*Journal of Food Protection, Vol. 64, No. 6, 2001, Pages 820–825*


# Microbiological Meat Quality in High- and Low-Capacity Slaughterhouses in Sweden

**INGRID B. HANSSON***

*Department of Bacteriology, Swedish Veterinary Institute, Box SE-751 89, Uppsala, Sweden*

MS 00-44: Received 16 February 2000/Accepted 18 October 2000

## ABSTRACT

The purpose of this study was to investigate the bacterial count on beef and pork carcasses, a comparison being made between different-sized slaughterhouses in Sweden. Samples were taken from the flank and sternum of 200 beef and 200 pork carcasses, with half of the samples being collected from low-capacity slaughterhouses. Sampling was carried out at the end of the slaughter-line from 25 beef carcasses and/or 25 pork carcasses in each abattoir. Analyses were performed of the aerobic microorganisms, coliform bacteria, coagulase-positive staphylococci, and presumptive *Escherichia coli.* No significant differences were found in the amount of aerobic microorganisms between pork carcasses from low- and high-capacity slaughterhouses. In beef carcasses, however, there was a significantly greater amount of aerobic microorganisms in beef carcasses slaughtered at low-capacity slaughterhouses. Within the group of high-capacity abattoirs there was a very small variation in the amount of aerobic bacteria between the different slaughterhouses that could be explained by their having almost the same evisceration technique. The evisceration technique differs more among the low-capacity slaughterhouses, which is probably the main reason for the wide variation in the amount of aerobic bacteria. Coliform bacteria, coagulase-positive staphylococci, and presumptive *E. coli* were more common on pork carcasses than on beef carcasses. There were also significantly higher amounts of these bacteria in pork carcasses from the high-capacity slaughterhouses.

When animals are presented for slaughter they have a large and very variable population of aerobic microorganisms on their hooves, hide, and within their intestinal tract. An absolute guarantee can never be given that the alimentary tract of healthy animals will be free from microorganisms pathogenic to humans *(7).* Generally, the internal surfaces of the carcasses are sterile, and transfer of bacteria results from dressing and skinning defects occurring during the slaughter process *(2).* Meat is a nutrient-rich substrate that can support the growth of a wide range of microorganisms *(10).* However, contamination could be minimized by slaughtering in a proper hygienic way.

The meat inspection in all slaughterhouses in Sweden is done according to the ordinance on slaughter of domestic animals and farmed game *(23).* The meat inspectors today are mainly looking for visible pathological findings such as arthritis and pleuritis, but invisible hazardous elements such as pathogenic bacteria have been receiving more attention during recent years.

Minimizing bacterial contamination of carcasses during and immediately after slaughter improves the microbiological safety of the meat. Most bacterial contamination of carcass surfaces occurs during slaughter and/or dressing procedures from a variety of sources, such as hides, intestinal contents, contact surfaces, and handling by workers. Fecal contamination of the hide of the cattle already at the farm is registered by the veterinary inspector at the antemortem inspection. The incidence of registered contaminated hide of all slaughtered cattle in Sweden 1997 was 1.1% *(4).* These 1.1% do not include cattle whose hide became contaminated during transport to the slaughterhouse. Contaminated hide during transport can be reduced if food is withheld for 3 to 6 h before trucking *(8).* If feed is not withdrawn before slaughter, the intestinal tract contains a large amount of ingesta, it is more difficult to handle during evisceration, and it is more likely to break or be accidentally cut, causing carcass contamination *(9).*

In January 1999 there were 80 cattle and swine abattoirs in Sweden, 47 of which were low-capacity slaughterhouses. The low-capacity abattoirs slaughter about 1 to 2% of the cattle and 0.3 to 0.5% of the swine in Sweden. The low-capacity slaughterhouses in Sweden are allowed to slaughter a maximum of 20 units/week and/or a maximum of 1,000 units/year *(23).* The management of the animals and carcasses differs between abattoirs, which might be of importance for carcass contents of bacteria and meat quality. At the low-capacity slaughterhouses the amounts and rates of the slaughter are considerably lower. A lower slaughter rate should lead to a reduction in stress for the workers and may result in better hygiene. However, an investigation in the United States showed that a high volume of beef slaughter led to a reduction in the total aerobic bacteria counts on brisket and ground beef *(6).* One explanation is that the slaughter process generally involves more specialization of labor, with each worker making fewer

