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A SURVEY OF THE HYGIENIC QUALITY OF BEEF AND PORK CARCASSES IN NORWAY

By

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JOHANSON, LENNART, BJARNE UNDERDAL, KNUT GRØSLAND, OLIVER P. WHELEHAN and TERENCE A. ROBERTS: *A survey of the hygienic quality of beef and pork carcasses in Norway.* Acta vet. scand. 1983, *24*, 1—13. — The bacteriological quality of beef and pig carcasses was assessed at 9 Norwegian abattoirs by sampling 10 carcasses at multiple sites on each of several visits. On beef carcasses the following sites consistently carried higher numbers of bacteria: the Brisket, the Fore-ribs, the Flank groin, and the Round medial. There was no evidence that beef slaughter and dressing in the hanging position was superior to methods where the carcass was lying until the hide puller. On pork carcasses the Cheek, and the Abdomen lateral surface (belly) were most heavily contaminated. The hygienic quality of pork carcasses in abattoirs where singeing was a separate step tended to be better than where a combined singeing and dehairing machine was used.

This survey suggests that bacteriological monitoring of slaughter at this level of sampling and visiting is able to detect consistently poor hygienic practices.

Where direct comparisons with data from other countries could be made, the present investigation indicates that the bacterial counts on Norwegian beef and pork carcasses are of the same order or better.

abattoir; slaughter; beef; pork; hygiene.

The shelf-life of meat is largely determined by the initial numbers of microbes present and the temperature of storage. Lower microbial numbers result in increased shelf-life. Attempts are made during slaughter to minimise the numbers of microbes reaching the carcass surface from heavily contaminated areas such as the hide (fleece), hooves and gut. Operations are supervised and monitoret by visual inspection, but even visually clean carcasses may carry relatively large numbers of bacteria on their surface. The problems are discussed by *Roberts* (1980) who concluded that despite large and costly technical improvements

to claughterhouses there is no factual evidence that numbers of spoilage bacteria are lower than previously, or that meat is better than previously.

On freshly slaughtered carcasses most of the contamination is found on the surface, the consequence of direct or indirect contact with the hide and hooves or accidental contamination with gut contents or faecal material. The deep musculature from a healthy animal is relatively free from microbes (*Mackey & Derrick* 1979, *Gill* 1979). Even under refrigeration extensive microbial growth may develop at the meat surface including bacteria such as Pseudomonas, Acinetobacter, Moraxella and Enterobacteriaceae (*Gill & Newton* 1978) yeasts and moulds. When the surface count exceeds about 10^6 to 10^7 organisms/cm^2, deterioration usually becomes apparent by surface slime, tissue discolouration, souring and odour (*Ayres* 1955, 1960, *Meara et al.* 1977). Bacterial numbers on the carcass at the end of the slaughter line may serve as a useful monitor of hygienic practice during slaughter and dressing, but there are few publications where adequate numbers of carcasses have been sampled (*Nottingham et al.* 1974, *Ingram & Roberts* 1976).

The intention of this investigation was to determine levels of bacterial comtamination of Norwegian carcasses, and whether within an abattoir there were sites on the carcass which were consistently dirty (in a bacteriological sense), and if those sites were consistently dirty across a number of abattoirs. Such information might then be used to design a satisfactory sampling scheme for similar surveys in other abattoirs.

MATERIALS AND METHODS

The survey was carried out between September 1980 and February 1981. Nine abattoirs of varying sizes in Southern Norway were visited on 3 to 6 occasions. On each visit 10 beef and 10 pork carcasses were sampled at 8 sampling sites on beef and 6 on pork carcasses, alternating left and right side. Figs. 1 and 2 show the sampling sites chosen. The numbers in parenthesis are the corresponding numbers used at the Meat Research Institute England. The samples were taken at the end of the Slaughter line, before chilling, because the intention was to examine the hygiene of the slaughter process, and to facilitate comparisons with data published by *Ingram & Roberts* (1976) and *Roberts et al.* (1980).

