Food Safety and Inspection Service
Protecting Public Health and Preventing Foodborne Illness
NAMI Meeting 2016
Pathogen Control and Regulatory Compliance in Beef Processing
Hilton Rosemont, Chicago, IL 60018

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Assistant Administrator
Office of Public Health Science FSIS USDA
FSIS Updates: Presentation Outline

- FSIS Strategic Plan
- Whole Genome Sequencing (WGS)
- Human Health Evaluation Board (HHEB)
- Interagency Food Safety Analytics Collaboration
- *Salmonella* Attribution for Beef and Trends
- *Salmonella* Data
- STEC Data
- Concluding Remarks
FSIS Strategic Plan
Food Safety and Inspection Service: Whole Genome Sequencing and Strategic Planning at FSIS

**Goal 5: Effectively Use Science to Understand Foodborne Illness and Emerging Trends**

Outcome 5.1: FSIS continually improves its capacity for and use of cutting-edge science in policy development to better defend against public health risks

Outcome 5.2: FSIS increases the application of cutting-edge science across the farm-to-table supply chain to improve public health

**Application of Science, Technology and Innovation Continues**

- **Implementation of WGS**
  - Continue to develop criteria for the application of WGS in regulatory decision making

- **Upgrade Infrastructure**
  - SNP (Kmer, hqSNP) and wgMLST and new tools

- **WGS/NGS/other applications in routine use at FSIS**
  - Decreased reliance on non-WGS technologies

- **Explore Utilization of In-Field Real-time Technologies**
  - Fit-For-Purpose - Detection system
  - Partner collaborations
  - Pilot studies
  - Large Scale implementation
  - In-field detection, data-analysis and decision making capability

- **FSIS WGS**
  - FSIS set of Reference Genomes
  - Unique analytic capability
    - Community/Microbiome
    - Resistome, Virulome etc.
  - FSIS WGS data analysis pipelines
  - Pan-genome (core + variable) type of analysis
  - Less dependence on culture enrichment and isolates (!)
    - Complement CID
FSIS All-Illness Measure estimates the total number of foodborne illnesses from *Salmonella*, *Lm*, and *E. coli* O157:H7 from FSIS-regulated products. Objectives were produced using attribution estimates from 2005-2007 FDOSS data, quarterly FoodNet data, Scallan et al. scaling factors, and U.S. Census data with annual objectives tied to Healthy People 2020 pathogen-specific goals.
Since 2012, *Salmonella*-related illness clusters have comprised the largest proportion of outbreaks involving FSIS-regulated commodities.
Whole Genome Sequencing (WGS)
FSIS continues to build capacity for WGS of isolates obtained from FSIS sampling programs
- Currently 6 sequencers in operation at Eastern Laboratory
- Expect full capacity with 10 sequencers
- **Goal is to sequence all FSIS isolates (around 10,000 per year)**

To further understand the relationship between clinical and food isolates - in collaboration with our public health and regulatory partners, FSIS currently considers available WGS analyses in addition to PFGE and epidemiological information

FSIS works with National Antimicrobial Resistance Monitoring System (NARMS) partners (FDA, CDC) to understand the occurrence or introduction of antimicrobial resistance genes in pathogens of interest

FSIS is part of an interagency collaboration with CDC, FDA, and NCBI (Gen-FS) to harmonize efforts for implementation of WGS for food safety purposes within the US
Isolates Sequenced

Milestone Dates

- July 2014: *Salmonella* and *Listeria monocytogenes*
- December 2014: STECs
- February 2015: *Campylobacter*
- May 2015: Capability to directly upload WGS files to NCBI

As of 8/23/2016: 4,439 FSIS isolates have been sequenced and uploaded to NCBI

<table>
<thead>
<tr>
<th></th>
<th><em>Listeria monocytogenes</em></th>
<th>STEC</th>
<th><em>Salmonella</em></th>
<th><em>Campylobacter</em></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routine/Special Projects</td>
<td>553</td>
<td>383</td>
<td>782</td>
<td>80</td>
<td>1798</td>
</tr>
<tr>
<td>NARMS Cecal Sampling</td>
<td></td>
<td></td>
<td>1377</td>
<td>1264</td>
<td>2641</td>
</tr>
<tr>
<td>Total</td>
<td>553</td>
<td>383</td>
<td>2159</td>
<td>1344</td>
<td>4439</td>
</tr>
</tbody>
</table>

Note: Initially 636 FSIS isolates were sequenced by FDA
FSIS is also currently exploring use of WGS as a tool to understand potential harborage or reoccurrence of contamination in establishments.

