ON, Canada) which had been moistened with 0.1% w/v peptone water. Each swab was placed in a separate Stomacher bag (Baxter Diagnostic, Edmonton, AB, Canada) which was then immersed in slush ice and processed within 3 h of being collected.

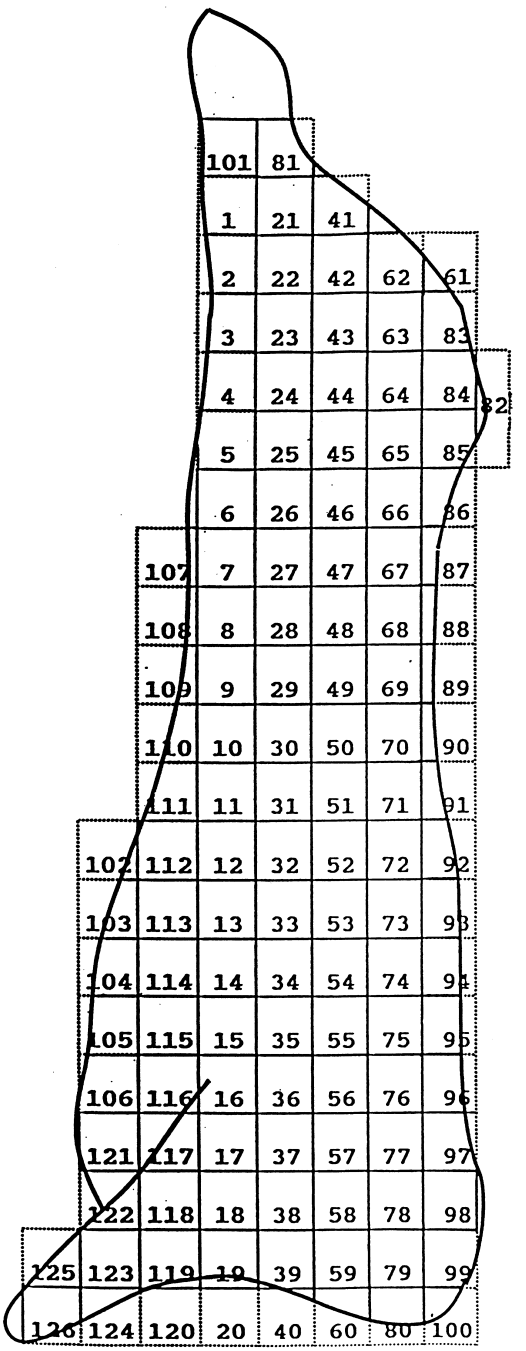

Fig. 1. The grid used in the selection of sites for sampling on beef carcass surfaces.

2.3. Enumeration of bacteria

Each swab was stomached for 2 min with 10 ml of 0.1% w/v peptone water. Bacteria were enumerated by hydrophobic grid membrane filtration techniques (Entis and Boleszczuk, 1990; IGMM, 1989).

Serial, ten-fold dilutions of the stomacher fluid were prepared, with dilution of 1 ml each of the undiluted, ten-fold diluted or 100-fold diluted stomacher fluid in nine ml volumes of 0.1% peptone water. The whole nine or ten ml volumes of each