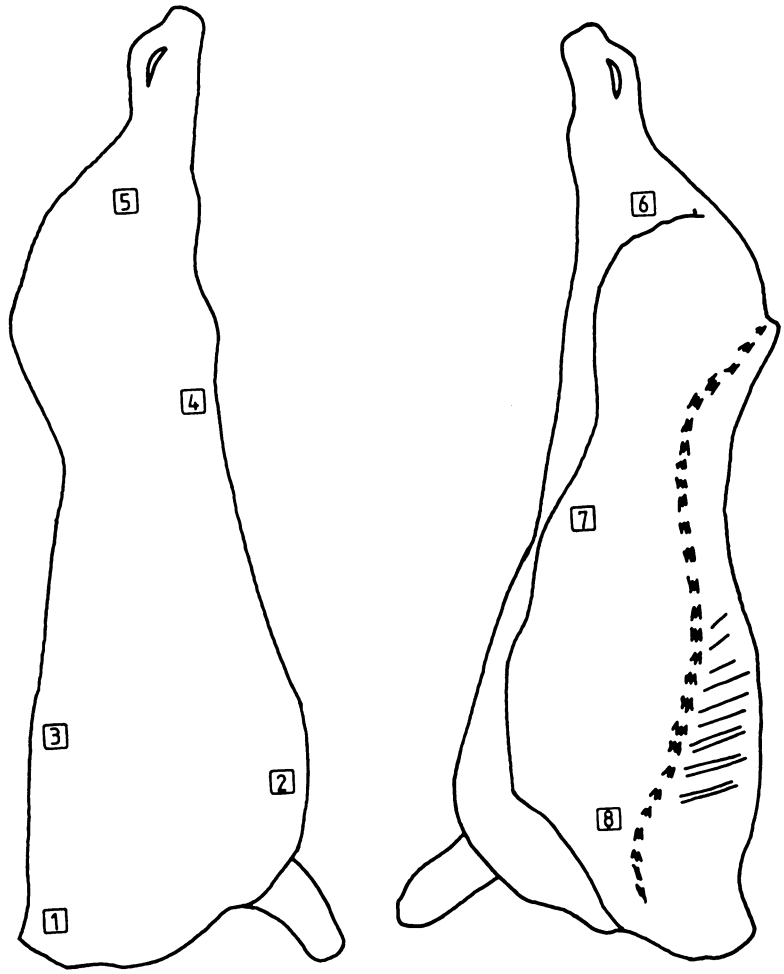

Figure 1. Sampling sites on beef carcasses. The numbers in parenthesis are the corresponding numbers used at the Meat Research Institute (see *Roberts et al.* 1980).
1 Neck (1), 2 Brisket (2), 3 Forerib, lateral (3), 4 Flank, groin (6), 5 Round, lateral (8), 6 Round, medial (9), 7 Flank, medial (10) and 8 Fore-rib, medial (13).

