SALMONELLA INTERVENTIONS FOR BEEF

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PATHOGEN SOURCES

SOURCES OF MICROBIAL CONTAMINATION

- People
- Facilities
- Equipment
- Food
- Animals
- Pests
- Environment
  - Feces, Soil, Water, Dust
PATHOGEN RELATIONSHIPS

- Diarrheagenic *Escherichia coli* vs. *Salmonella*?
- Correlations/Interactions/Associations?
- Presence/absence/levels relationships?
- No available indicators or indices
- *Salmonella* and *E. coli* O157:H7: fecal
- No trends evident
- Data collected with one do not necessarily reflect or predict the behavior of another
- Certain interventions may affect them similarly
- Data may be indicative of overall picture
SALMONELLA vs. OTHER PATHOGENS

No trends or associations evident

![Bar chart showing prevalence of Salmonella and other pathogens in different stages of production.](chart.png)

Prevalence (%)

- **SA**: 6.1 (Lairage), 17.7 (Hide at slaughter)
- **EC**: 7.2 (Lairage), 28.8 (Hide at slaughter)
- **CA**: 1.1 (Lairage), 0 (Hide at slaughter)

Small et al. 2002. J. Food Prot. 65:931-936
Field and Feedlot:

- Numerous environmental sources:
  - Cattle pens
  - Feed
  - Water
  - Feces
  - Hides
  - Any site, object or material exposed to animal feces
SALMONELLA CONTAMINATION DISTRIBUTION/SOURCES/PREVALENCE

Variation in incidence and prevalence:

- Cattle age
- Finishing program
- Time on feed
- Animal sex
- Animal health
- Animal body site
- Animal group
- Feces vs. hide
- Transportation effects
- Lairage sources
- Seasonal variation
- Regional or geographic variation
SALMONELLA CONTAMINATION
DISTRIBUTION/SOURCES/PREVALENCE

Animal sex variation: No clear trend

Barham et al. 2002. J. Food Prot. 65:280-283
**SALMONELLA CONTAMINATION DISTRIBUTION/SOURCES/PREVALENCE**

*Animal body site variation (hides)*

![Bar chart showing prevalence of salmonella contamination in different body sites.]

- **Prevalence (%)**
  - 60
  - 40
  - 20
  - 0

- **Body Sites**
  - Rump
  - Flank
  - BRISKET

- **Prevalence Data**
  - SA: 2.2%
  - EC: 3.3%, 4.4%, 22.2%
  - CA: 0%

Animal group and animal site variation (Australia)

Fegan et al. 2002. J. Food Prot. 68:1147-1153
SALMONELLA CONTAMINATION DISTRIBUTION/SOURCES/PREVALENCE

Hide seasonal and geographic variation

SALMONELLA vs. OTHER PATHOGENS

Seasonal variation on hides

SALMONELLA CONTAMINATION DISTRIBUTION/SOURCES/PREVALENCE

Regional/Geographic variation

SALMONELLA CONTAMINATION DISTRIBUTION/SOURCES/PREVALENCE

Animal age and transportation stress effects:

Beach et al. 2002a. J. Food Prot. 65:1687-1693
SALMONELLA CONTAMINATION DISTRIBUTION/SOURCES/PREVALENCE

Transportation stress effects

Barham et al. 2002. J. Food Prot. 65:280-283
Salmonella vs. E. COLI O157:H7

Transportation stress effects: Conflicting results

Barham et al. 2002. J. Food Prot. 65:280-283

Salmonella  EHEC
### SALMONELLA CONTAMINATION DISTRIBUTION/SOURCES/PREVALENCE

<table>
<thead>
<tr>
<th>Lairage site</th>
<th>Salmonella</th>
<th>O157</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unloading rump</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Corner: unloading area/lairage pens</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Pen walls</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pen floor</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Water trough</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Corner: lairage pens and race</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Funnel walls</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Crush</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Gates</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td>Stunning box</td>
<td>18</td>
<td>4</td>
</tr>
</tbody>
</table>

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Small et al. 2002. J. Food Prot. 65:931-936
SALMONELLA CONTAMINATION
DISTRIBUTION/SOURCES/PREVALENCE

- Additional sources of contamination
- Slaughter plant environment and humans

- **Knock boxes:**
  - Facility A: 64.3 % positive
  - Facility B: 83.3 % positive

