Salmonella in Poultry

Sources, Colonization & Mitigation

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Interim Associate Dean for Research
John Bekkers Professor in Poultry Science
Poultry & *Salmonella*

- Poultry meat has consistently been linked to salmonellosis, with over 23% of foodborne illnesses attributable to poultry consumption.
- Of those attributed to poultry, 17% were from chicken (broilers and parts) and 6% from turkey.
- Poultry industry has made significant progress by reducing the incidence in poultry meat through control at processing, using antimicrobial interventions.
- An understanding of the sources and potential control at production followed by incorporation of control strategies at production may be necessary to achieve further reductions.
Salmonella – Sources in Poultry Production

A systematic review and meta-analysis of the sources of Salmonella in poultry production (pre-harvest) and their relative contributions to the microbial risk of poultry meat

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2023 Poultry Science 102:102566
https://doi.org/10.1016/j.psj.2023.102566
Salmonella – Sources in Poultry Production

Poultry House Environment
1. Exterior
   - Soil & grass
   - Personnel/Vehicles
   - Wild & farm animals
   - Feed Mill
   - Waterfowl

2. Interior
   - Rodents
   - Pests (darkling beetles & flies)
   - Fan blades & floors

Salmonella Colonization in Poultry

6. FECES & LITTER
5. FEED & WATER
4. CHICKS
3. HATCHERY
Salmonella Sources – Exterior Environment
Salmonella Sources – Exterior Environment
Salmonella Sources – Feed
Salmonella Sources – Hatchery
### Salmonella Sources – Chicks

<table>
<thead>
<tr>
<th>Study</th>
<th>Region = US</th>
<th>Proportion</th>
<th>95% CI</th>
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<tbody>
<tr>
<td>LiJ<del>ej</del>1~ke et al., 2005</td>
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<td>Rama et al., 2022</td>
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<td>Byrd et al., 1999</td>
<td>0.12</td>
<td>[0.10; 0.15]</td>
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</tr>
<tr>
<td>Random effects model</td>
<td>0.06</td>
<td>[0.04; 0.10]</td>
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<table>
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<th>Study</th>
<th>Region = Non-US</th>
<th>Proportion</th>
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<tr>
<td>Random effects model</td>
<td>0.07</td>
<td>[0.02; 0.25]</td>
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</tbody>
</table>

Random effects model

Test for subgroup differences: $\chi^2 = 0.03, df = 1 (p = 0.85)$

Prevalence

```
0 0.2 0.4 0.6 0.8 1
```
Salmonella Sources – Environment, Interior
Salmonella Sources – Water
Salmonella Sources – Excreta
Salmonella Sources – Litter

<table>
<thead>
<tr>
<th>Study</th>
<th>Proportion</th>
<th>95%-CI</th>
</tr>
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<tbody>
<tr>
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<td>Berghaus et al., 2013</td>
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<td>[0.39; 0.50]</td>
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<td>Thakur et al., 2013</td>
<td>0.06</td>
<td>[0.04; 0.08]</td>
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<tr>
<td>Higgins et al., 2006</td>
<td>0.54</td>
<td>[0.42; 0.67]</td>
</tr>
<tr>
<td>De Rezende et al., 2021</td>
<td>0.24</td>
<td>[0.17; 0.32]</td>
</tr>
<tr>
<td>Lijepa et al., 2005</td>
<td>0.18</td>
<td>[0.16; 0.21]</td>
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<td>Volkova et al., 2009</td>
<td>0.19</td>
<td>[0.16; 0.22]</td>
</tr>
<tr>
<td>Rodriguez et al., 2006</td>
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<td>[0.00; 0.02]</td>
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<tr>
<td>English et al., 2015</td>
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<td>[0.16; 0.18]</td>
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<td>Roy et al., 2002</td>
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<td>Gu et al., 2010</td>
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<td>[0.36; 0.54]</td>
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<tr>
<td>Hwang et al., 2020</td>
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<tr>
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<td>[0.41; 0.81]</td>
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<td>[0.17; 0.30]</td>
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<td>[0.17; 0.37]</td>
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<td>0.30</td>
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<td>[0.08; 0.21]</td>
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<td>Tabo et al., 2013</td>
<td>0.67</td>
<td>[0.22; 0.98]</td>
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<td>Sheng et al., 2016</td>
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<td>[0.06; 0.15]</td>
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<tr>
<td>Limawongprapanee et al., 1999</td>
<td>0.72</td>
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<tr>
<td>Kingston et al., 1991</td>
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<td>[0.03; 0.06]</td>
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<td>Random effects model</td>
<td>0.25</td>
<td>[0.10; 0.52]</td>
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</table>