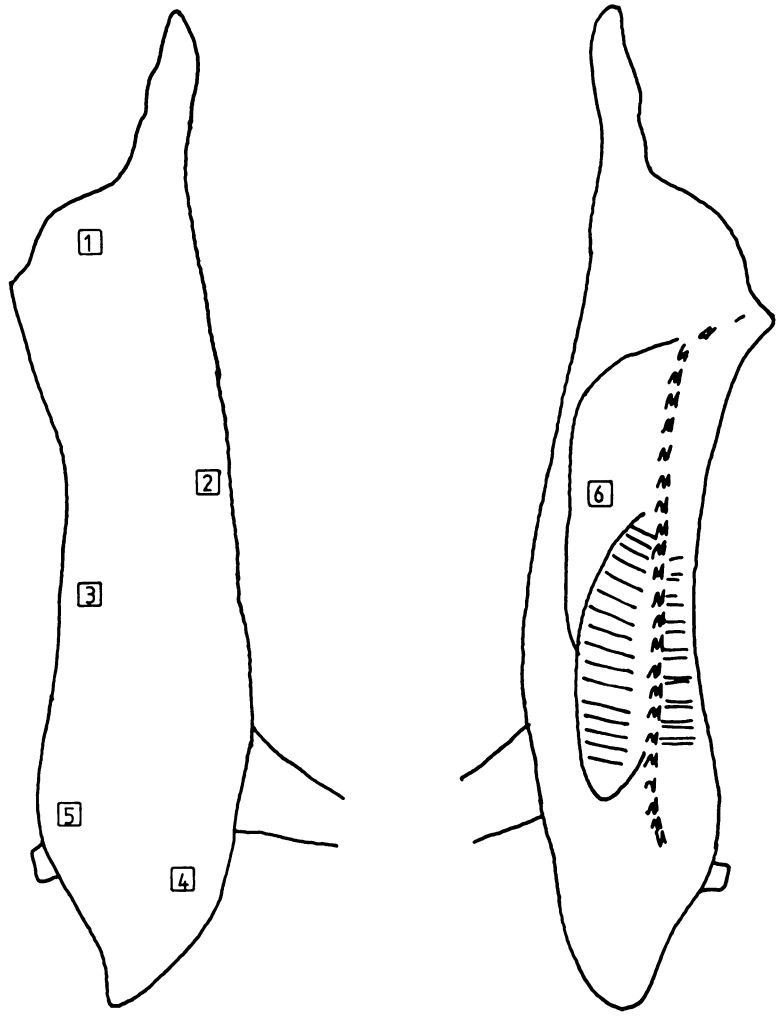

Figure 2. Sampling sites on pork carcasses. The numbers in parenthesis are the corresponding numbers used at the Meat Research Institute (see *Roberts et al.* 1980).
1 Hind limb, lateral surface (2) 2 Abdomen, lateral surface (belly) (3), 3 Mid-dorsal region (Mid-back) (4), 4 Cheek (7), 5 Back of Neck (5) and 6 Abdomen, medial surface (10).

Beef

On the beef lines all the abattoirs had mechanical hidepullers, which pulled the hide upwards while the carcass was hanging. In abattoirs D, E and I the carcasses were lying from the stunning to the hide removal. The remaining abattoirs had hanging lines.

Pork

All abattoirs except A had traditional pork lines. In abattoir A the carcasses were scalded by spraying with recirculating water instead of immersing in the traditional scalding tank. Most of the abattoirs had combined dehairing and singeing machines, whereas in abattoirs A, E, H and I singeing was a separate step. In abattoir A singeing was done automatically in a cabinet, in the others manually.

The sampling procedure was the swab method essentially as described by *Kitchell et al.* (1973) and bacterial numbers were determined by the loop-tile method (*Roberts et al.* 1980).

The following minor modifications were made:

— the areas sampled were 50 cm^2;
— the swabs were sterile dental tampons cut in halves (Flawa No. 3);
— Plate Count Agar (Difco) was used;
— the incubation temperature was 20°C for 3 days.

Statistical analyses

The counts were analysed after transformation to logarithms which was assumed to make the counts normally distributed (*Roberts et al.* 1980). Analysis of variance was then considered applicable.

The analysis of variance carried out was of a split-plot design with the visits to each abattoir forming the whole-plots, and the 10 carcasses examined at each visit forming the sub-plots. Thus to test for significant overall abattoir differences the mean square due to abattoir variation was compared with the whole-plot residual mean square (visit within abattoir variation). Significant overall site differences were tested for by comparing the mean square due to site variation with the sub-plot residual mean square and if significant the abattoir $\times$ site interaction mean square.

This analysis takes into account variation between replicate carcasses on each visit and between replicate visits, to test whether the bacterial numbers at different abattoirs differ significantly. Large variations between replicate carcasses, or replicate visits, makes differentiation between abattoirs impossible.

RESULTS

Throughout bacterial counts are expressed as $\log_{10}$ bacteria/cm^2. In the tables different subscripts are used to denote significantly different mean values in the same row or column as specified. Tabulated values with the same subscript letter do not differ significantly at the 5 % level of significance.

Table 1 gives the overall abattoir means for beef and pork, respectively. They include results from all sites on all the visits. Table 2 gives the results from each site including all the abattoirs. Tables 3, 4, 5 and 6 give the abattoir $\times$ site interactions. Note that Tables 3 and 5 compare the sites for a given abattoir (horizontally), and Tables 4 and 6 compare the abattoirs for a given site (vertically) by different subscripts.

