Salmonella in Poultry: Surveillance and risk assessment to evaluate the public health impact of the presence of serotypes of concern and levels of contamination at production

Craig Hedberg, PhD
Humans are the ultimate bioassay for the food supply

The Cycle of Public Health Prevention

Provide feedback on effectiveness of food safety systems

Surveillance

Epidemiological, laboratory environmental investigation:
- Peri-harvest contamination of produce
- Primary contamination of specific poultry products or sources
- Cross-contamination at point of service

Root cause

Prevention measures

Applied research

Identify new hazards

Adapted from Rob Tauxe, CDC
Interventions Should Lead to Better Control

Restaurant Inspection Letter Grades and *Salmonella* Infections, New York, New York, USA

Validation that Surveillance Improves Prevention

Salmonella Outbreaks for PulseNet Adopters
(relative to 1994-96 baseline - 3 year moving average)

Reported Salmonella Illnesses for PulseNet Adopters
(relative to 1994-96 baseline - 3 year moving average)

Prioritization of Chicken Meat Processing Interventions on the Basis of Reducing the *Salmonella* Residual Relative Risk

- Quantitative microbial risk assessment studies on *Salmonella* have reflected that the most impactful input parameter on reducing the number of illnesses is the ingested dose (CFU) that is intimately related to the final pathogen concentration.

- Future research studies focused on collecting data about the impact of current and novel food safety interventions on *Salmonella* levels under real or closely simulated processing conditions would greatly improve the accuracy of the predictions by simulation models.
Risk Assessment Model: *Salmonella* in Ground Turkey

**Input variable**

<table>
<thead>
<tr>
<th>Input variable</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>National <em>Salmonella</em> prevalence</td>
<td>11.9%</td>
<td>Average proportion (2010-2016) FSIS (FOIA request)</td>
</tr>
<tr>
<td>Concentration levels</td>
<td>Normal (0.15, 1.00) log MPN/g</td>
<td>FSIS (2010-2016) FOIA request</td>
</tr>
<tr>
<td>Proportion of <em>Salmonella</em> high- and low-virulent serotypes&lt;sup&gt;a&lt;/sup&gt;</td>
<td>37% (High) 63% (low)</td>
<td>Average proportion (2010-2016) FSIS (FOIA request)</td>
</tr>
<tr>
<td>Proportion of <em>Salmonella</em> cells in ground turkey centre point</td>
<td>Pert (0.1, 0.16, 0.2)</td>
<td>[9]</td>
</tr>
</tbody>
</table>

**Revised Inputs**

- Salmonella prevalence: 14.0%
- Proportion of highly virulent serotypes: 47%
Risk Assessment Model: *Salmonella* in Ground Turkey

- Cooking temperatures at home
- Salmonella concentration
- Proportion high pathogenic serotypes
- Serving size
- Salmonella prevalence
- Cooking time frozen turkey

Total predicted illnesses in millions: Baseline = 128,131
<table>
<thead>
<tr>
<th>Effect of Mitigation Measures</th>
<th>Number of Illnesses</th>
<th>% Reduction in Illnesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline estimate</td>
<td>23,073 (0-105,189)</td>
<td>NA</td>
</tr>
<tr>
<td>Remove high-virulence serotypes</td>
<td>3,228 (0-12,980)</td>
<td>96.9</td>
</tr>
<tr>
<td>Remove highly contaminated lots (&gt;1 MPN/g)</td>
<td>1,328 (0-6,586)</td>
<td>94.2</td>
</tr>
<tr>
<td>Remove contaminated lots (&gt;1 MPN/ 25g)</td>
<td>65 (0-262)</td>
<td>99.7</td>
</tr>
</tbody>
</table>

Illnesses associated with individual 2,000 lb. lots, % likelihood of detecting a cluster.
<table>
<thead>
<tr>
<th>Yr(s)</th>
<th>Serotype</th>
<th>No. of cases</th>
<th>Median age in yr (range)</th>
<th>% male</th>
<th>Duration of outbreak (mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998–1999</td>
<td>Typhimurium</td>
<td>33</td>
<td>17 (1–78)</td>
<td>48</td>
<td>5</td>
</tr>
<tr>
<td>2005</td>
<td>Heidelberg</td>
<td>4</td>
<td>30 (18–81)</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>2005–2006</td>
<td>Enteritidis</td>
<td>27</td>
<td>31 (5–85)</td>
<td>63</td>
<td>11</td>
</tr>
<tr>
<td>2006</td>
<td>Typhimurium</td>
<td>3</td>
<td>18 (16–25)</td>
<td>100</td>
<td>2</td>
</tr>
</tbody>
</table>
• States that reported more outbreaks were more likely to be part of illness-associated recalls.
## Estimated Number of *Salmonella* Cases Prevented by Recall of Implicated Frozen Raw Breaded Chicken Products, 2014-2021

<table>
<thead>
<tr>
<th>Year</th>
<th>Agent</th>
<th>No. Cases (MN)</th>
<th>Lbs. Recalled</th>
<th>Lbs. Recovered</th>
<th>Illness Rate (per 100,000 lbs.)</th>
<th>No. Cases Prevented (Adjusted *)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>SE</td>
<td>9 (8)</td>
<td>28,980</td>
<td>1,234</td>
<td>43.2</td>
<td>&lt;1 (16)</td>
</tr>
<tr>
<td>2015</td>
<td>SE</td>
<td>15 (8)</td>
<td>58,000</td>
<td>0</td>
<td>34.0</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1,707,494</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>2015</td>
<td>SE</td>
<td>6 (6)</td>
<td>1,978,680</td>
<td>554,412</td>
<td>0.6</td>
<td>3 (100)</td>
</tr>
<tr>
<td>2021</td>
<td>SE</td>
<td>36 (4)</td>
<td>59,251</td>
<td>24,806</td>
<td>178.0</td>
<td>44 (1,294)</td>
</tr>
</tbody>
</table>

*Adjusted for underdiagnosis and underreporting.

Data from MDH, CDC, FSIS
Salmonella Enteritidis Associated with Frozen Raw Breaded Chicken Products, Epidemic Curve and Event Timeline, 2021

Recalled Product Made, 2/24-25
Retail Product Match, 4/26
Public Health Advisory, 6/2
Recall, 8/9

44 cases prevented
11 cases preventable
9 cases preventable

- Recall prevented 56% of potential cases.
- Delay in recall missed opportunity to prevent 56% of cases that occurred.

Data from MDH, CDC, FSIS
Lessons Learned from Outbreaks Associated with Frozen Raw Breaded Chicken Products

• Outbreaks are associated with serovars of concern, rather than full range of *Salmonella* detected in products.
  - *S.* Enteritidis, *S.* Typhimurium, *S.* Heidelberg

• Outbreak durations persist over several months, even when associated with 1-2 days’ production.

• Routine use of WGS for human illness surveillance will improve detection of outbreaks and give more accurate picture of size and geographic spread of outbreak.

• Episodic nature of outbreaks suggests that contamination of specific lots with high levels of serovars of concern cause outbreaks associated with products that are frequently mishandled.

• Product recalls can prevent illnesses-dependent on speed and effectiveness of investigation.