Listeria monocytogenes: Got a positive environmental sample; now what?

Oregon Dairy Industries 106th Annual Conference

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Scope of the Problem

- Where are we when it comes to Listeria in dairy?
- Why is Listeria problematic in dairy industry?

Environmental Monitoring for Listeria (EML)

- How to address positives?
- What does new FDA draft guidance on Listeria say?

Take home message
Where are we when it comes to *Listeria* in dairy?

Selected Multistate Outbreaks

https://www.cdc.gov/listeria/outbreaks/index.html

2017
- Vulto Creamery Soft Raw Milk Cheese - Listeriosis

2016
- Frozen Vegetables - Listeriosis
- Raw Milk - Listeriosis
- Packaged Salads - Listeriosis

2014
- Commercially Produced, Prepackaged Caramel Apples - Listeriosis
- Bean Sprouts - Listeriosis

2013
- Cheese - Listeriosis
- Dairy Products - Listeriosis

2012
- Ricotta Salata Cheese - Listeriosis

2011
- Cantaloupes - Listeriosis
2017 Listeriosis outbreak - Vulto Creamery Soft Raw Milk Cheese

➢ At a Glance:
  o Case Count: 6
  o States: 4
  o Deaths: 2
  o Hospitalizations: 6
  o Recall: Yes

➢ Epi and lab evidence indicates source to be soft raw milk cheese made by Vulto Creamery of Walton, New York

➢ Cheeses were distributed nationwide, with most being sold at retail in California, Chicago, Portland, Oregon, and Washington, D.C.

https://www.cdc.gov/listeria/outbreaks/soft-cheese-03-17/index.html
At a Glance:

- **Case Count:** 2
- **States:** 2
- **Deaths:** 1
- **Hospitalizations:** 2
- **Recall:** No

Raw milk produced by Miller's Organic Farm in Pennsylvania, was the likely source.

Two illnesses seen in 2014

Connected to raw milk on January 29, 2016 using whole genome sequencing (WGS)

- Close genetic relatedness of *L. monocytogenes* (*Lm*) in raw chocolate milk from Miller’s Organic Farm and *Lm* from patients

2015 Listeriosis outbreaks – Soft cheeses and ice cream

**At a Glance:**
- **Case Count:** 30
- **States:** 10
- **Deaths:** 3
- **Hospitalizations:** 28
- **Recall:** Yes

*Lm* from environmental samples closely related to *Lm* from ill people

**Soft Cheeses Distributed by Karoun Dairies, Inc.**

**At a Glance:**
- **Case Count:** 10
- **States:** 4
- **Deaths:** 3
- **Hospitalizations:** 10
- **Recall:** Yes

**Blue Bell Creameries Ice Cream**

Complex multistate outbreak investigation of listeriosis cases occurring from 2010 to 2014 using WGS

Linked to ice cream, frozen yogurt, sherbet and frozen snacks

Advances in technology allowed...

- Development of genotyping methods to identify diseases faster
  - e.g. Multilocus sequence typing (MLST)
  - Whole genome sequencing (WGS)

- Better tracing of contamination sources
  - e.g. WGS in outbreak investigation, contamination investigations

- Identifying new genes and their roles
  - e.g. Use of WGS, molecular manipulations (insertions/deletions) to assess function, RNAseq

- Tackling AMR, mutations and sharing of genetic material
  - e.g. Sequencing genomic content in environmental sources, foods
Why is Listeria monocytogenes (Lm) problematic in dairy?
Listeria background

➢ 17 species

- *L. monocytogenes* (*Lm*)
  - listeriosis in humans and animals

- *L. ivanovii*
  - listeriosis in animals

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**2014-2015**
- *L. fleischmannii*
- *L. newyorkensis*
- *L. acquatica*
- *L. floridensis*
- *L. cornellensis*
- *L. grandensis*
- *L. weihenstephanensis*
- *L. riparia*
- *L. booriae*

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Fig 1. Phylogeny of *Listeria* spp. Adapted from Cossart (2011; PNAS 108:19484-91).

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Lm contamination routes

Natural environment ➔ Food processing environment ➔ Ready-to-eat food ➔ Human host
Why is \( Lm \) problematic?

➢ Because of its ubiquity and hardiness...