FSIS works collaboratively with FDA in dual-jurisdiction establishments that produce both FDA and FSIS-regulated products.

When one agency identifies potential harborage through bacterial characterization of Lm isolates (PFGE and/or WGS), information is shared to inform a collaborative regulatory response within the establishment.
FSIS food and environmental samples from one investigation were compared to clinical isolates with an epidemiological link to the establishment where sampling occurred.

The isolates from the investigative sampling had 2 different primary PFGE patterns and 3 different secondary PFGE patterns.

If we had WGS information on these isolates in real-time – Could it have been of any use!!
FSIS food and environmental samples from one investigation were compared to clinical isolates with an epidemiological link to the establishment where sampling occurred.

The isolates from the investigative sampling had 2 different primary PFGE patterns and 3 different secondary PFGE patterns.

WGS was able to show high similarity between differing primary PFGE patterns and primary/secondary combinations.
Comparison of Clinical isolates to food/environmental isolates from an establishment

- Red: Food/environmental isolate (year 2)
- Blue: Clinical (year 2)
- Green: Clinical (year 1)
- Yellow: Unrelated (No epi)

Settings: The analysis was generated with Lyve-SET version 1.1.4f. Reads were cleaned with CG Pipeline, SNPs were called with VarScan, and Lyve-SET was run with the following options: minimum coverage - 10, min alternative fraction - 0.90, and allowed flanking - 5 bp. Maximum Likelihood Tree built in Mega Version 7 with 500 bootstraps.
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FSIS Updates: Potential Use in Outbreak Investigations (Ex-2)

Comparison of isolates from an establishment over a 2 year period

Settings: The analysis was generated with Lyve-SET version 1.1.4f. Reads were cleaned with CG Pipeline, SNPs were called with Varscan, and Lyve-SET was run with the following options: minimum coverage - 10, min alternative fraction - 0.90, and allowed flanking - 5 bp. Maximum Likelihood Tree built in Mega Version 7 with 500 bootstraps
In 2015, FDA isolated *Salmonella* with extended spectrum beta-lactamase (ESBL) resistance from a NARMS retail poultry product purchased in December 2014.

- Contained *bla* CTX-M-65 plasmid based resistance gene
- Never-before reported in *Salmonella* from food items in the US

Patients with *Salmonella* infection expressing this resistance pattern have few treatment options.

**FSIS actions**
- Determined *bla* CTX-M-65 ESBL resistance in FSIS isolates
  - Phenotype and genotype (ResFinder)
- Isolates with a match were investigated for their sources/origin and possible connections to human cases
  - No human illnesses were found connected to FSIS-regulated products
- FSIS promptly notified all corporations with ESBL matches
Case definitions: FSIS depends on its public health partner (CDC/States) for case definitions, the descriptions of the outbreak strain(s) and the subtyping method used to define the strain(s)

Higher resolution subtyping and evolving strains: Food and environmental samples collected as part of an outbreak investigation may span a period of time longer than the outbreak – genetic drift should be considered

Using WGS for regulatory decisions: FSIS is exploring how to interpret and apply the case definitions established by our public health partners that include WGS criteria to FSIS surveillance and investigative results
Human Health Evaluation Board (HHEB)
Serves as the primary FSIS group of experts to evaluate risk of potential human health hazards associated with meat, poultry and egg products

Convened on an ad hoc basis

Addresses novel situations not explicitly covered by existing laws, regulations, or policies

* FSIS Directive 8091.1: Procedures for the FSIS Health Hazard Evaluation Board (HHEB)
Chaired by the Applied Epidemiology Staff (AES) Director or designee from the Office of Public Health Science

May include health scientists, microbiologists, toxicologists, risk analysts, epidemiologists, and other experts

May also include other government experts within and outside of FSIS, industry, or academia depending on expertise needed

HHEB member composition may depend on nature of hazard

- Biological, chemical, physical, radiological, etc.

Industry is not currently invited to participate directly in HHEB
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FSIS Updates: HHEB - Foreign Object Contamination and FSIS Recalls

- FSIS Directive 7310.5, Presence of Foreign Material in Meat or Poultry Products, defines foreign materials as “non-animal objects, such as metal, plastic, rubber, glass, wood, steel, or lead shot”

- The FSIS (1995) Public Health Hazard Analysis Board on bone particles concluded the following:
  - Bone particles smaller than 1 cm are not a safety hazard.
  - Bone particles 1–2 cm are a low risk
  - Bone fragments larger than 2 cm have the potential to be a safety hazard and may cause injury.
  - Material other than bone may pose a potential hazard, and each instance should be considered on a case-by-case basis, irrespective of size

- FDA Health Hazard Evaluation Board found that hard or sharp objects 7 mm or longer in size were a potential health hazard due to laceration, perforation, and possible secondary infection.
  - Objects less than 7 mm in size represent a possible hazard, particularly in at-risk groups, such as infants or the elderly (Olson, 1998)
Interagency Food Safety Analytics Collaboration
Published on July 1, 2016 an article in *Emerging Infectious Diseases* (EID) on an IFSAC project to assess the differences between outbreak and sporadic illnesses. Publication was announced to stakeholders via Constituent Updates, and an accompanying Research Brief was published to support the release.

