Microbiological Produce Safety Issues at Retail

Michael Doyle

- International sources of produce
- Produce as vehicle of foodborne illnesses
- Food safety issues with fresh-cut produce
- Cantaloupe
- Salsa
- Parasites/Cyclospora
- Chemophobia/Natural Foods

United States Food Imports

- Approximately 15% of food consumed in USA in 2006 was imported; currently approaching 20%

Import Shares (Percentage) of Major Foods Consumer in United States, by selected food categories (2009, 2010)

<table>
<thead>
<tr>
<th>Food Category</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>9.8</td>
<td></td>
</tr>
<tr>
<td>Lamb</td>
<td>52.4</td>
<td></td>
</tr>
<tr>
<td>Fish (fresh or frozen)</td>
<td>96.4</td>
<td></td>
</tr>
<tr>
<td>Fruits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh</td>
<td>26.0</td>
<td></td>
</tr>
<tr>
<td>Canned</td>
<td>38.9</td>
<td></td>
</tr>
<tr>
<td>Dried</td>
<td>21.3</td>
<td></td>
</tr>
<tr>
<td>Juices</td>
<td>62.4</td>
<td></td>
</tr>
<tr>
<td>Orange</td>
<td>28.3</td>
<td></td>
</tr>
<tr>
<td>Apple</td>
<td>85.2</td>
<td></td>
</tr>
</tbody>
</table>

www.fas.usda.gov/gats
Import Shares (Percentage) of Major Foods
Consumer in United States, by selected food categories (2009, 2010)

- Tree nuts: 41.1%
- Vegetables:
  - Fresh: 20.0%
  - Canned: 14.6%
- Honey: 63%
- Spices: 89.9%

www.fas.usda.gov/gats

Microbiological Safety Issues
Associated with Imported Foods

- Sanitation practices for food production and preparation are not universally equivalent throughout the world.
- Importing foods can move pathogens from areas where pathogen is indigenous to locations where it seldom or does not exist.
  - Example, *Cyclospora* in raspberries from Guatemala to U.S. and Canada.

Examples of Food Safety Concerns
Associated with Imported Produce

- Centuries old tradition of using human excreta on farmland is widespread in east Asia, especially in China and Vietnam.
- Irrigation water contaminated with untreated human and animal fecal waste.
- Insanitary harvesting practices of importing countries.
  - Children infected with norovirus or hepatitis A accompany parents in produce field during harvest.

Foodborne Disease Outbreaks Attributed to a Single Commodity by Leading Food Vehicles, 2006-2010

<table>
<thead>
<tr>
<th>Year</th>
<th>Rank</th>
<th>Food Vehicle</th>
<th>% of Outbreaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>1</td>
<td>Produce</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Meat</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Fish and Shellfish</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Poultry</td>
<td>14</td>
</tr>
<tr>
<td>2007</td>
<td>1</td>
<td>Meat</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Produce</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Poultry</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Fish and Shellfish</td>
<td>17</td>
</tr>
</tbody>
</table>

CDC, MMWR 58:609-615 (2009)
MMWR 59:573-979 (2010)
MMWR 60:1197-1320 (2011)

Foodborne Disease Outbreaks Attributed to a Single Commodity by Leading Food Vehicles, 2008-2010

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<tr>
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<th>Rank</th>
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</tr>
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<tbody>
<tr>
<td>2008</td>
<td>1</td>
<td>Produce</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Meat</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Poultry</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Fish and Shellfish</td>
<td>14</td>
</tr>
<tr>
<td>2009 - 2010</td>
<td>1</td>
<td>Produce</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Meat</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Fish and Shellfish</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Dairy</td>
<td>12</td>
</tr>
</tbody>
</table>

Attribution of Foodborne Illnesses and Deaths to Food Commodities (U.S. Outbreak Data 1998 - 2010)

<table>
<thead>
<tr>
<th>Commodity</th>
<th>% Illnesses</th>
<th>% Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produce</td>
<td>46</td>
<td>23</td>
</tr>
<tr>
<td>Leafy</td>
<td>22</td>
<td>6</td>
</tr>
<tr>
<td>Fruits - nuts</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Vine - stalk</td>
<td>7.9</td>
<td>7</td>
</tr>
<tr>
<td>Root</td>
<td>3.6</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Examples of Produce Not Previously Associated with Foodborne Outbreaks Until 2006 - 2013

- Bagged spinach (*E. coli* O157:H7)
- Carrot juice (Botulism)
- Peanut butter and peanut paste (*Salmonella*)
- Broccoli powder on snack food (*Salmonella*; China)
- Jalapeno peppers (*Salmonella*; Mexico)
- Turkish pine nuts (*Salmonella*; Turkey)
- Pistachios (*Salmonella*)
- Whole papaya (*Salmonella*)
- Hazelnuts (*E. coli* O157:H7)
- Bagged organic spinach and spring mix (*E. coli* O157:H7)
- Bagged salad mix (lettuce, cabbage, carrots) (*Cyclospora*; Mexico)
- Cilantro (*Cyclospora*; Mexico)

Earthbound Farm Spinach & Vegetables Test & Hold:
Raw SJB & Yuma 2007 thru SJB & Yuma 2010

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Raw MC Incidents</td>
<td>32</td>
<td>13</td>
<td>86</td>
<td>8</td>
<td>242</td>
<td>13</td>
<td>107</td>
</tr>
<tr>
<td>Total Samples</td>
<td>41,025</td>
<td>29,340</td>
<td>44,067</td>
<td>26,884</td>
<td>44,862</td>
<td>28,037</td>
<td>38,681</td>
</tr>
<tr>
<td>% Raw MC Incidents</td>
<td>0.08%</td>
<td>0.04%</td>
<td>0.18%</td>
<td>0.03%</td>
<td>0.48%</td>
<td>0.04%</td>
<td>0.60%</td>
</tr>
</tbody>
</table>

Fresh-cut Produce is Wounded Plant Tissue

- Preparing **fresh-cut** produce involves cutting (lettuce, apples, pears), shredding (carrots, cabbage), dicing (tomatoes), or peeling (carrots, oranges)
- Microbes attach more easily to cut or bruised surfaces than intact produce
- Cut surfaces of produce release large amounts of liquid containing nutrients that are readily utilized by the attached microbes

Food Safety Risks Associated with Field Processing of Lettuce

- Most fresh-cut (shredded and bagged) iceberg lettuce is **cut and cored in the field**
- Field coring involves using a knife with a cylindrical coring ring on the opposite end to sever the lettuce heads from roots near the soil surface and then remove the core with the coring ring
- Blades may contact soil and transfer it to lettuce tissue along with microbial contaminants in the soil
- Lettuce forms white "latex" on cut surfaces soon after it is cut
  - Latex prevents contact with wash water or disinfectant

*Fresh-cut produce: fresh produce that has been processed by peeling, dicing, chopping, shredding, coring, trimming, or washing, with or without washing or other treatment, prior to being packaged for consumption.*

*FDA data*
**Iceberg Lettuce Field Harvesting and Coring Knives**

*Image of two coring knives.*

**E. coli O157:H7 in iceberg lettuce heads sequentially cut and cored with the same field-coring device with a blade that had been immersed in soil containing ca. 500 E. coli O157:H7/g**

<table>
<thead>
<tr>
<th>Lettuce piece</th>
<th>Number of samples positive by enrichment per three replicate samples analyzed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem end</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>Inner core</td>
<td>2 2 2 3 3 3 2 2 2 2</td>
</tr>
<tr>
<td>Outer core</td>
<td>2 2 2 2 3 3 3 2 2 1</td>
</tr>
</tbody>
</table>


**Effectiveness of Chlorine to Inactivate E. coli O157:H7 on Lettuce**

<table>
<thead>
<tr>
<th>Treatment Conditions</th>
<th>Log Reduction E. coli O157</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 ppm, 5 min, 22°C</td>
<td>0.7 (on surface) 1.0 (on cut-edge)</td>
<td>Takeuchi and Frank (2000)</td>
</tr>
<tr>
<td>20 ppm, 9 sec, 20°C or 50°C</td>
<td>No different than water control</td>
<td>Li et al. (2001)</td>
</tr>
<tr>
<td>100 ppm, 3 min, 4°C</td>
<td>1.0</td>
<td>Delaquis et al. (2002)</td>
</tr>
</tbody>
</table>

**Examples of Salmonellosis Outbreaks Associated with Cantaloupes**

<table>
<thead>
<tr>
<th>Year</th>
<th>Pathogen</th>
<th>Location</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989-90</td>
<td>S. Chester</td>
<td>Multistate</td>
<td>295</td>
</tr>
<tr>
<td>1991</td>
<td>S. Poona</td>
<td>Multistate</td>
<td>&gt; 400</td>
</tr>
<tr>
<td>1997</td>
<td>S. Saphra</td>
<td>California</td>
<td>24</td>
</tr>
<tr>
<td>1998</td>
<td>S. Oranienburg</td>
<td>Canada</td>
<td>22</td>
</tr>
<tr>
<td>2000</td>
<td>S. Poona</td>
<td>Multistate</td>
<td>46</td>
</tr>
<tr>
<td>2001</td>
<td>S. Poona</td>
<td>Multistate</td>
<td>50</td>
</tr>
<tr>
<td>2002</td>
<td>S. Poona</td>
<td>Multistate, Canada</td>
<td>58</td>
</tr>
<tr>
<td>2006</td>
<td>S. Oranienburg</td>
<td>10 States, Canada</td>
<td>41</td>
</tr>
<tr>
<td>2007</td>
<td>S. Litchfield</td>
<td>16 States, Canada</td>
<td>60</td>
</tr>
<tr>
<td>2008</td>
<td>S. Javiana</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>S. Panama</td>
<td>10 States</td>
<td>20</td>
</tr>
<tr>
<td>2011</td>
<td>S. Uganda</td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

**Listeria monocytogenes Infections from Foods in Commercial Establishments**

- Case-control study of 169 sporadic case patients with L. monocytogenes infection from 2000 - 2003
- L. monocytogenes infections were associated with:
  1. Eating *melons* at a commercial establishment
  2. Eating *hummus* prepared in a commercial establishment


**Cantaloupe-associated Listeriosis Outbreak**

- September - November 2011 a total of 146 cases of listeriosis, including 31 deaths and 1 miscarriage, in 28 states; mostly elderly
- Vehicle was Rocky-Ford brand *cantaloupes* grown by Jensen Farms, Granada, CO
Fresh-cut Melons are a Convenience Food Pushing the Limits of Safety

- pH of melons
  - Cantaloupe: 6.2 - 7.1
  - Honeydew: 6.3 - 6.7
  - Watermelon: 5.2 - 5.8

- Examples of Outbreaks
  - >400 cases of salmonellosis - cantaloupe at salad bars
  - 18 cases of salmonellosis - watermelon cut at supermarket
  - 17 cases of salmonellosis - watermelon cut at supermarket
  - 206 cases of norovirus infection - melon cut by infected foodhandler

Pathogen growth on precut melons
- $10^6$ increase of Salmonella in watermelon at 23°C for 24 h
- $10^5$ increase of Listeria monocytogenes in watermelon at 20°C for 2 d
- $10^4$ increase of Listeria monocytogenes in Valenciano amarelo (Brazilian) melon at 10°C for 4 d or 20°C for 1 d
- Salmonella generation times at 23°C
  - Cantaloupe: 1.2 h
  - Honeydew: 1.1 h
  - Watermelon: 1.0 h

Evaluation of Sanitizers for the Removal of Salmonella and Listeria from the Surface of Eastern Cantaloupes

Cathy Webb
Inoculate melons with *Salmonella* or *L. mono* at stem scar and netted rind

**Sanitizers:**
- *Salmonella*
  - Water
  - Chlorine 120 ppm
  - Fit® 2% Levulinic acid/0.2% SDS
- *L. mono*
  - Chlorine 200 ppm
  - Chlorine dioxide 3 ppm
  - 5% Levulinic acid / 2% SDS

Comparison of simulated dump tank treatments on populations of *S. Poona* on netted rind and stem scar tissue of cantaloupes

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Stem Scar Mean surviving S. Poona log reduction</th>
<th>log reduction</th>
<th>Netted Rind Mean surviving S. Poona log reduction</th>
<th>log reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>6.98 ± 0.35 A^a</td>
<td>NA^a</td>
<td>5.78 ± 0.58 A</td>
<td>NA</td>
</tr>
<tr>
<td>Water</td>
<td>6.67 ± 0.54 AB</td>
<td>0.31</td>
<td>4.81 ± 0.61 B</td>
<td>0.97</td>
</tr>
<tr>
<td>Chlorine, 120 ppm</td>
<td>6.39 ± 0.62 B</td>
<td>0.59</td>
<td>4.19 ± 0.88 BC</td>
<td>1.59</td>
</tr>
<tr>
<td>Fit® 1% Levulinic acid/0.1% SDS</td>
<td>5.86 ± 0.53 C</td>
<td>1.32</td>
<td>3.72 ± 1.09 C</td>
<td>2.86</td>
</tr>
<tr>
<td>Fit® 2% Levulinic acid/0.2% SDS</td>
<td>5.61 ± 0.49 C</td>
<td>1.37</td>
<td>2.41 ± 1.21 D</td>
<td>3.37</td>
</tr>
</tbody>
</table>

* Log reduction calculated by subtracting log CFU/g of each treatment from log CFU/g of control.
^a Mean data in each column not followed by the same letter are significantly different (p<0.05).

Detection of *Salmonella Poona* in cantaloupe flesh after 18 hrs at 22°C following surface inoculation

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Stem Scar Flesh Number of positive flesh samples/Number of samples tested</th>
<th>Netted Rind Flesh Number of positive flesh samples/Number of samples tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>5/12</td>
<td>5/12</td>
</tr>
<tr>
<td>Water</td>
<td>10/10</td>
<td>10/10</td>
</tr>
<tr>
<td>120 ppm Chlorine</td>
<td>7/10</td>
<td>6/10</td>
</tr>
<tr>
<td>Fit® 2% Levulinic acid/0.2% SDS</td>
<td>14/20</td>
<td>0/20</td>
</tr>
</tbody>
</table>

Conclusions

- Fit® 2% Levulinic acid / 0.2% SDS treatment reduced *S. Poona* by 3.5 log compared to 2.3 log reduction by 120 ppm chlorine on the netted rind
- Fit® 2% Levulinic acid / 0.2% SDS and 120 ppm chlorine reduced *S. Poona* by 1.5 log at the stem scar
- Fit® 2% Levulinic acid / 0.2% SDS applied on the netted rind resulted in no contaminated flesh samples but did not prevent infiltration (cross contamination) at the stem scar

Survival and growth of *Salmonella* in salsa and related ingredients

- Li Ma^1
- Guodong Zhang^1^*
- Michael P. Doyle^1
- Peter Gerner-Smidt^2
- Robert V. Tauxe^2

^1Center for Food Safety, University of Georgia
^2Center for Food Safety and Applied Nutrition, FDA
^3Centers for Disease Control and Prevention

J. Food Prot. 73:434-444 (2010)
**Background**

- A multistate outbreak of *Salmonella* Saintpaul infections associated with multiple raw produce items, 2008
- Jalapeno peppers
- Salsa
  - Two clusters of cases (47 & 33) associated with eating salsa
  - Low in pH, hot, herbal components

**Objectives**

- To determine the survival and growth characteristics of *Salmonella* on raw and chopped jalapeno peppers, Roma tomatoes, and cilantro, and in salsa
- To identify ingredients in salsa that substantially influence the survival and growth of *Salmonella* during storage

**Methods**

- *Salmonella* strains: 5-strain mixture
- Chopped vegetables and inoculation:
  - Tomatoes, jalapeno peppers, and cilantro, chopped into small pieces; direct inoculation.
- Salsa preparation and inoculation:
  - 1st set: 4 recipes (A, B, C, and R), direct inoculation, 21°C
  - 2nd set: recipe manipulation, A, B, and C
- Storage and sampling: 4, 12, and 21°C; 0, 4h, 1, 2, 5, and 7 days.

**Survival and growth of *Salmonella* in chopped vegetables**

**Survival and growth of *Salmonella* in salsas**
Conclusions

- *Salmonella* grew in chopped jalapeno peppers, Roma tomatoes, and cilantro at 12 and 21°C, with chopped jalapeno pepper being the most supportive of *Salmonella* growth.
- *Salmonella* neither grew nor was inactivated in chopped jalapeno peppers, Roma tomatoes, or cilantro held at 4°C for 7 days.

Foodborne Parasites: Cyclosporiasis Outbreak in USA in 2013

- 631 cases of persons infected with *Cyclospora cayetanensis* between June - August 2013
- More than one outbreak:
  - IA and NE cases associated with a salad mix consumed at national chain restaurants and supplied by Taylor Farms de Mexico
  - TX cases associated with contaminated fresh cilantro from Puebla, Mexico

CDC (http://www.cdc.gov/parasites/cyclosporiasis/outbreaks/investigation_2013.html)

Cyclosporiasis Outbreak - 2014

- 304 Cases of cyclosporiasis reported in US in 2014, as of August 26
- 64% of cases in Texas; all reported July 2014
- Several illnesses associated with cilantro from Puebla, Mexico

CDC, Outbreak Investigations, 2014
Global ranking by importance of Top 15 FOODBORNE PARASITES and their primary food vehicle:

- *Taenia solium* – pork
- *Echinococcus granulosus* – fresh produce
- *Echinococcus multilocularis* – fresh produce
- *Trichinella spiralis* – pork
- *Opisthorchiidae* – fresh water fish
- *Opisthorchis viverrini* – fresh produce
- *Ascaris lumbricoides* – fresh produce
- *Cryptosporidium spp.* – fresh produce, fruit juice, milk
- *Entamoeba histolytica* – fresh produce
- *Trichinella spiralis* – pork
- *Opisthorchiidae* – fresh water fish
- *Ascaris lumbricoides* – fresh produce
- *Cryptosporidium spp.* – fresh produce, fruit juice, milk
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- *Cryptosporidium spp.* – fresh produce, fruit juice, milk
- *Entamoeba histolytica* – fresh produce
- *Trichinella spiralis* – pork
- *Opisthorchiidae* – fresh water fish
- *Ascaris lumbricoides* – fresh produce

Chemophobia/"Natural Foods" and the Blogosphere

- Consumer movement, initially in Europe, to remove food additives/"chemicals" from foods
  - Using "blogosphere" to communicate, which includes misinformation that is not grounded in science-based data
- "Processed foods" are a target
  - Marion Nestle's (New York University) definition of "processed foods" is based on number of food additives, especially those with esoteric names

Chemophobia/"Natural Foods"

- Can have adverse public health consequences
  - Remove benzoate from foods
    - Pressure from retailers on food manufacturers to remove benzoate from processed foods
    - Next on list is sorbate (naturally occurring in certain berries such as European mountain ash berries)

Chemophobia/"Natural Foods"

- Significance of removing benzoate
  - Frequently used in foods (e.g., beverages, dairy-based fillings in baked goods) to control molds and yeasts
  - Can also inhibit growth of foodborne bacterial pathogens such as *Staphylococcus aureus*
  - Benzoic acid is a naturally-occurring antimicrobial in cranberries, blackberries, apricots, cherries, plums, cinnamon, cloves, coffee beans, honey

Chemophobia/Preservative-free Foods

- Recent recalls or consumer complaints of preservative-free foods
  - Organic baby food (microbial spoilage)
  - String cheese (microbial spoilage)
  - Yogurt (microbial spoilage)
  - UHT-packaged juice-like beverage (microbial spoilage)
Learnings

- Removing certain food preservatives can have unintended consequences with regard to the microbiological safety of a product
- Can also substantially reduce shelf life of many foods
- Base use of microbial inhibitors on public health implications and sound science

Concluding Comments

- Produce is a leading vehicle of foodborne illness, with fresh-cut leafy greens and melons of particular concern
- Cantaloupe is prone to pathogen contamination, and many commonly used sanitizers are not fully effective in mitigating pathogen contamination, especially at the stem scar
Concluding Comments

- Salsa and chopped vegetable ingredients (cilantro, jalapeno peppers, tomatoes) can support prolific growth of *Salmonella*, especially at room temperature

- Cilantro is a prominent vehicle of *Salmonella* and *Cyclospora*

Concluding Comments

- "Natural" foods that do not contain antimicrobial preservatives may be a disaster in the making, depending on the food’s ability to support the growth of pathogens and spoilage microbes and storage temperature