Test for subgroup differences: $\chi^2 = 0.00, df = 1 (p = 0.98)$

Life cycle of the darkling beetle (40-100 days)

- Eggs
- Larvae
- Pupa
- Adult
Salmonella Sources - Summary

Poultry House Environment
1. Exterior
   - Soil & grass
   - Personnel/Vehicles
   - Wild & farm animals
   - Feed Mill
   - Waterfowl

2. Interior
   - Rodents
   - Pests (darkling beetles & flies)
   - Fan blades & floors

3. HATCHERY
   - 49%

4. CHICKS
   - 5%

5. FEED & WATER
   - 5%

6. FECES & LITTER
   - 16 & 25%

49%
Poultry Feeding Habits -
Poultry Gut & Importance

- **Crop**: Food enters crop whole and undergoes bacterial fermentation. Main bacterial species is Lactobacillus.
- **Duodenum**: Lining secretes acid - low pH environment.
- **Jejunum**: Site of mechanical grinding of feed. Low pH environment.
- **Grizzard**: Serves rate of passage through the GIT. Hard pellets or large grid size require more grinding; rate of passage is slowed. Fine textured mash or poor quality pellets require less grinding; rate of passage is faster.
- **Small Intestine (SI)**: Digests feed from gizzard is mixed with bile salts and digestive enzymes in the SI.
- **Colon**: Major site of chemical digestion and nutrient absorption.
- **Caeca**: Little absorption/digestion occurs. After leaving the colon, the fecal pellet passes into the cloaca where it is mixed with uric acid and expelled via the vent.
- **Rectum and Cloaca**:
Salmonella Colonization in Broilers

Salmonella Species and Campylobacter jejuni Cecal Colonization Model in Broilers

N. J. Stern

Poultry Microbiological Safety Research Unit, Russell Research Center Agricultural Research Service, USDA, Athens, GA 30604

2008 Poultry Science 87:2399–2403
doi:10.3382/ps.2008-00140
Salmonella Transmission and Infection

Salmonella Colonization of the Poultry Gut

1. Infection through fecal-oral route
2. Production of acid shock proteins against acidic environment
3. Attachment to enterocyte facilitated by flagella and fimbriae and expression of injectisome, a type III secretion system (T3SS), a protein complex for uptake and invasion
4. Secretion of effector proteins to interact with extended cytoskeleton for facilitation of engulfment
5. Internalization of Salmonella by vacuole and macrophage
6. Transportation of Salmonella to mesenteric lymph nodes
7. Septicemia and translocation in various organs
### Table 1. Colonization of chicks challenged at 2 d posthatch with a composite of 3 serotypes of *Salmonella* spp.¹

<table>
<thead>
<tr>
<th>Challenge level</th>
<th>d 4</th>
<th>wk 1</th>
<th>wk 2</th>
<th>wk 3</th>
<th>wk 4</th>
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<td>Negative control</td>
<td>ND²</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>10⁹ cfu</td>
<td>5.46 ± 1.42</td>
<td>4.64 ± 0.91</td>
<td>2.80 ± 0.79</td>
<td>0.61 ± 0.91</td>
<td>ND</td>
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<tr>
<td>10⁸ cfu</td>
<td>6.03 ± 1.06</td>
<td>6.02 ± 0.20</td>
<td>4.95 ± 1.24</td>
<td>3.01 ± 1.88</td>
<td>0.50 ± 0.70</td>
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<tr>
<td>10⁷ cfu</td>
<td>5.34 ± 0.69</td>
<td>5.50 ± 0.71</td>
<td>1.79 ± 0.98</td>
<td>1.09 ± 1.00</td>
<td>ND</td>
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<tr>
<td>10⁶ cfu</td>
<td>5.56 ± 1.41</td>
<td>5.14 ± 0.27</td>
<td>3.03 ± 1.39</td>
<td>1.47 ± 1.36</td>
<td>1.47 ± 1.68</td>
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<tr>
<td>Negative control</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
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<tr>
<td>10⁹ cfu</td>
<td>4.92 ± 1.21</td>
<td>4.97 ± 0.78</td>
<td>4.80 ± 1.67</td>
<td>5.34 ± 0.68</td>
<td>2.09 ± 1.93</td>
</tr>
<tr>
<td>10⁸ cfu</td>
<td>6.68 ± 0.58</td>
<td>6.62 ± 0.40</td>
<td>5.89 ± 0.26</td>
<td>4.97 ± 0.51</td>
<td>2.47 ± 1.42</td>
</tr>
<tr>
<td>10⁷ cfu</td>
<td>5.35 ± 0.84</td>
<td>5.85 ± 1.14</td>
<td>4.35 ± 1.57</td>
<td>3.56 ± 0.54</td>
<td>1.90 ± 2.18</td>
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<tr>
<td>10⁶ cfu</td>
<td>6.02 ± 0.36</td>
<td>5.34 ± 1.02</td>
<td>4.46 ± 1.35</td>
<td>5.02 ± 1.15</td>
<td>2.17 ± 1.92</td>
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</tbody>
</table>