Delivered 6 presentations (4 oral, 2 posters) on a variety of IFSAC projects/analyses at the 2016 International Association for Food Protection (IAFP) meeting in St. Louis, Missouri.

Finalized and posted on IFSAC website the new IFSAC Charter.

Work began on the new IFSAC Strategic Plan for FY2017-2021, including drafting new goals, objectives, and measures and a general Plan framework.
Salmonella Attribution for Beef and Trends
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FSIS Updates: *Salmonella* Attribution for Beef and Trends

- Attribution for any pathogen commodity pair is uncertain; however, outbreak data are still one of the best data sets to determine what foods are making consumers ill

- Two methods are demonstrated:
  - FSIS method – uses only the 3 most recent years of outbreak illness data
  - IFSAC method – used all the outbreak illness data starting in 1998, but prioritizes the 5 most recent years and then downgrades the impact of earlier years

- Beef outbreak overview (1998-2014):
  - About 11 known outbreaks/year
  - About 340 known illnesses/year
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FSIS Updates: *Salmonella* Attribution for Beef and Trends

Beef Attribution - 1998 to 2014 (IFSAC data preliminary)

3-year moving average (FSIS method); IFSAC method starts with data beginning in 1998
Salmonella Data
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FSIS Updates: *Salmonella* in Beef and Ground Beef

*Salmonella (% Positive) – Random Sampling: July 2014 to July 2016*

- Raw ground beef components other than trim (MT64 (54)) appears to be more contaminated

<table>
<thead>
<tr>
<th>Project Code</th>
<th>Total Analyzed</th>
<th><em>Salmonella</em> Positive</th>
<th>Percent Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>MT64(54) (components)</td>
<td>956</td>
<td>62</td>
<td>6.49%</td>
</tr>
<tr>
<td>MT60 (manufacturing trim)</td>
<td>6,791</td>
<td>187</td>
<td>2.75%</td>
</tr>
<tr>
<td>MT43 (GB)</td>
<td>22,759</td>
<td>427</td>
<td>1.88%</td>
</tr>
<tr>
<td>MT65(55) (bench trim)</td>
<td>2,610</td>
<td>28</td>
<td>1.07%</td>
</tr>
<tr>
<td>MT08 (imports GB)</td>
<td>36</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>MT51 (imports other than GB)</td>
<td>1,269</td>
<td>10</td>
<td>0.79%</td>
</tr>
</tbody>
</table>
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FSIS Updates: *Salmonella* in Beef and Ground Beef

*Salmonella* (% Positive) MT64(54) - Components: July 2014 to July 2016

<table>
<thead>
<tr>
<th>Row Labels</th>
<th>Total Analyzed</th>
<th><em>Salmonella</em> Positive</th>
<th>Percent Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced meat recovery (AMR)</td>
<td>14</td>
<td>1</td>
<td>7.14%</td>
</tr>
<tr>
<td>Cheek meat</td>
<td>192</td>
<td>22</td>
<td>11.46%</td>
</tr>
<tr>
<td>Head meat</td>
<td>119</td>
<td>14</td>
<td>11.76%</td>
</tr>
<tr>
<td>Heart meat</td>
<td>372</td>
<td>10</td>
<td>2.69%</td>
</tr>
<tr>
<td>Finely Textured Beef</td>
<td>27</td>
<td>1</td>
<td>3.70%</td>
</tr>
<tr>
<td>Weasand (esophagus) meat</td>
<td>34</td>
<td>5</td>
<td>14.71%</td>
</tr>
<tr>
<td>All Other</td>
<td>198</td>
<td>9</td>
<td>4.55%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>956</strong></td>
<td><strong>62</strong></td>
<td><strong>6.49%</strong></td>
</tr>
</tbody>
</table>
Generally the samples from follow-up programs appear to be more contaminated with *Salmonella*

