A Six Year Study of the Persistence of *Salmonella* Typhimurium DT104 on a Farrow to Finish Pig Farm

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Abstract

A 400 sow farrow to finish farm was sampled for 6 consecutive years to determine the distribution and persistence of *Salmonella* Typhimurium DT104 and other serovars. 25g bulked faeces samples were taken from every separate pen on the farm and a range of samples from the environment and wildlife were also collected resulting in 300-400 samples per visit.

At the first visit 4 different plasmid profile types of DT104 and DT104B were found in breeding stock and in weaner and finishing pigs. Most isolates were resistant to ampicillin, chloramphenicol, streptomycin, sulphonamide, neomycin and trimethoprim. Some isolates were also resistant to ampramycin. *S.*Livingstone, *S.*Derby and *S.*Anatum were also found in breeding stock. By the second year of sampling DT104 was not found and DT104B with a different plasmid profile was present. The farmer had also introduced an improved cleaning and disinfection regime and the proportion of positive finishing pens fell from 80% to 9%. In the third year of the study *S.*Typhimurium U302 and DT193 appeared to add to the DT104B. *S.*Panama also appeared in breeding stock but was not found in pigs after weaning. In the fourth year of the study the farm was totally depopulated, cleaned and disinfected then left empty for 6 months. *Salmonella* was found in the soil of dry sow and gilt paddocks 6 months after depopulation and in mice after cleaning and disinfection had been completed. *S.*Typhimurium DT104 and *S.*Derby was also found in replacement breeding stock on arrival at the farm. In the early period after repopulation the level of *Salmonella* in pigs after weaning remained low but after a further year *S.*Typhimurium DT104 was widespread in breeding stock, growers and mice.

Introduction

During the 1990s *Salmonella* contamination of pigmeat has become a politico-economic issue in major pig producing nations as a result of the widespread publicising of the Danish *Salmonella* Control Policy (Mousing et al 1997). Large
outbreaks of *Salmonella* and a significant proportion of sporadic cases associated with contaminated pig meat have occurred in countries where raw or lightly cooked pork is eaten (Steinbach & Hartung 1999). In many countries, including Great Britain, the predominant *Salmonella* strains in pigs are multiple antimicrobial resistant *S*.Typhimurium (Wray et al 1997, Mathew et al 1999, Anon 2000). In current livestock production there are few instances of continuous infection with *Salmonella* as the infection is largely self limiting in cattle and sheep herds and can be eliminated by good hygiene and biosecurity in poultry meat production. The exception to this is persistent contamination of multistage laying farms and incubators in hatcheries and cooling systems in feed processors where the same *Salmonella* serovar may persist for many years. Unlike farms in the poultry meat sector, continuous occupation of pig farms and lack of all in-all out systems leads to recycling of *Salmonella* between the environment and pigs, usually after weaning (Davies et al 1999, Sandvang et al 2000). This paper describes the behaviour of *Salmonella* on a farrow to finish farm during a six year study.

**Materials and Methods**

The 400 sow farm was first identified as a result of clinical *Salmonellosis* in weaners. At the start of the study dry sows were housed in tether stalls and gilts in outdoor paddocks. From the third year of the study dry sows were also housed in paddocks. The farm was visited at least once each year and intensive sampling of bulked faeces from every pig pen carried out. Samples were also taken from equipment and wildlife droppings and carcasses. Typically between 300 and 400 samples were taken per visit. In addition, for year 5, bulked faeces samples from newly delivered replacement boars and gilts were collected by the farmer and posted to the laboratory. Intensive visit samples of approximately 25g were collected directly into 225ml jars of Buffered Peptone Water (BPW: Merck: 107228). These were returned to the laboratory on the day of collection and incubated at 37°C for 18 hours. 0.2ml of incubated broth was then inoculated into 20ml DIASSALM (Merck: 109803) medium in a petri dish. This was incubated for 48 hours at 41.5°C and subcultures were streaked on Rambach Agar (Merck: 7500) after 24 and 48 hours. The Rambach plates were incubated at 37°C for 24 hours and suspect colonies confirmed bacteriologically and serologically. Serotyping and phage typing was carried out and the antimicrobial susceptibility of selected isolates was tested by disk diffusion.