In both surveys the analysis of variance showed that the visit within abattoir variation was significantly greater than the residual error, and there was a significant abattoir $\times$ site interaction effect (Table 7). However, the effects of abattoir and site differences were significant over and above these. Hence overall abattoir and site comparisons may be made in both surveys.

Table 1. Bacterial contamination of beef and pork carcasses at 9 abattoirs.[1]

Abattoir	Beef ($\log_{10}$)	Pork ($\log_{10}$)
A	2.46_{bcd}	2.65_{ab}
B	2.24_{abc}	3.33_{c}
C	2.87_{d}	3.90_{d}
D	2.09_{ab}	2.99_{bc}
E	2.56_{cd}	2.86_{ab}
F	2.42_{bc}	3.29_{c}
G	2.36_{abc}	2.76_{ab}
H	1.98_{a}	2.58_{a}
I	2.23_{ab}	2.72_{ab}
	s.e.d. = 0.209	s.e.d. = 0.187

[1] Each tabulated value ($\log_{10}$ bacteria/cm^2) includes all results from that abattoir.

Table 2. Bacterial contamination[1] at different sites on beef[2] and pork[3] carcasses.

Site	Beef (log_{10})	Pork (log_{10})
1	2.16_{b}	3.06_{b}
2	2.87_{d}	3.28_{d}
3	2.54_{c}	3.06_{b}
4	2.52_{c}	3.41_{e}
5	2.16_{b}	3.14_{c}
6	2.80_{d}	2.28_{a}
7	1.83_{a}	
8	1.78_{a}	
	s.e.d. = 0.050	s.e.d. = 0.034

[1] Each tabulated value (log_{10} bacteria/cm^2) includes results from 9 abattoirs.
[2] See Fig. 1.
[3] See Fig. 2.

Table 3. Effect of sampling site on bacterial contamination of beef carcasses at 9 abattoirs: comparison of sites for a given abattoir (horizontally).

Site / Abattoir	1	2	3	4	5	6	7	8
A	2.28_{b}	2.89_{de}	2.35_{bc}	2.50_{bc}	2.65_{cd}	3.17_{e}	1.92_{a}	1.94_{a}
B	2.28_{bc}	2.68_{d}	2.22_{b}	2.61_{d}	1.53_{a}	2.56_{cd}	2.02_{b}	2.04_{b}
C	2.66_{b}	3.85_{d}	2.73_{b}	3.52_{c}	2.79_{b}	3.49_{c}	2.01_{a}	1.88_{a}
D	2.11_{bc}	2.76_{d}	2.33_{c}	1.90_{ab}	1.58_{a}	2.79_{d}	1.60_{a}	1.63_{a}
E	2.35_{c}	3.16_{e}	3.15_{e}	2.69_{d}	2.27_{bc}	2.98_{de}	1.90_{a}	1.95_{a}
F	1.97_{a}	2.64_{bc}	2.62_{b}	2.96_{c}	2.56_{b}	2.81_{bc}	1.97_{a}	1.81_{a}
G	2.12_{abc}	2.92_{e}	2.60_{de}	2.44_{cd}	2.29_{bcd}	2.53_{d}	2.10_{ab}	1.86_{a}
H	1.72_{b}	2.71_{f}	2.43_{ef}	1.84_{bc}	2.08_{cd}	2.23_{de}	1.55_{ab}	1.26_{a}
I	2.13_{c}	2.80_{ef}	2.62_{def}	2.49_{de}	1.91_{bc}	2.87_{f}	1.44_{a}	1.60_{ab}

s.e.d. = 0.167
Different subscripts across a row indicate significant differences in numbers (log_{10} bacteria/cm^2).

Table 4. Effect of sampling site on bacterial contamination of beef carcasses at 9 abattoirs: comparison of abattoirs for a given site (vertically).