* Author for correspondence. Tel: 0046-(0)18-674686; Fax: 0046-(0)18-674093. E-mail: Ingrid.Hansson@sva.se.

types of cuts, resulting in better control of contamination during the slaughter process. Among the high-capacity slaughterhouses, clean and unclean parts should be separated either by a wall or by a distance of at least 5 m *(23)*. The low-capacity slaughterhouses do not have to do this if they separate the management in time, which in practice means that the low-capacity abattoirs slaughter one animal at a time. Most of the low-capacity abattoirs have a small slaughter hall, and the same personnel do numerous different tasks that might lead to a higher risk of carcass contamination.

Fecal contamination of carcasses is not only responsible for spoilage of the meat, it also involves a risk of spreading pathogenic bacteria such as *Salmonella, Campylobacter, Yersinia,* and *E. coli*. These bacteria can inhibit the gut of healthy animals and may contaminate the carcass during slaughter. Infections of *Salmonella* and *Campylobacter* were the most reported foodborne infections in Sweden during the 1990s *(22)*.

The purpose of the study was to investigate the occurrence of different bacteria on the carcasses and compare the differences between the low- and the high-capacity slaughterhouses. The results are discussed in relation to the different sizes and evisceration techniques at the slaughterhouses.

## MATERIALS AND METHODS

**Slaughterhouses.** This study was conducted in 1998 at different-sized abattoirs that slaughter cattle and/or swine. Samples were taken from eight abattoirs that slaughtered cattle. The four high-capacity slaughterhouses designated A, B, C, and D in the study slaughtered between 30,000 and 75,000 cattle/year and the four low-capacity slaughterhouses designated i, k, l, and m slaughtered between 125 and 750 cattle/year. Among the eight swine slaughterhouses, the four big ones designated E, F, G, and H slaughtered between 250,000 and 1,300,000 pigs/year, and the four small, designated n, o, p, and r, slaughtered between 450 and 800 pigs/year. The low-capacity slaughterhouses were randomly selected, whereas the four of those with the highest slaughter volume in Sweden were selected.

The evisceration technique was about the same within the group of high-capacity slaughterhouses, whereas in the group of low-capacity abattoirs there was more variation in the slaughtering hall and the evisceration technique. When slaughtering pigs, all of the high-capacity slaughterhouses used scalding by water with the carcass suspended from a rail, followed by dehairing. The low-capacity abattoirs used scalding by water in a vat with simultaneous dehairing.

At the high-capacity abattoirs, the slaughtering was done 5 days a week, but at the low-capacity slaughterhouses the slaughtering ranged from 1 to 5 days/week. A factor common to the low-capacity slaughterhouses, l, p, and r, was that the slaughter was done by at least four workers and they had only 1 slaughter day a week. Each worker did only a few tasks, and there was nearly no movement of staff between the clean and unclean parts of the slaughtering line. At these abattoirs one worker made an extra control and removed any contamination on the carcass before it was placed in the cold room.

All of the high-capacity abattoirs, together with the low-capacity slaughterhouses l and p, used a plastic bag when sealing off the rectum to avoid fecal contamination during slaughter.

The abattoir with the biggest slaughtering hall among the low-capacity slaughterhouses was l for beef and p for pork. The smallest slaughtering halls in the study were i for cattle and n for swine, and at these abattoirs the entire slaughtering routine was done at the same place, and one worker did almost everything, including handling the animal in the stable.

In low-capacity abattoir m, one worker did the killing, bleeding, took away the head and bone, and started the dehiding in one hall. In the next hall, another worker finished the dehiding and the rest of the slaughter. In abattoir r, the killing, bleeding, and initial cleaning of the pigs was done in a separate compartment.

**Bacterial sampling.** Samples were taken from 100 $cm^2$ of the loin and 100 $cm^2$ at the sternum of 200 beef and 200 pork carcasses, half of the samples being collected from low-capacity slaughterhouses. Sampling was carried out at the end of the slaughter-line from 25 beef carcasses and/or 25 pork carcasses in each abattoir on at least three occasions. The same operator collected all samples that were cultured within 24 h. Sampling was carried out with sterile cotton swabs moistened with 0.1% peptone water (Oxoid L 37, Basingstoke, UK) and using a sterile glove.

