Risk assessment of Salmonella in feed and pig production
Finnish Risk Assessment in Focus
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Risk assessment and cost-benefit analysis of salmonella in feed and animal production

RISK:
Risk of salmonella-infection from Finnish domestic pork, originating from pig feed?

COST-BENEFIT:
Costs of salmonella control *versus* benefits of preventing domestic salmonella infections?
Salmonella in Finland

- **Human cases per year** (exl typhoid and paratyphoid fever): 1600-3000
  - Of which 300-400 of domestic origin
    - Most common serotypes: Typhimurium, Enteritidis and Group B (together > 50 % of domestic cases)
    - Sporadic food-borne outbreaks (2 outbreaks in 2013)

- **Salmonella in pigs**
  - Positive findings from pig farms (5 in 2013) and from lymph node samples at slaughterhouses (4/6400 in 2013) are rare

- **Salmonella in pig feeds**
  - A few salmonella positive findings from feed raw materials per year
    - In 2013: 2/1280 rapeseed, 7/1737 soy, 1/445 from molasses escalope, all imported feed ingredients from EU and beyond
  - Positive findings from feed are rare
Control of Salmonella in Finland

- **Finnish Salmonella Control Programme**
  - Stricter regulations on the level of salmonella (all serotypes) prevalence in production animals and products thereof than in EU Control Programme
    - Level in animals (including pigs) under 1 % with 95% certainty
    - Level at slaughterhouses under 5 % with 95% certainty
  - Zero tolerance
    - Every salmonella finding triggers action (withdrawal, traceback, increased sampling, hygiene measures)
  - Additional guarantees
    - Certain types of meat, eggs and product thereof have to be tested negative for salmonella before arrival

- **Feed act**
  - Imported feeds and feed ingredients are tested for salmonella before arrival as part of self-control
Salmonella transmission in pork production chain

True prevalence of salmonella in feed raw materials, feeds and pigs?

Proportion of feed-borne salmonella infections in pigs?

Share of human-cases attributable to pork and pig feed?
Feed chain

Feed, non-domestic

Feed ingredient, non-domestic

Feed ingredient, domestic but not own farm

Feed ingredient, own farm

Storage and transport

Feed mill

Mobile mixer

Transport

Pig farm

85% of the farms used supplement feeds mixed with feed ingredients from the farm
Pig farms and pigs per municipality in Finland

In 2013:

190 million kilograms of pork was produced in Finland.

An average Finn consumed 35,6 kilograms of pork.

Figures: Juha Tuomola
Method

- Bayesian probability network computed with OpenBugs

Feed model
- Salmonella prevalence and concentration in the feed ingredients
- Salmonella prevalence and concentration in the feed types mixed from the ingredients on certain proportions
- Salmonella prevalence and concentration in the feeds mixed from the feed types on certain proportions and ± treated with heat or acid

Pig model
- Risk to pig from the environment, source attribution
- Risk to pig
- Feed consumption and dose-response, pig and sow

Human model
- Population risk
- Human cases of salmonella attributed to pork
- Salmonella cases in humans
## Results: estimated true prevalences

### Estimated true salmonella prevalences in feed raw materials

<table>
<thead>
<tr>
<th></th>
<th>Prevalence (Mean,%)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic grains</td>
<td>0.009</td>
<td>0.008</td>
</tr>
<tr>
<td>Domestic soy and rapeseed</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Non-domestic soy and rapeseed</td>
<td>0.5</td>
<td>0.1</td>
</tr>
</tbody>
</table>

### Estimated true salmonella prevalences in feeds

<table>
<thead>
<tr>
<th></th>
<th>Prevalence (Mean,%)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial complete feeds</td>
<td>0.09</td>
<td>0.03</td>
</tr>
<tr>
<td>Industrial supplement feeds, dry</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Industrial supplement feeds, fluid</td>
<td>0.1¹</td>
<td>0.2¹</td>
</tr>
<tr>
<td>Farm mixes (excl supplements)</td>
<td>0.04¹</td>
<td>0.05¹</td>
</tr>
<tr>
<td>Non-domestic feeds</td>
<td>5¹</td>
<td>5¹</td>
</tr>
</tbody>
</table>