¹Birds were grown for 4 wk. Colonization quotient expressed as log₁₀ cfu g⁻¹ of cecal materials of 8 individuals.

²ND = not detected.
Translocation of *Salmonella* from the Gastro-intestinal Tract to Internal Organs in Broilers

Jinquan Wang¹, Davis Fenster¹, Sasikala Vaddu¹, Sujitha Bhumanapalli¹, Rami Dalloul¹, Cortney Leone², Manpreet Singh², Harshavardhan Thippareddi¹

¹Department of Poultry Science, University of Georgia, Athens, GA, USA
²Department of Food Science and Technology, University of Georgia, Athens, GA, USA
Salmonella Colonization Dynamics - Ceca
Salmonella Colonization Dynamics - Spleen
Salmonella Colonization Dynamics - Liver

![Graph showing Salmonella colonization dynamics in liver over days for different dose levels.]
Salmonella Colonization Dynamics - Probabilities
### Salmonella Colonization Dynamics – Ceca, 35d

<table>
<thead>
<tr>
<th>Dose</th>
<th><strong>S. Typhimurium</strong></th>
<th><strong>S. Infantis</strong></th>
<th><strong>S. Reading</strong></th>
<th><strong>Pooled Data</strong></th>
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<tbody>
<tr>
<td>Low</td>
<td>$1.67 \pm 0.49^{bx}$</td>
<td>$1.27 \pm 0.7^{bx}$</td>
<td>$3.02 \pm 0.36^y$</td>
<td>$3.28 \pm 0.35$</td>
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<tr>
<td>Med</td>
<td>$1.10 \pm 1.10^{abx}$</td>
<td>$0.19 \pm 0.19^{ax}$</td>
<td>$2.48 \pm 2.48^y$</td>
<td>$2.69 \pm 0.85$</td>
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<tr>
<td>High</td>
<td>$0.82 \pm 0.82^{bx}$</td>
<td>$0.25 \pm 0.25^{ax}$</td>
<td>$3.41 \pm 3.41^y$</td>
<td>$3.45 \pm 0.71$</td>
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**p-values**

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<th>Quad</th>
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<tr>
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<td>&lt;0.001</td>
<td>0.797</td>
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<tr>
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<td>&lt;0.001</td>
<td>0.507</td>
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<tr>
<td></td>
<td>0.003</td>
<td>0.154</td>
</tr>
<tr>
<td></td>
<td>0.673</td>
<td>0.063</td>
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</table>
Salmonella risk reduction at production
Strategies to mitigate *Salmonella* risk at production

• Management strategies
  • Biosecurity and hygienic measures
  • Cleaning and disinfection of poultry houses between flocks
  • Litter management
Salmonella Control - Biosecurity

• Biosecurity
  • Preventive measures undertaken to stop or minimize the introduction and spread of disease
Strategies to mitigate *Salmonella* risk at production

- Nutritional strategies
  - Organic acids
  - Botanicals/Essential oils
  - Bacteriocins
  - Bacteriophages
  - Novel compounds and feed additive combinations
  - Probiotics, competitive exclusion and prebiotics
Salmonella – Organic Acids

- Organic acids
  - Naturally occurring compounds with carboxyl (-COOH) functional groups.
    - Acetic acid, lactic acid, citric acid, propionic acid, butyric acid etc.
  - Can enter bacterium in undissociated form and dissociate within cell environment causing disruption of proton pump

