Control of *Salmonella* in Animal Feed

**IMPORTANCE OF BACTERIAL CONTROL FOR FOOD SAFETY AND ANIMAL PERFORMANCE**

*Presented by:*

Ferdie Nel  
Anitox  
USA
ANIMAL FEEDS CONTAIN A WIDE RANGE OF MICROBIAL CONTAMINANTS

- Moulds/ mycotoxins
- Yeasts
- Bacteria

- Most research has focussed on moulds and mycotoxins
- Bacterial contamination of feed is less well understood and frequently overlooked
WHY IS BACTERIAL CONTAMINATION OF FEED A CONCERN?

- Animal feeds and feed ingredients can serve as carriers for a variety of bacteria
- A proportion of those bacteria present can be pathogenic to human and animal health
- Feed can therefore introduce bacteria into the farm and processing plant which can:
  - Compromise safety of animal products and public health
  - Adversely affect animal performance and health status
  - Have legislative and enforcement implications
## EU Zoonoses 2008

<table>
<thead>
<tr>
<th>Animal Type</th>
<th>Target Date Set</th>
<th>Compulsory Testing Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry Breeders</td>
<td>June 2005</td>
<td>Jan 2007</td>
</tr>
<tr>
<td>Laying hens</td>
<td>June 2006</td>
<td>Jan 2008</td>
</tr>
<tr>
<td>Broilers</td>
<td>June 2007</td>
<td>Jan 2009</td>
</tr>
<tr>
<td>Turkeys &amp; fattening pigs</td>
<td>June 2008</td>
<td>Jan 2010</td>
</tr>
<tr>
<td>Breeding pigs</td>
<td>June 2009</td>
<td>Jan 2011</td>
</tr>
</tbody>
</table>

*Salmonella typhimurium & enteritidis*
EU Zoonoses 2008

An annual minimum % reduction of +ve flocks

*equal to at least*

(i) 10% if prevalence in previous year was less than 10%
(ii) 20% if prevalence was between 10% and 19%
(iii) 30% if prevalence was between 20% and 39%
(iv) 40% if prevalence was 40% or more
KEY BACTERIA FOUND IN FEED INGREDIENTS

- Clostridia
- E.Coli
- Salmonella
- Listeria
- Staphylococcus
- Streptococcus

- Pseudomonas
- Proteus
- Bacillus
- Pasteurella
- Citrobacter
- Enterobacter
WHEN AND HOW DO FEED INGREDIENTS BECOME CONTAMINATED WITH BACTERIA?

- **When?**
  - Growing
  - Harvesting
  - Processing
  - Storage/transport
  - Feed mill intake and storage

- **How?**
  - Environmental contact
    - Direct - soil, rodents, birds, dust, humans, water
    - Indirect – water, sewage, animal manure
  - Cross contamination
    - Storage, processing, transport, mill intake
BACTERIAL CONTAMINATION - NOT ONLY A PROBLEM IN FEED INGREDIENTS OF ANIMAL ORIGIN (% *Salmonella* positive samples per ingredient – Canada 1990-2003)

Barakat, 2004
ENTEROBACTERIACEAE

(30 Genera)

The genera Arsenophonus and Pantonea were added later.
Enterobacteriaceae contamination of processed soya

Enterobacteriaceae contamination of processed soya

Enterobacteriaceae contamination of processed soya

Enterobacteriaceae contamination of processed soya
ENTEROBACTERIACEAE LEVEL IS RELATED TO RISK OF SALMONELLA CONTAMINATION

Other materials, Mainly Wheat

Anon, 2001
FEED AND FOOD SAFETY – A HISTORY OF FOOD SCARES

• Various food related scares witnessed over last few years
  • BSE
  • Food borne microbial infections
  • Dioxins
  • Microbial resistance to antibiotics
  • Drug and chemical residues
  • Melamine in Pet food

• Food safety has become a major concern to:
  • Food industry
  • Consumer
  • Legislator
  • Producer
Feed has been shown to be a major vector for transmission of Salmonella to the farm and processing plant (Corry et al, 2002; Hald et al, 2006)

Feed can introduce other human pathogens into the poultry house and processing plant e.g. E.coli, Listeria, Clostridia

Most attention has been on Salmonella although prevalence of others may be higher (Whyte et al, 2003)
HUMAN BACTERIAL FOOD BORNE ILLNESS - USA

76 million cases/year (25% of population)