¹ small number of samples, high uncertainty

- Concentrations for the dose-response² in pigs:
  - $6.5 \times 10^{-4}$ to $2.5$ cfu/g (95%: from $1.4 \times 10^{-7}$ cfu/g to 17 cfu/g)
    - in positive feed raw materials are from the literature
    - in positive feed is based on samples taken during a feed-borne outbreak in Finland in 2009

² Loynachan, AT; Harris DL. Dose Determination for Acute Salmonella Infection in Pigs. Applied and Environmental Microbiology, 2005, 71(5), 2753-2755
Results: feed-borne infections in pigs

- Estimated true prevalence in pigs
  - In sows 0.54% (95% CI: 0.18–1.2%)
  - In pigs 0.27% (95% CI: 0.09–0.53%)

- Estimate of the relative exposure of pigs to salmonella in feed versus the environment, taking into account the production volume of sows and pigs
  - For sows 60% (95% CI: 22–93%)
  - For pigs 38% (95% CI: 9–74%)

Välttilä, V., Ranta, J., Rönnqvist, M., Tuominen, P. Bayesian model for tracing Salmonella contamination in the pig feed chain. Food Microbiology.
Results: human infections due to pork

- Comparative exposure assessment approach + Microbial subtyping approach

A point estimate of the relative salmonella exposure of humans to domestic pork

14 %

Estimate of the relative salmonella exposure of humans to domestic pork, originating from pig feed:

5.3% (95% CI 1.2–10.3%)
Scenarios

What happens if the control of Salmonella in feed was relaxed?

1. Current Salmonella prevalence in feed raw materials was replaced with the prevalence data obtained from other EU areas
   - Resulting prevalence in pigs:
     0.4 % (median 0.4 %, 95 % CI 0.2-0.8) ~2-fold increase

2. Current Salmonella prevalence data on feed from Finland were replaced with prevalence data from other EU areas
   - Resulting prevalence in pigs:
     10.6 % (median 9.9 %, 95 % CI 0.5-25.7)
     ~38 –fold increase

Rönnqvist, M., Väättilä, V., Ranta, J., Tuominen, P. Salmonella risk to consumers via pork is related to the Salmonella prevalence in pig feed. Food Microbiology.
The Salmonella prevalence of foreign protein-rich feed ingredients was replaced with the lower value of domestic ingredients (as if there was no import of these ingredients)

Resulting prevalence in pigs:

0.2 % (median 0.2 %, 95 % CI 0.08-0.5)
Under current low prevalence in pigs, contaminated feed can be a relatively significant source of the prevailing salmonella infections in pigs in Finland.

Pork can be a relatively important source of domestic human salmonellosis cases, yet all prevalences are low.

Alleviation of feed control practices could increase the Salmonella infections in pigs, especially if Salmonella prevalence in feed increased.

Highest uncertainty in the model is associated with feeds mixed on farm, especially with liquid raw materials and feeds.

Model can be utilized to evaluate impact of feed on salmonella infections also in other production animals.
Future work

Next project: Impact of pests on persistence and spreading of zoonotic bacteria on production farms (PESTANIMAL)

- Aims:
  - To examine the impact of pest animals to food security at farm-level
  - To investigate the routes of pathogenic, potentially antibiotic resistant bacteria from feed, pest animals and the environment to production farms
  - To give recommendations regarding pest management
  - To provide tools to plan financial supporting systems to production farms based on their biosecurity level regarding pest management
Pilot study:

Campylobacter was a common finding from rodents from farm environments (4/8 trap checks) and from control (urban) environments (2/8 trap checks).

Salmonella was isolated once from yellow-necked mice.
Risk assessment and cost-benefit analysis of salmonella in feed and animal production

- **Project team:**
  - Evira: Pirkko Tuominen, Jukka Ranta, Maria Rönnqvist, Ville Välttilä
  - Natural Resources Institute Finland LUKE: Jarkko Niemi, Katriina Heinola

- **Steering group**

- **Funding:** Development Fund Agriculture and Forestry, Evira, LUKE

Two papers are in press:
Välttilä, V., Ranta, J., Rönnqvist, M., Tuominen, P. Bayesian model for tracing Salmonella contamination in the pig feed chain. Food Microbiology.

Rönnqvist, M., Välttilä, V., Ranta, J., Tuominen, P. Salmonella risk to consumers via pork is related to the Salmonella prevalence in pig feed. Food Microbiology.