○ If you build a food production plant, \( Lm \) will contaminate it

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*Journal of Food Protection, Vol. 73, No. 2, 2010, Pages 286–291*

**Colonization of a Newly Constructed Commercial Chicken Further Processing Plant with *Listeria monocytogenes*†**

MARK E. BERRANG,1* RICHARD J. MEINERSMANN,1 JOSEPH F. FRANK,2 AND SCOTT R. LADELY1†

Within 4 months, several subtypes of *L. monocytogenes* were detected in floor drains, both before and after cleaning and sanitizing operations. No *L. monocytogenes* was detected on filters for incoming air, samples associated with plant employees, or a nearby discount shopping center. One subtype of *L. monocytogenes* was detected in a natural stream near the plant; however, this subtype was never detected inside the plant. Eight subtypes of *L. monocytogenes* were detected in raw meat staged for further processing; one of the raw meat subtypes was indistinguishable from a persistent drain subtype recovered after cleaning on eight occasions in four different drains. Poultry further processing plants are likely to become colonized with *L. monocytogenes*; raw product is an important source of the organism to the plant.
34 dairy processing plants in Vermont sampled

<table>
<thead>
<tr>
<th>Yersinia</th>
<th>Samples</th>
<th>Listeria % positive</th>
<th>Yersinia % positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sites negative</td>
<td>314</td>
<td>87.0</td>
<td></td>
</tr>
<tr>
<td>Sites positive for</td>
<td>47</td>
<td>13.0</td>
<td></td>
</tr>
<tr>
<td>Yersinia* species</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>361</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>*Y. enterocolitica</td>
<td>38</td>
<td>10.5</td>
<td></td>
</tr>
<tr>
<td>*Other Yersinia species</td>
<td>9</td>
<td>2.5</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 2. Distribution of Yersinia and Listeria in environmental samples as a function of plant type.**

FPE* as a microbial reservoir

➢ Complex reservoir indirectly influencing finished products

➢ What are potential reservoirs?

  o Raw materials
    ▪ Recurring introduction of new microorganisms

  o Personnel
    ▪ Fecal (coliform, enterococci, pathogens)
    ▪ Nasal, skin (*Staphylococcus aureus*)
    ▪ Hair
    ▪ Ill and asymptomatic employees
      • Viruses (Norovirus, Hepatitis)

  o Water

  o Production environment
    ▪ Food contact surfaces (FCS)
    ▪ Floors, drains, utensils
    ▪ Production equipment
      • Fork lifts, hydraulic hand lifts, mats

*FPE, food processing environment.
Soft ripened cheese (SRC) caused over 130 foodborne illnesses in British Columbia (BC), Canada, during two separate listeriosis outbreaks. Multiple agencies investigated the events that lead to cheese contamination with *Listeria monocytogenes* (L.m.), an environmentally ubiquitous foodborne pathogen. In both outbreaks pasteurized milk and the pasteurization process were ruled out as sources of contamination. In outbreak A, environmental transmission of L.m. likely occurred from farm animals to personnel to culture solutions used during cheese production. In outbreak B, birds were identified as likely contaminating the dairy plant’s water supply and cheese during the curd-washing step. Issues noted during outbreak A included the risks of operating a dairy plant in a farm environment, potential for transfer of L.m. from the farm environment to the plant via shared toilet facilities, failure to clean and sanitize culture spray bottles, and cross-contamination during cheese aging. L.m. contamination in outbreak B was traced to wild swallows defecating in the plant’s open cistern water reservoir and a multibarrier failure in the water disinfection system. These outbreaks led to enhanced inspection and surveillance of cheese plants, test and release programs for all SRC manufactured in BC, improvements in plant design and prevention programs, and reduced listeriosis incidence.
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Point source contamination - 2002 listeriosis outbreak in BC, Canada

Dairy processing plant building (plant B)

Expanded view

Open roof
Ladder

Concrete cistern walls
Water level control mechanism

Metal bar

Above ground cistern (open)
Copper pipe

Filtration housing

20 μ, 5 μ iron pipe

UV disinfection

Hot water heater

Factor number 1

Factor number 2

Factor number 3

Deep water well

Pump

Cold water

Hot water

Root cause analysis of factors leading to Listeria monocytogenes outbreak

Factor 1, design failure: Listeria monocytogenes intrusion from avian source into cistern water supply

Factor 2, maintenance error: incorrect piping material leads to fouling of quartz tube (iron oxide) rendering UV disinfection ineffective

Factor 3, operational change: cheese curds are washed with lukewarm water (45°C), rather than hot water (66°C)

Figure 2: Schematic diagram of water supply system in dairy processing plant B.

Why is *Lm* problematic?