**Microbiological analysis.** For quantitative analysis, 10-fold serial dilution's were made in peptone water.

Aerobic microorganisms were detected and counted on plate count agar (1.05463; Merck, Rahway, N.J.), incubated at 30°C for 3 days. Coagulase-positive staphylococci were detected on Baird-Parker-agar (Oxoid CM 275) and incubated at 37°C for 2 days, and suspected colonies were confirmed by the coagulase test on horse plasma at 37°C for 24 h. Coliform bacteria were detected on violet red bile agar (Oxoid CM 107), incubated at 37°C for 24 h, and confirmed in brilliant green bile salt lactose broth (Oxoid CM 31) within 24 h at 37°C. Presumptive *E. coli* were preincubated in tryptone soya agar (Oxoid CM 131) for 1 to 2 h at room temperature (20 to 25°C), and after that violet red bile agar (Oxoid CM 107) was poured on top of the agar. The dishes were incubated at 44°C for 24 h, and colonies with a typical appearance were confirmed in lactose tryptone lauryl sulfate broth (Oxoid CM 921) and incubated for 24 h at 44°C.

**Statistical analysis.** The data from the study were compiled and analyzed by use of StatView software *(20)*, and the statistical significance was determined by the chi-square test *(13)*.

## RESULTS

**Aerobic microorganisms.** In beef carcasses, there was a significantly higher amount of aerobic bacteria in carcasses slaughtered at low-capacity slaughterhouses. In the study, a mean of 2.59 $\log_{10}$ CFU/$cm^2$ aerobic microorganisms was found in samples from beef at the high-capacity slaughterhouses, and a mean of 3.44 $\log_{10}$ CFU/$cm^2$ was detected at low-capacity abattoirs (Table 1).

There were no significant differences in the count of aerobic microorganisms between pork carcasses from low- and high-capacity slaughterhouses. The mean of the pork carcasses was 3.44 $\log_{10}$ CFU/$cm^2$ at the high-capacity and 3.34 $\log_{10}$ CFU/$cm^2$ at the low-capacity slaughterhouses (Table 1).

Within the group of high-capacity slaughterhouses there was no difference in the amount of aerobic microorganisms (Tables 2 and 3). The variation in aerobic microorganisms was bigger within the group of low-capacity slaughterhouses (Tables 2 and 3).

TABLE 1. *The amount of aerobic microorganisms in samples from beef carcasses and pork carcasses from the different-sized slaughterhouses*

| | Mean $\log_{10}$ CFU/ $cm^2$ | SD | Minimum $\log_{10}$ CFU/ $cm^2$ | Maximum $\log_{10}$ CFU/ $cm^2$ |
|---|---|---|---|---|
| Beef | | | | |
| High-capacity slaughterhouses | 2.59 | 0.64 | 1.30 | 4.92 |
| Low-capacity slaughterhouses | 3.44 | 1.01 | 1.29 | 6.88 |
| Pork | | | | |
| High-capacity slaughterhouses | 3.44 | 0.40 | 2.64 | 4.95 |
| Low-capacity slaughterhouses | 3.34 | 1.03 | 1.54 | 6.04 |

**Coagulase-positive staphylococci.** In beef carcasses, coagulase-positive staphylococci were detected in 9% of the samples from the high-capacity and in 16% of the beef samples from the low-capacity slaughterhouses (Fig. 1). All of the nine samples from the high-capacity abattoirs were from the same slaughterhouse (Table 4). In beef lines more than 10 staphylococci/$cm^2$ were found in 3% of the high-capacity and 8% of the low-capacity abattoirs. The largest amount of staphylococci on a beef carcass came from a low-capacity slaughterhouse and was 266 CFU/$cm^2$ (Table 4).

On pork carcasses, coagulase-positive staphylococci were detected in 49% of the samples from the high-capacity slaughterhouses. Among the low-capacity abattoirs coagulase-positive staphylococci were detected in 16% of the pork carcasses (Fig. 1). This difference in staphylococci on pork carcasses from the different-sized slaughterhouses was statistically significant ($P < 0.001$). The largest amount of staphylococci from pork carcasses was taken at a high-capacity slaughterhouse and was 145 CFU/$cm^2$ (Table 5). On pork carcasses, 32% of the samples from high-capacity and only 2% of the low-capacity slaughterhouses had more than 10 coagulase-positive staphylococci/$cm^2$ (Table 5).