325000 hospitalizations/year

5000 deaths/year

Mead et al, 1999
## SALMONELLA SEROVARS IN THE FEED MILL, HATCHERY AND PROCESSING PLANT

<table>
<thead>
<tr>
<th>Location</th>
<th>Salmonella Serovars</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>Company A Feed mill</td>
<td>16</td>
</tr>
<tr>
<td>Company A Hatchery</td>
<td>4</td>
</tr>
<tr>
<td>Company B Feed mill</td>
<td>11</td>
</tr>
<tr>
<td>Company B Hatchery</td>
<td>6</td>
</tr>
</tbody>
</table>
## INCIDENCE OF HUMAN FOOD BORNE PATHOGENS IN FEED

| Feed type                      | Incidence (%) |  |
|-------------------------------|---------------|
|                               | Salmonella    | E. Coli | Listeria |
| Poultry mash feed (mill)¹     | 8.3           | 61.7    | 27.1     |
| Poultry mash (mill) ²         | 0             | N/A     | 25       |
| Pelleted poultry feed (mill) ¹| 1.7           | 1.7     | 0        |
| Pelleted poultry feed (mill) ²| 0             | N/A     | 13.3     |
| Pelleted poultry feed (farm) ²| 57.1          | N/A     | 100      |
| Swine mash feed ³             | N/A           | N/A     | 20.0     |

¹ Blank et al, 1996
² Whyte et al, 2003
³ Norrung et al, 1991
## SALMONELLA IN FEED INGREDIENTS - SEROTYPES OF PUBLIC HEALTH CONCERN - NETHERLANDS

<table>
<thead>
<tr>
<th>Feed Material</th>
<th>S. positive 2006</th>
<th>% critical serological classification</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>South American Soya meal</td>
<td>1.7</td>
<td>20%</td>
<td>7 x Livingstone, 7 x Senftenberg, 4 x Agona, 4 x Infantis, 2 x Orion, 3 x Rissen, 1 x Lexington, 2 x Havana, 2 x Mbandaka, 1 x Give, 1 x Tennessee, 1 x Salmonella C1 group, 5 x unknown</td>
</tr>
<tr>
<td>Fish meal (treated)</td>
<td>0.8</td>
<td>0%</td>
<td>1 x E4 group, 2 x Anatum</td>
</tr>
<tr>
<td>Rape/Canola meal and flakes</td>
<td>3.4</td>
<td>20%</td>
<td>2 x Cubana, 1 x Lexington, 2 x Anatum, 28 x Lexington, 18 x Senftenberg, 10 x Parath. B. Java, 9 x Tennessee, 12 x Agona, 5 x Serogr E1, 5 x Mbandaka, 5 x Infantis, 2 x Kentucky, 1 x Livingstone, 1 x Rissen, 1 x C1 group, 1 x E4 group, 1 x B group, 1 x Virchow, 1 Enteritidus, 1 x Stanley, 1 x Duisburg, 1 x Brandenburg, 2 x classification to follow, 34 x unknown</td>
</tr>
<tr>
<td>Soya beans toasted</td>
<td>2.0</td>
<td>11%</td>
<td>1 x Lexington, 1 x Infantis, 1 x Rissen, 1 x Virchow, 6 x Anatum, 2 x Agona, 19 x Rissen, 2 x Enterica Spp, 2 unknown</td>
</tr>
<tr>
<td>European Sunflower meal</td>
<td>0.9</td>
<td>50%</td>
<td>1 x Infantis, 3 x Agona, 1 x Livingstone, 1 x Tennessee, 1 x Havana, 1 x B group</td>
</tr>
</tbody>
</table>

Productschap Dievoeder, Quality Series No. 120, June 2007
FEED CAN INTRODUCE ANTIBIOTIC RESISTANT BACTERIA INTO THE FOOD CHAIN

- Feed can be contaminated with antibiotic resistant bacteria
- 1994 – Multi-antibiotic resistant strain of *Salmonella* (*S. typhimurium DT104*) found in feed (MAFF, 1994)
- 1999 – Multi-antibiotic resistant strain of *Streptococcus* found in feed (Morris *et al.*, 1999)
- 2001 – Multi-antibiotic resistant strains of numerous enteric bacteria isolated from rendered animal products (Hofacre *et al*, 2001)
- Antibiotic resistant enterococci and *E.coli* isolated in Portuguese feed ingredients and complete feed and linked to introduction into the farm (P.M. da Costa *et al*, 2007)
1991 - Program to monitor S. enterica in feed introduced as part of a ‘farm to fork’ Salmonella control system
7000 samples of feed tested annually
More extensive testing and corrective measures implemented when Salmonella positive feed samples detected
2000 - S. enterica virtually eliminated from animal feed and meat
Annual rates of salmonellosis in human population dropped from 14 cases to 8 cases per 100,000

