Salmonella – factoids

- **Salmonella enterica**
  - Primary source: intestinal track of humans/animals
  - Approximately 2,500 serovars
    - Enteritidis, Montevideo, Typhimurium are serovars
  - Serovars can be subtyped by many different methods
    - Phage typing
      - Salmonella Enteritidis PT 8, 13a, 4, are common
      - Salmonella Enteritidis PT 30, 9c are rare
    - Fingerprinting (PFGE)
      - Used to further distinguish serovars of Salmonella and other pathogens

Salmonellosis factoids

- Associated with many foods
  - Animal origin (meat, poultry, eggs, dairy)
  - Raw fruits and vegetables
  - Low-moisture foods

- Symptoms range:
  - None to severe (septicemia infection of blood)
  - Most common: diarrhea, fever, vomiting, dehydration, cramps

- Long-term impact: reactive arthritis

- Infective dose:
  - In some cases estimated less than 15 to 20 cells
  - Low in dried foods?
  - Depends on age and health
  - Possibly serovar, physiological state, food matrix

Outbreaks with spices

- “Veggie Bootie” seasoning (2007)

Outbreaks with nuts, seeds, legumes:

- Coconut (dried) (1999)
- Sesame seed

Outbreaks with other dry foods and ingredients:

- Chocolate (2001-02, 2006)
- Cereal (1998, 2008)
Why Apparent Increase?

- Increased National focus on food safety
- Epidemiology
  - Increased investigation, cooperation, technology
- Microbiology
  - Improved methodologies
    - Routine subtyping (serotyping/fingerprinting)
    - Digital sharing of fingerprints across the US
    - International collaboration
  - To date, most low-moisture food/ingredient outbreaks have been associated with rare serovars or unique fingerprints
    - Facilitated investigation of widespread, sporadic illnesses

Almond Outbreaks 01,04,06

- Raw almonds from California
  - 10/2000 - 7/2001
    - *Salmonella* Enteritidis Phage Type (PT) 30
    - 168 cases Canada and U.S.
    - *Salmonella* Enteritidis PT 9c
    - 47 cases in U.S. and Canada
    - Handler (processor) unrelated to 2001 outbreak
    - *Salmonella* Enteritidis Phage Type 30
    - 15 cases Sweden

Outbreak of salmonellosis (S. Enteritidis PT 30) in raw almonds

- # of Cases
- Protracted outbreak (8 months)

Outbreak of salmonellosis (S. Enteritidis PT 30) in raw almonds

- # of Cases
- Rare strain (Phage Type) of *Salmonella*

Peanut Butter 2008-2009

- *Salmonella* Typhimurium, rare fingerprint

Peanut Butter 2008-2009

- *Salmonella* Typhimurium, rare fingerprint

- 666* (691) cases in 45 (46) states and Canada (1)
  - >119 hospitalizations, 9 deaths

*Cases reported as of February 24, 2009. Cases reported in the previous 3 weeks might not yet be reported. CDC, 2009
666* (691) cases in 45 (46) states and Canada (1)
>119 hospitalizations, 9 deaths

Peanut Butter Outbreak
2008-2009
- Peanut Corporation of America
  - Passed AIB audit, state audit
  - Failed Nestle audit
- November 08 – March 09
  - 691 cases, 9 deaths
  - 46 states and Canada
- Recall of 3908 products over 2 years
  - 2007 to 2008
- Product used as an ingredient
  - Peanut paste
  - Items as diverse as pet food, ice cream and energy bars
- Raised issues related to ingredients in general

Salami 2009-2010 (9 months, 44+ states)
(Black and Red Pepper - ingredient)

Salmonella Montevideo
- Common serovar (top 10), common fingerprint
  - CDC used new statistical method to determine if
cases from PulseNet (reporting system) were above
historical normal
  - Shopper card information used to narrow foods/brands
    - Ill persons gave permission, case control study
    - More identified outbreaks in future?

E. coli O157:H7
- Nestle cookie dough outbreak
  - June 2009
  - 72 cases, 10 HUS
- January 2010 Nestle announces switch to heat-
treated flour after E. coli O157:H7 detected in 2
dough samples
  - We do not know that flour is the source for E. coli O157:H7.
  - It is however a raw agricultural commodity and raw agricultural
commodities can carry some risk. To improve our product safety
and minimize risk we’ve made a prudent decision to switch to
heat-treated flour.