  Beach et al. 2002a. J. Food Prot. 65:1687-1693

- **Aprons:** 26 % positive for *E. coli* O157

- **Knives:** 29 % positive for *E. coli* O157

  Tutenel et al. 2003. J. Food Prot. 66:1564-1469
SALMONELLA CONTAMINATION DISTRIBUTION/SOURCES/PREVALENCE

Slaughter plant and human sources of contamination

SALMONELLA CONTAMINATION DISTRIBUTION/SOURCES/PREVALENCE

Plant variation

Prevalence (%)

- Fecal
- Hide
- Carcass

Ransom et al. 2002. J. Food Prot. 65:621-626
SALMONELLA CONTAMINATION DISTRIBUTION/SOURCES/PREVALENCE

Slaughter day variation

Barham et al. 2002. J. Food Prot. 65:280-283
Carcass site variation

SALMONELLA CONTAMINATION DISTRIBUTION/SOURCES/PREVALENCE

Prevalence (%)

- Brisket: Pre-evisceration 2.5%, Post-evisceration 0.6%
- Flank: Pre-evisceration 8.5%, Post-evisceration 3.0%
- Rump: Pre-evisceration 3.6%, Post-evisceration 0.8%

Sofos et al. 1999. J. Food Prot. 62:467-473
HIDE sampling method variation

Ransom et al. 2002. J. Food Prot. 65:621-626

SALMONELLA CONTAMINATION
DISTRIBUTION/SOURCES/PREVALENCE

Percent Positive Samples

- E. coli O157:H7
- Salmonella

Sponge  Excision  Gauze  Hair Clip  Rinse
### Counts (MPN/g or cm²) of Salmonella

**Live animal to carcass (Australia)**

<table>
<thead>
<tr>
<th>Group</th>
<th>Feces</th>
<th>Hide</th>
<th>Rumen</th>
<th>Oral</th>
<th>Prechill carcass</th>
<th>Chilled carcass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ND-93</td>
<td>&lt;0.06-0.46</td>
<td>ND-43</td>
<td>ND-3.6</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>2</td>
<td>ND-&lt;3</td>
<td>ND-&lt;0.18</td>
<td>ND-&lt;3</td>
<td>ND-&lt;3</td>
<td>----</td>
<td>ND-0.31</td>
</tr>
<tr>
<td>3</td>
<td>ND-93</td>
<td>ND-4.8</td>
<td>ND-&lt;3</td>
<td>ND-9.2</td>
<td>ND-&lt;0.1</td>
<td>----</td>
</tr>
</tbody>
</table>

Fegan et al. 2002. J. Food Prot. 68:1147-1153
USA REGULATIONS FOR PATHOGEN CONTROL

- Visible Contamination: “Zero Tolerance”
- Ground Beef: “Adulterant” *E. coli* O157:H7
- Pathogen Reduction/HACCP Rule (1996):
  - SSOP
  - HACCP
- Microbiological Criteria:
  - Performance Criteria: *E. coli*
  - Pathogen Reduction Standard: *Salmonella*
- Beef HACCP Revision (2002)
- Directives and Guidances
STRATEGY FOR PATHOGEN CONTROL

- Pre-harvest or Field Control
  - Minimize sources and levels
  - Minimize access or transfer
- Post-harvest or Processing Factory Control
  - Minimize or reduce contamination
  - Inactivate contamination
  - Inhibit or retard growth
- Foodservice control
  - Inhibit growth
  - Inactivate contamination
  - Prevent cross-contamination
- Education
Reasons for pre-harvest pathogen control
- Reduce pathogen sources and levels
- Water contamination
- Produce contamination
- Animal-to-human transmission

Ideal pre-harvest interventions:
- Animal friendly
- Environmentally compatible
- Effective against various pathogens
- Practical to apply
- Cost effective
PATHOGEN CONTROL IN THE FIELD

Interventions explored:
- Diet manipulation
- Feed additives/supplements
- Antibiotics
- Bacteriophages
- Vaccines/Immunization
- Competitive exclusion/Prebiotics/Probiotics
- Management practices
Management Practices:

Pathogens may be ubiquitous

Potential:

- Clean feed
- Pest control
- Pen condition
- Pen density
- Manure control
- Transportation stressing
- Chlorination/Ozonation/UV light
- Dust control
- Screens/filters for solids