**Results**

Table 1 shows the results of sampling in the breeding herd. In year one *S*.Typhimurium 104 and 104B, *S*.Derby, *S*.Livingstone and *S*.Anatum were found at a high prevalence throughout. *S*.Typhimurium was especially prevalent in
farrowing crates. After seeing these results the farmer upgraded his cleansing and disinfection, changing from a peroxygen to phenolic product and increasing the concentration. A peroxygen product was also used to disinfect drinker systems on emptying of pens. In the second year *Salmonella* infection in dry and lactating sows had improved but *S. Typhimurium* was still prevalent in gilt paddocks. In year 3 a low level of *S. Typhimurium* was found in farrowing rooms only but other serovars were still present throughout and *S. Panama* had appeared for the first time. Because of a high level of respiratory disease the farmer decided to totally depopulate the farm in year 4 and change to contract weaner production. Samples taken in year 4 after washing (4a) and after disinfection (4b) identified *S. Derby* surviving in soil and pooled water on paddocks 6 months after these were last occupied. After partial repopulation (year 5) *S. Derby* was found in fresh faeces from gilt paddocks, service pens, farrowing crates and especially dry sow paddocks. *S. Typhimurium DT104* was also found in dry sow paddocks. In year 6, after full repopulation, *S. Typhimurium* had once again become more widespread in the breeding herd.

Table 2 shows the results of sampling in post-weaning flat decks and slatted grower and finishing houses. In year 1 *S. Typhimurium DT104B* was widespread in all groups. After introducing improved disinfection, as above, by year 2 *S. Typhimurium* had fallen and other serovars became more prominent. In year 3 *S. Typhimurium U302* and DT193 appeared and overall *S. Typhimurium* levels increased slightly. After washing (4a) and disinfection (4b) *S. Typhimurium* was found in weaner, grower and finishing pens but not in sick pens. After redisinfecton and partial repopulation no *Salmonella* was found but by year 6 *S. Typhimurium* was again widespread.

Table 3 shows the results of sampling miscellaneous elements of the environment and wildlife vectors. Contamination of water troughs in paddocks was common. Samples taken from disinfected pens show that even after improvement in year 2 there was still significant residual contamination. Similarly, mouse droppings and carcases taken from cleaned and disinfected pens contained *Salmonella*. In the first 3 years of the study *Salmonella* was also found in wild bird and fox droppings in areas around the outdoor paddocks. *S. Typhimurium* was again found in fox droppings in year 6.