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<thead>
<tr>
<th>Project Code</th>
<th>Total Analyzed</th>
<th><em>Salmonella</em> Positive</th>
<th>Percent Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>MT52 (Follow-up testing at supplier establishments following MT43, MT44, or MT55 positive)</td>
<td>147</td>
<td>15</td>
<td>10.2%</td>
</tr>
<tr>
<td>MT44 (Follow-up testing to a round ground beef <em>E. coli</em> O157:H7 positive)</td>
<td>125</td>
<td>6</td>
<td>4.8%</td>
</tr>
<tr>
<td>MT53 (Follow-up testing to an MT60, MT54, MT55, or MT52 positive)</td>
<td>1,509</td>
<td>72</td>
<td>4.8%</td>
</tr>
<tr>
<td>MT44T (Traceback not at slaughter and other special cases – recalls, O/B, state results etc.)</td>
<td>249</td>
<td>3</td>
<td>1.2%</td>
</tr>
</tbody>
</table>
Possible performance standards

- Ground beef
- Trim

Possible Additional Sampling Related to Ground Beef Components

- Additional exploration of *Salmonella* in
  - Other ground beef components
  - Bench trim
- Exploration of the impact of major lymph nodes in *Salmonella* contamination of ground beef
Food Safety and Inspection Service
FSIS Updates

STEC Data
### 2016 YTD Results from Analysis of Raw Ground Beef Component Samples for STEC

<table>
<thead>
<tr>
<th>Raw Ground Beef Components (RGBC)</th>
<th>Federal Plants</th>
<th>Import</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEC</td>
<td>Trim Verification</td>
<td>Follow-up to RGB Positive at Supplier</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------</td>
<td>------------------</td>
</tr>
<tr>
<td><strong>E. coli O157:H7</strong></td>
<td>0.2%</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>(4/2551)</td>
<td>(0/20)</td>
</tr>
<tr>
<td><strong>All non-O157 STECs</strong></td>
<td>0.9%</td>
<td>5.0%</td>
</tr>
<tr>
<td></td>
<td>(21/2468)</td>
<td>(1/20)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O26</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>O45</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>O103</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>O111</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>O121</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>O145</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
### 2016 -YTD Results from Analysis of Raw Ground Beef Component Samples for STEC

#### Raw Ground Beef Components (RGBC)

<table>
<thead>
<tr>
<th>STEC</th>
<th>Federal Plants</th>
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<tbody>
<tr>
<td></td>
<td>Trim Verification</td>
<td>Follow-up to RGB Positive at Supplier</td>
</tr>
<tr>
<td><strong>E. coli O157:H7</strong></td>
<td>0.2%</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>(4/2487)</td>
<td>(0/20)</td>
</tr>
<tr>
<td><strong>All non-O157 STECs</strong></td>
<td>0.62%</td>
<td>5.00%</td>
</tr>
<tr>
<td></td>
<td>(15/2407)</td>
<td>(1/20)</td>
</tr>
<tr>
<td><strong>Beef</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O26</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>O45</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>O103</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>O111</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>O121</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>O145</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
### 2016 - YTD Results from Analysis of Raw Ground Beef Component Samples for STEC

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<th>Raw Ground Beef Components (RGBC)</th>
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<tbody>
<tr>
<td></td>
<td>Trim Verification</td>
<td>Follow-up to RGB Positive at Supplier</td>
</tr>
<tr>
<td>STEC</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>E. coli</em> O157:H7</td>
<td>0.0%</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>(0/62)</td>
<td>(0/0)</td>
</tr>
<tr>
<td>All non-O157 STECs</td>
<td>8.5%</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>(5/59)</td>
<td>(0/0)</td>
</tr>
<tr>
<td>Veal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O26</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>O45</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>O103</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>O111</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>O121</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>O145</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
FSIS is committed to Healthy People 2020 Pathogen Reduction Goals and beyond.

FSIS is fully committed to utilizing the analytical power and resolution of WGS in its ‘pathogen reduction – public health protection’ efforts.

- FSIS will continue to engage with stakeholders and share information on WGS and its applications to food safety and public health.
- FSIS utilizes WGS analyses in combination with all available evidence and other relevant information for investigative and regulatory purposes.

FSIS follows Directive 8091.1 Procedures for the FSIS HHEB – to evaluate the risk potential of human health hazards in FSIS regulated products.

IFSAC and FSIS methods are currently used and the application of WGS is expected to help further refine the estimates.

- FSIS method (3-year moving average) and the IFSAC method – both show an upward trend for beef.
- While progress is being made in controlling *Salmonella*
  - Additional attention will be needed to control *Salmonella* in certain RGBC
  - STEC follow-up samples appear to be more contaminated with *Salmonella*
- Industry is doing a good job in controlling both O157:H7 and other adulterant STEC
  - Veal may need additional attention.
Discussion and Questions