Bringing Food Safety Back To The Farm: A Swine Perspective

Annette O’Connor, Iowa State University
Presentation for: Swine Committee
National Institute of Animal Agriculture
Columbus Ohio, Tuesday, April 4, 2017
10:00 a.m. – 12:30 p.m.
Efficacy of Food Safety Interventions

- The impact of the rest of the system
  - Does the effect remain
<table>
<thead>
<tr>
<th>Pork chain steps:</th>
<th>Primary Production</th>
<th>Processing</th>
<th>Distribution Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Primary Production</td>
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<td>2. Transport to Slaughter</td>
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<td>3. Receive and Unload</td>
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<td>4. Lattrage</td>
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<td>5. Stunning</td>
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<td>6. Sticking/Bleeding</td>
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<td>7. Scalding</td>
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<td>8. Dehairing</td>
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<td>9. Gambrelling</td>
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<td>10. Singeing</td>
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<td>11. Polishing</td>
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<td>12. Bunging</td>
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<td>13. Midline Opening</td>
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<td>14. Evisceration</td>
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<td>15. Splitting</td>
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<td>16. Head Dropping/Removal</td>
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<td>17. Post Mortem inspection</td>
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<td>18. Chilling</td>
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<td>19. Carcass Fabrication</td>
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<td>20. Mechanical Tenderization/Mincing</td>
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<tr>
<td>21. Packing Product</td>
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<tr>
<td>22. Transport to Distribution Channels</td>
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<tr>
<td>23. Cold Storage</td>
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<td>24. Distribution/Retail</td>
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<td>25. Consumer</td>
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Efficacy of Food Safety Interventions

• The impact of the rest of the system
  • Does the effect remain

• Interventions are non serotype specific
  • Most challenge are Typhimurium
Important aspects

• Don’t look at single studies- single random events

• Sources of information
  • Systematic reviews of the literature
  • Models of the system
  • Primary studies when no review is available
GENERIC FUNNEL PLOT

y-axis

x-axis

RR=1
Reviews on Salmonella prevalence

- Two narrative reviews
- Updated using a systematic review methodology in 2012

- 15 primary US based studies,
- 49 datapoints
- 6 methods of measuring the outcome

O’Connor- Final reported NPB submitted 5th July 2012.
Salmonella Prevalence in the United States

1 between herd serum
2 between herd culture
3 within herd serum
4 within herd culture
5 sample serum
6 sample culture

O’Connor- Final reported NPB submitted 5th July 2012.
Salmonella Prevalence in the United States

O'Connor- Final reported NPB submitted 5th July 2012.
Interventions for the Control of Nontyphoidal Salmonella spp. in Beef and Pork
Salmonella: On-farm control

- On-farm control approaches
  - Antimicrobials, including bacteriophage therapy
  - Biosecurity
  - Feed/water acidification
  - Feed management
  - Manipulation of gut microbiota
  - Vaccination
Antibiotic therapy including phages