Combined efforts needed for control
PATHOGEN CONTROL IN THE FIELD

Difficulties in pre-harvest pathogen control

- Limited scientific information
- Unknown reservoirs
- Numerous complicating variables
- Asymptomatic animals
- Sporadic or low shedding
- Low pathogen cell numbers
- Large numbers of total contamination
- Inadequate detection methodology
- Ubiquitous presence of some pathogens
- Economic issues
- Lack of proven interventions
INTERVENTIONS TO REDUCE CARCASS CONTAMINATION

- Animal Cleaning
- Chemical dehairing
- Knife-trimming and Steam-Vacuuming
- Pre-Evisceration Washing
- Carcass washing
- Thermal Pasteurization
- Organic Acid Rinsing
- Sequential Hurdles
CATTLE HIDE WASHING

### Around Tailhead

**Whole Hide**

- **Hosing**
- **“Beauty Parlor”**

### Treatment

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Salmonella Positive (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-treatment</td>
</tr>
<tr>
<td>Single wash</td>
<td>58</td>
</tr>
<tr>
<td>Double wash</td>
<td>36</td>
</tr>
<tr>
<td>Chlorine</td>
<td>60</td>
</tr>
<tr>
<td>Lactic acid</td>
<td>50</td>
</tr>
</tbody>
</table>

N=90; Mies et al. (J. Food Prot. 2004. 67:579-582)

### Diagram

Graph showing the effectiveness of different treatments in reducing the presence of:
- E. coli O15:H7
- Salmonella Typhimurium
- Listeria monocytogenes

- Untreated Water
- 0.5% CPC
- 1.0% CPC

Hosing and treatment effects on the reduction of pathogens.
## CATTLE HIDE WASHING

<table>
<thead>
<tr>
<th>Treatment</th>
<th>(%)</th>
<th>Mean Log Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>-</td>
<td>0.7</td>
</tr>
<tr>
<td>Lactic acid</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>5.1</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>2</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>4.8</td>
</tr>
<tr>
<td>Chlorine</td>
<td>0.01</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>0.04</td>
<td>1.3</td>
</tr>
<tr>
<td>Ethanol</td>
<td>70</td>
<td>5.2</td>
</tr>
</tbody>
</table>

Inoculated: 6.1 Log *Salmonella*; Mies et al. (J. Food Prot. 2004. 67:579-582)
SLAUGHTER INTERVENTIONS

Pre-harvest

Post-processing

FIGURE 1. Overall prevalence of E. coli O157:H7, Salmonella, non-O157 STEC, and stx-positive cells by sampling site.

BARKOCY-GALLAGHER ET AL.
Inoculated Dehaired

Bacterial Counts (log CFU/cm²)

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>Inoculated</th>
<th>Dehaired</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. coli</td>
<td>7.7</td>
<td>1.1</td>
</tr>
<tr>
<td>Salmonella</td>
<td>4.8</td>
<td>0.7</td>
</tr>
<tr>
<td>L. monocytogenes</td>
<td>4.4</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Hide samples

Graves Delmore et al. (1996)
KNIFE-TRIMMING, STEAM-VACUUMING, SPRAY-WASHING

- Knife-Trimming
- Steam-vacuuming
- Carcass spraying-washing

**Diagram:**

*STEAM VACUUM, CARCASS DECONTAMINATION MONFORT PLANTS (SUMMER 1995)*

**Legend:**

- Steam Vac
- Knife Trim
- Control

**Source:** Sherrre Kochevar et al. (1995). Colorado State University
# CARCASS DECONTAMINATION

## Commercial Beef Decontamination in 6 Plants

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Listeria</th>
<th>Salmonella</th>
<th>E. coli O157:H7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>44</td>
<td>30</td>
<td>0.7</td>
</tr>
<tr>
<td>Trimmed (T)</td>
<td>25</td>
<td>8</td>
<td>2.1</td>
</tr>
<tr>
<td>Washed (W)</td>
<td>27</td>
<td>9</td>
<td>0.7</td>
</tr>
<tr>
<td>T + W</td>
<td>13</td>
<td>1.4</td>
<td>1.4</td>
</tr>
</tbody>
</table>

CARCASS DECONTAMINATION

Thermal
- Hot water (>74°C)
- Pressurized steam

Graves Delmore et al. (1997)