Abattoir \ Site	1	2	3	4	5	6	7	8
A	2.28_{bc}	2.89_{ab}	2.35_{a}	2.50_{bc}	2.65_{e}	3.17_{cd}	1.92_{abc}	1.94_{b}
B	2.28_{bc}	2.68_{ab}	2.22_{a}	2.61_{bc}	1.53_{a}	2.56_{ab}	2.02_{bc}	2.04_{b}
C	2.66_{c}	3.85_{c}	2.73_{ab}	3.52_{d}	2.79_{e}	3.49_{d}	2.01_{bc}	1.88_{b}
D	2.11_{ab}	2.76_{ab}	2.33_{a}	1.90_{a}	1.58_{ab}	2.79_{bc}	1.60_{abc}	1.63_{ab}
E	2.35_{bc}	3.16_{b}	3.15_{b}	2.69_{bc}	2.27_{cde}	2.98_{bc}	1.90_{abc}	1.95_{b}
F	1.97_{ab}	2.64_{a}	2.62_{a}	2.96_{c}	2.56_{de}	2.81_{bc}	1.97_{bc}	1.81_{b}
G	2.12_{ab}	2.92_{ab}	2.60_{a}	2.44_{b}	2.29_{cde}	2.53_{ab}	2.10_{c}	1.86_{b}
H	1.72_{a}	2.71_{ab}	2.43_{a}	1.84_{a}	2.08_{bcd}	2.23_{a}	1.55_{ab}	1.26_{a}
I	2.13_{ab}	2.80_{ab}	2.62_{a}	2.49_{bc}	1.91_{abc}	2.87_{bc}	1.44_{a}	1.60_{ab}

s.e.d. = 0.261

Different subscripts within a column indicate significant differences in numbers ($\log_{10}$ bacteria/cm^2).

Table 5. Effect of sampling site on bacterial contamination of pork carcasses at 9 abattoirs: comparison of sites for a given abattoir (horizontally).

Abattoir \ Site	1	2	3	4	5	6
A	2.09_{a}	2.95_{c}	2.58_{b}	2.86_{c}	2.52_{b}	2.91_{c}
B	3.33_{b}	3.44_{b}	3.47_{b}	3.45_{b}	3.32_{b}	2.98_{a}
C	4.07_{bc}	4.04_{bc}	3.97_{b}	4.43_{d}	4.22_{c}	2.67_{a}
D	3.07_{c}	3.00_{bc}	2.83_{b}	3.42_{d}	3.29_{d}	2.31_{a}
E	2.84_{bc}	3.11_{d}	3.04_{cd}	3.23_{d}	2.79_{b}	2.16_{a}
F	3.61_{b}	3.60_{b}	3.43_{b}	3.57_{b}	3.42_{b}	2.10_{a}
G	2.92_{c}	3.12_{c}	2.62_{b}	3.67_{d}	2.92_{c}	1.32_{a}
H	2.63_{bc}	3.07_{d}	2.60_{b}	2.81_{c}	2.56_{b}	1.83_{a}
I	2.65_{b}	3.04_{c}	2.71_{b}	3.03_{c}	2.94_{c}	1.92_{a}

s.e.d. = 0.102

Different subscripts across a row indicate significant differences in numbers ($\log_{10}$ bacteria/cm^2).

Table 6. Effect of sampling site on bacterial contamination of pork carcasses at 9 abattoirs: Comparison of abattoirs for a given site (vertically).

Site:	1	2	3	4	5	6
A	2.09_{a}	2.95_{a}	2.58_{a}	2.86_{ab}	2.52_{e}	2.91_{a}
B	3.33_{de}	3.44_{bc}	3.47_{d}	3.45_{de}	3.32_{e}	2.98_{cd}
C	4.07_{f}	4.04_{d}	3.97_{e}	4.43_{f}	4.22_{de}	2.67_{e}
D	3.07_{cd}	3.00_{a}	3.83_{ab}	3.42_{cd}	3.29_{cd}	2.31_{cd}
E	2.84_{bc}	3.11_{ab}	3.04_{bc}	3.23_{bcd}	2.79_{bc}	2.16_{ab}
F	3.61_{e}	3.60_{c}	3.43_{cd}	3.57_{de}	3.42_{bc}	2.10_{d}
G	2.92_{bc}	3.12_{ab}	2.62_{a}	3.67_{e}	2.92_{a}	1.32_{bc}
H	2.63_{b}	3.07_{ab}	2.60_{a}	2.81_{a}	2.56_{b}	1.83_{ab}
I	2.65_{b}	3.04_{a}	2.71_{ab}	3.03_{abc}	2.94_{bc}	1.92_{bc}