• 32 sources of information
• 28 primary research studies investigated the use of antimicrobials for reduction of Salmonella in pork,
  • 8 controlled trials
  • 9 challenge trials
  • 11 cross-sectional studies
• 2 systematic reviews
• 2 models
<table>
<thead>
<tr>
<th>Author</th>
<th>Method of allocation</th>
<th>Antibiotic regimen</th>
<th>Challenge exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Claussen et al. (1998)</td>
<td>Blocked by gender, and body weight within gender</td>
<td>Chlorotetracycline 200 g/ton of feed <em>ad libitum</em></td>
<td><em>S.</em> Typhimurium $2 \times 10^9$ cfu twice orally on day 0 and day 14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oxytetracycline 5 mg/lb body weight, intramuscular on days 3, 4, 5, 17, 18, 19 post-exposure</td>
<td></td>
</tr>
<tr>
<td>Dealy and Moeller (1976)</td>
<td>Blocked weight, sex and litter number</td>
<td>Bambermycin 4.4 mg/kg of feed 5 days prior to challenge</td>
<td><em>S.</em> Typhimurium $2.5 \times 10^{11}$ cfu orally</td>
</tr>
<tr>
<td>DeGeeter et al. (1976)</td>
<td>Randomly assigned</td>
<td>Lincomycin 110 mg/kg of feed 7 days before exposure and throughout the experimental period</td>
<td><em>S.</em> Typhimurium $1 \times 10^{11}$ cfu orally</td>
</tr>
<tr>
<td>Delsol et al. (2003)</td>
<td>Randomly assigned</td>
<td>Aureomycin 1.5 mg/kg of feed for 7 days</td>
<td><em>S.</em> Typhimurium $2 \times 10^9$ cfu orally</td>
</tr>
<tr>
<td>Ebner and Mathew (2000)</td>
<td>Blocked by litter</td>
<td>$T_1$. Ceftiofur intramuscular for 3 days</td>
<td><em>S.</em> Typhimurium $3.6 \times 10^9$ cfu intranasal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_2$. Apramycin 150 g/ton of feed for 14 days</td>
<td><em>S.</em> Typhimurium $3.6 \times 10^9$ cfu intranasal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oxytetracycline 100 g/ton of feed rest of the trial</td>
<td></td>
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<td></td>
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<td>$T_3$. Caradox 50 g/ton of feed until pigs reached 35 kg</td>
<td></td>
</tr>
<tr>
<td>Evangelisti et al. (1975)</td>
<td>Blocked by weight and sex</td>
<td>Oxytetracycline 150 g/ton – 5 days prior to exposure and throughout the experimental period</td>
<td><em>S.</em> Typhimurium $3.6 \times 10^9$ cfu intranasal</td>
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<td>Girard et al. (1976)</td>
<td>Randomly assigned</td>
<td>Oxytetracycline 150 g and Neomycin 150 g/ton – 5 days prior to exposure and throughout the experimental period</td>
<td><em>S.</em> Typhimurium $1.4 \times 10^{11}$ cfu orally</td>
</tr>
<tr>
<td>Gutzmann et al. (1976)</td>
<td>Blocked by litter, sex and weight</td>
<td>$T_1$. Chlorotetracycline 220.5 g/metric ton – starting from 5 days before exposure and throughout the experimental period</td>
<td><em>S.</em> Typhimurium $1 \times 10^{11}$ cfu orally</td>
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<td>$T_2$. Chlorotetracycline 110.2 g, Sulfamethazine 110.2 g and Penicillin G 55.1 g/metric ton – 5 days before exposure and throughout the experimental period</td>
<td><em>S.</em> Typhimurium $1 \times 10^{11}$ cfu orally</td>
</tr>
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<td>Jacks et al. (1988)</td>
<td>Blocked by litter, sex and weight</td>
<td>Efrotomycin 16 mg/kg of feed <em>ad libitum</em></td>
<td><em>S.</em> Typhimurium $1.7 \times 10^{10}$ cfu orally</td>
</tr>
<tr>
<td>Jones et al. (1983)</td>
<td>Blocked by weight within sex</td>
<td>$T_1$. Chlorotetracycline 55 mg/kg of feed <em>ad libitum</em></td>
<td><em>S.</em> Typhimurium $5.1 \times 10^9$ cfu orally</td>
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<tr>
<td>Letellier et al. (2000)</td>
<td>Randomly assigned</td>
<td>$T_2$. Virginiamycin 55 mg/kg of feed <em>ad libitum</em></td>
<td><em>S.</em> Typhimurium $5.1 \times 10^9$ cfu orally 14 days after treatment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flavomycin 0.5 g/ton of feed</td>
<td></td>
</tr>
<tr>
<td>Author</td>
<td>Outcome</td>
<td>Reported analysis</td>
<td>Time points (days)</td>
</tr>
<tr>
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<td>Claussen et al. (1998)</td>
<td>Presence/absence</td>
<td>Uncorrected chi-square</td>
<td>14</td>
</tr>
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<td>Dealy and Moeller (1976)</td>
<td>cfu/g</td>
<td>ANOVA</td>
<td>9</td>
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<tr>
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<td>ANOVA</td>
<td>10</td>
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<td>Delsol et al. (2003)</td>
<td>cfu/g</td>
<td>Repeated measures by ANOVA</td>
<td>8</td>
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<td>Ebner and Mathew (2000)</td>
<td>Presence/absence</td>
<td>Mixed model</td>
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<td>Trapezoid test</td>
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<td>Gutzmann et al. (1976)</td>
<td>cfu/g</td>
<td>4-fold contingency tables</td>
<td>7</td>
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<td>Jacks et al. (1988)</td>
<td>cfu/g</td>
<td>Univariate repeated measures ANOVA</td>
<td>13</td>
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<td>Jones et al. (1983)</td>
<td>cfu/g</td>
<td>Generalized linear model</td>
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</tr>
<tr>
<td>Letellier et al. (2000)</td>
<td>Not discernable</td>
<td>Not described</td>
<td>4</td>
</tr>
<tr>
<td>Shryock et al. (1998)</td>
<td>cfu/g</td>
<td>Repeated measures ANOVA</td>
<td>10</td>
</tr>
</tbody>
</table>
Denagmange et al (2010) conclusion

• No evidence of efficacy, work too inconsistent
Wilhelm et al. (2012) conclusion

• A significantly harmful treatment effect for one specific antimicrobial (oral tetracycline) using faecal Salmonella spp. shedding as the outcome measure.

• OR range:
  • 14 (1.9, 108)
  • 1.0 (0.43, 2.5)
FAO conclusion: antimicrobial drugs

• Non-therapeutic use of antimicrobial drugs and medications was not recommended for consideration as a food safety intervention for the control of Salmonella in pigs on farm, due to inconsistent evidence for efficacy and the serious potential for the development of
Summary-of-findings table for phage therapy

**Table 1.1: Challenge trials investigating phage therapy, measuring prevalence**

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Population/sample</th>
<th>No. trials/studies</th>
<th>Odds ratio for intervention effect&lt;sup&gt;a&lt;/sup&gt;</th>
<th>% Samples <em>Salmonella</em> positive in study population&lt;sup&gt;c&lt;/sup&gt;</th>
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<td>Phage therapy</td>
<td>Weaners (Lymph node culture)</td>
<td>3/3</td>
<td>MA = 0.39 (95% CI: 0.12, 1.22)</td>
<td>45.8%</td>
<td>Very low</td>
<td>(Callaway et al., 2011; Saez et al., 2011; Wall et al. 2010)</td>
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<td>Weaners (Faecal culture)</td>
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<td>1.00</td>
<td>100%</td>
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MA=meta-analysis average estimate from random-effects model; CI=confidence interval.
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very low=the true effect is likely to be substantially different from the measured estimate;
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<td></td>
<td>Weaners (Faecal culture)</td>
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<td></td>
<td>100% (95% CI: 9.2, 50.8)</td>
<td>Very low</td>
<td>(Saez et al., 2011; Wall et al. 2010)</td>
</tr>
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MA = meta-analysis average estimate from random-effects model; CI = confidence interval.
FAO Conclusions: Bacteriophage therapy

• Bacteriophage therapy was **not recommended for consideration** as a hazard-based intervention for the control of Salmonella in pigs on farm given the limited data currently available.
Salmonella: On-farm control

• Antimicrobials - not recommended
• Biosecurity - recommended for consideration
• Feed/water acidification - recommended for consideration BUT
• Feed management
  • Those with proven efficacy recommended for consideration
    Sodium chlorate - not recommended
• Manipulation of microbiota not recommended
• Vaccination recommended for consideration BUT
Options: Biosecurity

- Bird control - (Cardinale et al., 2010; Choe et al., 2011; Vico and Mainar-Jaime, 2012)
- Presence of rodents (Correia-Gomes et al., 2012; 2013),
- Hygienic lock facility (Hautekiet et al., 2008; Lo Fo Wong et al., 2004; van der Wolf et al., 2001a).
- Failure to disinfect farm vehicle wheels (Choe et al., 2011; Twomey et al., 2010a).
- Introduction of animals and/or semen (Correge et al., 2009; Lo Fo Wong et al., 2004, Correia-Gomes et al. 2012; 2013, Dahl (2009)
- Farms allowing visitors  (Bahnson et al. 2007),
- Strategic movement of pigs at weaning (Dahl et al., 1997; Nietfeld et al., 1998),
- Farm staff wearing dirty boots ((Gotter et al., 2012)
- Presence of a toilet on-site (Funk et al. 2001)
Evidence base: Biosecurity

• Evidence provided by

• 68 relevant studies were captured investigating biosecurity interventions for mitigation of *Salmonella* in pigs:
  • 5 controlled trials,
  • 3 quasi-experiments
  • 2 cohort studies,
  • 1 case-control study
  • 14 cross-sectional studies,
  • 16 stochastic models
  • 1 systematic review.
FAO Conclusions: Biosecurity

• Biosecurity was recommended for consideration as an important GFP to control *Salmonella* in pigs on farm.
Salmonella: On-farm control

- Antimicrobials - not recommended
- Biosecurity - recommended for consideration
Options: Feed and water acidification

• 40 primary research studies investigated organic acids in feed:
• 14 controlled trials,
• 1 quasi-experiment,
• 16 challenge trials,
• 9 cross-sectional studies
• 5 risk assessments or stochastic models.
• 2 systematic reviews
Evidence: Feed and water acidification

• O’Connor et al. (2008), using systematic review methodology, reported no strong evidence for an association between presence of *Salmonella* and feed acidification.

• Wilhelm et al. (2012) used systematic review-meta-analysis methodology and reported a protective, but heterogeneous, treatment effect for the inclusion of organic acids in finisher rations for reduction of *Salmonella*, with low confidence.
Table 3.1: Controlled trials investigating feed and water acidification, sampling finisher pigs

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Population (Sample)</th>
<th>No. trials/studies</th>
<th>Odds ratio for intervention effect&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Without treatment</th>
<th>With treatment</th>
<th>GRADE rating&lt;sup&gt;c&lt;/sup&gt;</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acidification</td>
<td>Finishers (Faecal culture)</td>
<td>9/3</td>
<td>Median = 0.08 (Range: 0.01, 26.0)</td>
<td>20.1%</td>
<td>2.0% (Range: 0.3, 86.7)</td>
<td>Low</td>
<td>(Arguello et al., 2013a; Cook et al., 2006; Willaml et al., 2011)</td>
</tr>
<tr>
<td>Acidification</td>
<td>Finishers (Serum ELISA)</td>
<td>19/6</td>
<td>Median = 0.46 (Range: 0.01, 6.82)</td>
<td>39.0%</td>
<td>22.7% (95% CI: 0.6, 81.3)</td>
<td>Low</td>
<td>(Arguello et al., 2013a; Creus et al. 2007; Cook et al., 2006; Van der Wolf et al., 2001b; Wingstrand et al., 1997; Willaml et al., 2011)</td>
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*low = the true effect may be substantially different from the measured estimate;*
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FAO Conclusions: Feed and water acidification

- Acidification of feed or water using organic acids was recommended for consideration as a hazard-based intervention for the control of Salmonella in infected herds.

- The effect of organic acids depends on other factors (e.g. Salmonella contamination, disease status, type of feed, other management factors).

- The use of acids alone might have a limited effect on reducing Salmonella prevalence in the finishers leaving the farm, in an infected herd.
Salmonella: On-farm control

• Antimicrobials - not recommended
• Biosecurity - recommended for consideration
• Feed/water acidification - recommended for consideration BUT
Evidence: Feed management and feed additives

• Controlled trials and observational studies support that
  • feeding meal (vs. pellets),
  • coarse feed (vs. fine feed)
  • fermented liquid feed (vs. dry feed)
• Varying magnitude of effect in reducing *Salmonella* prevalence on an infected farm

• Sodium chlorate addition to feed was not recommended for consideration
Salmonella: On-farm control

• Antimicrobials - not recommended
• Biosecurity - recommended for consideration
• Feed/water acidification - recommended for consideration BUT
• Feed management
  • Those with proven efficacy recommended for consideration
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Evidence: Manipulation of gut microbiota

• 31 primary research studies
  • 9 controlled trials,
  • 21 challenge trials
  • 3 cross-sectional studies.
Options: Manipulation of gut microbiota

• Feeding *Lactobacillus* spp. a range of findings:
  • 3 reported a significant protective treatment effect
    • (Ahmed et al., 2014b; Casey et al., 2007; Naqid et al., 2015)
  • 3 reported a non-significant treatment effect
    • (Afonso et al., 2013; LeJeune et al., 2006; Letellier et al., 2000).
Options: Manipulation of gut microbiota

• *E. faecium*:

• 3 reported a non-significant treatment effect on *Salmonella* prevalence or load,
  • (Kreuzer et al., 2012; Spiehs et al., 2008; Walsh et al., 2012)

• Significantly greater faecal shedding and organ colonization in pigs treated with *E. faecium* relative to controls
  • Szabo et al. (2009)
FAO Conclusions: Manipulation of gut microbiota

- Manipulation of microbiota using pre- or pro-biotics was not recommend for consideration as a hazard-based intervention for the control of *Salmonella* in pigs due to the limited available evidence.
Salmonella: On-farm control

• Antimicrobials - not recommended
• Biosecurity - recommended for consideration
• Feed/water acidification - recommended for consideration BUT
• Feed management
  • Those with proven efficacy recommended for consideration
  Sodium chlorate - not recommended
• Manipulation of microbiota not recommended
Evidence: Vaccination

• Vaccination of pigs for reduction of *Salmonella* was investigated in three systematic reviews (Denagamage et al., 2007; Wilhelm et al., 2012; Wisener et al., 2014).

• Denagamage et al. (2007) concluded that there was evidence that some vaccines were effective; however, because of the methodological quality of the underpinning evidence, this conclusion might be incorrect.

• Wilhelm et al. (2012) concluded that evidence regarding vaccine effectiveness in finisher pigs was inconsistent.

• Wisener et al. (2014) investigated the use of challenge trials to assess *Salmonella* vaccine effectiveness in pigs, concluding that challenge trials tend to report a more favourable outcome relative to controlled trials.
Options: Vaccination

• 19 studies
• 10 controlled trial
• 9 challenge studies
• 3 systematic reviews
Vaccination in finishers

**Table 5.1: Controlled trials investigating vaccination, measuring outcomes in finisher pigs**

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Population/sample</th>
<th>No. trials/studies</th>
<th>Odds ratio for intervention effect(^a)</th>
<th>% Samples <em>Salmonella</em> positive in study population(^b)</th>
<th>GRADE rating(^c)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaccine</td>
<td>Individual faecal culture</td>
<td>4/2</td>
<td>Median = 0.22 (Range: 0.02, 0.78)</td>
<td>26.7%</td>
<td>7.4% (Range: 0.7, 22.1)</td>
<td>Moderate</td>
</tr>
<tr>
<td>Vaccine</td>
<td>Pen faecal culture</td>
<td>4/2</td>
<td>Median = 1.41 (Range: 0.17, 4.42)</td>
<td>22.5%</td>
<td>29.0% (Range: 5.3, 56.2)</td>
<td>Very Low</td>
</tr>
</tbody>
</table>
## Vaccination on carcass

### Table 5.2: Controlled trials measuring outcomes in pork carcasses

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Population/sample</th>
<th>No. trials/studies</th>
<th>Odds ratio for intervention effect&lt;sup&gt;a&lt;/sup&gt;</th>
<th>% Samples <em>Salmonella</em> positive in study population&lt;sup&gt;b&lt;/sup&gt;</th>
<th>GRADE rating&lt;sup&gt;c&lt;/sup&gt;</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaccine</td>
<td>Lymph nodes</td>
<td>6/4</td>
<td>Median = 0.41 (Range: 0.12, 0.86)</td>
<td>47.5% (Range: 12.2, 43.8)</td>
<td>Moderate</td>
<td>(Arguello et al., 2013b; De Ridder et al., 2014; Maes et al., 2001; Schwarz et al., 2011)</td>
</tr>
<tr>
<td>Vaccine</td>
<td>Caecal content</td>
<td>3/2</td>
<td>Median = 0.53 (Range: 0.18, 0.89)</td>
<td>46.3% (Range: 13.4, 43.4)</td>
<td>Moderate</td>
<td>(Arguello et al., 2013b; De Ridder et al., 2014)</td>
</tr>
</tbody>
</table>
FAO Conclusions: Vaccination

• Vaccination was recommended for consideration as a hazard-based intervention for the control of *Salmonella* in pigs on farm; however, only where the context is carefully described and considered.
HOWEVER

• 1-2 logs change required to significantly reduce human salmonellosis would be very difficult to achieve nationally via on-farm strategies such as vaccination.
  • Hill et al. (2011b)

• The authors concluded that vaccination, even with a vaccine of hypothetically perfect effectiveness, was not sufficient to eliminate *Salmonella* infection on a high-risk farm.
  • Soumpasis et al. (2012), Hotes et al. (2011)
Salmonella: On-farm control

• Antimicrobials - not recommended
• Biosecurity - recommended for consideration
• Feed/water acidification - recommended for consideration BUT
• Feed management
  • Those with proven efficacy recommended for consideration
  Sodium chlorate - not recommended
• Manipulation of microbiota not recommended
• Vaccination recommended for consideration BUT
• If measures are taken only pre-harvest, then there may be a limited effect on the reduction of *Salmonella* on carcasses.
FAO : On-Farm Summary

• Several relevant risk assessments and stochastic models were identified (n=24), often describing multiple levels of the pork production chain.

• Across these studies, the generalizability of data and assumptions from target population to others was frequently unclear (n = 14 of 24 studies), making the wider applicability of these studies’ findings uncertain.
FAO : On-Farm Summary

• Results from stochastic models studying the farm-to-fork continuum were consistent in identifying post-farm levels of the chain as the areas containing points for more effective applications of intervention, regardless of outcome modelled (e.g. carcass prevalence vs. human clinical cases of salmonellosis).
Table 1.1: Controlled trials investigating the effect of presence or absence of lairage

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Outcome sample</th>
<th>No. trials/studies</th>
<th>Odds ratio for intervention effect(^a)</th>
<th>% Samples expected to be <em>Salmonella</em> positive in study population(^b)</th>
<th>GRADE rating (^c)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>No lairage</td>
<td>Carcasses (Caecal content)</td>
<td>8/5</td>
<td>Median = 0.19 (Range: 0.12, 1.06)</td>
<td>20.7% (Range: 4.8%, 2.4, 24.7)</td>
<td>Low</td>
<td>(Fravalo et al., 2003; Hurd et al., 2001; Hurd et al., 2002; Larsen et al., 2004; Rostagno et al., 2005)</td>
</tr>
<tr>
<td>No lairage</td>
<td>Carcasses (Lymph nodes)</td>
<td>4/4</td>
<td>Median = 0.79 (Range: 0.37, 2.19)</td>
<td>35.6% (Range: 30.4%, 14.5, 54.3)</td>
<td>Low</td>
<td>(Fravalo et al., 2003; Hurd et al., 2001; Hurd et al., 2002; Larsen et al., 2004)</td>
</tr>
</tbody>
</table>

MA=meta-analysis average estimate from random-effects model; CI=confidence interval.
Abattoir-based interventions

• Carcass decontamination treatments with proven efficacy were recommended for consideration as potential hazard-based interventions before chilling.
Process map of Salmonella Prevalence on Carcasses: Systematic Review Approach

Annette M. O’Connor, Bing Wang, Thomas Denagamage, and James McKean, Process Mapping the Prevalence of Salmonella Contamination on Pork Carcass from Slaughter to Chilling: A Systematic Review Approach. FOODBORNE PATHOGENS AND DISEASE Volume 9, Number -, 2012
Breeding Pig Analysis (2011)

• “On the basis of current scientific advice and the experience of Member States, it is not possible at this time to demonstrate cost-beneficial interventions to reduce Salmonella infections at EU level in either breeding pigs or slaughter pigs, or in combinations of both herds. Sensitivity analyses indicate that positive cost-benefits can be found only in extreme scenarios.”

Systematic reviews on Salmonella in pork

• In-plant interventions – effective
• In-plant interventions – cost effective

Annette M. O’Connor, Bing Wang,1 Thomas Denagamage,2 and James McKean, Process Mapping the Prevalence of Salmonella Contamination on Pork Carcass from Slaughter to Chilling: A Systematic Review Approach  FOODBORNE PATHOGENS AND DISEASE Volume 9, Number -, 2012

Salmonella surveillance and control for finisher pigs and pork in Denmark — A case study  L. Alban a,⁎, F.M. Baptista b, V. Møgelmose a, L.L. Sørensen a, H. Christensen c, S. Aabo d, J. Dahl a
Pork chain steps:

1. Primary Production
   - Primary Production
2. Transport to Slaughter
3. Receive and Unload
4. Ltrage
5. Stunning
6. Sticking/Bleeding
7. Scalding
8. Dehairing
9. Gambrelling
10. Singeing
11. Polishing
12. Bunging
13. Midline Opening
14. Evisceration
15. Splitting
16. Head Dropping/Removal
17. Post Mortem inspection
18. Chilling
19. Carcass Fabrication
20. Mechanical Tenderization/Mincing
21. Packing Product
22. Transport to Distribution Channels
23. Cold Storage
24. Distribution/Retail
25. Consumer

Processing

Distribution Channels
Major references( not complete- see reviews for individual studies)

- UPDATED version available @ http://www.who.int/foodsafety/publications/mra_30/en/
Learn more about research synthesis

Travel support provided by National Pork Board
Bringing Food Safety Back To The Farm: A Swine Perspective

Annette O’Connor, Iowa State University
Presentation for: Swine Committee
National Institute of Animal Agriculture
Columbus Ohio, Tuesday, April 4, 2017
10:00 a.m. – 12:30 p.m.