Effect of separate transport, lairage, and slaughter on occurrence of Salmonella Typhimurium on slaughter carcasses

Der Einfluss von Einzeltransport, Ausruhzeit und Schlachtung auf das Vorkommen von Salmonella Typhimurium auf Schlachtkörpern

Jaap Boes\textsuperscript{1}, Jan Dahl\textsuperscript{1}, Bent Nielsen\textsuperscript{1}, Hans Henrik Krog\textsuperscript{2}

\textsuperscript{1} Veterinary and Food Advisory Service, Danish Bacon & Meat Council, Axelborg, Axeltoft 3, DK-1609 Copenhagen, Denmark, Email: jbo@danishmeat.dk; \textsuperscript{2} Stoff-Houlberg, Bragesvej 18, PO Box 120, DK-4100 Ringsted, Denmark

Summary:
The study aimed to reduce cross-contamination between finishers from Salmonella-positive and Salmonella-negative herds during transport, lairage, and slaughter, thereby reducing the prevalence of Salmonella Typhimurium on slaughter carcasses. In Phase 1 of the study, pigs from Salmonella-negative herds were kept in lairage for 2-4 hours either in clean pens (intervention group) or pens contaminated with Salmonella-infected faeces (control group). All pigs were slaughtered on the same slaughterline, and carcass swabs 24 hours after slaughter revealed a low degree of cross-contamination in the pens: there was no difference in Salmonella-positive carcasses between intervention (1.7\%) and control groups (0.8\%). In Phase 2, control pigs from Salmonella-negative herds were mixed with pigs from Salmonella-positive herds during lairage for 2 - 4 hours, while the intervention group still consisted of pigs from Salmonella-negative herds. All pigs were slaughtered on the same line: first intervention, then control. Carcass swabs taken 24 hours after slaughter failed to show a reduction in Salmonella-positive carcasses in the intervention group (4.5\%) compared with the originally Salmonella-negative pigs in the control group (3.6\%). In pigs from Salmonella-positive herds the occurrence of Salmonella was substantially higher at 10.4\%. When the results were corrected for 6 carcass samples found positive with S. Heidelberg on the same day, which was attributed to a transient hygiene failure, only 2.2\% of the carcasses in the intervention group were Salmonella-positive. We conclude that even though cross-contamination occurs in the abattoir pens, its importance on the slaughter line may be greater. However, the final results of this
study should be awaited to conclude whether separate slaughter of pigs from Salmonella-positive and Salmonella-negative herds should be recommended.

Keywords: Salmonella, pigs, lairage, carcass swabs, cross-contamination

Introduction
The lairage at slaughterhouses is considered an important source for Salmonella infections in finishing pigs. The percentage of Salmonella-positive samples collected in the lairage may be as high as 90 % when pigs are present (Swanenburg et al., 2001). Regular cleaning and disinfection procedures may reduce the prevalence of Salmonella in the lairage to 25 % (Swanenburg et al., 2001) but will not eliminate the problem. In fact, 8 % of environmental samples collected before the onset of slaughter have been shown to be Salmonella-positive (Hald, 2001).
Upon ingestion, Salmonella rapidly colonizes various body parts of the pig and can be found in the caecum 3-4 hours after uptake (Fedorka-Cray et al., 1995). Therefore, cross-contamination with Salmonella in the lairage contributes significantly to the number of Salmonella-positive pigs slaughtered. This is even more important for pigs originating from Salmonella-free herds, which are very likely to become infected in lairage.
Cross-contamination also occurs during the different slaughter procedures. Especially insufficient cleaning of equipment has been shown to contribute to carcass contamination (Hald, 2001). In addition, contamination increases as the day progresses (Berends et al., 1997; Hald, 2001). This constitutes another major risk of Salmonella-free finishers becoming contaminated during slaughter.
In the Danish Salmonella Surveillance Program (Mousing et al., 1997) more than 60 % of the finishing herds in Denmark are seronegative as measured by the meat juice ELISA. In an attempt to further improve the Surveillance Program, it was proposed to limit contact between finishers from Salmonella-negative herds and finishers from Salmonella-positive herds, including the low level infected herds, during transport and at the slaughterhouse. The aim of this study was to reduce cross-contamination between finishers from Salmonella-positive and Salmonella-negative herds during transport, lairage and slaughter, thereby reducing the prevalence of Salmonella Typhimurium on slaughter carcasses.