s.e.d. = 0.201
Different subscripts within a column indicate significant differences in numbers ($\log_{10}$ bacteria/cm^2).

Table 7. Analysis of variance based on the total data from the beef and pork survey.

Beef				
Source	d.f.	SS	MS	F-ratio
Whole-plots				
Abattoir	8	152.61	19.08	3.13
Residual (visit variation)	32	194.97	6.09	12.55
Total	40	347.58		
Sub-plots				
Site	7	481.43	68.78	141.65
Abattoir × site	56	149.92	2.68	5.51
Abattoir × visit × site	224	190.20	0.85	1.75
Abattoir × visit × animal	355	278.93	0.79	1.62
Residual	2411	1170.63	0.49	
Total	3053	2271.11		
Grand total	3093	2618.69		

Pork				
Source	d.f.	SS	MS	F-ratio
Whole-plots				
Abattoir	8	419.32	52.41	11.53
Residual (visit variation)	35	159.06	4.54	18.03
Total	43	578.38		
Sub-plots				
Site	5	342.56	68.51	271.81
Abattoir × site	40	171.87	4.30	17.05
Abattoir × visit × site	175	153.03	0.87	3.47
Abattoir × visit × animal	396	239.96	0.61	2.40
Residual	1932	486.97	0.25	
Total	2548	1394.39		
Grand total	2591	1972.77		

DISCUSSION

Bacterial counts on pork carcasses were consistently higher than those on beef, probably because of differences in slaughter methods. Beef slaughtering leaves a relatively clean carcass surface after the hide has been removed while on pork the contaminated skin remains on the carcass during and after the slaughter process.

In both surveys the insides of the carcasses were considerably less contaminated than the outsides. Several sites gave little information about differences in hygienic quality: sites 7 (10) and 8 (13) on beef carcasses (Tables 3 and 4) and site 6 (10) on pork carcasses (Tables 5 and 6). These sites could be omitted from future studies.

Beef Survey

Carcasses at abattoir C carried the highest numbers of bacteria although not significantly higher than at abattoirs A and E (Table 1). Abattoir C was the smallest in the survey and had no strict separation of the slaughter line into contaminated and clean zones. All the work along the slaughter line, including stunning the animals, was done by only 2—3 men.

Of the 3 abattoirs with partly lying lines (Abattoirs D, E and I), only E had results indicating greater contamination than those abattoirs with hanging lines. Compared with the other 2 abattoirs where evisceration and dressing the carcass were partly in the lying position, excessive amounts of water were used in abattoir E. Some water even sprayed the carcass before the hide was completely removed, thereby transferring dirt from the skin to the carcass. Setting aside this bad practice, there was no evidence to support the generally held view that slaughter and dressing in the hanging position is bacteriologically advantageous over the lying position (see also *Roberts* 1980). To a large extent the result must depend on the care and expertise of the operatives.

The ventral part of the carcass and the medial part of the upper hind limb were most heavily contaminated, probably due to the manual dressing in preparing the carcass for the hide puller (Table 2).

Sites 2 (the Brisket) and 6 (the Round) were consistently the dirtiest sites across abattoirs (Table 2), and when the bacte-

riological data for each abattoir was analysed separately (Table 3). By ranking the sites in decreasing order of contamination, 4 pairs of sites, significantly different from each other, became apparent.

Decreasing order of contamination ↓	Site 2 (2) and 6 (9)	Brisket and Round medial;
	„ 3 (3) and 4 (6)	Forerib and Flank groin;
	„ 1 (1) and 5 (8)	Neck and Round lateral;
	„ 7 (10) and 8 (13)	Flank medial and Forerib medial.

