Pre-Harvest Control of Food-Borne Pathogens

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Department of Animal Sciences
Results of raw ground beef products analyzed for *E. coli* O157:H7 in federal plants. 2004 data as of April 30.

* In 1998, FSIS increased sample size from 25 g to 375 g.
** In July 1999, FSIS changed to a more sensitive analytical method.
*** During October 2005, a new screening method was introduced to reduce the number of screen positives that do not confirm positive
FSIS Prevalence of *Salmonella* spp. in Ground Beef*

*FSIS results of ground beef analyzed for *Salmonella* spp.

**Represents data available as of 10-27-05.
**Incidence of Foodborne Illness 1996-2003: E. coli O157**

*Preliminary FoodNet Data on the Incidence of Foodborne Illnesses --- Selected Sites, United States, 2003.*
The U.S. Beef Industry by Segment

1.1 Million Cow/Calf Producers

44,000 Feeders

4 Packers

30,000 Retailers

720,000 Foodservice

250 Million Consumers

“7% have 100+ cows that represents 50% of the U.S. cow herd”

“2,100 feedlots feed 87% of the cattle harvested”

The “Big Four” Harvest 87% of the cattle offered

“Intervention steps become easier to universally implement as the hourglass narrows”
Cow/Calf & *E. coli O157*

- **Gannon (2002) found:**
  - No dams positive pre-partum.
  - Up to 26% of dams 1 wk postpartum shed.
  - By 1 wk old, up to 25% of calves positive.
  - Calves shed again after weaning (up to 14.1%)
  - Some with new strain i.e., reinfection possible.

- 9.1% of non-lactating dams in Florida positive *(Riley et al 2003)*

- Infection occurs early in life – most prior to weaning.
Following exposure, cattle that become infected either:

- **Clear the infection (days to weeks)**
- **Become colonized indefinitely i.e. ‘carrier state’.**
  - Cattle shedding is intermittent

Because (a) some animals colonized indefinitely, and (b) reinfection occurs:

- **Commingling will result in exposure to novel strains and subsequent infection/shedding.**

Prior infection might not always provide protection against new strains.
Prevalence of *E. coli* O157:H7 on Live Cattle

- **Hancock et al., 1997**
  - 1.6 % incidence in fecal samples (188 of 11,881)
  - 61 % incidence in feedlots (61 of 100) in 13 states

- **Elder et al., 2000**
  - 27.8 % incidence in fecal samples (91 of 327)
  - 10.7 % incidence on hides (38 of 355)
  - 43.4 % incidence pre-evisceration (148 of 341)
  - 17.8 % incidence post-evisceration (59 of 332)
  - 1.8 % incidence post-processing (6 of 330)

- **Smith et al., 2001**
  - 23 % incidence in fecal samples
  - 100 % incidence in pens (29) and feedlots (5)
Prevalence of *E. coli* O157:H7 in feedlot cattle feces, hides, & carcasses

- Of 15 lots tested:
  - 87% at least one positive feedlot fecal sample.
  - 54% positive hide sample.
  - 80% positive colon.
  - 47% positive pre-evis.
  - 6% positive post-evis.
  - 6% positive final intervention.

<table>
<thead>
<tr>
<th>Samples</th>
<th>&gt; 20%</th>
<th>&lt; 20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hide</td>
<td>20%</td>
<td>5.7%</td>
</tr>
<tr>
<td>Colon</td>
<td>46.3%</td>
<td>7.1%</td>
</tr>
<tr>
<td>Pre-Evis</td>
<td>12.5%</td>
<td>7.1%</td>
</tr>
<tr>
<td>Post-Evis</td>
<td>2.5%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Post-Final</td>
<td>0.6%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Ransom *et al.* (2003) Funded by USDA-CSREES
• 139 animals (60 bulls, 79 steers); 4 non-adjacent pens in same feedlot sampled (7 sites) within 1 wk of harvest.
• 99.3% of show-list cattle positive on at least one site.
• Back greater prevalence than ventrum, flank and hock!
• Find most positives if sample mouth, feces, and back.

Keen and Elder JAVMA 2002
Feedlot Epidemiology of *E. coli* O157

- Large study of 73 feedlots (KS, OK, NE, TX)
  - May - August *(Sargeant AVC 2002; Sargeant et al CRWAD 2001)*
  - Collected ~14,000 samples
    - *E. coli* O157 recovered from 10% of feces.
    - 13.1% of water & tank sediment positive.
    - 17% of feed samples positive.
  - Looked at over 150 factors.
  - Associations:
    - Associated with water
      - But cleaning water troughs not effective.