Materials and Methods
The study was carried out at a large slaughterhouse in Ringsted, Denmark. The majority of finisher herds supplying pigs to this slaughterhouse are classified as Salmonella Level 1 herds (a low level of Salmonella), with a sub-classification “Level 0” which indicates that these herds are considered to be Salmonella-free, as monitored in the Danish Salmonella Surveillance Program. The abattoir also slaughters Level 2 and 3 finishers on separate days on 2 of the 4 slaughter lines. All Level 1 finishers that were included in this study originated from “Level 0” herds.
Each month at least six Level 0 herds were selected to supply finishers for the study. In addition, two or three Level 2 herds were selected each month to supply *Salmonella*-infected finishers to contaminate part of the lairage.

**Phase 1**
The first part of the study was carried out over a period of 13 weeks, on 2 slaughter days per week. At the abattoir 6 large waiting pens were allocated as follows: 3 pens to a control group and 3 pens to an intervention group. Control was defined as “exposed to *Salmonella*”, which meant contact with *Salmonella*-containing faeces in the pens. Intervention was defined as “not exposed to *Salmonella*”, which meant housing in clean pens. Each pen housed approximately 40 pigs on each occasion, i.e. 120 pigs in the control group and 120 pigs in the intervention group per slaughter day. All pigs were slaughtered on the same slaughter line, the intervention group before the control group.

Finishers from *Salmonella*-negative herds (Level 0 herds) were exposed to *Salmonella*-containing faeces only. This was achieved by housing 120 finishers from two or three known Level 2 herds in 3 of the 6 pens for 2-4 hours. After this contamination period the Level 2 pigs were removed from the pens and slaughtered at a different slaughter line not involved in the study. Subsequently, all 6 pens were filled with Level 0 finishers. Pigs from each herd were divided equally between control and intervention pens. After 2-4 hours all pigs were slaughtered.

Two pooled faeces samples were collected from each pen: 1 before the arrival of the pigs and 1 after the pigs had left the pen, as a rough estimate of the amount of *Salmonella* present. When no faeces was present (intervention pens before the pigs arrived) a swab sample was taken of the pen floor. At 24 hours after slaughter, carcass swab samples were taken in the cooling room. On each carcass 3 areas were sampled: 100 cm$^2$ on the hind leg, near the tail; 100 cm$^2$ near the sternum; and 100 cm$^2$ on the jowl. Carcass samples were pooled as follows: 5 individual samples were pooled into one sample before bacteriological analysis, resulting in 20 pooled samples per slaughter day per group. Bacteriological analysis was carried out according to standard procedures (Anonymous, 1991).

**Phase 2**
The number and origin of the pigs, as well as the pens included in Phase 2 was the same as in Phase 1. Phase 2 also lasted for 13 weeks with samplings on 2 slaughter days each week.

During this phase, finishers from *Salmonella*-negative herds were exposed to *Salmonella*-infected pen mates. The control group consisted of both Level 0 and Level 2 finishers, mixed in equal numbers in 3 pens. The intervention group consisted of Level 0 pigs only, as in Phase 1. This time the Level 2 finishers were not removed from the pens but slaughtered together with the other control pigs. As
in Phase 1, the intervention group was slaughtered before the control group on the same slaughter line. Faeces samples were not collected in this part of the study. Carcass swab samples were collected as described for Phase 1, with the exception that in the control group pooled carcass samples were distinguished between Level 0 and Level 2 pigs. This way, 20 carcass samples were collected from Level 0 finishers in the intervention group, while in the control group 10 pooled samples were collected from Level 0 pigs and 10 samples from Level 2 pigs.