TABLE 2. *The amount of aerobic microorganisms in samples from beef carcasses from the high-capacity slaughterhouses A through D and the low capacity slaughterhouses i through m*

| | Mean $\log_{10}$ CFU/$cm^2$ | SD | Minimum $\log_{10}$ CFU/$cm^2$ | Maximum $\log_{10}$ CFU/$cm^2$ |
|---|---|---|---|---|
| High capacity | | | | |
| Slaughterhouse A | 2.82 | 0.47 | 2.19 | 4.26 |
| Slaughterhouse B | 2.40 | 0.58 | 1.48 | 3.45 |
| Slaughterhouse C | 2.66 | 0.77 | 1.43 | 4.92 |
| Slaughterhouse D | 2.47 | 0.64 | 1.30 | 3.78 |
| Low capacity | | | | |
| Slaughterhouse i | 4.63 | 0.67 | 3.52 | 6.88 |
| Slaughterhouse k | 3.43 | 0.37 | 2.83 | 4.40 |
| Slaughterhouse l | 2.55 | 0.96 | 1.29 | 5.14 |
| Slaughterhouse m | 3.20 | 0.53 | 2.41 | 4.58 |

TABLE 3. *The amount of aerobic microorganisms in samples from pork carcasses from the high-capacity slaughterhouses E through H and the low capacity slaughterhouses n through r*

| | Mean $\log_{10}$ CFU/$cm^2$ | SD | Minimum $\log_{10}$ CFU/$cm^2$ | Maximum $\log_{10}$ CFU/$cm^2$ |
|---|---|---|---|---|
| High capacity | | | | |
| Slaughterhouse E | 3.50 | 0.43 | 2.91 | 4.59 |
| Slaughterhouse F | 3.55 | 0.31 | 3.06 | 4.41 |
| Slaughterhouse G | 3.29 | 0.48 | 2.72 | 4.95 |
| Slaughterhouse H | 3.43 | 0.36 | 2.64 | 4.00 |
| Low capacity | | | | |
| Slaughterhouse n | 4.71 | 0.56 | 3.72 | 6.04 |
| Slaughterhouse o | 3.61 | 0.45 | 3.01 | 5.10 |
| Slaughterhouse p | 2.53 | 0.62 | 1.54 | 4.01 |
| Slaughterhouse r | 2.55 | 0.36 | 1.96 | 3.35 |

**Coliform bacteria.** Coliform bacteria were found at all abattoirs in at least two samples (Tables 6 and 7).

On beef carcasses, coliform bacteria were found in 50% of the samples from high-capacity and 42% of the samples from low-capacity slaughterhouses (Fig. 1). The highest value of coliform bacteria on beef from high-capacity abattoirs was 370 bacteria/$cm^2$ and from low-capacity abattoirs 15,000 coliform bacteria/$cm^2$ (Table 6).

A significant difference ($P < 0.001$) in coliform bacteria on pork carcasses was found between the different-sized abattoirs. At the high-capacity abattoirs, coliform bacteria were detected in 86% of the samples and 58% from low-capacity slaughterhouses (Fig. 1). The highest value of coliform bacteria on pork carcasses from high-capacity abattoirs was 345 coliform bacteria/$cm^2$ and from low-capacity 5,500 coliform bacteria/$cm^2$.

At two of the pork abattoirs, F and n, coliform bacteria were found in all of the samples (Tables 6 and 7).

**Presumptive *E. coli*.** Presumptive *E. coli* were found at all slaughterhouses in one or more sample. At the high-capacity abattoirs, presumptive *E. coli* were found in 34% of the samples of the beef carcasses and in 41% of the samples from the low-capacity slaughterhouses (Fig. 1). The highest values of presumptive *E. coli* found on beef from the high-capacity abattoirs were 15 CFU/$cm^2$ and from low-capacity slaughterhouses 315 CFU/$cm^2$ (Table 8).

