SALMONELLA
INTERVENTIONS FOR SWINE

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** and colleagues – M Rostagno, S Hurd, A O’Connor, et al.
The problem...

- F Subclinical infections/carriers
  - f Food safety problem
    - f Risk for pork contamination

F Proposed solution:
  - f Reduction of meat contamination by reducing/eliminating contaminants at the pre-harvest level (on-farm);

Is that an appropriate strategy??
Intervention Considerations

- Epidemiology and ecology of hazard
  - source(s) for contaminant
  - ability to multiply under handling conditions

- Potentials for “downstream” contamination

- Contamination attribution – significance

- Control measures – feasibility/costs

- Control measures – implementation
  - successful implementation – incentive/penalty
  - monitoring for action completion/efficacy
Salmonella Intervention Considerations

- ~2,400 serovars with wide range of hosts
- Exposure levels variable for carriage
- Survival in environment for +/- 6 years
- Infections/carriage - often indistinguishable
- Infection may result in intermittent shedding
- Detection methods – relatively insensitive
  - culture – 30-70% sensitive
  - antibodies – shedding vs. response, herd vs. individual
  - PCR – live vs. dead, test costs
Salmonella Intervention
Considerations

First principle = stop contamination at farm
- practicality of interventions
- attribution of risk evaluations
- “downstream” recontamination

On-farm Salmonella controls
- most experiences developed in Europe
- measures for success in dispute (??)
- current focus on feeds/feeding practices
On-farm interventions – hygiene based

- hand washing prior to entry to swine facility*
- toilet facilities on site
- boot and outer clothing changes prior to entry*
- reduced human entry to site
- cleaning/disinfection – equivocal results
- All-in/All-out – equivocal results*
- *additive effects from multiple applications
- pen sanitation may not influence culture results
Salmonella Intervention
Considerations

- On-farm interventions – feed based
  - feed as contaminant source
    - different serovars present in feed and animals
    - common environmental contaminant
    - presence/absence of infective dose – $>10^3$ ??
  - variable effects from processing
    - pellets vs. mash
    - particle sizes – larger are protective
    - wet vs. dry – fermented vs. non-fermented
Salmonella Intervention Considerations

- Acidification of feeds or water
  - “natural” — fermentation of liquid feeds
  - addition of whey as major feed ingredient
  - organic and inorganic acids investigated
    - *acid de jour* = benzoic acid alone or in combination
    - apply in either feed or water

- Miscellaneous observations
  - stocking density — equivocal results
  - seasonality — winter/spring — higher ??
  - Intergenerational transfer — break with early weaning ??
Good Manufacturing Practices –
On-farm activities - Danish

▪ Eliminate carrier sow herds
  – S. typhimurium specific??

▪ Acidification of feed/water
  – expenses in feed/water and equipment wear

▪ Coarse ground feed vs. pellets/fine grind

▪ Farm level classification
  – reduce abattoir and transport contamination??
  – limit to continued reductions = interventions
NOW FOR THE REST OF THE STORY!!
Potential Sources of Contamination on Pork Carcasses
--Farm to Cooler Continuum--

On-farm Infection
Carcass-associated Lymph Nodes (farm sourced)

Transport & Lairage
Cecum and Gut-associated Lymph Nodes

Pre-slaughter
Dressing Process
Carcass Swab (dressing sourced)
Carcass Contamination

Antemortem → Postmortem
Good Manufacturing Practices – Salmonella

- Abattoirs
  - Processing controls – HACCP
  - Antemortem pens
    - Routine recontamination
    - Rapid infection from environment
    - May require complete isolation - ??
Acute (2hr) infection is feasible!