The abattoir × site interactions (Tables 3 and 4) suggest that much information about abattoir cleanliness could still be gained by reducing the number of sites to 4, namely 2 (2) Brisket, 3 (3) Forerib, 4 (6) Flank groin and 6 (9) Round medial.

Pork Survey

In this survey abattoir C was the most contaminated (Table 1).

The results from the abattoirs with singeing as a separate step (abattoirs A, E, H and I) were significantly better than the results from abattoirs B, C and F suggesting that machines which combine dehairing and singeing are less efficient than 2 separate processes.

Site 4 (7) Cheek was the most contaminated site overall followed by site 2 (3) Abdomen, lateral surface (Table 2).

Decreasing order of contamination ↓	Site 4 (7)	Cheek;
	„ 2 (3)	Abdomen, lateral surface;
	„ 5 (5)	Back of Neck;
	„ 1 + 3 (2 + 4)	Hind limb, lateral surface and Mid-dorsal region;
	„ 6 (10)	Abdomen, medial surface.

From inspection of the abattoir/site interactions (Tables 5 and 6) it appears that only site 6 can be ignored in future surveys. In most abattoirs site 2 (Abdomen), 4 (Cheek) and 5 (Neck) seem to be most contaminated.

Comparison with other data

Comparison of Norwegian data with that from other countries is difficult because small differences in sampling methodology, e.g. differences in the pressure with which the swab is applied, might be reflected in higher or lower recovery of bacteria from the carcasses. Assuming there to be no difference as a

consequence of different sampling methods, numbers of bacteria from different sites on beef carcasses in Norway, expressed as $\log_{10}$ per cm^2 (1.26—3.85; see Table 3) are (from *Ingram & Roberts* 1976, their Table V) of the same order as, and perhaps marginally lower than, England (1.90—3.7), Sweden (2.2—3.4) and New Zealand (1.3—4.3). The lowest counts recorded seem to be of the same order in all countries — between 10 and 100/cm^2.

Comparison of abattoir means (1.98—2.87, Table 1) with data from 1 abattoir in the UK (*Ingram & Roberts* 1976; their Table VIII) (2.84 ± 0.56 to 3.40 ± 0.60) show counts on Norwegian beef carcasses to be up to about 10 times lower.

Considering pork carcasses, data from England (*Ingram & Roberts* 1976; their Table VIII) shows bacterial counts on carcasses at 1 slaughterhouse to be of the same order (2.52 ± 0.35 to 3.29 ± 0.48 on 4 consecutive days) as presented here (2.58—3.90, Table 1).

Despite concern over the method of sampling and the simplified method of making viable counts, the data suggested that surveys at this level of visits and sampling would be adequate to detect slaughtering practice and improvements in hygienic performance.

Comparisons of this nature would be greatly facilitated if all future studies took into account variation between visits, carcasses and sites. If preliminary studies of the type described above are made, examining fewer sites per carcass may be justified.

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SAMMENDRAG

Hygienisk kvalitet av storfe- og svineslakt i Norge.

Den bakteriologiske kvaliteten på storfe- og griseslakt ble undersøkt ved 9 norske slakterier. Hvert slakteri ble besøkt flere ganger, og ved hvert besøk ble 10 storfe og 10 griseslakt undersøkt. På storfe var følgende steder på slaktet gjennomgående mest forurenset: brystet, ryggen, buken og innsiden av låret. Det ble ikke funnet at hengende storfeslakting hygienisk sett var bedre enn metoder hvor slaktet ligger inntil hudavtrekket. På gris var kinnet og buken mest forurenset. Den hygieniske kvaliteten på gris i slakterier hvor sviingen ble utført som eget trinn, synes å være bedre enn der hvor det ble brukt en kombinert svi- og skrapemaskin.

Der de metodiske forhold tillader en direkte sammenligning mellom resultater, tyder foreliggende undersøkelse på at den bakteriologiske kvaliteten på norske storfe- og griseslakt er den samme eller noe bedre enn i en del andre land.

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