The highest percentage (74%) of presumptive *E. coli* was in samples taken on pork at high-capacity abattoirs; in

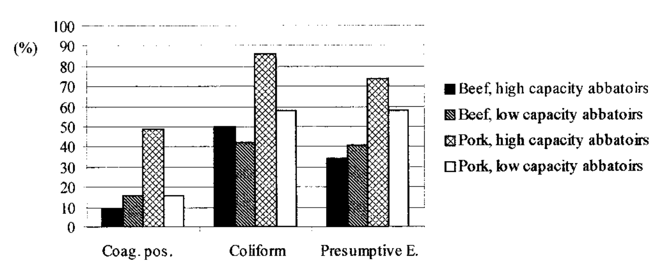


FIGURE 1. *Percentage of the samples with coagulase-positive staphylococci, coliform bacteria, and presumptive* E. coli.

TABLE 4. *The amount of coagulase-positive staphylococci on beef carcasses at the different slaughterhouses*

| | Not detected | 1–10 CFU/ cm² | 11–50 CFU/ cm² | 51–100 CFU/ cm² | 101–300 CFU/ cm² |
|---|---|---|---|---|---|
| All high capacity | 91 | 6 | 3 | 0 | 0 |
| Slaughterhouse A | 16 | 6 | 3 | 0 | 0 |
| Slaughterhouse B | 25 | 0 | 0 | 0 | 0 |
| Slaughterhouse C | 25 | 0 | 0 | 0 | 0 |
| Slaughterhouse D | 25 | 0 | 0 | 0 | 0 |
| All low capacity | 84 | 8 | 7 | 0 | 1 |
| Slaughterhouse i | 18 | 2 | 4 | 0 | 1 |
| Slaughterhouse k | 25 | 0 | 0 | 0 | 0 |
| Slaughterhouse l | 21 | 3 | 1 | 0 | 0 |
| Slaughterhouse m | 20 | 3 | 2 | 0 | 0 |

TABLE 6. *The amount of coliform bacteria on beef carcasses at the different slaughterhouses*

| | Not detected | 1–10 CFU/cm² | 11–100 CFU/cm² | 101–1,000 CFU/ cm² | 1,001–15,000 CFU/ cm² |
|---|---|---|---|---|---|
| All high capacity | 50 | 45 | 4 | 1 | 0 |
| Slaughterhouse A | 10 | 13 | 1 | 1 | 0 |
| Slaughterhouse B | 21 | 4 | 0 | 0 | 0 |
| Slaughterhouse C | 13 | 11 | 1 | 0 | 0 |
| Slaughterhouse D | 6 | 17 | 2 | 0 | 0 |
| All low capacity | 58 | 28 | 10 | 2 | 2 |
| Slaughterhouse i | 7 | 8 | 6 | 2 | 2 |
| Slaughterhouse k | 10 | 13 | 2 | 0 | 0 |
| Slaughterhouse l | 20 | 3 | 2 | 0 | 0 |
| Slaughterhouse m | 21 | 4 | 0 | 0 | 0 |

pork from low-capacity slaughterhouses presumptive *E. coli* were found in 58% of the samples (Fig. 1). These differences of presumptive *E. coli* were significant ($P < 0.05$) between the different-sized abattoirs. At swine slaughterhouses F and n, presumptive *E. coli* were found in all of the samples. Swine carcasses at these abattoirs had more bristle left on the rind compared with pork carcasses from other abattoirs. In samples from pork, the highest values of presumptive *E. coli* were 315 CFU/cm² at the high-capacity and 107 CFU/cm² from the low-capacity slaughterhouses (Table 9).

## DISCUSSION

Within the group of high-capacity abattoirs there were very small variations in the amount of aerobic bacteria between the different slaughterhouses (Tables 2 and 3), which could be explained by almost the same evisceration technique being used in both places. The evisceration technique differs more among the low-capacity slaughterhouses, which probably is the main reason for the big variation in the amount of aerobic bacteria (Tables 2 and 3).

To avoid contamination during removal of the skin, it is essential that the hide does not touch the already dehided surfaces. The great majority of mesophilic or psychrotrophic bacteria found on cattle carcasses immediately after slaughter and dressing derive from the hide *(12)*. Wet and dirty hides from cattle may be the source of a strong contamination of the dehided carcasses *(19)*. Excessive moisture conditions generally result in higher levels of hide contamination *(10)*. At abattoirs i and n, with the greatest amount of aerobic microorganisms, one worker did almost all the slaughtering work, including handling the animal in the stable, which involved the risk of transferring bacteria from the stable and hide onto the carcasses.

