Livestock and the global burden of zoonotic and foodborne diseases

Arie Havelaar, University of Florida

Photo credit: Rod Waddington, ACDIVOCA
ANIMALS AS RESERVOIRS OF EMERGING INFECTIOUS DISEASES

- 61% of known human pathogens have animal reservoirs
- 60-75% of emerging infectious diseases are zoonotic
- 72% of these originate from wildlife

(Jones et al., Nature 2008)

Number of EID events and reservoirs per decade
LIVESTOCK RELATED ZOONOSES

• Pandemic threats (e.g. MERS coronavirus)
  • Low incidence, potentially transmissible between humans
  • High case-fatality ratio
  • High fear factor: emerging zoonoses

• Endemic zoonoses (e.g. salmonellosis)
  • High incidence, low transmission between humans
  • Low case-fatality ratio or long incubation period
  • Low fear factor: neglected tropical diseases

• LSIL focus is on endemic zoonoses
WHO ESTIMATES OF THE GLOBAL BURDEN OF FOODBORNE DISEASES

- Global estimates for 31 hazards
  - 11 acute diarrheal disease; 7 invasive infectious disease; 10 helminths; 3 chemicals
  - 13 livestock-related pathogens
    - 5 acute diarrheal disease; 4 invasive infectious disease; 4 helminths
- Document current and future burden (sequelae, chronic exposures)
- Illnesses, deaths, Disability Adjusted Life Years
- Attribution to food and other pathways
TRANSMISSION PATHWAYS OF ENDEMIC LIVESTOCK RELATED ZOONOSSES

Wagenaar et al., Clin Infect Dis. 2013;57(11):1600-1606
<table>
<thead>
<tr>
<th>Hazard group</th>
<th>Foodborne illnesses (millions)</th>
<th>Foodborne deaths (thousands)</th>
<th>Foodborne DALYs (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>600</td>
<td>420</td>
<td>33</td>
</tr>
<tr>
<td>Diarrheal</td>
<td>549</td>
<td>230</td>
<td>18</td>
</tr>
<tr>
<td>Invasive</td>
<td>36</td>
<td>117</td>
<td>8</td>
</tr>
<tr>
<td>Helminths</td>
<td>13</td>
<td>45</td>
<td>6</td>
</tr>
<tr>
<td>Chemicals</td>
<td>0.2</td>
<td>19</td>
<td>0.9</td>
</tr>
</tbody>
</table>
BURDEN OF LIVESTOCK RELATED ZOONOSES

Incidence (millions)  Deaths (thousands)  DALYs (millions)
### ATTRIBUTION TO FOOD GROUPS

<table>
<thead>
<tr>
<th>Food group</th>
<th>Campylobacter</th>
<th>STEC</th>
<th>Salmonella</th>
<th>Cryptosporidium</th>
<th>Giardia</th>
<th>Brucella</th>
<th>E. granulosis</th>
<th>Toxoplasma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry</td>
<td>38-55</td>
<td></td>
<td>17-35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6-14</td>
</tr>
<tr>
<td>Pork</td>
<td>0-16</td>
<td></td>
<td>4-24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2-22</td>
</tr>
<tr>
<td>Beef</td>
<td>5-17</td>
<td>7-54</td>
<td>1-9</td>
<td></td>
<td></td>
<td>3-5</td>
<td></td>
<td>18-34</td>
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<tr>
<td>SR meat</td>
<td>4-11</td>
<td>7-26</td>
<td>2-7</td>
<td></td>
<td></td>
<td>3-19</td>
<td></td>
<td>8-44</td>
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<tr>
<td>Dairy</td>
<td>4-15</td>
<td>13-17</td>
<td>2-6</td>
<td>2-8</td>
<td></td>
<td>68-91</td>
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<tr>
<td>Eggs</td>
<td>9-26</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>Fruits</td>
<td>0-3</td>
<td>1-12</td>
<td>1-7</td>
<td>23-31</td>
<td>26-34</td>
<td>21-23</td>
<td>2-7</td>
<td></td>
</tr>
<tr>
<td>Vegetables</td>
<td>3-33</td>
<td>9-17</td>
<td>5-9</td>
<td>56-65</td>
<td>63-81</td>
<td>77-78</td>
<td>14-23</td>
<td></td>
</tr>
</tbody>
</table>

Range of median proportions of disease attributed to different food groups by pathogen across subregions

Hoffmann et al., submitted for publication
GLOBAL DISTRIBUTION OF THE BURDEN OF 13 LIVESTOCK RELATED ZOONOSES
## Zoonoses Causing Highest Burden Per Region

