Pathogens on meat and infections in animals - establishing a relationship

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Salmonella

- Effects of environment on pathogen behaviour and host resistance
- Epidemiology and prevention
- Host-pathogen interactions
- Pathogen diversity
- Stress and persistence mechanisms
- Animal welfare and infection

Campylobacter

Campylobacter jejuni
Microbial ecology

Immunological competence

Susceptibility to colonisation, disease and carriage
Intervention points to control food borne disease

- On the farm
- In the abattoir or processing plant
- During retail sale
- In the home or restaurant
- Control points differ with pathogen
- Passage along the food chain will change the nature of pathogen populations
Successful control requires knowledge on:

- Trends in human and animal infection.
- Routes and vehicles of transmission.
  - Pathogen persistence on farm
  - Interactions with host and environment
  - Survival in foods and during processing
- Cost-effective control measures.
- Techniques applied to determine pathogen populations differ according to position in the food chain
- Thus techniques/media used with foods may not be the same as those applied to samples from animals
- There is inherent bias, which obscures true epidemiology
Defining the problem
Red meat animals as a source of zoonotic pathogens

- All red meat animals have the potential to carry/be infected with salmonella and campylobacter
- Ruminants can also carry *Escherichia coli* O157:H7
- Red meat has been implicated in outbreaks of human infection caused by all three pathogens
- The above animals will also carry *Clostridium perfringens* and each year will see many outbreaks caused by this pathogen
- This is almost always the results of poor catering practice
Pathogens of importance

- O 157
- LM
- Cl perf
- Salm
- NV
- Camp
- Others

% IFD

Cases
GP
Hosp
Beds
Deaths
Red-meat-associated pathogens of importance

• Difficult to present a global picture of the risks posed by pathogens in red meat animals and foods from them
• Production methods and food consumption patterns differ across Europe
• Thus, pork is a much more important source of *Campylobacter coli* on continental Europe that in the UK and Ireland
• In terms of serious cases caused, *Salmonella* spp are most important
• Politically, and because of high mortality rates, *Escherichia coli* O157:H7 is of supreme importance
Reported cases of campylobacter and salmonella infection: England and Wales 1986-2005
## Estimated annual impact of red meat infections: England and Wales 1996-2000*

<table>
<thead>
<tr>
<th>Food type</th>
<th>Cases</th>
<th>Deaths</th>
<th>Case-fatality rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry</td>
<td>502634</td>
<td>191</td>
<td>38</td>
</tr>
<tr>
<td>Chicken</td>
<td>398420</td>
<td>141</td>
<td>35</td>
</tr>
<tr>
<td>Turkey</td>
<td>87798</td>
<td>45</td>
<td>52</td>
</tr>
<tr>
<td>Red Meat</td>
<td>287485</td>
<td>164</td>
<td>57</td>
</tr>
<tr>
<td>Beef</td>
<td>115929</td>
<td>67</td>
<td>58</td>
</tr>
<tr>
<td>Pork</td>
<td>46539</td>
<td>24</td>
<td>53</td>
</tr>
<tr>
<td>Lamb</td>
<td>46239</td>
<td>27</td>
<td>59</td>
</tr>
</tbody>
</table>

Adak *et al.* 2005
Establishing a link between animals and man
Salmonella and campylobacter in foods and animals

- Both pathogens can be isolated frequently from all red meat animals.
- Campylobacter is more common with ~ 50% of animals carrying the bacteria.
- With this pathogen there appears to be two broad populations:
  - ‘Host-specific’
  - Non-host-specific
- Salmonella common in red meat animals are often not those most commonly found in man.
Identification of salmonella and campylobacter

- Long-established techniques based on surface antigens (LPS and flagella) has worked well for salmonella
- With common serovars like S. Enteritidis and S. Typhimurium, phage typing (PT) provides valuable additional discrimination
- PTs can be used to identify source
- Future typing will be genome-based and will identify attributes
- Thus is the isolate a Tom Humphrey or a Jim Sheridan?
- The typing of *Campylobacter* spp. is a nightmare!
The typing of *Campylobacter* spp.