Mode of Action
1. pH reduction causing unfavorable environment for *Salmonella* colonization or multiplication
2. Internalization and dissociation causing disruption of bacterial cell
3. Inhibition of bacterial enzymes
4. Modulation of gut microbiome
5. Immunomodulation such as regulation of cytokines, activation of complement system and the production of nitric oxide to defend against *Salmonella*
**Salmonella Control – Botanicals/Essential Oils**

- **Essential oils**
  - Complex mixture of volatile form of plant extract with antimicrobial effect
    - e.g., Oregano, Eucalyptus, Rosemary, Thyme, etc.
  - Contains terpenes, phenolics, aldehydes, ketones, alcohols, etc.

**Mode of Action**

1. Interaction with lipid bilayer of *Salmonella* and causing disruption and leakage of cellular components
2. Inhibition of bacterial ATPase enzyme
3. Disrupt quorum sensing and biofilms
4. Alteration in bacterial physiology and metabolism by up-regulating stress response genes and downregulating virulence genes
Salmonella Control – Bacteriocins

• Bacteriocins
  • Antimicrobial peptides produced by some bacteria to inhibit or kill other competing bacteria

Mode of Action
1) Increased permeability of Salmonella cell membra
2) Inhibition of bacterial protein synthesis causing arrest of growth,
3) Bacterial DNA binding and replication arrest
4) Bind to receptors in Salmonella and disrupt cell function
Salmonella Control – Bacteriophages

- Bacteriophages
  - Virus that can infect bacteria, replicate using their cell machinery and cause their death while liberating

Mode of Action
1) Adsorption and penetration in bacterium,
2) Use bacterium machinery to replicate,
3) Cause lysis of bacterium (Salmocins against Salmonella)
Strategies to mitigate *Salmonella* risk at production

- Immunization
  - Oral vaccination
    - Breeder
    - Broiler
Salmonella Control - Probiotics

• Probiotics
  • Microorganisms, especially of bacterial and fungal origin that competes with pathogenic organism and provides health benefits to the host
  • They can be the part of normal gut microbiome or could be introduced from in vitro cultures

Mode of Action
1. Competitive exclusion by Probiotics for receptor binding and nutrients with Salmonella
2. Immunomodulation and change in gene expression of immunoglobulins, cytokines and antioxidants
3. Acidification of gut by increased fermentation metabolites such as lactic acid and other SCFA
4. Disruption/eradication of extracellular polymeric substances (biofilms) of Salmonella through surfactants, bacteriocins and other metabolites
**Salmonella Control - Prebiotics**

- **Prebiotics**
  - Can be carbohydrates or peptides that are non-digestible by the host but utilized by beneficial microbes as the source of fermentation substrate
  - Can interact with some cell receptors and stimulate immune cells

**Mode of Action**

1. Promote beneficial bacteria for competitive exclusion of *Salmonella*
2. Immunomodulation and change in gene expression of adaptive immune cells and cytokines
3. Acidification of gut by increased fermentation metabolites such as lactic acid and SCFA
4. Prebiotics like mannan-oligosaccharides can bind to *Salmonella* and prevent their adhesion to the gut wall
Salmonella Control – Phytogenic Feed Additives

• Phytogenic additives
  • Different active ingredients from plants with antimicrobial effects

Mode of Action
1. Disruption of bacterial cell membrane
2. Inhibition of bacterial motility
3. Modulation of beneficial microbiota
4. Stimulation of immune system against Salmonella
5. Antioxidation and anti-inflammatory response to reduce the severity of infection
Is *Salmonella* Control Necessary at Pre-Harvest?
Salmonella in Poultry & Risk Reduction

• Several sources of Salmonella in the poultry production environment

• The microorganism can colonize the gastro-intestinal tract of the poultry and persist in the gut throughout the production timeframe

• Several strategies are available for poultry producers to reduce the risk
  • However, no silver bullets to eliminate the microorganism from the poultry under current production system

• Salmonella control at production is necessary to reduce the prevalence and concentrations at or subsequent to processing
Thank You

Harshavardhan Thippareddi, Ph.D.
Interim Associate Dean for Research
John Bekkers Professor of Poultry Science

Email: harsha.thippareddi@uga.edu
Salmonella in Poultry—Proposed Regulatory Changes and Intervention Strategy Advancements

Mindy Brashears, PhD
Paul Whitfield Horn Distinguished Professor
Associate Vice President for Research
Director-International Center for Food Industry Excellence
Roth and Letch Family Endowed Chair in Food Safety
Texas Tech University
Salmonella
What Drives Decisions?