Recalls – Spices
- 1970-2003
  - Vij et al., 2006. J. Food Prot. 69:233-237
    - 21 recalls
    - 20 for Salmonella
    - 1 for Listeria monocytogenes
- 2004-present
  - ?
Recalls – Nut Products

- almonds (01, 04), hazelnuts (09),
  macadamia (09), peanut butter (07, 09),
  pecans (09), pistachios (09), pine nuts (10)
  - Salmonella

- walnuts (09)
  - Listeria monocytogenes

Recalls? What’s New?

- Buyer testing programs
  - have increased sampling and sample size

- FDA directive
  - Field assignment to inspect nut facilities and to do
    environmental swabs of facilities
  - Reportable Food Registry (2009)

- Success of nut industry?
  - Record crops, increased consumption, switch to out
    of hand, raw

FDA Reportable Food Registry

- New – Fall 2009
  – Amendment to FDCA, 2007
- All foods covered by FDA except infant
  formula and dietary supplements
- Electronic portal for Industry
  http://rfr.fda.gov
  – to report when there is reasonable probability
  that an article of food will cause serious adverse health consequences

Surveys

- Few have been done
  – Typically: small sample size, multiple products
- Retail Surveys – UK
    - Salmonella in 25-g samples
      - 2 of 469 Brazil nut samples (0.4%) - Salmonella Senftenberg or Tennessee 9 or 23 per 100 g
      - 1 of 105 mixed kernels (5 nuts, 0.9%)
    - Salmonella in 1 of 727 (0.1%) roasted nuts (pistachio)
    - Willis et al., 2010. Food Microbiol. 26:847-852
    - Salmonella in 23 of 3735 “seeds” (0.6%): 13 sesame seed

Can Salmonella be isolated from Almonds?
Survey of Almonds from Huller/Sheller (100 g)

<table>
<thead>
<tr>
<th>Year</th>
<th>Number Positive</th>
<th>% Positive (%)</th>
<th>MPN/100 g</th>
<th>Number MPN &gt;1.2/100 g</th>
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<td>0.83</td>
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Average 0.99% positive samples per year

Over 100 isolates – 50 unique serovars

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Average 0.99% positive samples per year
FDA Test Data

### Isolation of *Salmonella* from Nuts

<table>
<thead>
<tr>
<th>Nut / Nut Products</th>
<th>Serovar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almond</td>
<td>Enteritidis (&gt;34, Danylik et al., 2007)</td>
</tr>
<tr>
<td>Cashew</td>
<td>Montevideo, Weltevreden</td>
</tr>
<tr>
<td>Hazelnut</td>
<td>Thompson, Typhimurium</td>
</tr>
<tr>
<td>Macadamia nut</td>
<td>pending</td>
</tr>
<tr>
<td>Peanut</td>
<td>Altona, Montevideo, Tennessee, Typhimurium, Livingstone, Newport, Senftenberg, Lexington</td>
</tr>
<tr>
<td>Pecan</td>
<td>Anaturn, Typhimurium, Hadel, Javana, Newport, Panama, Kentucky, Sandiego</td>
</tr>
<tr>
<td>Pistachio</td>
<td>Montevideo, Cuba, Senftenberg, Newport</td>
</tr>
</tbody>
</table>

*Courtesy of Dave Melka, FDA and Jenny Scott, FDA*

### Surveys

- Processors “surveys”
  - Routine testing is unpublished
  - Suppliers and buyers
- Data is likely significant
  - In volume
- Lack of method standardization
- Not typically shared or published

### Hazard Analysis - Nuts

- **Salmonella**
  - Primary pathogen of concern
  - Given: Outbreaks, recalls, surveys
- Prevalence and levels low
  - Few available studies
  - (none for non-*Salmonella*)

### Salmonella – myths and misconceptions

- *Salmonella* is only of animal/fecal origin
- *Salmonella* doesn’t survive at cold temperatures
- *Salmonella* doesn’t survive in dry foods
- *Salmonella* has a high infectious dose
- *Salmonella* is easily killed by heat (in dry foods)
- Traditional cleaning and sanitation can be applied to dry food processes.

### M/M: *Salmonella* is only of animal/fecal origin

### Routes of Contamination

*Beuchat, 1996*
Does Salmonella survive in soil?

- **Soil type**
  - Cerini clay loam (outbreak-associated orchard)
  - Milham sandy loam (distant orchard)

- **Temperature**
  - 35 ± 2 ºC
  - 20 ± 2 ºC

- **Moisture levels**
  - Field capacity
  - Saturated

Temperature is the most important factor influencing Salmonella survival.