- Growth temperature: 31 to 113°C or -0.4 to 45°C

**Table 1.** Generation times for *L. monocytogenes*.¹

<table>
<thead>
<tr>
<th>Temperature (°C/°F)</th>
<th>0 to 1°C</th>
<th>4 to 5°C</th>
<th>9 to 10°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>32 to 34°F</td>
<td>39 to 41°F</td>
<td>48 to 50°F</td>
</tr>
<tr>
<td>Time (h)</td>
<td>62 - 131</td>
<td>13 - 25</td>
<td>5 - 9</td>
</tr>
</tbody>
</table>

- Heat resistant?
  - No...
  - Does not survive pasteurization
  - Depends on strain, environment, previous heat shock

Why is *Lm* problematic?

➢ What about salt resistance?
  - One of the most halotolerant foodborne pathogens\(^2,^3\)
    - Grows at 10% (w/v) NaCl
    - Survives at 40% (w/v) NaCl

➢ What about pH?
  - Will grow at 4.3 to 9.4
  - Most food adjusted between 4-5
    - Pathogen control
    - *Clostridium botulinum*

➢ Water activity required for growth\(^2\)
  - About 0.92

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Listeriosis disease

Healthy adults:
• mild gastroenteritis
NON-INVASIVE

Crossing of the intestinal barrier

Listeria

Intestinal barrier
Gastroenteritis

Multiplication in the liver

Invasion of the brain

Brain
Blood-brain barrier
Meningitis, Encephalitis

Placenta
Placental barrier
Fetal Infections

Colonization of uterus and fetus

Fig 2. *Listeria* infectious process and dissemination in human body. Adapted from Lecuit, 2007.
Listeriosis disease

**Fig 2.** *Listeria* infectious process and dissemination in human body. Adapted from Lecuit, 2007.

- **Intestinal barrier**
  - Gastroenteritis

- **Contaminated food**
  - Intestine

- **Blood**
  - Invasion of the brain
  - Brain: Blood-brain barrier
    - Meningitis, Encephalitis

- **Lymph node**
- **Spleen**

- **Placenta**
  - Placental barrier
    - Fetal Infections

- **Immunocompromised adults:**
  - mild gastroenteritis followed by septicemia, meningitis, endocarditis

**INVASIVE**
Listeriosis disease

Fig 2. *Listeria* infectious process and dissemination in human body. Adapted from Lecuit, 2007.

Colonization of uterus and fetus

Pregnant women:
- mild gastroenteritis, flu-like but fatal or severe complications for fetus

INVASIVE
Listeriosis disease

Pregnant women:
• mild gastroenteritis, flu-like but fatal or severe complications for fetus

Immunocompromised adults:
• mild gastroenteritis followed by septicemia, meningitis, endocarditis

INVASIVE listeriosis fatality rate
20 to 40%

Fig 2. Listeria infectious process and dissemination in human body. Adapted from Lecuit, 2007.
Fig 3. Schematic representation of *L. monocytogenes* stress-response mechanisms (Hill et al., 2002).
How does \textit{Lm} end up in food?

- **Environmental contamination**
  - Post-processing contamination
    - Slicers
    - Conveyor belts
    - Non-food contact surfaces (non-FCS)
      - Drains, chillers, condensate, aerosols
  - Persistence of strains
    - Biofilms

- **Employee hygiene**

- **Raw materials**
  - Cross-contamination
  - Materials from unsafe sources/suppliers
    - e.g. pasteurized milk vs. raw milk cheese

(A) And (B) from Farber, 2010. BCFPA presentation.
You decide to implement EML in your plant...

(To verify preventive controls)
Goals

- Verify effectiveness of control programs for *Lm*
- Find *Lm* and niches/harborage sites
- Effective elimination of *Lm* through appropriate corrective actions

Design

Corrective actions

- Food contact surfaces (FCS)
- Non-food contact surfaces (non-FCS)

Analysis of data for trends

EML program

**Zone Concept**

**ZONE 1**
Direct & Indirect Food Contact Surfaces (FCS)

**ZONE 2**
Surfaces adjacent to Zone 1.
- Exterior of FCS equipment
- Sides of weight scales
- Lubricant points etc.

**ZONE 3**
Surfaces adjacent to Zone 2; in RTE areas.
- Floors, walls
- Refrigeration units
- Drains
- Floor mats
- Forklifts, traffic pathways
- Piping, etc.