*No management factors to control* *E. coli* O157
Feedlot Epidemiology of *E. coli* O157

- Study of all cattle in 29 pens from 5 feedlots (Smith et al. *JFP* 2001).
- 23% of 3,162 cattle were positive.
- 24% of pens had a positive water sample
  - But not associated with shedding (*P*=0.15)
- Only association was with muddy pen floor
  - But cleaning pens does not affect shedding.
- Did not detect an association with other variables.

No management factors identified.
Seasonal effect also detected by others (e.g., Smith et al. *CRWAD* 2002)
Molecular Characterization of *Escherichia coli* O157:H7 Hide Contamination

- Samples were collected until 25 hides in both the Northeastern & Southwestern regions of the U.S. were confirmed positive for *E. coli* O157:H7.
- Virulent *E. coli* O157:H7 was recovered from all sample collection sites, except feed & feed bunks.
- 130 (1.11%) of the 1,165 total samples were positive for *E. coli* O157:H7.
- In total, 322 *E. coli* O157:H7 isolates were collected from the 130 positive samples; all isolates were analyzed for known PCR gene markers & PFGE genetic homology to other isolates.
## Molecular Characterization of *Escherichia coli* O157:H7 Hide Contamination PFGE’s

<table>
<thead>
<tr>
<th>Sample Types</th>
<th>Genes Present</th>
<th>No. fragment</th>
<th>Epidemiologic differences</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedlot pen floor fecal/Plant pen floor fecal</td>
<td>eaeAO157, stx1, stx2, hlyA, rfbEO157, fliC</td>
<td>1</td>
<td>Indistinguishable</td>
<td></td>
</tr>
<tr>
<td>Loading chute side panel/Plant pen side rail</td>
<td>eaeAO157, stx1, stx2, hlyA, rfbEO157, fliC</td>
<td>2</td>
<td>Closely related</td>
<td></td>
</tr>
<tr>
<td>Loading chute side panel/Plant pen side rail</td>
<td>eaeAO157, stx1, stx2, hlyA, rfbEO157, fliC</td>
<td>4</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Feedlot Pen 1/Feedlot Pen 2 (Same feedlot)</td>
<td>eaeAO157, stx1, stx2, hlyA, rfbEO157, fliC</td>
<td>6</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Hide/Truck trailer side wall</td>
<td>eaeAO157, stx1, stx2, hlyA, rfbEO157, fliC</td>
<td>5</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Feedlot pen floor fecal/Plant pen side rail</td>
<td>eaeAO157, stx1, stx2, hlyA, rfbEO157, fliC</td>
<td>6</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Truck trailer side wall/Feedbunk swab</td>
<td>eaeAO157, stx2, hlyA, rfbEO157, fliC</td>
<td>6</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Hide/Truck trailer side wall</td>
<td>eaeAO157, stx1, hlyA, rfbEO157, fliC</td>
<td>4</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Colon/Colon</td>
<td>eaeAO157, stx1, hlyA, rfbEO157, fliC</td>
<td>4</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Hide/Feedlot pen floor fecal</td>
<td>eaeAO157, stx1, hlyA, rfbEO157, fliC</td>
<td>2</td>
<td>Closely related</td>
<td></td>
</tr>
<tr>
<td>Hide/Feedlot pen floor fecal</td>
<td>eaeAO157, stx1, hlyA, rfbEO157, fliC</td>
<td>4</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Colon/Colon</td>
<td>eaeAO157, stx1, hlyA, rfbEO157, fliC</td>
<td>6</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Hide/Hide</td>
<td>eaeAO157, hlyA, rfbEO157, fliC</td>
<td>4</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Hide/Hide (Consecutive carcasses)</td>
<td>eaeAO157, hlyA, rfbEO157, fliC</td>
<td>3</td>
<td>Closely related</td>
<td></td>
</tr>
<tr>
<td>Hide/Hide</td>
<td>eaeAO157, hlyA, rfbEO157, fliC</td>
<td>4</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Truck trailer side wall/Plant pen water</td>
<td>eaeAO157, hlyA, rfbEO157, fliC</td>
<td>4</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Hide/Plant pen water</td>
<td>eaeAO157, hlyA, rfbEO157, fliC</td>
<td>5</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Hide/colon</td>
<td>eaeAO157, hlyA, rfbEO157, fliC</td>
<td>5</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Hide/Hide</td>
<td>eaeAO157, hlyA, rfbEO157, fliC</td>
<td>4</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Loading chute fecal/Truck trailer side wall</td>
<td>eaeAO157, hlyA, rfbEO157, fliC</td>
<td>5</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Hide/Hide</td>
<td>hlyA, rfbEO157, fliC</td>
<td>4</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Hide/Hide</td>
<td>hlyA, rfbEO157, fliC</td>
<td>4</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Hide/Hide</td>
<td>hlyA, rfbEO157, fliC</td>
<td>4</td>
<td>Possibly related</td>
<td></td>
</tr>
<tr>
<td>Hide/Pen water</td>
<td>hlyA, rfbEO157, fliC</td>
<td>4</td>
<td>Possibly related</td>
<td></td>
</tr>
</tbody>
</table>
Molecular Characterization of *Escherichia coli* O157:H7 Hide Contamination