Results
Due to logistical problems it was not always possible to identify all carcasses in the cooling room the day after slaughter. Especially at the start of Phase 2, several carcass swab samples of the Level 0 finishers in the control group could not be taken.

Phase 1
The results of the faecal sampling are shown in Table 1A and 1B. In the control group, 19% of the pooled pen samples were *Salmonella*-positive. There was an increase in *Salmonella* prevalence during the lairage period: from 16.7% to 20.8% at pen level. In the intervention group, 24% *Salmonella*-positive pen samples were found, but the number of positive samples decreased during the lairage period from 26.9% to 20.8%. The serotypes identified were *S. Typhimurium*, *S. Derby* and *S. 4.12:-:-*.

The results of the carcass swabbing are shown in Table 2. In the control group, 0.8% of the pooled carcass samples were *Salmonella*-positive. In the intervention group, 1.7% of the samples were positive. This difference was not significant. We noted that in the intervention group 4 of the 8 *Salmonella*-positive samples were found on the same day and were all typed *S. Infantis*. The previous day there had been found 1 *S. Infantis* in the control group. This suggests that perhaps the 4 samples positive with *S. Infantis* were the result of a transient hygiene failure at the slaughter line. The other serotypes found in carcasses were *S. Ohio* and *S. 4.12:b:-:-*, while *S. Typhimurium* was not found on the carcasses in Phase 1.

Phase 2
The preliminary results of the carcass swab samples of the first 7 weeks are shown in Table 3. In the control group, 3.6% of the samples collected from Level 0 pigs were *Salmonella*-positive, while 10.4% of the samples collected from Level 2 pigs were positive. In the intervention group, *Salmonella* was found in 4.5% of the carcass samples. The serotypes found were *S. Typhimurium*, *S. Livingstone*, *S. Derby*, *S. Heidelberg* and *S. Ru*. It should be noted that of the 12 positive carcass samples found in the Level 0 pigs in the intervention group, 6 were collected on the same day and are all typed *S. Heidelberg*, which is a serotype very rarely seen at
this slaughterhouse. Again, this suggests that perhaps these 6 positive samples were the result of a transient hygiene failure at the slaughter line.

Discussion
Our study confirms that substantial cross-contamination occurs both during lairage and during the slaughter process. This is in agreement with earlier studies (Morgan et al. 1987; Berends et al., 1997; Swanenburg et al., 2001; Hald, 2001). Finishers from Salmonella-free herds are at risk of becoming contaminated with Salmonella when in contact with faecal material or other finishers carrying Salmonella.

The overall aim of the study was to keep finishers from Salmonella-free herds free from Salmonella through separate lairage and separate slaughter. However, even though these pigs were housed in pens that had been cleaned (though not disinfected), both floor swab samples taken before their entrance and faeces samples taken after the pig had left for slaughter showed the presence of Salmonella. Interestingly, the level of Salmonella (as measured by the number of positive samples) before introduction of the pigs was higher in the clean pens compared to the pens contaminated with Salmonella-containing faeces. This difference had disappeared by the time the pigs went for slaughter. However, it cannot be excluded that some finishers from the Salmonella-free herds used in this study excreted Salmonella.

Even though contamination with Salmonella in the lairage was around 20 % in the first phase of this study, the number of carcasses contaminated with Salmonella was limited (below 2 %) and not significantly different between control and intervention groups. This suggests that the effect of Salmonella contamination in the lairage may be limited if pigs originating from Salmonella-free herds are slaughtered separately. If we disregard the results on one of the slaughter days where 4 samples were found positive for S. Infantis, which possibly can be attributed to hygienic failure on the slaughter line, the percentage of positive carcasses in the Salmonella-free intervention group is 0.8 %, exactly equal to that in the control group.