<table>
<thead>
<tr>
<th>°C</th>
<th>Initial</th>
<th>3</th>
<th>6</th>
<th>9</th>
<th>12</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>87.8</td>
<td>5.7</td>
<td>0.1</td>
<td>0.2</td>
<td>0</td>
<td>0.2</td>
<td>0.7</td>
</tr>
<tr>
<td>93.3</td>
<td>5.6</td>
<td>0</td>
<td>1.3</td>
<td>1.6</td>
<td>1.7</td>
<td>2.7</td>
</tr>
<tr>
<td>98.9</td>
<td>5.6</td>
<td>1.4</td>
<td>2.9</td>
<td>3.6</td>
<td>3.5</td>
<td>4.8</td>
</tr>
</tbody>
</table>


Salmonella Reduction (log CFU/cm²) Following Steam Pasteurization of Pre-rigor Beef for Various Times (sec)
CARCASS DECONTAMINATION

**Chemical; Organic Acid Rinsing**
- Lactic or Acetic (1.5-5%; 55°C)

### E. coli O157 Reductions (log CFU)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Carcass site variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trimming</td>
<td>3.2 - 3.3</td>
</tr>
<tr>
<td>Water (W)</td>
<td>2.0 - 3.0</td>
</tr>
<tr>
<td>W/Lactic acid (2%; 55°C)</td>
<td>3.0 - 4.2</td>
</tr>
<tr>
<td>W/Acetic acid (2%; 55°C)</td>
<td>2.4 - 3.0</td>
</tr>
</tbody>
</table>

### Salmonella Reductions (log CFU)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Carcass site variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trimming</td>
<td>2.9 - 3.9</td>
</tr>
<tr>
<td>Water (W)</td>
<td>2.2 – 2.5</td>
</tr>
<tr>
<td>W/Lactic acid (2%; 55°C)</td>
<td>3.4 – 5.0</td>
</tr>
<tr>
<td>W/Acetic acid (2%; 55°C)</td>
<td>3.2 – 5.1</td>
</tr>
</tbody>
</table>

Hardin et al. 1995. J. Food Prot. 58:368-374
MULTIPLE INTERVENTIONS

Sequential application of:
- Animal cleaning
- Chemical dehairing
- Knife-trimming
- Steam-vacuuming
- Pre-evisceration washing
- Final carcass washing
- Chemical and/or thermal
- Carcass chilling

Combinations of treatments:
- Warm acid solutions
- Steam and vacuum

Graves Delmore et al. (1998)
CARCASS DECONTAMINATION

Contamination concerns following slaughter:

- Chilling
- Fabrication
- Post-fabrication

- New and additional contamination
- Cross-contamination
- Spreading and redistribution
- Microbial growth
- Sanitation and hygiene
- Temperature/Time
- Potential decontamination
- Processing / Packaging
MEAT RECONTAMINATION (6 Plants)

Kain et al. (1996)
POST-FABRICATION DECONTAMINATION

Geornaras et al. (2006)

Salmonella in Beef

E. coli O157:H7 in Beef

Control
- Hot Water (75°C, 30 s)
- Lactic Acid (2%; 55°C, 30 s)
- Lactic Acid – Hot Water
- Hot Water – Lactic Acid

10°C

Storage days

Log CFU/cm²

Storage days
CARCASS DECONTAMINATION

**Ideal carcass or meat decontamination:**
- Environment friendly
- Plant personnel friendly
- Consumer friendly
- No residues
- Achieve objective
- Effective against multiple pathogens
- Practical to apply
- Maintain product shelflife
- Do not mask spoilage
- Cost effective
CARCASS DECONTAMINATION

SUMMARY

Decontamination interventions are useful:
- Reduce carcass contamination (1–3 logs)
- Reduce pathogen prevalence
- Assist plants meet regulatory/industry criteria

However, they should be:
- Evaluated for potential unpredictable risks
- Optimized for maximum benefits with no risks

Consider potential long term effects of interacting sublethal interventions on the microbial ecology of plants and raw and ready-to-eat products
Select treatments, intensity and sequence to maximize control and minimize selection
- Alternate, or use simultaneously
- Validate technologies in the field
- Minimize variations
- Research new technologies
- Not ready-to-eat until processed or cooked

Potential benefits:
- Reduce probability of illness when product intentionally or unintentionally undercooked
- Reduce potential cross-contamination
FOOD SAFETY RESPONSIBILITIES

- Integrated approach
- Farm-to-Table
- Producer, packer, processor, distributor, retailer, food service and consumer