Crump et al, 2002
BACTERIA IN FEED – RELATIONSHIP WITH CLINICAL DISEASE

- Cellulitis/Dermatitis (Clostridia)
- Necrotic Enteritis (Clostridia)
- Avian Cholera (Pasteurella)
- Air Sacculitis (E. Coli)
- Pericarditis (E. Coli)
- Endocarditis (Streptococcus)
- Septicemia (Streptococcus, Staphylococcus, E. Coli, Bacillus)
- Diarrhea and Enteritis (Streptococcus, Pseudomonas, E. Coli, Bacillus)
Foreign bacteria from feed can:
Compete with the normal micro flora for binding sites on the intestinal epithelium disrupting the homeostatic environment
Inhibit nutrient uptake by preventing extension of villi through a bacteria laden mucus blanket
Elicit a mucosal immune response creating inflammation of the gut and increasing feed passage
Produce toxic compounds/enzymes which damage the gut mucosa (e.g. E.coli, Clostridia)
Transform proteins
BACTERIA IN FEED – THE SUBCLINICAL CONSEQUENCES

- Poor digestion and absorption of nutrients
- Decreased growth rate
- Reduced feed efficiency
- Decreased flock uniformity
- Uneven pigmentation
- Increased susceptibility to coccidial and viral infections
- Increased mortality
- Response to vaccination (Lowered titres)
CONTROL OF BACTERIA IN FEED

- Understand and adopt the principles of HACCP
- Select raw materials carefully
  - Know your suppliers
  - Don't select raw materials on nutrient specification alone
- Know your own processes
  - Where cross contamination potential exists
  - Where bacteria accumulate/recontamination could occur
- Control rodents, wild birds and dust
- Store materials correctly/site hygiene
- Use chemical or physical control measures at the feed mill/ with your supplier
CHEMICAL AND PHYSICAL CONTROL METHODS

• Aim:
  • Eliminate pathogenic bacteria in the feed
  • Prevent recontamination until consumed by the animal

Options

• Irradiation
• Thermal treatment
• Chemical treatment
• Combination
THERMAL TREATMENT

- Effective if correct temperature, residence time and moisture are achieved
- Control of E.coli and Salmonella requires 85°C for >4 minutes with 145g moisture/kg
- Clostridium can survive pelleting at 90°C due to heat resistant spores
- Requires procedures to prevent against recontamination
- Increasingly expensive (high capital and rising energy costs)
- Reduces mill throughput
- Selection for heat resistance
- Start up hygiene issues
- Nutrient and digestibility changes (e.g. heat labile vitamins)
BACTERIAL CONTAMINATION OF ANIMAL FEED AND ANIMAL PERFORMANCE

• The gastrointestinal tract is inhabited by a complex bacterial community
• Composition is influenced by environment including feed
• Variation in composition affects gut health and ability to express genetic potential
• High levels of bacteria in feed has been shown to be associated with reduced animal performance (Tabib et al., 1981; Anderson and Richardson, 1999; DeRouchey et al., 2000)
FOR BACTERIA SURVIVING THE HEAT TREATMENT, THE COOLER IS LIKE STAYING IN A 5 STAR HOTEL!
POST HEAT TREATMENT RECONTAMINATION OCCURS

Enterobacteriaceae (cfu/g)

Principal feed mill sampling points

Mixer
Min
Max

After Press Pre Cooler
Min
Max

Out bins
Min
Max

POST HEAT TREATMENT RECONTAMINATION OCCURS
CHEMICAL TREATMENTS

• Organic acids
• Organic acids and salts
• Formaldehyde/acid mixtures
# Level of Organic Acid Required to Reduce Enterobacteriaceae in Feed

<table>
<thead>
<tr>
<th>Organic acid</th>
<th>Days required for 90% reduction at different treatment levels</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>5 kg/t</td>
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<tr>
<td>Formic</td>
<td>12</td>
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<tr>
<td>Propionic</td>
<td>No reduction</td>
</tr>
<tr>
<td>Lactic</td>
<td>No reduction</td>
</tr>
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</table>

Vanderval (1979)
FORMALDEHYDE PROVIDES MORE EFFECTIVE BACTERIAL CONTROL IN LAYER MASH THAN ORGANIC ACID BLENDS

Tested 24h after treatment

Enterobacteriaceae Count (Log 10 CFU/g)

Treatment (kg/MT)

Organic acid/salt product

Formaldehyde/acid blend
CHEMICAL TREATMENT CAN GIVE LONG TERM PROTECTION AGAINST RECONTAMINATION

Enteros in poultry feed production +28 days after delivery
CAN ANIMAL PERFORMANCE BE IMPROVED BY REDUCING BACTERIAL LEVELS IN FEED?