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</tr>
</thead>
<tbody>
<tr>
<td>AFR</td>
<td><strong>Non-typhoidal S. enterica</strong></td>
<td><strong>Toxoplasma gondii</strong></td>
<td><strong>Campylobacter spp.</strong></td>
<td><strong>Non-typhoidal S. enterica</strong></td>
<td><strong>Taenia solium</strong></td>
<td><strong>Non-typhoidal S. enterica</strong></td>
<td><strong>Campylobacter spp.</strong></td>
<td><strong>Campylobacter spp.</strong></td>
<td><strong>Cryptosporidium spp.</strong></td>
<td><strong>Toxoplasma gondii</strong></td>
<td><strong>Echinococcus granulosus</strong></td>
<td><strong>Taenia solium</strong></td>
<td><strong>Non-typhoidal S. enterica</strong></td>
<td><strong>Brucella spp.</strong></td>
<td><strong>Brucella spp.</strong></td>
<td><strong>Toxoplasma gondii</strong></td>
<td><strong>Cryptosporidium spp.</strong></td>
</tr>
</tbody>
</table>
CHILDREN UNDER FIVE YEARS OF AGE …

• … make up 9% of the world population
• … suffer from 38% of all foodborne illnesses
• … succumb to 30% of foodborne deaths
• … bear 40% of global foodborne DALYs
PEOPLE LIVING IN THE POOREST AREAS OF THE WORLD …

- … make up 41% of the world population
- … suffer from 53% of all foodborne illnesses
- … succumb to 75% of foodborne deaths
- … bear 72% of global foodborne DALYs

- D and E subregions: high child and high – very high adult mortality
LIMITATIONS OF WHO RESULTS

• Data availability and quality
  • Particularly in low-income countries where burden is highest
    • Imputation and expert judgment
  Presentation at regional level rather than country level
  Large uncertainty intervals

• Underestimation
  Limited number of hazards
  Not all endpoints considered, e.g. malnutrition and stunting; irritable bowel syndrome; chronic (psychiatric) consequences of toxoplasmosis
  Burden in HIV-positives preventable by food safety interventions
  Model uncertainty, e.g. multiplicative or additive models for chemicals
  Public health metrics do not quantify the full societal impact of foodborne diseases; economic burden
THE VICIOUS CYCLES OF DISEASES OF POVERTY

Enteric infections +/- diarrhoea

Water Sanitation
Worsened infection intensity and damage
Impaired innate and acquired mucosal defences
Probiotics Microflora

Antimicrobials Vaccines
Intestinal damage and inflammation
Nutrient malabsorption and/or loss
Repair nutrients

Environment
Repeated and persisting infections

Human genome
Microbiome

Malnutrition
Impaired vaccine responses +
Cognitive impairment

Poverty
Obesity and associated comorbidities and costs

ANIMAL OWNERSHIP, CHILD GROWTH AND ENVIRONMENTAL ENTERIC DYSFUNCTION

• Relationships between animal ownership and child growth are complex
• Several studies report net beneficial effects
• Beneficial effects can be reduced or even negated by exposure of children to animal feces
  • Headey et al. (2016) – Ethiopia
    • Poultry ownership beneficial; poultry but not larger animals in home overnight detrimental
  • Headey et al. (2016) – Ethiopia, Bangladesh, Vietnam
    • Negative association between HAZ and visible animal feces in BGD and ETH, but not in VNM
  • Ngure et al., 2013 – Zimbabwe
    • Of 23 children, 3 ingested soil and 2 chicken feces in a 6-hour period
  • George et al. (2013) – Bangladesh
    • Animals in child sleeping rooms associated with increased markers of environmental enteric dysfunction
ENVIRONMENTAL ENTERIC DYSFUNCTION

EE’s effect on intestinal health

EE impacts the villi that line the small intestine to absorb nutrients.

A. EE FLATTENING Villi
B. UNABSORBED BY THE DAMAGED GUT LINING, SOME NUTRIENTS PASS OUT OF THE BODY.
C. PATHOGENS LEAK THROUGH THE GUT LINING, TRIGGERING AN IMMUNE RESPONSE THAT DIVERTS NUTRIENTS FROM FUELING GROWTH TO FIGHTING INFECTIONS.

DAMAGED GUT

NUTRIENTS

IMMUNE CELLS

EED may cause up to 40% of growth faltering in the developing world (Trehan et al., 2016)

https://www.defeatdd.org/blog/make-handwashing-habit-prevent-diarrhea...-and-grow-taller-too
CAMPYLOBACTER AND STUNTING

• MAL-ED study
• 24-month length-for-age Z (LAZ) score negatively associated with Campylobacter burden

Beneficial effects of animal ownership and ASF consumption negated by EED?

Less Campylobacter? Less EED? Better growth?
CONCLUSIONS

• Animals are important reservoirs of human infectious diseases
• Transmission pathways are complex
• Livestock contributes to \( \sim 1/3 \) of the global burden of foodborne diseases
• A similar burden is associated with other transmission pathways
• Young children in Africa and South East Asia are disproportionately affected
• There are major data gaps in these regions, further studies at country level are needed
• The impact of livestock related zoonoses on malnutrition have not been quantified
• Exposure to animal excreta, particularly poultry, may negate the beneficial effects of animal ownership and consumption of animal sourced foods
• Studies to further understand these complex relationships and to test sustainable interventions are needed