- It was evident that feedlot, transportation trailer, & packing plant holding pen environments, as well as cross-contamination events, contributed to pathogenic contamination of slaughter-ready cattle hides.

- It also was apparent that pathogens deposited at these sites via previous lots of cattle were allowed to persist, sustaining constant potential for pathogenic contamination of subsequent cattle hides.
Possible Pre-Harvest Interventions

- **Vaccination**
  - BioNiche—Inhibits Intimin (Brett Finlay/Andy Potter)
  - Fort Dodge Animal Health—Antibody Stimulant

- **Direct Fed Microbials (DFM’s; Probiotics)**
  - *Lactobacillus acidophilus* (Brashears)
  - Short-chained caprylic (Octanoic) acid

- **Chlorate Supplementation**
  - Targets Nitrate Reductase (Anderson)

- **Terminal Antibiotic Treatment**
  - Neomycin sulfate (Elders)

- **Bacteriophages**
  - Trojan calf model (Hancock)
  - USDA on-going research

- **Plant Derived Feed Additives**
  - **Tasco™** (Seaweed)
  - Swainsonine (Pigweed; Larkspur)
### E. Coli O157 prevalence (difference from control) on hide, in feces, or combined (N = 1172)

% Presumptive Positive

<table>
<thead>
<tr>
<th>E. coli O157 isolates</th>
<th>Hide</th>
<th>Fecal</th>
<th>Hide + Fecal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatments</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>40.3</td>
<td>45.8</td>
<td>56.9</td>
</tr>
<tr>
<td>Lactobacillus acidophilus (LAB)</td>
<td>22.7 (17.6)</td>
<td>13.3 (32.5)</td>
<td>32.0 (24.9)</td>
</tr>
<tr>
<td>Neomycin sulfate (Neo)</td>
<td>8.5 (31.8)</td>
<td>0.0 (45.8)</td>
<td>8.5 (48.4)</td>
</tr>
<tr>
<td>E. coli O157:H7 Vaccine (Vac)</td>
<td>20.0 (20.3)</td>
<td>14.7 (31.1)</td>
<td>32.0 (24.9)</td>
</tr>
<tr>
<td>Vac + LAB</td>
<td>16.4 (23.9)</td>
<td>32.9 (12.9)</td>
<td>48.0 (8.9)</td>
</tr>
<tr>
<td>Vac + Neo</td>
<td>6.7 (33.6)</td>
<td>26.7 (19.1)</td>
<td>30.7 (26.2)</td>
</tr>
<tr>
<td>Neo + LAB</td>
<td>7.1 (33.2)</td>
<td>1.3 (44.5)</td>
<td>8.6 (48.3)</td>
</tr>
<tr>
<td>Vac + LAB + Neo</td>
<td>6.7 (33.6)</td>
<td>2.7 (43.1)</td>
<td>8.0 (48.9)</td>
</tr>
</tbody>
</table>
Supplementation of Cattle with Octanoic Acid

**Trial 1**
- 521 feeder cattle
  - 216 in Treated Group
  - 314 in Control Group
- 8 head pens
  - Individual cattle were experimental unit
- Treated cattle were supplemented octanoic acid at 0.70% of diet
  - Supplemented for three days