**ZONE 4**
Conveyors, slicers, dicers, shredders, overhead pipes, cutting boards and tables, aprons and gloves, etc.

Outside RTE food processing areas.
- Offices, locker rooms, cafeteria, hallways, waste area, maintenance shops, warehouses, corridors of production areas.


FDA, Subchapter 4.3. Collection Technique.
Designed to give you an early warning if *Listeria* spp. are present in the environment

**Non-FCS**

- **Zone 2:** Items above exposed product, equipment legs, framework, tank lids, control panels, conveyor parts, HVAC vents, floor mats at packaging

- **Zone 3:** RTE processing room floors, walls, surfaces, cleaning tools, floor scrubbers, forklifts, floor drains, ceiling drainpipes, wash stations, ingredients storage areas, transition rooms

**Scenario 1:** *Listeria* spp. on a non-FCS

**Scenario 2:** *Lm* on a non-FCS

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FDA (2017) recommends minimum 5 FCS & 5 NFCS on each line!
Scenario 1: Routine EML non-FCS sample

1\textsuperscript{st} positive
- Clean & sanitize +ve site
- Retest site & surrounding area during next production cycle

All negative
- Continue production & routine monitoring

2\textsuperscript{nd} positive

Foods support $Lm$ growth
1. Intensified cleaning and sanitizing; equipment disassembly
2. Intensified sampling and testing

Foods do NOT support $Lm$ growth
1. Intensified cleaning and sanitizing
2. Intensified sampling and testing

All negative
- Continue production & routine monitoring

3\textsuperscript{rd} positive
1. Root cause analysis
2. Escalate mitigation strategies
3. Expert consultation
FDA recommended corrective actions – *Listeria* spp.

<table>
<thead>
<tr>
<th>Non-FCS &amp; With growth</th>
<th>Non-FCS &amp; No growth</th>
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Routine sampling positive #1
- Clean & sanitize positive site
- Retest during next production cycle

Follow-up sampling positive #2

Follow-up sampling positive #3
FDA recommended corrective actions – *Listeria* spp.

<table>
<thead>
<tr>
<th>Non-FCS &amp; With growth</th>
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<tbody>
<tr>
<td><strong>Routine sampling positive #1</strong></td>
<td><strong>Follow-up sampling positive #2</strong></td>
</tr>
<tr>
<td>• Clean &amp; sanitize positive site</td>
<td>• Intensified cleaning &amp; sanitizing; equipment disassembly</td>
</tr>
<tr>
<td>• Retest during next production cycle</td>
<td>• Intensified sampling &amp; testing</td>
</tr>
<tr>
<td><strong>Follow-up sampling positive #3</strong></td>
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</table>
FDA recommended corrective actions – *Listeria* spp.

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<tr>
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</table>
| **Routine sampling positive #1** | • Clean & sanitize positive site  
• Retest during next production cycle |
| **Follow-up sampling positive #2** | • Intensified cleaning & sanitizing; equipment disassembly  
• Intensified sampling & testing |
| **Follow-up sampling positive #3** | • Root cause analysis |
FDA recommended corrective actions – *Listeria* spp.

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</tr>
<tr>
<td>• Retest during next production cycle</td>
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</tr>
<tr>
<td>Follow-up sampling positive #2</td>
<td></td>
</tr>
<tr>
<td>• Intensified cleaning &amp; sanitizing; equipment disassembly</td>
<td></td>
</tr>
<tr>
<td>• Intensified sampling &amp; testing</td>
<td></td>
</tr>
<tr>
<td>Follow-up sampling positive #3</td>
<td></td>
</tr>
<tr>
<td>• Root cause analysis</td>
<td></td>
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</tbody>
</table>
FDA recommended corrective actions – *Listeria* spp.

<table>
<thead>
<tr>
<th></th>
<th>Non-FCS &amp; With growth</th>
<th>Non-FCS &amp; No growth</th>
</tr>
</thead>
</table>
| **Routine sampling positive #1** | Clean & sanitize positive site  
Retest during next production cycle | Clean & sanitize positive site  
Retest during next production cycle |
| **Follow-up sampling positive #2** | Intensified cleaning & sanitizing; equipment disassembly  
Intensified sampling & testing | Intensified cleaning & sanitizing  
Intensified sampling & testing |
| **Follow-up sampling positive #3** | Root cause analysis |                      |
FDA recommended corrective actions – *Listeria* spp.