Table 4 shows the results of faeces samples taken from replacement breeding stock on arrival at the farm. Both *S. Typhimurium DT104* and *S. Derby* were found regularly.
<table>
<thead>
<tr>
<th>Year</th>
<th>Gilts</th>
<th>Boars</th>
<th>Service Pens</th>
<th>Sows and Litters</th>
<th>Dry Sows</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6[2]/32 (18.7) [24.9] 104(B), Derby</td>
<td>1[1]/3 (33.3) [66.6] 104, Livingstone</td>
<td>6[12]/27 (22.2) [66.6] 104(B), Livingstone</td>
<td>14[6]/33 (42.4) [60.6] 104B, Livingstone, Anatum</td>
<td>3[17]/38 (7.9) [52.6] 104, Livingstone, Anatum</td>
</tr>
<tr>
<td>2</td>
<td>9[6]/37 (24.3) [40.5] 104B, Untypable, Derby, Livingstone</td>
<td>2[3]/10 (20.0) [50.0] 104B, Livingstone</td>
<td>0[5]/7 (0) [71.4] Livingstone</td>
<td>3[12]/40 (7.5) [37.5] 104B, Livingstone</td>
<td>0[11]/29 (0) [37.9] Livingstone</td>
</tr>
<tr>
<td>3</td>
<td>0[12]/22 (0) [54.4] Derby, Livingstone, Panama</td>
<td>0[5]/14 (0) [35.7] Panama</td>
<td>0[2]/20 (0) [10] Panama</td>
<td>3[2]/34 (8.8) [14.7] 104B, Panama, Livingstone</td>
<td>0[7]/36 (0) [19.4] Panama</td>
</tr>
<tr>
<td>4(a)*</td>
<td>0[8]/35 (0) [22.8] Derby, Panama</td>
<td>0[1]/10 (0) [10.0] Derby</td>
<td>0[1]/8 (0) [12.5] Derby</td>
<td>0/38 (empty/washed)</td>
<td>1[7]/73 (1.4) [11.0] 104B, Derby, Panama</td>
</tr>
<tr>
<td>4(b)**</td>
<td>0[14]/56 (0) [25.0] Derby (soil/water)</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>0[10]/54 (0) [18.5] Derby (soil/water)</td>
</tr>
<tr>
<td>5***</td>
<td>0[4]/5 (0) [80.0]</td>
<td>0/4</td>
<td>0[2]/56 (0) [3.6] Derby</td>
<td>0[2]/56 (0) [3.6] Derby</td>
<td>3[15]/56 (5.4) [32.2] 104, Derby</td>
</tr>
<tr>
<td>6</td>
<td>0[3]/10 (0) [30.0] Derby</td>
<td>1[1]/13 (7.7) [15.4] STM/Derby</td>
<td>0[1]/6 [16.6] Derby</td>
<td>1[2]/49 (2.0) [6.1] STM/Derby</td>
<td>1[2]/31/(3.2) [9.6] STM/Derby</td>
</tr>
</tbody>
</table>

NS - not sampled
* mainly depopulated/washed 3 months
** depopulated 3 months post cleaning and disinfection
*** partially repopulated
**Table 2: Periodic Intensive Sampling on Farm A**

*Salmonella* isolation from bulked faeces from various pig categories and environment: Growers/Finishers

<table>
<thead>
<tr>
<th>Year</th>
<th>Weaners</th>
<th>Nurse Pens</th>
<th>Growers</th>
<th>Finishers</th>
<th>Sick Pens</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21[0]/29 (72.4) 104(B)</td>
<td>3[0]/3 (100.0) 104B</td>
<td>31[1]/42 (73.8) [76.2] 104(B), Derby</td>
<td>20[0]/25 (80.0) 104(B)</td>
<td>2[0]/2 (100.0) 104</td>
</tr>
<tr>
<td>2</td>
<td>5[5]/47 (10.6) [21.2] 104B, Livingstone, Derby</td>
<td>5[0]/5 (100.0) 104B</td>
<td>8[0]/55 (14.5) 104B, Untypable, 30</td>
<td>4[3]/45 (8.8) [15.5] 104B, Derby, Agona, Alachua</td>
<td>4[1]/5 (80.0) [100.0] 104B, Untypable, Livingstone</td>
</tr>
<tr>
<td>3</td>
<td>1[1]/15 (6.7) [13.4] U302, Livingstone</td>
<td>6[0]/6 (100.0) U302, 104B</td>
<td>23[0]/49 (46.9) U302, 104B, 193</td>
<td>3[0]/17 (17.6) 104B</td>
<td>0/2</td>
</tr>
<tr>
<td>4(a)*</td>
<td>4[0]/59 (6.8) 104B</td>
<td>0/1</td>
<td>6[2]/46 (13.0) [17.3] 104B, Derby</td>
<td>1[4]/36 (2.8) [13.9] 104B, Derby</td>
<td>0/2</td>
</tr>
<tr>
<td>4(b)**</td>
<td>2[0]/44 (4.5) (disinfected pens) 104B, U302</td>
<td>NS</td>
<td>0/33 (disinfected pens)</td>
<td>1[0]/22 (4.5) 104B (disinfected pens)</td>
<td>NS</td>
</tr>
<tr>
<td>5***</td>
<td>0/8</td>
<td>NS</td>
<td>0/48</td>
<td>N/A</td>
<td>0/10</td>
</tr>
<tr>
<td>6</td>
<td>17[0]/29 (58.6) STM</td>
<td>NS</td>
<td>23[0]/45 (51.1) STM</td>
<td>N/A</td>
<td>11[0]/14 (78.6) STM</td>
</tr>
</tbody>
</table>