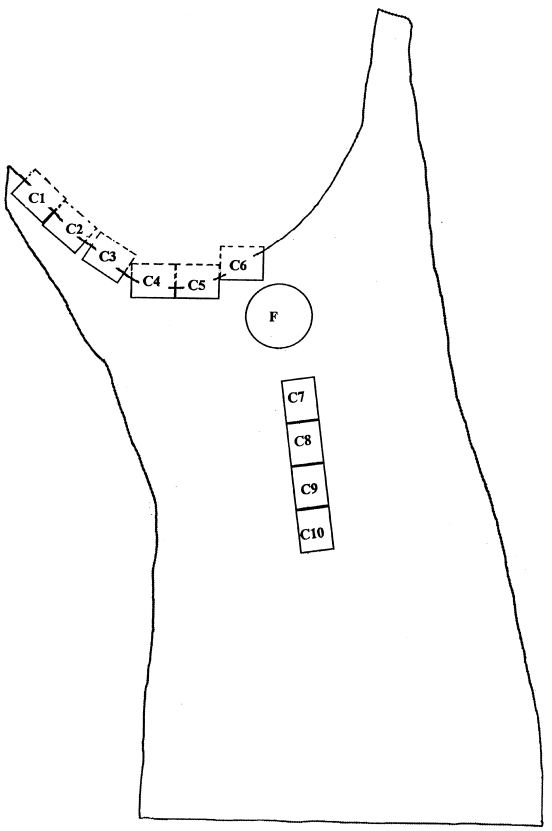

Fig. 2. The grid used in the selection of sites for sampling along the lines of the opening cuts in the skins of beef carcasses. The surface of cod fat in the region F was not sampled.

dilution were each filtered through a hydrophobic grid membrane filter (QA Life Science, San Diego, CA, USA). Each filter was placed on a plate of tryptone soy fast green agar (TSFG: QA Life Sciences) which was incubated at 25°C for 3 days. Squares containing green or blue–green colonies on filters preferably bearing between 20 and 200 such colonies were counted, and a most probable number (MPN) for aerobic counts was obtained by application of the formula:

$$\mathrm{MPN} = N \times \mathrm{Log}_n\,(N/N - X)$$

where N is the total number of squares on a filter and X is the count of squares containing green or blue–green colonies.

A 0.1-ml portion of the stomacher fluid was diluted into 10 ml of 0.1% w/v peptone water. The diluted fluid and the remaining 8.9 ml of undiluted fluid were then each filtered through a hydrophobic grid membrane filter. Each filter was placed first on a plate of lactose monensin gluconurate agar (LMG; QA Life Sciences) which was incubated at 35°C for 24 h. Squares containing blue colonies were counted, preferably on the filter used for the undiluted fluid but on the filter used for the diluted fluid when the number of colony-bearing squares on the other filter were too numerous to count. From the count of blue colonies, a MPN value for coliforms was obtained by the same calculation as was used for the total counts.

The filter used for the coliform count was then transferred to a plate of buffered 4-methylumbelliferyl-β-D-glucuronide agar (BMA; QA Life Sciences) which was incubated at 35°C for 3 h. After incubation the filter was illuminated with long-wave length ultraviolet light, and squares containing blue-white fluorescent colonies were counted. A MPN value for *E. coli* was obtained from that count.

2.4. Analysis of microbiological data from carcasses

All bacterial counts were transformed to $\log_{10}$ values. Log_{10} values of $-0.5 \cdot 100$ cm^{-2} were assumed for the samples in which coliforms or *E. coli* were not detected. Values for the mean $\log_{10}$ ($\bar{\times}$) and the standard deviation (s.d.) of the log values were calculated for each set on the assumption of a log normal distribution of the counts in each set (Brown and Baird-Parker, 1982). A value for the $\log_{10}$ of the arithmetric mean (log A) for each set was also calculated, from the formula (Kilsby and Pugh, 1981).

$$\log_{10} A = \bar{\times} + \log_n 10 \cdot \mathrm{s.d.}^2/2$$

The counts in each set were summed, and the sum transformed to a $\log_{10}$ total number recovered (N).

All calculations were performed with Microsoft Excel (Version 4, statistical functions, Microsoft, Redmond, WA, USA).

3. Results and discussion

The hindquarters skinning portion of the carcass dressing process at plant A consists of eight operations (Table 1), which are performed sequentially as

Table 1
Hindquarters skinning operations in the beef carcass dressing process at plant A

1.	Open skin of crotch, belly and left hock.
2.	Skin left hock and medial surface of left leg. Remove left hoof.
3.	Skin left rump, working from anterior to posterior or vice versa.
4.	Gambrel left leg. Unchain right leg.
5.	Skin right hock and medial surface of right leg. Remove right hoof.
6.	Skin right rump, working from anterior to posterior or vice versa.
7.	Raise and gambrel right leg.
8.	Skin hindquarters to waist, with freeing of the skin over the back bone.