Attribution Data?

Regulations?

Science and Data?
Figure 2: Estimated percentage of foodborne *Salmonella* illnesses (with 90% credibility intervals) for 2019, in descending order, attributed to each of 17 food categories, based on multi-year outbreak data,* United States. Click here to download relevant data.

*Based on a model using outbreak data that gives equal weight to each of the most recent five years of data (2015-2019) and exponentially less weight to each earlier year (1998-2014).*
Confirmed Infections

Salmonella infections by year; 1996-2020

Incidence per 100,000 population – FoodNet sites; all test methods
* Culture-confirmed includes those infections confirmed by culture only or by culture following a positive CIDT.

Source: FoodNet, Centers for Disease Control and Prevention
Current Regulatory Drivers

Salmonella Framework

“Adulterant” Status for Raw Poultry

Performance Standards
Proposed Regulatory Framework to Reduce *Salmonella* Illnesses Attributable to Poultry

**Component 1**
Requiring incoming flocks be tested for *Salmonella* before entering an establishment

**Component 2**
Enhancing establishment process control monitoring and FSIS verification

**Component 3**
Implementing an enforceable final product standard
**Component 2**
- Statistical Process Control of EB or APC and *Salmonella* presence
- Pre-Chill and Post-Chill
- Actionable Data
Why Biomap Salmonella?

Correlation of Indicators to Salmonella Behavior
Vargas et al 2023 (Foods)
- Indicators should be used for Process control
- Not useful for targeting Salmonella

Vargas et al, 2022*

Pearson Correlation
Salmonella Enumeration vs Prevalence

Sanchez-Plata et al, 2021
Salmonella Enumeration vs Prevalence

Sanchez-Plata et al, 2021
Salmonella Biomapping for Decision Making

Little correlation of *Salmonella* quantification and Indicators

Indicators are still a good measurement of process control

Quantification Data Gives more insight

- Wing and Tender prevalence is similar to Post-Evisceration Carcasses
- Quantification is much different
  - 3 logs post-evisc vs <0.5 log on parts – Lower Risk

Drive allocation of Resources

Performance Standards do not allow for Strategic Decision-Making
Component 3

- Actionable and Enforceable Final Product Standards
Salmonella as an “Adulterant” in Raw Poultry

USDA Announces Action to Declare Salmonella an Adulterant in Breaded Stuffed Raw Chicken Products

Press Release
Release No. 0167.22

Contact: USDA Press
Email: press@usda.gov

WASHINGTON, August 1, 2022 – The U.S. Department of Agriculture’s (USDA) Food Safety and Inspection Service (FSIS) is announcing that it will be declaring Salmonella an adulterant in breaded and stuffed raw chicken products.
“Big 7” ADULTERANTS in Raw Ground Beef and RGB Components

Very Specific to a Pathogen in a Product that has a high consumption
Salmonella as Adulterant

“Figure it Out” Approach
(Not Science-based or Data-Driven)

Not specific to virulent strains or in a highly consumed product
State of the Science

Quantification (Dose-Response)

Serotyping

Highly-Pathogenic *Salmonella*
4 of 18 Positive for *Salmonella* = 22.2%
But only 1 > 4 logs (> 10,000) CFU

*Slide Credit: Dr. Marcos Sanchez-Plata*
Probability of Illness vs. Log Dose

1 Log = 10 ufc/g
2 Log = 100 ufc/g
3 Log = 1,000 ufc/g
4 Log = 10,000 ufc/g
5 Log = 100,000 ufc/g
6 Log = 1,000,000 ufc/g
7 Log = 10,000,000 ufc/g

…………….
Rapid Quantification Methods
AOAC Approved

Time to Results is no Difference than Detection

SalQuant-Hygenia

Quant Sal-bioMerieux

bioMérieux Inc. Obtains AOAC Approval for GENE-UP QUANT Salmonella Assay
Pathogenicity