NS - not sampled  
* mainly depopulated/washed 3 months  
** depopulated 3 months post cleaning and disinfection  
*** partially repopulated
Table 3: Periodic Intensive Sampling on Farm A
*Salmonella* isolation from bulked faeces from various pig categories and environment: Environmental and Wildlife Vectors
No. of STM isolates [No. of other serovars]/No. samples taken (% STM) [% total *Salmonellas*]

<table>
<thead>
<tr>
<th>Year</th>
<th>Outdoor Water Troughs</th>
<th>Disinfected Pens</th>
<th>Mouse Droppings/Carcases</th>
<th>Wild Bird Droppings</th>
<th>Fox Droppings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3[0]/8 (37.5) 104(B)</td>
<td>6[2]/24 (25.0) [33.3] 104B, Livingstone</td>
<td>2[0]/3 (66.7) 104</td>
<td>3[0]/5 (60.0) 104(B)</td>
<td>3[0]/5 (60.0) 104(B)</td>
</tr>
<tr>
<td>2</td>
<td>3[0]/6 (50.0) 104B, Untypable</td>
<td>2[0]/14 (14.3) 104B</td>
<td>2[0]/4 (50.0) 104B</td>
<td>2[1]/7 (28.6) [42.9] 104B, Livingstone</td>
<td>1[1]/3 (33.3) [66.6] 193</td>
</tr>
<tr>
<td>3</td>
<td>3[3]/13 (23.1) [46.2] 193, Panama, Livingstone,</td>
<td>4[1]/34 (11.8) [14.7] U302, Livingstone</td>
<td>7[0]/11 (63.6) 104B, U302</td>
<td>0/6</td>
<td>1[0]/3 (33.3) 193</td>
</tr>
<tr>
<td>4(a)*</td>
<td>0[1]/5 (0) [20.0] Derby</td>
<td>NS</td>
<td>1[0]/1 (100.0) 104B</td>
<td>0[1]/3 (0) [33.3] Derby</td>
<td>0/6</td>
</tr>
<tr>
<td>4(b)**</td>
<td>NS</td>
<td>2[1]/127 (1.6) [2.3] 104B/U302/Panama</td>
<td>4[0]/5 (80.0) U302</td>
<td>0/3</td>
<td>0/2</td>
</tr>
<tr>
<td>5***</td>
<td>NS</td>
<td>0/18</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>6</td>
<td>3[2]/18 (16.6) [27.7] STM, Derby, Goldcoast</td>
<td>0/14</td>
<td>6[0]/10 [60.0] STM</td>
<td>0/4</td>
<td>1[0]/2 (50.0) STM</td>
</tr>
</tbody>
</table>