the carcass moves continuously along the dressing rail. The carcass enters the dressing process suspended by a chain around the right hock. In the first operation, five cuts are made in the skin. The first two are made on each side of the anus, from the posterior to the anterior aspect, to meet in the anterior midline of the crotch. The third cut is made from the midline, cranial to the pizzle or udder, to the right of the pizzle or udder, then returning to the midline to join the junction of the first two cuts. The fourth cut is made on the medial surface of the left hock and leg, and the fifth cut is made from the navel to join the third cut. Some workers vary that basic pattern by, for example, combining cuts three and five in a single, third cut starting at the navel, or making the fourth cut by cutting from the first cut towards the hock instead of commencing the cut at the hock and finishing the cut before it joins the first cut.

In the second operation, the skin of the distal end of the left hock is cut around and the hock is skinned. The fourth opening cut is extended to join the first, if that was not done previously, and the medial surface of the left leg is skinned. The hock is cut off with powered shears.

In the third operation, the skin on the left side of the belly and over the lateral surface of the left leg and the rump is cut free from the underlying tissue. The skin may be freed first at the navel and then, progressively, towards the rump, or the operation may be commenced at the leg.

In the fourth operation, one arm of a gambrel is inserted between the left hock and the Achilles' tendon. The gambrel is then raised so that the carcass is supported by the left leg, and the chain is removed from the right leg. The procedures in operations two and three are repeated on the right leg in operations five and six and, in operation seven, the skinned, right leg is raised and the previously free gambrel arm inserted as on the left leg so that the carcass is then suspended from both rear legs.

In operation eight, hindquarters skinning is completed by the freeing of the skin over the back, including the area over the back bone, from the base of the tail to the waist. The skin remains attached at the tail as well as the waist until the tail skin is cut along the length of the anterior surface and the tail is skinned by mean of a hook placed between the base of the tail and the skin, the hook being mechanically drawn along the tail to strip the skin from it.

A minimum of 11 workers are involved in the hindquarters skinning operations. That number may be increased to 14 or 15 when the throughput of carcasses is maximal and skinning is rendered difficult by, for example, much hardened mud adhering to hides. The workers involved in the hindquarters skinning operations frequently exchange jobs throughout the course of the working day.

Hindquarters skinning at plant B involves ten operations (Table 2). The carcass enters the dressing process suspended by a chain around the left hock, and is subjected to a shaving operation before the skin is cut. The operations for opening the skin, skinning the legs and rumps, and gambreling the legs are similar to the equivalent operations at plant A. However, skinning of the right rump always proceeds from the navel to the leg, while in subsequent skinning of the left rump, skinning always proceeds from the leg to the navel; and the skin over the backbone is not freed along with the rest of the skin over the back in operation nine, but is freed during a separate operation eleven, which follows operation nine and the simultaneous operation ten to open the skin of the tail. As operation ten does not affect the hindquarters, it was not regarded as a hindquarters skinning operation.

Table 2
Hindquarters skinning operations in the beef carcass dressing process at plant B

1.	Shave crotch and belly and, sometimes, legs.
2.	Open skin of crotch, belly and right hock.
3.	Skin right back and medial surface of right leg. Remove right hoof.
4.	Skin right rump, working from navel to leg.
5.	Gambrel right leg. Unchain left leg.
6.	Skin left hock and medial surface of left leg. Remove left hoof.
7.	Skin left rump, working from leg to navel.
8.	Raise and gambrel left leg.
9.[a]	Skin hindquarters to waist.
10.[a]	Open tail skin.
11.	Free skin over the back bone.

[a] Operations with the superscript are performed simultaneously.

Twenty two workers are always employed in the hindquarters skinning operations at plant B. Although jobs are exchanged by workers, the changes are made on a daily basis so that a worker is generally employed on only one operation on any given day.