Addition of Hull Extract to Soil

Almonds are shaken from the trees to the ground where they dry for 7 to 10 days.

Dried almonds are gathered into windrows.
Almonds are harvested from the field and may be stockpiled before hulling and shelling.

Huller/Shellers Handlers

How well does Salmonella survive on almonds?

M/M

Salmonella doesn’t survive dry conditions or in the cold

Long-term survival (months) noted in:
- Chocolate
- Halva
- Pecans (Beuchat, unpublished)
- Pistachios (Harris, unpublished)
- Black pepper
- Walnut kernels (Harris, unpublished)

1 log is a 10-fold or 90%

M/M

Salmonella has a high infectious dose

1950s estimates near 100,000/serving

Assumption - growth:
- nutrients, moisture, temperature and time
- critical factors for outbreaks
Dose Response Model

\[ \beta \text{-Poisson Dose-Response model for Salmonella spp. FAO, 2002.} \]

Examples of salmonellosis outbreaks with known low infectious doses

<table>
<thead>
<tr>
<th>Food</th>
<th>Salmonella</th>
<th>Infectious Dose (cells per serving)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheddar cheese (1976)</td>
<td>Heidelberg</td>
<td>100</td>
</tr>
<tr>
<td>Cheddar cheese (1984)</td>
<td>Typhimurium</td>
<td>1 to 10</td>
</tr>
<tr>
<td>Chocolate (1973-74)</td>
<td>Eastbourne</td>
<td>100</td>
</tr>
<tr>
<td>Chocolate (1982)</td>
<td>Napoli</td>
<td>10 to 100</td>
</tr>
<tr>
<td>Chocolate (1987)</td>
<td>Typhimurium</td>
<td>≤10</td>
</tr>
<tr>
<td>Paprika coated potato</td>
<td>Saint-paul, Javiana, chreds (1993)</td>
<td>≤45</td>
</tr>
<tr>
<td>Ice cream (1994)</td>
<td>Enteritidis</td>
<td>≤28</td>
</tr>
<tr>
<td>Almonds (2001)</td>
<td>Enteritidis PT30</td>
<td>&lt;10 to 200+</td>
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Salmonella in low-moisture foods: Survey of Almond Kernels (100 g)

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Levels less than 3 to 15.5 MPN/100 g

Salmonella is easily killed by heat

Survival of S. Enteritidis PT30 on almonds exposed to hot oil 240, 250 and 260°F

Moist heat is more effective, increased product moisture improves kill

Du, Abd, McCarthy, and Harris, in press.
Time to 4- or 5-log reduction of *Salmonella* Enteritidis PT 30 on almonds exposed to hot oil, according to the Weibull model 99% Confidence Interval

<table>
<thead>
<tr>
<th>Temperature (°C/°F)</th>
<th>Time required for reduction (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4-log 10,000 fold</td>
</tr>
<tr>
<td></td>
<td>5-log 100,000 fold pasteurized</td>
</tr>
<tr>
<td>116/240</td>
<td>114 234 2 X</td>
</tr>
<tr>
<td>121/250</td>
<td>72 132 2 X</td>
</tr>
<tr>
<td>127/260</td>
<td>39 72 2 X</td>
</tr>
</tbody>
</table>

M/M
Traditional cleaning and sanitation can be applied to dry food processing facilities.

*Salmonella* Grows in Wet Almond Dust

*Salmonella* is Unaffected by Addition of 200 ppm Aqueous QUAT to H/S Dust

Risk Assessment of salmonellosis from Consumption of Raw Almonds (Annual Illness) (@Risk Modeling Program)

Mean: 8 cases/year
78% chance of > 1 case/year
48% chance of > 10 cases/year
21% chance of > 100 cases/year
Risk Assessment of salmonellosis from Consumption of Raw Almonds (Annual Illness) (@Risk Modeling Program)

Mean: 8 cases/year
78% chance of > 1 case/year
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21% chance of > 100 cases/year

A 4 (10,000-fold) or 5 (100,000-fold) log reduction reduced chance of >1 case/year to a probability of less than 1 in 100 years. Almond Board based mandatory 4-log reduction on these data.

<table>
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<th>Log predicted illness (cases per year)</th>
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<td>-3</td>
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Summary

- Low-moisture foods including are increasingly recognized for association with *Salmonella* and salmonellosis
- Challenges: low level prevalence, long-term survival, enhanced resistance, low dose?
- Nuts
  - Large category
  - Risks may differ but generally categorized as one
- Control
  - Good Agricultural Practices, Validated Processes, post-process Good Manufacturing Practices