At the low-capacity abattoirs, fewer animals are slaughtered per hour, and the same personnel do more different cuts on the same carcass. The whole slaughter process might be done in one place because of lack of space, which might involve a higher risk of fecal contamination. A larger slaughtering hall results in a longer distance between the clean and unclean parts of the abattoir. The low-capacity abattoirs in the study that have separated clean and unclean parts of the slaughter and have minimized the movement of workers between the unclean and the clean areas appear to be associated with decreased carcass contamination levels. This has also been observed in a Finnish study *(15)*.

Staphylococci can colonize the nasal cavity, skin, and

TABLE 5. *The amount of coagulase-positive staphylococci on pork carcasses at the different slaughterhouses*

| | Not detected | 1–10 CFU/cm² | 11–50 CFU/cm² | 51–100 CFU/ cm² | 101–300 CFU/ cm² |
|---|---|---|---|---|---|
| All high capacity | 51 | 17 | 28 | 2 | 2 |
| Slaughterhouse E | 11 | 5 | 9 | 0 | 0 |
| Slaughterhouse F | 4 | 6 | 11 | 2 | 2 |
| Slaughterhouse G | 16 | 5 | 4 | 0 | 0 |
| Slaughterhouse H | 20 | 1 | 4 | 0 | 0 |
| All low capacity | 84 | 14 | 2 | 0 | 0 |
| Slaughterhouse n | 18 | 6 | 1 | 0 | 0 |
| Slaughterhouse o | 25 | 0 | 0 | 0 | 0 |
| Slaughterhouse p | 18 | 6 | 1 | 0 | 0 |
| Slaughterhouse r | 23 | 2 | 0 | 0 | 0 |

TABLE 7. *The amount of coliform bacteria on pork carcasses at the different slaughterhouses*

| | Not detected | 1–10 CFU/cm² | 11–100 CFU/cm² | 101–1,000 CFU/cm² | 1,001–10,000 CFU/ cm² |
|---|---|---|---|---|---|
| All high capacity | 14 | 54 | 25 | 7 | 0 |
| Slaughterhouse E | 1 | 21 | 2 | 1 | 0 |
| Slaughterhouse F | 0 | 4 | 16 | 5 | 0 |
| Slaughterhouse G | 12 | 13 | 0 | 0 | 0 |
| Slaughterhouse H | 1 | 16 | 7 | 1 | 0 |
| All low capacity | 42 | 38 | 7 | 10 | 3 |
| Slaughterhouse n | 0 | 13 | 4 | 6 | 2 |
| Slaughterhouse o | 1 | 16 | 3 | 4 | 1 |
| Slaughterhouse p | 18 | 7 | 0 | 0 | 0 |
| Slaughterhouse r | 23 | 2 | 0 | 0 | 0 |

TABLE 8. *The amount of presumptive* E. coli *on beef carcasses at the different slaughterhouses*

| | Not detected | 1–10 CFU/cm² | 11–50 CFU/cm² | 51–100 CFU/cm² | 101–350 CFU/cm² |
|---|---|---|---|---|---|
| All high capacity | 66 | 32 | 2 | 0 | 0 |
| Slaughterhouse A | 9 | 15 | 1 | 0 | 0 |
| Slaughterhouse B | 24 | 1 | 0 | 0 | 0 |
| Slaughterhouse C | 14 | 10 | 1 | 0 | 0 |
| Slaughterhouse D | 19 | 6 | 0 | 0 | 0 |
| All low capacity | 59 | 36 | 3 | 0 | 2 |
| Slaughterhouse i | 7 | 14 | 2 | 0 | 2 |
| Slaughterhouse k | 9 | 16 | 0 | 0 | 0 |
| Slaughterhouse l | 22 | 2 | 1 | 0 | 0 |
| Slaughterhouse m | 21 | 4 | 0 | 0 | 0 |