- Dayna Harhay, PhD
- USMARC
**Beef Results**

**FSIS-ARS-IAA 2021-22**

<table>
<thead>
<tr>
<th>Serotype</th>
<th>n</th>
<th>%</th>
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<td>Enteritidis</td>
<td>5</td>
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<td>Newport</td>
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<tr>
<td>Manhattan</td>
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<tr>
<td><strong>Total</strong></td>
<td>136</td>
<td>67.0</td>
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**Non-HPS ≤ 4 markers amplified**

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<tr>
<th>Serotype</th>
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<td>Muenster</td>
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<td>Give</td>
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<td>Meleagridis</td>
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<tr>
<td>Adelaide</td>
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<td>Appa</td>
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<td>Kiambu</td>
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<td>Orion</td>
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<tr>
<td><strong>Total</strong></td>
<td>136</td>
<td>67.0</td>
</tr>
</tbody>
</table>

**Salmonella from Beef (n=203)**
Multiple Serotypes

- Nikki Shariat, PhD
- University of Georgia
Picking a few colonies limits *Salmonella* surveillance

- Picking 1-2 colonies only identifies the most abundant serovars
- Background serovars remain undetected
- Limitations:
  - Source tracking and *Salmonella* control
  - Hidden serovars = hidden phenotypes (risk assessment)
  - Prevents understanding of serovar dynamics

**CRISPR-SeroSeq:** Amplicon-based NGS tool for “deep serotyping” to identify multiple serovars within a *Salmonella* population
Deep Serotyping using CRISPR-SeroSeq

1. **Serovar A**
2. **Serovar B**

3. PCR #1
4. PCR #2

5. Short read sequencing
6. CRISPR-SeroSeq bioinformatics pipeline

7. Relative serotype frequency
   - Serovar A: 0, 0.5, 1
   - Serovar B: 0, 0.5, 1

8. CRISPR-SeroSeq bioinformatics pipeline

What about Performance Standards?

*Salmonella* Baselines of Percent Positive

Human Illness Data

HP2030 Reduction (25%)

Reduction of the Percentage Positive to achieve HP2030 Goals
Points to Consider - Performance Standards

- Most Isolates are Kentucky
- Most fall below enumeration limits
- No information on Pathogenicity
Have performance standards been effective?

- **Salmonella Prevalence** or % in Cat. 3
- **Chicken Parts Prevalence 12-month Moving Average**
- Source: FSIS
“Despite FSIS sampling data showing reductions in Salmonella contamination in poultry products, the current approach to Salmonella has not led to a demonstrable reduction in Salmonella infections.” – FSIS Leadership, 2022
STAKEHOLDERS STATE THAT PERFORMANCE STANDARDS AREN’T WORKING...

- *Salmonella* in Poultry
  - Declines in product have been steady

- *E. coli* O157:H7 Adulterant in 1994

Too soon to tell.... Attribution Data Impact in 2003...
Limitations of Attribution Data

- Culture-Independent Diagnostic Tests
- Epidemiological
- Biased Consumer Perceptions
- Doesn’t consider Cross-Contamination
- Assumptions
<table>
<thead>
<tr>
<th><strong>Data-Driven</strong></th>
<th><strong>Regulatory</strong></th>
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</thead>
<tbody>
<tr>
<td>• Evaluation of Process</td>
<td>• Focused on One Product for Adulterant Status</td>
</tr>
<tr>
<td>• Strategic</td>
<td>• All “parts” are equal</td>
</tr>
<tr>
<td>• <em>Salmonella</em> Quantification</td>
<td>• <em>Salmonella</em> Detection</td>
</tr>
<tr>
<td>• <em>Salmonella</em> Serotypes/HP <em>Salmonella</em></td>
<td>• Little focus on Serotypes or Pathogenicity</td>
</tr>
<tr>
<td>• Targeted Decision-Making based on Science and Data</td>
<td>• Changes take a LONG time</td>
</tr>
<tr>
<td>• DRIVE THE NARRATIVE!</td>
<td></td>
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</tbody>
</table>
Conclusions

• Three Components of Proposed Regulatory Framework have some merit.
• Data and Science are missing to support some of the assumptions
• “They will figure it out” is a misinformed statement and is insulting to the scientific community.
• There is a discrepancy in stating that reducing *Salmonella* in poultry hasn’t resulted in a reduction in human illnesses and then implementing strategies to reduce *Salmonella* in poultry.
• Adulterant status in raw, breaded, stuffed chicken breasts will not impact human, public health data.
Questions