NS - not sampled
* mainly depopulated/washed 3 months
** depopulated 3 months post cleaning and disinfection
<table>
<thead>
<tr>
<th>Sampling date</th>
<th>Pig Category</th>
<th>No. samples positive for <em>Salmonella</em> No. samples taken (%)</th>
<th><em>Salmonella</em> serovars and definitive types</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/03/99</td>
<td>gilts</td>
<td>1/4 (25.0)</td>
<td>S. Derby</td>
</tr>
<tr>
<td>19/03/99</td>
<td>gilts</td>
<td>1/4 (25.0)</td>
<td>S. Typhimurium DT104</td>
</tr>
<tr>
<td>31/03/99</td>
<td>boars</td>
<td>0/4</td>
<td>S. Typhimurium DT104</td>
</tr>
<tr>
<td>01/04/99</td>
<td>gilts</td>
<td>0/4</td>
<td>S. Typhimurium DT104</td>
</tr>
<tr>
<td>09/04/99</td>
<td>gilts</td>
<td>0/4</td>
<td>S. Typhimurium DT104</td>
</tr>
<tr>
<td>16/04/99</td>
<td>boars</td>
<td>0/4</td>
<td>S. Typhimurium DT104</td>
</tr>
<tr>
<td>16/04/99</td>
<td>gilts</td>
<td>1/4 (25.0)</td>
<td>S. Typhimurium DT104</td>
</tr>
<tr>
<td>26/04/99</td>
<td>gilts</td>
<td>0/4</td>
<td>S. Typhimurium DT104</td>
</tr>
<tr>
<td>04/05/00</td>
<td>gilts</td>
<td>0/4</td>
<td>S. Typhimurium DT104</td>
</tr>
<tr>
<td>10/05/99</td>
<td>gilts</td>
<td>1/4 (25.0)</td>
<td>S. Typhimurium DT104</td>
</tr>
<tr>
<td>17/05/99</td>
<td>gilts</td>
<td>0/4</td>
<td>S. Typhimurium DT104</td>
</tr>
<tr>
<td>24/05/99</td>
<td>gilts</td>
<td>2/4 (50.0)</td>
<td>S. Typhimurium DT104</td>
</tr>
<tr>
<td>01/06/99</td>
<td>gilts</td>
<td>0/4</td>
<td>S. Typhimurium DT104</td>
</tr>
<tr>
<td>07/06/99</td>
<td>gilts</td>
<td>1/4 (25.0)</td>
<td>S. Typhimurium DT104</td>
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<tr>
<td>14/06/99</td>
<td>gilts</td>
<td>1/4 (25.0)</td>
<td>S. Derby</td>
</tr>
<tr>
<td>21/06/99</td>
<td>gilts</td>
<td>0/4</td>
<td>S. Derby</td>
</tr>
<tr>
<td>28/06/99</td>
<td>gilts</td>
<td>0/4</td>
<td>S. Derby</td>
</tr>
<tr>
<td>02/07/99</td>
<td>gilts</td>
<td>0/4</td>
<td>S. Derby</td>
</tr>
<tr>
<td>30/03/00</td>
<td>gilts</td>
<td>0/9</td>
<td>S. Derby</td>
</tr>
<tr>
<td>30/05/00</td>
<td>gilts</td>
<td>1/6 (16.6)</td>
<td>S. Derby</td>
</tr>
<tr>
<td>22/06/00</td>
<td>gilts</td>
<td>0/6</td>
<td>S. Derby</td>
</tr>
<tr>
<td>31/07/00</td>
<td>gilts</td>
<td>0/6</td>
<td>S. Derby</td>
</tr>
<tr>
<td>19/09/00</td>
<td>gilts</td>
<td>0/5</td>
<td>S. Derby</td>
</tr>
<tr>
<td>10/11/00</td>
<td>gilts</td>
<td>3/5 (60.0)</td>
<td>S. Derby</td>
</tr>
</tbody>
</table>
Discussion

This study demonstrates that a substantial reduction in *Salmonella* in finishing pigs can be achieved by improved management, after the widespread infection associated with peak of herd infection (Davies & Wray 1997) has passed and a reversion to mean infection levels has occurred. In this case the balance of herd immunity/infection was disturbed by depopulation and repopulation, together with the introduction of replacement breeding stock which were carrying *Salmonella*. Unless virtual sterilisation of farm premises, total elimination of pets and *Salmonella*-free replacement stock can be achieved then depopulation-repopulation is contra-indicated for *Salmonella* control (Dahl 1999, Møgelmose et al 1999).

In this case, even though pelleted feed was used, a low level of *Salmonella* in finishing pigs was achieved by improved hygiene. It is possible that further reductions may have been achieved if fermented liquid feeding for finishers had been used (Dahl 1997, Mikkelsen & Jensen 2000).

Following the identification of significant levels of *Salmonella* in slaughter pigs in Great Britain (Davies et al 2000) the UK pig industry is considering an integrated approach to *Salmonella* surveillance and control. Total elimination of foodborne pathogens from specific sectors of pig production is possible but costly (Weijtens et al 2000). A top-down reduction strategy will help safeguard international trade and reduce the small number of human cases associated with undercooked and poorly stored pig-meat (Maguire et al 1993, Thornton et al 1993, Ward L, CPHL, Colindale - personal communication).

Acknowledgements

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References