TABLE 9. *The amount of presumptive* E. coli *on pork carcasses at the different slaughterhouses*

| | Not detected | 1–10 CFU/cm² | 11–50 CFU/cm² | 51–100 CFU/cm² | 101–350 CFU/cm² |
|---|---|---|---|---|---|
| All high capacity | 26 | 44 | 17 | 7 | 6 |
| Slaughterhouse E | 6 | 15 | 3 | 0 | 1 |
| Slaughterhouse F | 0 | 6 | 10 | 5 | 4 |
| Slaughterhouse G | 15 | 9 | 1 | 0 | 0 |
| Slaughterhouse H | 5 | 14 | 3 | 2 | 1 |
| All low capacity | 42 | 44 | 12 | 1 | 1 |
| Slaughterhouse n | 0 | 18 | 7 | 0 | 0 |
| Slaughterhouse o | 1 | 19 | 3 | 1 | 1 |
| Slaughterhouse p | 23 | 1 | 1 | 0 | 0 |
| Slaughterhouse r | 18 | 6 | 1 | 0 | 0 |

mucous membranes and can be transient in the intestinal tract *(14)*. The high amount of coagulase-positive staphylococci in slaughterhouses F and n are probably due to them having more bristle left on the rind compared with the other slaughterhouses. However, the finding of staphylococci suggests contamination either from the animal or from humans. *S. aureus* is usually carried by humans, as shown by Heinzel *(5)* and De Wit and Kampelmacher *(1),* and Saide et al. *(16)* showed a linear increase of *S. aureus* isolates from carcasses sampled during the slaughtering processes.

Siragusa et al. *(17)* showed that the presence of *E. coli* was more common in beef carcasses with large amounts (>4 $\log_{10}$ CFU/cm²) of mesophilic aerobic microorganisms. In this study, beef slaughterhouse i that had a mean of 4.6 $\log_{10}$ CFU/cm² aerobic microorganisms was the abattoir with the greatest amount and percentage of *E. coli.* Grau *(3)* showed that the perianal area and rectal cavity are usually contaminated by *E. coli* during removal of the lower intestinal tract. By sealing off the rectum with a plastic bag immediately after it had been freed, the spread of bacteria on the carcasses could be considerably reduced. Nesbakken et al. *(11)* showed that the plastic bag technique prevents the dissemination of *Yersinia enterocolitica* and other pathogens that are spread by the feces. All of the high-capacity slaughterhouses, together with low-capacity slaughterhouses l and p, used the plastic bag technique. Among the low-capacity slaughterhouses, l and p were the ones with the lowest percentage of detected *E. coli* (Tables 8 and 9).

The greatest reduction of bacterial load on the skin of the swine is achieved by singeing or flaming *(7, 19, 21).* Carcasses from abattoirs F and n had more bristle left on the rind compared with the other slaughterhouses. These abattoirs were the only ones with coliform bacteria in all the samples, and they also had the greatest amount of coliform bacteria and *E. coli* (Tables 7 and 9). By scalding at the right temperature, the count from pork skin can be reduced by 2 $\log_{10}$ CFU *(7, 18).* However, there is a risk that in the backscraping and polishing machine, pig carcasses may often be severely recontaminated *(7, 19, 21).*

## CONCLUSIONS

The study shows that the level of carcass contamination cannot be related to the size of the slaughterhouse. Good manufacturing practices during slaughtering could reduce the level of contamination remarkably. There were no significant differences in aerobic microorganism counts between pork carcasses from the different-sized slaughterhouses. However, among beef samples, there was a significantly greater amount of aerobic bacteria in carcasses slaughtered at low-capacity slaughterhouses.

Within the group of high-capacity slaughterhouses, there were no significant differences in aerobic microorganisms (Tables 2 and 3), and the evisceration technique was also about the same at these abattoirs. The evisceration technique differs more among the low-capacity slaughterhouses, which probably is the main reason for the wide variation in the amounts of aerobic bacteria. The low-capacity abattoirs that have separated clean and unclean parts of the slaughter procedure and have minimized the movement of workers between the unclean and the clean areas appear to be associated with decreased carcass contamination level.

Bacteria such as coagulase-positive staphylococci, coliform bacteria and presumptive *E. coli* were more common in samples of pork carcasses than in beef. These bacteria were found more often in pork carcasses from the big abattoirs than in pork carcasses from low-capacity slaughterhouses.

## ACKNOWLEDGMENTS

The author gratefully acknowledges the Elsa and Ivar Sandbergs Research Foundation for financial support and the staff at the slaughterhouses participating in the study for making this work possible. The author also thanks the staff at the Food Laboratory of the Department of Food Hygiene at the Swedish University of Agricultural Sciences for assistance with the microbiological analysis.

## REFERENCES

1. De Wit, J. C., and E. H. Kampelmacher. 1981. Some aspects of microbial contamination of hands of workers in food industries. Zbl. Bakt. Hyg. I. Abt. Orig. B 172:390–400.
2. Gill, C. O., and N. Penny. 1979. Survival of bacteria in carcasses. Appl. Environ. Microbiol. 37:667–669.