<table>
<thead>
<tr>
<th><strong>Non-FCS &amp; With growth</strong></th>
<th><strong>Non-FCS &amp; No growth</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Routine sampling positive #1</strong></td>
<td></td>
</tr>
<tr>
<td>• Clean &amp; sanitize positive site</td>
<td></td>
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<tr>
<td>• Retest during next production cycle</td>
<td></td>
</tr>
<tr>
<td><strong>Follow-up sampling positive #2</strong></td>
<td></td>
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<tr>
<td>• Intensified cleaning &amp; sanitizing; equipment disassembly</td>
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<tr>
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<td><strong>Follow-up sampling positive #3</strong></td>
<td></td>
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<td>• Root cause analysis</td>
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<tr>
<td>• Root cause analysis</td>
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</tr>
</tbody>
</table>
Scenario 2 – *Lm* on non-FCS

FDA (2017) recommends:

“...there is minimal value in determining whether *Listeria* spp. detected on non-FCS is *Lm.*” [pg. 43]

You should eliminate *Listeria* spp. regardless of whether it is *Lm*!
What if FCS are positive?

Or

RTE food?

Scenario 3: *Listeria* spp. on a FCS

Scenario 4: *Lm* on a FCS

Scenario 5: *Listeria* spp. in food
FDA recommended corrective actions – *Listeria* spp.

<table>
<thead>
<tr>
<th>FCS &amp; With growth</th>
<th>FCS &amp; No growth</th>
</tr>
</thead>
</table>
| Routine sampling positive #1 | • Clean & sanitize positive site  
• Retest during next production cycle  
• Conduct comprehensive investigation |

Follow-up sampling positive #2
FDA recommended corrective actions – *Listeria* spp.

<table>
<thead>
<tr>
<th>Routine sampling positive #1</th>
<th>FCS &amp; With growth</th>
<th>FCS &amp; No growth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clean &amp; sanitize positive site</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Retest during next production cycle</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Conduct comprehensive investigation</td>
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</tbody>
</table>

Follow-up sampling positive #2

- Intensified cleaning & sanitizing; equipment disassembly
- Intensified sampling & testing
- Hold & test product
- Reprocess, divert or destroy product on hold if there is positive product
- Comprehensive investigation
FDA recommended corrective actions – *Listeria* spp.

<table>
<thead>
<tr>
<th>Follow-up sampling positive #3</th>
<th>FCS &amp; With growth</th>
<th>FCS &amp; No growth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Stop production and consult experts for comprehensive investigation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Intensified cleaning &amp; sanitizing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Intensified sampling &amp; testing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Resume production with product hold &amp; test until 3 consecutive days of product and FCSs are negative</td>
<td></td>
</tr>
</tbody>
</table>

Follow-up sampling positive #4
FDA recommended corrective actions – *Listeria* spp.

<table>
<thead>
<tr>
<th>Routine sampling positive #1</th>
<th>FCS &amp; With growth</th>
<th>FCS &amp; No growth</th>
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</thead>
<tbody>
<tr>
<td>• Clean &amp; sanitize positive site</td>
<td>• Clean &amp; sanitize positive site</td>
<td></td>
</tr>
<tr>
<td>• Retest during next production cycle</td>
<td>• Retest during next production cycle</td>
<td></td>
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<tr>
<td>• Conduct comprehensive investigation</td>
<td>• Conduct comprehensive investigation</td>
<td></td>
</tr>
</tbody>
</table>

Follow-up sampling positive #2

| Intensified cleaning & sanitizing; equipment disassembly |  |  |
| Intensified sampling & testing |  |  |
| Hold & test product |  |  |
| Reprocess, divert or destroy product on hold if there is positive product |  |  |
| Comprehensive investigation |  |  |
FDA recommended corrective actions – *Listeria* spp.

<table>
<thead>
<tr>
<th></th>
<th>FCS &amp; With growth</th>
<th>FCS &amp; No growth</th>
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<tbody>
<tr>
<td>Routine sampling</td>
<td>• Clean &amp; sanitize positive site</td>
<td>• Clean &amp; sanitize positive site</td>
</tr>
<tr>
<td>positive #1</td>
<td>• Retest during next production cycle</td>
<td>• Retest during next production cycle</td>
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<tr>
<td></td>
<td>• Conduct comprehensive investigation</td>
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</tr>
<tr>
<td>Follow-up sampling</td>
<td>• Intensified cleaning &amp; sanitizing; equipment disassembly</td>
<td>• Intensified cleaning &amp; sanitizing; equipment disassembly</td>
</tr>
<tr>
<td>positive #2</td>
<td>• