Learning from the Caramel Apple Listeriosis Outbreak: A Focus on Prevention

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Outline

- *Listeria*
- Outbreak and investigation
- Research and results
- Regulations
- Preventive controls
**Listeria monocytogenes**

- Bacteria that can cause illness in humans if ingested (via contaminated food)
- Elderly, pregnant women, neonates, and people with certain medical conditions are more susceptible
- Listeriosis: disease with symptoms of fever, chills, diarrhea, nausea, muscle cramps, headache
- Severe cases lead to meningitis, death
# Bacterial pathogens causing foodborne illness in the U.S.

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Annual illnesses</th>
<th>Hospitalizations</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Bacillus</em></td>
<td>63,000</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td><em>Campylobacter</em></td>
<td>850,000</td>
<td>8,500</td>
<td>76</td>
</tr>
<tr>
<td><em>Clostridium</em></td>
<td>970,000</td>
<td>482</td>
<td>35</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>191,000</td>
<td>2,382</td>
<td>21</td>
</tr>
<tr>
<td><em>L. monocytogenes</em></td>
<td><strong>1,600</strong></td>
<td><strong>1,500</strong></td>
<td><strong>250</strong></td>
</tr>
<tr>
<td><em>Salmonella</em></td>
<td>1,000,000</td>
<td>19,000</td>
<td>380</td>
</tr>
<tr>
<td><em>Staphylococcus</em></td>
<td>240,000</td>
<td>1,100</td>
<td>6</td>
</tr>
<tr>
<td><em>Streptococcus</em></td>
<td>11,000</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><em>Vibrio</em></td>
<td>53,000</td>
<td>276</td>
<td>48</td>
</tr>
<tr>
<td><em>Yersinia</em></td>
<td>98,000</td>
<td>530</td>
<td>29</td>
</tr>
</tbody>
</table>

L. monocytogenes

- From 1998-2014, there were 58 foodborne outbreaks associated with:

  - Cheese
  - Ice cream
  - Cantaloupe
  - Hot dogs
  - Potato salad
  - Milk
  - Celery
  - Sprouts
  - Pâté
  - Deli meat
Outbreak

Multistate Outbreak of Listeriosis Linked to Commercially Produced, Prepackaged Caramel Apples Made from Bidart Bros. Apples (Final Update)

FDA Investigated Listeria monocytogenes Illnesses Linked to Caramel Apples

Food Safety News
Breaking news for everyone’s consumption

Apples Were Apparently the Contaminated Ingredient in Those Caramel Apples
BY DAN FLYNN | MARCH 20, 2015
Outbreak investigation

- 35 listeriosis illnesses
  - 34 hospitalizations (97%)
  - 7 deaths (20%)
- 12 states, Canada

How was trace back conducted?
  - Sequencing
  - Interviews
Outbreak investigation

- 35 illnesses
  - 7 to 92 years, median age of 66 years
  - 11 were pregnancy-related, 1 resulting in a fetal loss
  - 3 invasive illnesses (meningitis) were among healthy children

- 31 interviews
  - 28 consumed **commercially-produce pre-packaged caramel apples**
  - 3 reported eating sliced or whole apples
Outbreak investigation

- 3 manufacturers of caramel apples implicated
- 1 apple grower-packer determined to be source
  - *L. monocytogenes* isolated from food contact surfaces- brushes (outbreak strain)
  - Outbreak strain linked to clinical isolates by whole genome sequencing
  - Granny Smith and Gala variety apples
How did this happen?

- Never before seen vector
- Apples:
  - **Low pH** (less than 4)
  - Skin provides barrier
- Caramel:
  - High temperature for coating
  - **Low water activity** (less than 0.80)
    - Amount of water available for use by the bacteria
# pH

Minimum pH for growth of *L. monocytogenes* is ~4.3

<table>
<thead>
<tr>
<th>Food item</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crackers</td>
<td>7.0-8.5</td>
</tr>
<tr>
<td>Cantaloupe</td>
<td>6.2-7.1</td>
</tr>
<tr>
<td>Beef</td>
<td>5.1-7.0</td>
</tr>
<tr>
<td>Rice (cooked)</td>
<td>6.0-6.7</td>
</tr>
<tr>
<td>Chicken</td>
<td>6.5-7.0</td>
</tr>
<tr>
<td>Cheddar cheese</td>
<td>5.9</td>
</tr>
<tr>
<td>Lettuce</td>
<td>5.8-6.0</td>
</tr>
<tr>
<td>Bread</td>
<td>5.3-5.8</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>4.2-4.9</td>
</tr>
<tr>
<td><strong>Apples</strong></td>
<td><strong>3.3-3.9</strong></td>
</tr>
<tr>
<td>Oranges</td>
<td>3.1-4.1</td>
</tr>
</tbody>
</table>
Water activity

Minimum water activity for growth of *L. monocytogenes* is ~0.92

<table>
<thead>
<tr>
<th>Food item</th>
<th>Water activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh meat, fish</td>
<td>0.99</td>
</tr>
<tr>
<td>Raw vegetables</td>
<td>0.99</td>
</tr>
<tr>
<td>Raw fruits</td>
<td>0.98-0.99</td>
</tr>
<tr>
<td>Cooked meat, bread</td>
<td>0.91-0.98</td>
</tr>
<tr>
<td>Cheddar cheese</td>
<td>0.85</td>
</tr>
<tr>
<td>Flour, rice, beans</td>
<td>0.80-0.87</td>
</tr>
<tr>
<td><strong>Caramel</strong></td>
<td><strong>0.80</strong></td>
</tr>
<tr>
<td>Jam, marmalade</td>
<td>0.75-0.80</td>
</tr>
<tr>
<td>Peanut butter</td>
<td>0.70</td>
</tr>
<tr>
<td>Dried spices, coffee grounds</td>
<td>0.20-0.60</td>
</tr>
<tr>
<td>Chocolate</td>
<td>0.20</td>
</tr>
</tbody>
</table>
Research study

- Objective: Understand the factors contributing to risk of *L. monocytogenes* in fresh apples and caramel apples
  - Location of contamination
  - Storage temperature
  - Stick insertion
  - Does *L. monocytogenes* survive? Does it grow?
Variables

– Apple variety
– Contamination level
– Location of contamination
– Product type
– Storage temperature
– Type of stick

Gala vs. Granny Smith
High (7 log) vs. low (3 log)
Surface vs. stem end
Fresh vs. caramel apples
5°C vs. 25°C
Wood vs. plastic vs. paper
Methods

Contamination

Stick insertion

Caramel coating

Packaging and storage, 15-49 d

Drying
Results ~ *Listeria* survival on fresh apples

- At high and low contamination: both stem end and surface contaminated *L. monocytogenes* survived but did not grow on apples stored at refrigeration or room temperature
Results ~

*L. monocytogenes* grew on stem-end contaminated caramel apples

![Graph showing growth of L. monocytogenes on caramel apples over time.](image-url)
Results ~ 
*L. monocytogenes* grew on stem-end contaminated caramel apples
How does *L. monocytogenes* survive/grow on other food products?

Cantaloupe flesh

refrigeration
How does *L. monocytogenes* survive/grow on other food products?

**Queso Fresco cheese**

refrigeration

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How does *L. monocytogenes* survive/grow on other food products?

**Meat**

room temperature

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How does *L. monocytogenes* survive/grow on other food products?

Milkshakes
room temperature
Results ~

*L. monocytogenes* survival on different stick materials

![Graph showing survival of *L. monocytogenes* on different materials over time. The x-axis represents time in days (0 to 13), and the y-axis represents log CFU/stick. The graph compares survival on paper, wood, and plastic.]
Results ~

*L. monocytogenes* in caramel apples made with different stick materials- no differences
Conclusions

- *L. monocytogenes* survives and grows on stem end contaminated caramel apples regardless of level of contamination.
- Hot caramel dip is not a sufficient kill step.
- Storage of caramel apples at refrigeration reduces but does not eliminate growth.
- Type of stick does not influence outcome.
Fate of *Listeria monocytogenes* in Fresh Apples and Caramel Apples

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MS 15-442: Received 1 October 2015/Accepted 7 January 2016
Other research

- Caramel layer traps moisture next to the surface.
- Insertion of stick causes juice migration to the surface, increasing water activity.
- “Microenvironment” where *Listeria monocytogenes* is capable of growing.

*Growth of Listeria monocytogenes within a Caramel-Coated Apple Microenvironment*

Kathleen A. Glass, Max C. Golden, Brandon J. Wanless, Wendy Bedale, Charles Czuprynski
Food Research Institute, University of Wisconsin—Madison, Madison, Wisconsin, USA

Key parts of the apple (A) and the caramel-apple interface microenvironment (B).

Kathleen A. Glass et al. mBio 2015; doi:10.1128/mBio.01232-15
L. monocytogenes survival/growth in caramel apples with or without sticks

Kathleen A. Glass et al. mBio 2015; doi:10.1128/mBio.01232-15
Regulations

- Standards for the Growing, Harvesting, Packing and Holding of Produce for Human Consumption
  - “Produce Rule”

- Current Good Manufacturing Practice, Hazard Analysis, and Risk-based Preventive Controls for Human Food
  - “Preventive Controls Rule”
  - Includes fresh produce that is processed

  Caramel apples
Preventive Controls

- Sanitizer use in wash water
- Temperature/time conditions
- Chemical preservatives for caramel apples or sticks
Preventive Controls

- Sanitizer use in wash water
  - Some pathogen reduction on product surface
  - Prevents cross-contamination from contaminated to uncontaminated product
Preventive Controls

- Must maintain correct level of sanitizer in wash water

*pH levels:*
- 30 ppm
- 25 ppm
- 20 ppm
- 15 ppm
- 10 ppm
- “Low spot”
Preventive Controls

- Sanitizer effectiveness in wash water can be impacted by:
  - How much product in washing system
  - How much soil is washed into water
  - Ratio of product to water
  - Water pH
  - How much wash water is reused
  - Sanitizer feed rate
Preventive Controls

- Temperature/time conditions
  - Temperature:
    - Refrigeration vs. room temperature display of product
  - Time
    - Shelf-life of product

- Lower temperature for shorter time limits *L. monocytogenes* growth
Current research

- Chemical preservatives to inhibit *L. monocytogenes* growth in caramel apples
  - Preservatives in caramel
  - Pre-treatment of sticks with preservatives prior to insertion into apples
  - Potassium sorbate, nisin, sodium benzoate, etc.
Current research

- Potassium sorbate causes decrease in *L. monocytogenes* on wooden sticks
Current research

Effect of wooden sticks pre-treated with Potassium sorbate on *L. monocytogenes* survival in caramel apples
Conclusions

- *L. monocytogenes* survives on fresh apples
- *L. monocytogenes* grows on caramel apples regardless of storage temperature
- Preventive controls can aid in lowering the risk of illness from *L. monocytogenes*
Conclusions

- Chemical preservatives use for apples or sticks
  - Potassium sorbate
  - Future research will include additional chemicals
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