3. Grau, F. H. 1979. Fresh meats: bacterial association. Arch. Lebensmittelhyg. 30:87–92.
4. Hansson, I., C. Hamilton, T. Ekman, and K. Forslund. 2000. Carcass quality in certified organic production compared with conventional livestock production. J. Vet. Med. B 47:111–120.
5. Heinzel, M. 1984. Importance of personal hygiene during meat processing. Fleischwirtschaft 64:1366–1368.
6. Hogue, A. T., D. W. Dreesen, S. S. Green, R. D. Ragland, W. O. James, E. A. Bergeron, L. V. Cook, M. D. Pratt, and D. R. Martin. 1993. Bacteria on beef briskets and ground beef: correlation with slaughter volume and antemortem condemnation. J. Food Prot. 56: 110–113, 119.
7. Huis in't Veld, J. H. J., R. W. A. W. Mulder, and J. M. A. Snijders. 1994. Impact of animal husbandry and slaughter technologies on microbial contamination of meat; monitoring and control. Meat Sci. 36:123–154.
8. Mackey, B. M., and T. A. Roberts. 1990. Hazard analysis and critical control programmes in relation to slaughter hygiene, p. 3–18. World Association of Veterinary Food Hygienists, Dublin.
9. Miller, M. F., M. A. Carr, D. B. Bawcom, C. B. Ramsey, and L. D. Thompson. 1997. Microbiology of pork carcasses from pigs with differing origins and feed withdrawal times. J. Food Prot. 60:242–245.
10. National Advisory Committee on Microbiological Criteria for Foods. 1993. Generic HACCP for raw beef. Food Microbiol. 10:449–488.
11. Nesbakken, T., E. Nerbrink, O. J. Røtterud, and E. Borch. 1994. Reduction of *Yersinia enterocolitica* and *Listeria* spp. on pig carcasses by enclosure of the rectum during slaughter. Int. J. Food Microbiol. 23:197–208.
12. Newton, K. G., J. C. L. Harrison, and A. M. Wauters. 1978. Sources of psychrotrophic bacteria on meat at the abattoir. J. Appl. Bacteriol. 45:75–82.
13. Petrie, A., and P. Watson. 1999. Statistics for veterinary and animal science. Blackwell Science, Oxford.
14. Quinn, P. J., M. E. Carter, B. Markey, and G. R. Carter. 1998. Clinical veterinary microbiology. Mosby International, London.
15. Rahkio, T. M., and H. J. Korkeala. 1997. Airborne bacteria and carcass contamination in slaughter-houses. J. Food Prot. 60:38–42.
16. Saide-Albornoz, J. J., C. L. Knipe, E. A. Murano, and G. W. Beran. 1995. Contamination of pork carcasses during slaughter, fabrication, and chilled storage. J. Food Prot. 58:993–997.
17. Siragusa, G. R., W. J. Dorsa, C. N. Cutter, G. L. Bennett, J. E. Keen, and M. Koohmaraie. 1998. The incidence of *Escherichia coli* on beef carcasses and its association with aerobic mesophilic plate count categories during the slaughter process. J. Food Prot. 61:1269–1274.
18. Snijders, J. 1988. Good manufacturing practices in slaughter lines. Fleischwirtschaft 68:753–756.
19. Snijders, J. M. A., G. E. Gerats, and J. G. van Logtestijn. 1984. Good manufacturing practices during slaughtering. Arch. Lebensmittelhyg. 35:99–103.
20. StatView. 1998. Using statView. SAS Institute Inc., Cary, N.C.
21. Stolle, F. A. 1987. Factors in animal husbandry and slaughter methods which influence the carcass microflora, p. 131–146. Proc. Finnish Veterinary Days, Finnish Veterinary Association, Helsinki.
22. Swedish Institute for Infectious Disease Control. 1998. Annual epidemiological report. Infectious diseases in Sweden 1997.
23. The National Food Administration. 1996. SLV FS 1996:32, Saknr H 190, Livsmedelsverkets kungörelse om slakt av tamboskap och hägnat vilt (The National Food Administrations Ordinance on Slaughter of Domestic Animals and Farmed Game). Uppsala, Sweden.