<table>
<thead>
<tr>
<th>Treatment</th>
<th>mandibular lymph node</th>
<th>ileocecal lymph node</th>
<th>sublingual lymph node</th>
<th>cecal content</th>
<th>ileal sample and content</th>
<th>post-challenge fecal</th>
<th>Positive on any tissue</th>
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<tbody>
<tr>
<td>control</td>
<td>0/5</td>
<td>0/5</td>
<td>0/5</td>
<td>0/5</td>
<td>0/5</td>
<td>0/5</td>
<td>0/5</td>
</tr>
<tr>
<td>2 hour exposure</td>
<td>0/10</td>
<td>2/10(^{b})</td>
<td>0/10</td>
<td>3/10</td>
<td>7/10</td>
<td>5/10</td>
<td>8/10</td>
</tr>
<tr>
<td>3 hour exposure</td>
<td>1/10(^{a})</td>
<td>0/10</td>
<td>0/10</td>
<td>2/10</td>
<td>3/10</td>
<td>5/10</td>
<td>6/10</td>
</tr>
<tr>
<td>6 hour exposure</td>
<td>0/5</td>
<td>1/5(^{c})</td>
<td>1/5(^{d})</td>
<td>5/5</td>
<td>4/5</td>
<td>2/4</td>
<td>5/5</td>
</tr>
<tr>
<td>shedder</td>
<td>5/10</td>
<td>10/10</td>
<td>2/10(^{e})</td>
<td>10/10</td>
<td>10/10</td>
<td>10/10</td>
<td>10/10</td>
</tr>
</tbody>
</table>

\(^{a}\) enviromental dose equaled 4.4 X 10\(^{3}\) cfu per gram

\(^{b}\) enviromental doses equaled 1.5 X 10\(^{3}\) and 4.4 X 10\(^{3}\) cfu per gram

\(^{c}\) enviromental dose equaled 1.5 X 10\(^{3}\) cfu per gram

\(^{d}\) enviromental dose equaled and 4.5 X 10\(^{2}\) cfu per gram

\(^{e}\) inoculation dose equaled 9.0 X10\(^{8}\) cfu
Serotypes varied by week

<table>
<thead>
<tr>
<th>Serotype</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Total</th>
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<tbody>
<tr>
<td>Agona</td>
<td>26</td>
<td>1</td>
<td>4</td>
<td></td>
<td>5</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>39</td>
</tr>
<tr>
<td>Anatum</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>Derby</td>
<td>1</td>
<td>24</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>52</td>
</tr>
<tr>
<td>Manhattan</td>
<td>1</td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>13</td>
<td></td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>T var copen</td>
<td></td>
<td>12</td>
<td></td>
<td>1</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>Typhimurium²</td>
<td></td>
<td></td>
<td>31</td>
<td></td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td></td>
<td></td>
<td>37</td>
</tr>
<tr>
<td>Reading</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Uganda</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td><strong>Total typable³</strong></td>
<td>49</td>
<td>24</td>
<td>18</td>
<td>12</td>
<td>15</td>
<td>39</td>
<td>9</td>
<td>36</td>
<td>20</td>
<td>22</td>
<td>244</td>
</tr>
</tbody>
</table>
Summary: Increased fecal isolation, farm through slaughter, regardless of stress

- Farm fecal
  - 4.1%
  - 2.8%
  - n=134

- Colon contents at slaughter
  - 59.4%
  - 44.4%
  - n=136

18 hr. in clean barn
Diversity of serotypes and number isolated at each sampling site by sampling period - sows

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm</td>
<td>Infantis(1)</td>
<td>--------------</td>
<td>Derby(1)</td>
<td>Derby(1)</td>
<td>Derby(1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Infantis(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collection Point</td>
<td>--------------</td>
<td>--------------</td>
<td>--------------</td>
<td>Derby(1)</td>
<td>Derby(2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abattoir¹</td>
<td>Derby(1)</td>
<td>Derby(5)</td>
<td>Derby(50)</td>
<td>Derby(11)</td>
<td>Derby(29)</td>
</tr>
<tr>
<td>Manhattan(2)</td>
<td>Heidelberg(7)</td>
<td>Manhattan(1)</td>
<td>Manhattan(1)</td>
<td>Manhattan(1)</td>
<td>Manhattan(1)</td>
</tr>
<tr>
<td>Give(2)</td>
<td>Infantis(6)</td>
<td>Heidelberg(1)</td>
<td>Typhimurium(3)</td>
<td>Ohio(5)</td>
<td>Typhimurium(2)</td>
</tr>
<tr>
<td>London(1)</td>
<td>Anatum(3)</td>
<td>Uganda(3)</td>
<td>Muenster(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Uganda(2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Worthington(2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Newport(1)</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

¹ Consisted of colon contents, ileocecal lymph node, cecal contents, ventral thoracic, subiliac lymph nodes and right and left pre and postwash carcass swabs
What is the farm level problem??
## SALMONELLA CONCERNS BY SEROTYPE