• Control of bacteria in feed has been shown to:
  • Reduce incidence of pathogenic bacteria in the farm environment (litter samples)
  • Improve production parameters in breeding poultry, broilers and laying hens
  • Reduce bacterial contamination of egg shell surface
CHEMICAL TREATMENT OF FEED HELPED REDUCE THE NUMBER OF SALMONELLA POSITIVE BREEDER FLOCKS

### Litter Samples

<table>
<thead>
<tr>
<th>Farm</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
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<tbody>
<tr>
<td>1</td>
<td>O</td>
<td>E</td>
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<td>17</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>M</td>
<td>M</td>
</tr>
</tbody>
</table>

**Legend**
- No sample tested
- Salmonella Negative
- Salmonella Positive - O = Ohio, E = Enteritidis, M = Montevideo

31 Oct chemical treatment introduced to feed

8 Dec Chemical treatment rate increased
### CONTROL OF BACTERIA IN FEED CAN IMPROVE BROILER PERFORMANCE – AVERAGE OF 11 TRIALS

- **2.5 million birds in 11 trials**
- All birds fed commercial broiler diets either as crumble to 21 days followed by pellet to kill or crumble followed by mash
- Formaldehyde/propionic acid based feed treatment added at 1.5kg/tonne (0-21 days) and 1kg/tonne (21 days – slaughter)
- All birds either Ross 308 (trials 1-5 & 11) or Cobb 500 (trials 6 – 10)

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Treated</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liveweight (kg)</td>
<td>2.39</td>
<td>2.38</td>
<td>-0.01</td>
</tr>
<tr>
<td>FCR (g/g)</td>
<td>1.835</td>
<td>1.797</td>
<td>-0.038</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>4.25</td>
<td>3.58</td>
<td>-0.67</td>
</tr>
<tr>
<td>Culls (%)</td>
<td>2.05</td>
<td>0.94</td>
<td>-1.11</td>
</tr>
</tbody>
</table>
CONTROL OF BACTERIA IN FEED CAN IMPROVE EGG PRODUCTION AND QUALITY IN LAYING FLOCKs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Treatment¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
</tr>
<tr>
<td></td>
<td>Formaldehyde/acid</td>
</tr>
<tr>
<td>Feed consumption (g/bird)</td>
<td>113.7</td>
</tr>
<tr>
<td></td>
<td>113.5</td>
</tr>
<tr>
<td>Hen day egg production %</td>
<td>76.07</td>
</tr>
<tr>
<td></td>
<td>77.55</td>
</tr>
<tr>
<td>Hen housed eggs</td>
<td>270.07</td>
</tr>
<tr>
<td></td>
<td>274.71</td>
</tr>
<tr>
<td>Daily egg mass output (g)</td>
<td>46.69</td>
</tr>
<tr>
<td></td>
<td>47.78</td>
</tr>
<tr>
<td>Shell Surface Entero count (CFU/egg)</td>
<td>11660</td>
</tr>
<tr>
<td></td>
<td>1460</td>
</tr>
<tr>
<td><strong>Feed Quality</strong></td>
<td></td>
</tr>
<tr>
<td>Enterobacteriacea (CFU/g)</td>
<td>7233</td>
</tr>
<tr>
<td></td>
<td>42</td>
</tr>
<tr>
<td>Coliform (CFU/g)</td>
<td>597</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

Hyline W36 white layers (17-66 weeks of age)  
¹ Values represent average of 14 sampling intervals over 52 weeks

Anderson and Richardson, 1999
CONCLUSION

• Animal feeds can serve as carriers of pathogenic bacteria
• Feed contaminated with pathogenic bacteria can influence safety of animal products adversely
• Chemical and physical control measures can be used to control bacteria in feed
• Control of bacteria with chemical treatments consistently improves animal performance
• Bacterial control in feed should be seen as a method of improving economic performance of a farming enterprise not an extra cost
SOLUTIONS FOR SAFER FEED AND FOOD