- This is a personal view and may not reflect the views of the conference organisers or those of ACMSF
- *Campylobacter* cannot be typed in the same way as salmonella
- Schemes based on surface structures produce highly variable results and many strains are untypable
- The *campylobacter* genome can be highly plastic and subject to frequent change, often in response to environmental pressure
- The surface sugars of *campylobacter* will change, producing another ‘new’ strain
- Multi Locus Sequence Typing (MLST), based largely on housekeeping genes offers real promise
Pathogens in animals do not always end up in man
### Salmonella in food animals: England & Wales 2005

<table>
<thead>
<tr>
<th>Rank</th>
<th>Cattle</th>
<th>%</th>
<th>Sheep</th>
<th>%</th>
<th>Pigs</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dublin</td>
<td>69</td>
<td>Diarizonae</td>
<td>66</td>
<td>Typhimurium*</td>
<td>71</td>
</tr>
<tr>
<td>2</td>
<td>Typhimurium*</td>
<td>15</td>
<td>Dublin</td>
<td>9</td>
<td>Derby</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>Anatum</td>
<td>3</td>
<td>Typhimurium*</td>
<td>6</td>
<td>Reading</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>Agama</td>
<td>2</td>
<td>Montevideo</td>
<td>6</td>
<td>Goldcoast</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Newport*</td>
<td>1</td>
<td>Agama</td>
<td>3</td>
<td>Kedougou</td>
<td>3</td>
</tr>
</tbody>
</table>

* In human top 5
Pathogen frequency in animals is not always matched by that in foods
## Campylobacter in raw foods and animals

<table>
<thead>
<tr>
<th>Food or animal tested</th>
<th>Mean % positive</th>
<th>% Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy cows</td>
<td>30.0</td>
<td>6-64</td>
</tr>
<tr>
<td>Beef cattle</td>
<td>62.1</td>
<td>42-83</td>
</tr>
<tr>
<td>Sheep</td>
<td>31.1</td>
<td>18-44</td>
</tr>
<tr>
<td>Pigs</td>
<td>61.0</td>
<td>50-69</td>
</tr>
<tr>
<td>Chicken flocks</td>
<td>58.7</td>
<td>2.9-100</td>
</tr>
<tr>
<td>Retail chicken</td>
<td>57.4</td>
<td>23-100</td>
</tr>
<tr>
<td>Pork</td>
<td>2.0</td>
<td>0-5.1</td>
</tr>
<tr>
<td>Beef</td>
<td>2.7</td>
<td>0-9.8</td>
</tr>
<tr>
<td>Lamb</td>
<td>6.0</td>
<td>0-12.2</td>
</tr>
</tbody>
</table>

Data from papers from 25 countries
Campylobacter frequency in animals is not always matched by that in foods

- With poultry, infection rates in the live animal are often close to those in the raw product at retail
- This is only rarely the case with red meat animals and there can be orders of magnitude differences between the animal and the raw product
- This is because:
  - The slowness of red meat slaughter allows better hygiene
  - Extended chilling times reduces campylobacter numbers
  - Campylobacter is particularly sensitive to extra-intestinal conditions
- Salmonella numbers will also be affected by chilling etc.
Pathogen populations are inherently variable
Salmonella desiccation tolerance, RpoS and LPS

Cells on surfaces for 48 hours
Variations in *E. coli* O157:H7 phenotype

- Strain A from a fatal case.
- Link to environment.
- UV light and desiccation-tolerant.
- Enhanced heat, acid and peroxide tolerance.
Differences in salmonella (SE PT4) virulence

Hearts from salmonella-positive chickens
Pathogen populations in man and animals are subject to change
Salmonella Typhimurium infection
England and Wales 1990-2001
Changes in UK *S. Enteritidis* PTs

- Marked change in PTs ~ 2000
- >23 PTs in outbreaks 02-04
- Mainly egg-associated
- Imported eggs implicated

- Increase in imported eggs
- Marked from 1999
- Control differs across EU
- Imports from one state must not compromise control in another
Interaction of campylobacter and salmonella with the environment
Bacterial stress response mechanisms

- Vital to bacterial survival that they respond to change
- In the environment, pathogens will experience many different conditions, some of which may be damaging
- ~30% of the salmonella chromosome is devoted to genes, which regulate responses to environment change
- Many of these can also regulate aspects of virulence
- $rpoS$ is the most important regulatory gene
Salmonella stress responses

- Responses vary in speed
- Rapid with acid tolerance
- Whether temperature or pH
- RpoS-mediated
- Cells grown at 20°C
- Shifted to 45°C
- Tolerance to heat/acid tested
- Cooked foods and infection

![Graph showing D value over minutes at 45°C for 52°C and pH 2.8 conditions.](image-url)
Repeated stress and salmonella cell surfaces

- Exposure to repeat shock common
- UV, heat, desiccation
- Marked rise in tolerance
- Changes in LPS, flagella and fimbrial expression
- Important antigens in disease
- Extreme survival