<table>
<thead>
<tr>
<th>HUMAN %</th>
<th>SWINE %</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPHIM.</td>
<td>TYPHIM.</td>
</tr>
<tr>
<td>ENTERID.</td>
<td>ENTERID.</td>
</tr>
<tr>
<td>HEIDEL.</td>
<td>HEIDEL.</td>
</tr>
<tr>
<td>NEWPORT</td>
<td>NEWPORT</td>
</tr>
<tr>
<td>HADAR</td>
<td>HADAR</td>
</tr>
<tr>
<td>DERBY</td>
<td>DERBY</td>
</tr>
<tr>
<td>OTHERS</td>
<td>OTHERS</td>
</tr>
<tr>
<td>22.6</td>
<td>20.4</td>
</tr>
<tr>
<td>22.0</td>
<td>0.0</td>
</tr>
<tr>
<td>6.8</td>
<td>7.0</td>
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<tr>
<td>4.6</td>
<td>0.0</td>
</tr>
<tr>
<td>3.6</td>
<td>1.1</td>
</tr>
<tr>
<td>0.004</td>
<td>28.0</td>
</tr>
<tr>
<td>38.6</td>
<td>43.0</td>
</tr>
</tbody>
</table>
Good Manufacturing Practices – On-farm activities - ??

- All in/All out
- Age segregation/intergenerational transfer
- Pen density/group sizes
- Pen sanitation
- Bird proofing/wildlife exposures
- Feed contamination/processing
- Human contact/sanitation
How is success measured??

“Clean up” farms and **system** will be safer
- limitations on measurement – culture/ELISA

Reduce contamination levels/prevalence
- acceptable levels, if not zero??
- where to measure for farm level effect ??

Rationalize serotypes to human health
- Is derby = typhimurium = agona = infantis??
- link between farm and pork products??
Bacteriological (fecal) Salmonella prevalence in finishing pigs over time

Prevalence (%) vs. Sampling

Sampling: 1 2 3 4 5 6
Prevalence (%): 0 10 20 30 40 50

Lines:
- A
- B
- C
- D
- E
- F
Serological (meat juice) Salmonella prevalence in finishing pigs over time

Prevalence (%) vs. Sampling
Table 1 - Bacteriological (fecal samples) and serological (meat juice samples) *S. enterica* prevalence in finishing pig from multiple production systems

<table>
<thead>
<tr>
<th>Production System</th>
<th>Bacteriological Prevalence (Min.-Max.)</th>
<th>Serological Prevalence (Min.-Max.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>9.4% (\text{A,a} (0 - 26.7%))</td>
<td>39% (\text{A,b} (0 - 84%))</td>
</tr>
<tr>
<td>B</td>
<td>6.7% (\text{A,a} (0 - 13.3%))</td>
<td>11.3% (\text{A,a} (0 - 26%))</td>
</tr>
<tr>
<td>C</td>
<td>22.8% (\text{A,a} (6.7 - 40%))</td>
<td>55.7% (\text{A,b} (14 - 100%))</td>
</tr>
<tr>
<td>D</td>
<td>9.4% (\text{A,a} (0 - 46.7%))</td>
<td>51.8% (\text{A,b} (4 - 78%))</td>
</tr>
<tr>
<td>E</td>
<td>15% (\text{A,a} (0 - 36.7%))</td>
<td>20.4% (\text{A,a} (2 - 60%))</td>
</tr>
<tr>
<td>F</td>
<td>13.9% (\text{A,a} (0 - 43.3%))</td>
<td>30% (\text{A,a} (8 - 72%))</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td><strong>12.9% (\text{a} (0 - 46.7%))</strong></td>
<td><strong>35.4% (\text{b} (0 - 100%))</strong></td>
</tr>
</tbody>
</table>

*A,B: Comparison within columns (p<0.05)  
*a,b: Comparison within rows (p<0.05)*
Possible reasons for the wide variation found within production sites:

1- Clusters;

2- Intermittent shedding;

3- Evolution and resolution of infection epidemics.
Where should GMPs be applied??

- On-farm
- In transport/concentration
- At abattoir
  - ante-mortem pens management??
  - HACCP upgrades
- Need more information??
THE ALL AMERICAN PIG

THANK YOU FOR YOUR PARTICIPATION

QUESTIONS?