Hindquarters skinning at plant C involves eleven operations (Table 3), all of which are performed at the same work station by a single worker. Two other operations, for skinning the tail and freeing the bung, are interpolated before the final two operations for hindquarters skinning. The opening cuts operation at plant C differs from that at the other two plants in that the opening cut is made from the base of the tail, in the midline, around the right side of the anus then continues in the midline of the crotch. A second cut is made from the first cut, around the left side of the anus. The first cut is extended down the belly, to about 30 cm from the sternal notch. A fourth cut is made from the right hock, immediately proximal to the hoof, along the posterior surfaces of the hock and leg, to join the opening cut at the crotch. Thus, unlike with the other processes, fresh incisions in the skin are made at only two points, at the base of the tail and the distal end of the hock. All other cutting of the skin at plant C is by extension of existing cuts, with the skin being cut from the inside to the outside, whereas at the other plants each cut is commenced remote from previous cuts, with the knife being drawn across the outside of the skin for the whole length of most or all of the cuts.

The process at plant C also differs from those at the other plants in that portions of the brisket and the belly are skinned before the rumps are skinned, instead of only posterior parts of the belly being skinned, during the rump skinning operations. Moreover, trimming of a strip of fat tissue from the line of the opening cut in the belly and brisket skin whether

Table 3
Hindquarters skinning operations in the beef carcass dressing process at plant C

1.	Open the skin of the base of the tail, the crotch, belly, posterior, brisket, right hock and right leg.
2.	Skin right hock and medial surface of right leg.
3.	Skin right posterior brisket and belly working from anterior to posterior. Free the skin over the backbone between the rump and the waist.
4.	Skin the right rump and the base of the tail, from posterior to anterior.
5.	Trim visible dirt or hair from the right hock and leg. Remove right hoof.
6.	Raise and gambrel right leg. Unchain left leg.
7.	Skin left hock and medial surface of left leg.
8.	Skin left, posterior brisket and belly, working from anterior to posterior.
9.	Skin left rump from posterior to anterior. Free skin over the backbone in the rump region.
10.	Open skin on the anterior surface of the tail. Manually strip off the tail skin. Cut off the tail.
11.	Free and bag the bung.
12.	Remove left hoof. Raise and gambrel left leg.
13.	Trim midline of belly and brisket.

or not visible contamination is apparent is a routine operation at plant C, and trimming of the posterior surfaces of the legs and hocks is usual, in response to any perception of hairs or dirt. Such trimming during hindquarters-skinning at the other plants is relatively uncommon, and appears to be implemental only when large amounts of soil are evident on a carcass.

Because of differences in the standard deviations for equivalent sets of microbiological data from different plants, the performances of similar operations at the three plants cannot be compared by reference to mean log ($\bar{\times}$) values. Instead, they are preferably compared by reference to log mean (log *A*) values (Kilsby and Pugh, 1981; Gill, 1998). Differences in the values for log total numbers recovered (*N*) will usually be comparable to differences between log *A* values. However, when the number of bacteria-negative samples (no) in a set is >4, the estimation of log *A* is uncertain because of the non-normal distribution of the log counts (Gill et al., 1998). In such circumstances greater weight should be accorded to differences between *N* than between log *A* values. In assessing the relative hygienic performance of operations, differences between log values for equivalent statistics are likely to be of practical importance only if they approach or exceed 1, while differences of <0.5 can be regarded as of no practical importance (Gill and Jones, 1997).

The crotch site 61 is affected by the first cuts to open the skin. The values for both log *A* and *N* for sets of bacterial counts obtained from that site indicated that the numbers of total aerobes deposited at site 61 were less for carcasses at plant A than for carcasses at plants B or C but that the numbers of coliforms and *E. coli* deposited at that site were somewhat less and very much less for carcasses at plants B and C, respectively, than for carcasses at plant A (Table 4). It thus appeared that the operation for cutting open the skin of the hindquarters at plant C resulted in fewer faecal organisms being deposited on the meat than did the analogous operations at plants A and B.

The values for log *A* and *N* for the sets of bacterial counts obtained from randomly selected sites along the lines of the opening cuts also indicated that during the operations for cutting open the skin fewer total aerobes were deposited on the meat of carcasses at plant A than on the meat of carcasses at the other two plant, but that those operations resulted in fewer coliforms and *E. coli* being deposited on the meat of carcasses at plant C than on the meat of carcasses at the other two plants (Table 5). However, the differences were less than those indicated by the data from site 61.