**Trial 2**
- 64 yearling heifers
  - 32 in control group
  - 32 in treated group
- 4 head pens
- 3 replicates
- All animals were inoculated once orally with $1 \times 10^{10}$ CFU / 10 ml of a 5 strain cocktail of E. coli O157:H7
Prevalence of Shiga-toxin 1 positive fecal samples before & after treatment, Trial 1

*Treatment = 3 d supplementation with octanoic acid at 0.70% of DM diet.*
Prevalence of *E. coli* O157:H7 positive fecal samples before & after inoculation, & after treatment, Trial 2

*Treatment = 3 d supplementation with octanoic acid at 0.70% of DM diet.*
Octanoic acid was not detected in any of 10 fecal samples assayed by gas chromatography.

Octanoic acid did not reach the colon (terminal rectum).
  • Likely metabolized in the small intestine

It is possible to overload the small intestine with octanoic acid so that some will pass to the rest of the gastrointestinal tract.
  • Likely cost-prohibitive
  • Detrimental to animal health

Other strategies.
  • Lipid encapsulation
  • Rectal suppository

Octanoic acid is not a likely candidate for pre-harvest food safety due to cost of developing & implementing effective delivery strategies.
Industry Response to *E. coli* O157:H7 Risk (Pre-Harvest)

- NCBA Beef Quality Assurance Advisory Board began discussion of **pre-harvest interventions** and/or **HACCP programs** in 1994.

- Detailed consideration of research findings by the BQA Advisory Board, from 1994 to present, **have not identified any actions** -- other than adherence to "Good Production Practices" -- that could be endorsed for mitigation of risk.

**Good Production Practices:**

- Clean Facilities
- Uncontaminated Water
- Uncontaminated Feed
- Clean Trucks

**SOURCE:** G.C. Smith (Beef Industry *E. coli* Summit, San Antonio, TX, 2003)
Cargill sharpens its edge on E. coli O157:H7

A unique partnership yields a promising new carcass wash system

By Darrel J. Wendt, associate editor

During the previous weeks of the year, it’s not unusual for producers to bring their cattle to the plant in order to be washed and processed. This year is no exception, as cattle producers are seeing a significant increase in the incidence of E. coli O157:H7 at the plant.

The awareness of E. coli O157:H7 has prompted all packers to improve their food safety systems. The plant is no different, as it has implemented a unique partnership with Frontier food solutions, Inc., to enhance its food safety system.

“Through the combination of high-temperature pasteurization, high-pressure cleaning, and chemical treatments, we are able to provide a safe and wholesome product to our customers,” said the plant’s director of food safety.

Cargill’s system includes a water and sodium hydroxide mix to release contaminants, followed by a high-pressure rinse and lactic acid application.
Survival of aerobic bacteria, Enterobacteriaceae populations and the prevalence of *E. coli* O157 on hide and carcass surfaces treated with CPC

<table>
<thead>
<tr>
<th></th>
<th>Survival of Bacteria</th>
<th>Prevalence</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aerobic Plate Counts (log CFU/cm²)</td>
<td>Enterobact. Populations (log CFU/cm²)</td>
<td></td>
<td><em>E. coli</em> O157</td>
</tr>
<tr>
<td><strong>Hides</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>6.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>(14.5%)</td>
</tr>
<tr>
<td>CPC Treated</td>
<td>5.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>(5.5%)</td>
</tr>
<tr>
<td><strong>Carcasses</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>5.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>(4.5%)</td>
</tr>
<tr>
<td>CPC Treated</td>
<td>4.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>(10.5%)</td>
</tr>
</tbody>
</table>

Ransom et al. (2003)
# Effects of Hide on Decontamination Treatments

<table>
<thead>
<tr>
<th></th>
<th>APC</th>
<th>TCC</th>
<th>ECC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>10% Acetic Acid</td>
<td>2.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.2&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>2.7&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>10% Lactic Acid</td>
<td>2.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.6&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>3% Sodium Hydroxide</td>
<td>2.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.9&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>4% Sodium Metasilicate</td>
<td>1.8&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>2.2&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>2.1&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sodium Hydroxide + Lactic Acid</td>
<td>2.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.9&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>2.7&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a,b</sup> Means within each column bearing a common letter are not different (P>0.05)

Carlson et al., 2004
ULTIMATE FOOD SAFETY SYSTEM

WHAT'S IT DO TO THE MEAT?

IT COOKS IT.