The second part of our study showed that the percentage of Salmonella-positive carcasses may not increase when pigs from Salmonella-free herds are both housed and slaughtered together with pigs from Salmonella-infected herds - although there still will be more positive samples among Salmonella-infected pigs. When we disregard the results of the one slaughter day when 6 carcass samples were found positive with S. Heidelberg - which is most likely due to a hygienic failure on the line - there are only 2.2% Salmonella-positive carcasses in separately slaughtered Level 0 finishers, compared to 3.6% in those slaughtered together with Level 2 pigs. However, based on these preliminary results it is not possible to conclude that
there is a significant reduction in *Salmonella*-positive carcasses in separately slaughtered Level 0 pigs.

In conclusion, separate housing of finishers from *Salmonella*-free herds did not result in different levels of cross-contamination in the lairage, although cross-contamination in the pens was considerable. Separate slaughter of finishers from *Salmonella*-free herds may reduce the number of *Salmonella*-positive carcasses but the final results should be awaited to substantiate this. If the trend persists then our results would suggest that the effect of *Salmonella* contamination in the lairage may be reduced if finishers from *Salmonella*-free herds are slaughtered separately.

**References**


### Table 1A
Bacteriological results of the pooled swab samples collected from pen floors in the Intervention group (Level 0 finishers not exposed to *Salmonella* containing faeces) before and after lairage

<table>
<thead>
<tr>
<th></th>
<th><em>Salmonella</em>-negative</th>
<th><em>Salmonella</em>-positive</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intervention - before</td>
<td>38</td>
<td>14 (26.9%)</td>
<td>52</td>
</tr>
<tr>
<td>Intervention - after</td>
<td>38</td>
<td>10 (20.8%)</td>
<td>48</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>76</strong></td>
<td><strong>24 (24.0%)</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

### Table 1B
Bacteriological results of the pooled faeces samples collected in the Control group (Level 0 finishers exposed to *Salmonella*-containing faeces) before and after lairage

<table>
<thead>
<tr>
<th></th>
<th><em>Salmonella</em>-negative</th>
<th><em>Salmonella</em>-positive</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control - before</td>
<td>45</td>
<td>9 (16.7%)</td>
<td>54</td>
</tr>
<tr>
<td>Control - after</td>
<td>38</td>
<td>10 (20.8%)</td>
<td>48</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>83</strong></td>
<td><strong>19 (18.7%)</strong></td>
<td><strong>102</strong></td>
</tr>
</tbody>
</table>

### Table 2
Bacteriological results of the pooled carcass swab samples collected in both groups during Phase 1

<table>
<thead>
<tr>
<th></th>
<th><em>Salmonella</em>-negative</th>
<th><em>Salmonella</em>-positive</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intervention</td>
<td>466</td>
<td>8 (1.7%)</td>
<td>474</td>
</tr>
<tr>
<td>Control</td>
<td>496</td>
<td>4 (0.8%)</td>
<td>500</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>962</strong></td>
<td><strong>12 (1.2%)</strong></td>
<td><strong>974</strong></td>
</tr>
</tbody>
</table>

### Table 3
Bacteriological results of the pooled carcass swab samples collected in both groups during Phase 2

<table>
<thead>
<tr>
<th></th>
<th><em>Salmonella</em>-negative</th>
<th><em>Salmonella</em>-positive</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intervention</td>
<td>256</td>
<td>12 (4.5%)</td>
<td>268</td>
</tr>
<tr>
<td>Control - <em>Salmonella</em> free</td>
<td>81</td>
<td>3 (3.6%)</td>
<td>84*</td>
</tr>
<tr>
<td>Control - <em>Salmonella</em> pos.</td>
<td>121</td>
<td>14 (10.4%)</td>
<td>135</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>458</strong></td>
<td><strong>29 (5.9%)</strong></td>
<td><strong>487</strong></td>
</tr>
</tbody>
</table>

* Incomplete sampling due to logistical problems