Table 4
Statistics for sets of 25 aerobic counts (cfu cm^{-2}), coliform counts (cfu 100 cm^{-2}) or *Escherichia coli* counts (cfu 100 cm^{-2}) obtained from the crotch site 61 on randomly selected carcasses, immediately after the skinning of the medial surface of one leg in the beef carcass dressing processes at three plants

Plant	Count	Statistics				
		$\bar{\times}$	s.d.	no	log *A*	*N*
A	Aerobic counts	3.26	0.36	0	3.41	4.74[a]
	Coliform	3.67	1.15	0	5.19	5.82[b]
	E. coli	3.31	1.26	0	5.14	5.47[b]
B	Aerobic counts	4.02	0.60	0	4.43	5.75[a]
	Coliform	2.72	1.23	0	4.46	5.17[b]
	E. coli	2.68	1.23	0	4.42	5.03[b]
C	Aerobic counts	3.38	0.56	0	3.75	5.12[a]
	Coliform	0.79	0.96	3	1.85	3.54[b]
	E. coli	0.71	0.94	3	1.72	3.52[b]

$\bar{\times}$ = mean log.
s.d. = standard deviation.
no = number of samples from which bacteria were not recovered.
log *A* = estimated log of the arithmetic mean.
N = log of the total number recovered from [a] 25 or [b] 2500 cm^2.

The sets of counts obtained from randomly selected sites along the lines of the opening cuts on carcasses on which the opening cut operation had been performed by individual workers gave log mean values for the equivalent sets from each of plants A and B which generally differed by less than 0.5 log units (Table 6). It therefore appears that the performances of individual workers did not greatly vary the hygienic effects of the opening cuts operations at either plant.

The various data relating to the opening cuts operations show that the operation in each of the processes is both a critical and quality control point, as the operation can result in large numbers of *E. coli* and total aerobes being deposited on carcasses. The hide shaving operation before cutting of the skin at plant B is likely not a control point as its implementation apparently does not reduce bacterial contamination during the opening cuts operation. In controlling the contamination of meat during the opening cuts operation, the established form of the

Table 5
Statistics for sets of 25 aerobic counts (cfu cm^{-2}), coliform counts (cfu 100 cm^{-2}) or *Escherichia coli* counts (cfu 100 cm^{-2}) obtain from randomly selected sites along the lines of the opening cuts in the skins, on carcasses selected at random from the carcasses undergoing the dressing process at each of the three plants, at the stage of each process when the medial surface of the leg had been skinned

Plant	Count	Statistics				
		$\bar{\times}$	s.d.	no	log *A*	*N*
A	Aerobic counts	3.32	0.63	0	3.78	5.28[a]
	Coliform	2.34	1.22	1	4.05	5.11[b]
	E. coli	2.15	1.27	2	4.00	4.82[b]
B	Aerobic counts	3.96	0.78	0	4.66	5.81[a]
	Coliform	2.56	1.01	0	3.73	4.75[b]
	E. coli	2.35	1.04	0	3.59	4.62[b]
C	Aerobic counts	3.56	0.76	0	4.23	5.40[a]
	Coliform	1.55	1.27	3	3.39	4.09[b]
	E. coli	1.35	1.23	3	3.08	3.97[b]

$\bar{\times}$ = mean log.
s.d. = standard deviation.
no = number of samples from which bacteria were not recovered.
log *A* = estimated log of the arithmetic mean.
N = log of the total number recovered from [a] 25 or [b] 2500 cm^2.

Table 6
Estimated log mean (log *A*) values for the numbers of aerobic counts (cfu cm^{-2}), coliforms (cfu 100 cm^{-2}) or *Escherichia coli* (cfu 100 cm^{-2}) deposited on carcasses by the opening cuts in the hindquarters skin made by each of three workers at two beef packing plants

Plant	Workers	Log *A* values		
		Aerobic counts	Coliform	*E. coli*
A	1	3.71	4.53	4.12
	2	3.96	4.45	4.14
	3	4.11	3.84	3.60
B	1	4.59	4.08	3.96
	2	4.69	3.80	3.68
	3	4.67	3.45	3.31

operation rather than the skill of individual workers appears to determine the extent of the contamination. Thus, the relatively low numbers of *E. coli* recovered at plant C from sites associated with the opening cuts operation indicate that cutting the skin in the manner adopted at plant C results in substantially less contamination of the meat than the differing cutting practices at Plant A and perhaps less contamination than the practices at plant B. However, the relatively high total counts recovered from the same sites at plant C suggest contamination of the meat by contact with the hands of workers or equipment, without substantial transfer of bacteria from the carcass skin, which is apparently better controlled by the practices at plant A for freeing the skin around the opening cuts.

The carcass site 42 is associated with the operation for skinning the rump. The values for log *A*, and *N* for sets of counts obtained from site 42 indicated that greater numbers of total aerobes were deposited at that site on carcasses from plant C than on carcasses from plants A or B, but that the numbers of coliforms and *E. coli* deposited at site 42 were somewhat less and much less for carcasses at plants C and B, respectively, than for carcasses at plant A (Table 7). It therefore appears that during skinning of the rump at plant A bacteria are transferred from the skin of the animal to the meat. Such transfer is apparently better controlled during rump skinning at plant C, because of the relatively small numbers of *E. coli* recovered from site 42, but the relatively high numbers of total aerobes suggests extensive handling of the meat at plant C that does not occur at plant A. The rump skinning operation at plant B apparently results in few *E. coli* being transferred to the meat

Table 7
Statistics for sets of 25 aerobic counts (cfu cm^{-2}) coliform counts (cfu 100 cm^{-2}) or *Escherichia coli* counts (cfu 100 cm^{-2}) obtained from the rump site 42 on randomly selected carcasses, immediately after the completion of the hindquarters skinning operations in the beef carcass dressing processes of three plants

Plant	Count	Statistics				
		$\bar{\times}$	s.d.	no	log *A*	*N*
A	Aerobic counts	2.14	0.40	0	2.33	3.70[a]
	Coliform	1.16	1.17	3	2.75	4.15[b]
	E. coli	0.43	1.21	11	2.11	3.99[b]
B	Aerobic counts	2.70	0.50	0	2.98	4.34[a]
	Coliform	−0.15	0.48	14	0.12	1.52[b]
	E. coli	−0.34	0.28	18	−0.25	0.95[b]
C	Aerobic counts	3.45	0.64	0	3.92	5.42[a]
	Coliform	0.63	1.01	7	1.81	3.13[b]
	E. coli	0.33	0.91	10	1.28	2.75[b]

$\bar{\times}$ = mean log.
s.d. = standard deviation.
no = number of samples from which bacteria were not recovered.
Log *A* = estimated log of the arithmetic mean.
N = log of the total number recovered from [a] 25 or [b] 2500 cm^2.

from the skin of the animal, and containment of the numbers of aerobes deposited on the meat from hands or equipment.

The carcass site 45 is associated with the operation for skinning the flank. The findings for the contamination of site 45 on the carcasses at each plant were similar to the findings for site 42, except that the numbers of coliforms and *E. coli* at site 45 were similar for the carcasses at plants B and C (Table 8). Those data therefore indicate that, at each plant, the hygienic effects of the rump and flank skinning operations are similar, with the deposition of total aerobes being poorly controlled at plant C, but relatively well controlled at plants A and B, and the deposition of *E. coli* being poorly controlled at plant A, but relatively well controlled at plants B and C.

The sets of coliforms and *E. coli* counts obtained from randomly selected sites on the skinned hindquarters were as might be expected from the data collected from the specified sites, with similar, relatively low numbers being deposited on the hindquarters of carcasses from plants B and C, but with far greater numbers being deposited on the hindquarters of carcasses from plant A (Table 9). However, the numbers of aerobic counts deposited on the hindquarters of carcasses from plants B and C were also indicated to be similar, with higher mean numbers deposited on the carcasses from plant A, although the expectation from the data collected from specified sites would be that the numbers of aerobic counts would be lowest for the hindquarters of carcasses from plant A, and greatest for the hindquarters of the carcasses from plant C. It therefore appears that data from a specific site may not be entirely reliable as a guide to the hygienic performance of a beef carcass dressing operation with which it is associated. However, despite that discrepancy, the data allow initial assessments of the hindquarters skinning operations which could be used to direct possibly improving actions.

It is evident that, with the exception of the gambrelling operations and the operation for shaving the carcass skin at plant B, each operation in the series for skinning the hindquarters at each plant must be regarded as both a critical and a quality control point. All such operations at plant A would have to be regarded as poorly controlled, if not uncontrolled in comparison with the operations at the other plants. The plant A operations could likely be improved by adaptation of the plant C practices for the opening cuts operation and the plant B practices

Table 8
Statistics for sets of 25 aerobic counts (cfu cm^{-2}), coliform counts (cfu 100 cm^{-2}) or *Escherichia coli* counts (cfu 100 cm^{-2}) obtained from the waist site 45 on randomly selected carcasses immediately after completion of the hindquarters skinning operations in the beef carcass dressing processes at three plants

Plant	Count	Statistics				
		$\bar{\times}$	s.d.	no	log *A*	*N*
A	Aerobic counts	2.37	0.49	0	2.64	4.03[a]
	Coliform	2.00	1.04	0	3.23	4.15[b]
	E. coli	1.67	1.24	4	3.44	4.04[b]
B	Aerobic counts	1.93	0.75	0	2.58	3.91[a]
	Coliform	0.49	0.91	10	1.44	2.56[b]
	E. coli	0.45	0.88	10	1.33	2.49[b]
C	Aerobic counts	2.59	1.36	0	4.70	5.07[a]
	Coliform	0.43	0.95	9	1.47	2.81[b]
	E. coli	0.04	0.91	17	0.99	2.61[b]

$\bar{\times}$ = mean log.
s.d. = standard deviation.
no = number of samples from which bacteria were not recovered.
log *A* = estimated log of the arithmetic mean.
N = log of the total number recovered from [a] 25 or [b] 2500 cm^2.

Table 9
Statistics for sets of 25 aerobic counts (cfu cm^{-2}), coliform counts (cfu 100 cm^{-2}) or *Escherichia coli* counts (cfu 100 cm^{-2}) obtained from randomly selected sites on the hindquarters of randomly selected carcasses immediately after the completion of the hindquarters skinning operations in the beef carcass dressing processes at three plants

Plant	Count	Statistics				
		$\bar{\times}$	s.d.	no	log *A*	*N*
A	Aerobic counts	3.06	0.70	0	3.63	5.04[a]
	Coliform	2.36	1.42	3	4.67	5.24[b]
	E. coli	2.07	1.44	4	4.47	4.72[b]
B	Aerobic counts	2.27	0.64	0	2.74	3.97[a]
	Coliform	0.24	0.92	11	1.21	3.46[b]
	E. coli	0.19	0.94	13	1.21	3.42[b]
C	Aerobic counts	2.06	0.78	0	2.77	4.08[a]
	Coliform	0.42	0.98	8	1.52	2.82[b]
	E. coli	0.23	0.84	11	1.05	2.44[b]

$\bar{\times}$ = mean log.
s.d. = standard deviation.
no = number of samples from which bacteria were not recovered.
log *A* = estimated log of the arithmetic mean.
N = log of the total number recovered from [a] 25 or [b] 2500 cm^2.

for the other critical operations. The hindquarters skinning operations at plant B might be somewhat improved hygienically by adoption of plant C practices for the opening cuts operation and/or by instituting an operation for routinely trimming a strip of tissue from the midline of the belly and brisket, as at plant C. Conversely, the hindquarters skinning operations at plant C might be improved by the adoption of plant B practices for the other critical skinning operations. However, whether such changes would substantially improve the plants B and C operations could be decided only by their trial.

A disconcerting aspect of this study is that the dressing process at plant A is operated under a HACCP system implemented in accordance with regulatory recommendations and requirements. Obviously, those recommendations and requirements are not sufficient to ensure against the continuation of hygienically inferior practices. A procedure for objectively assessing the hygienic performances of carcass dressing processes must then be recognized and applied for there to be assurance that processing hygiene is controlled to attainable standards.

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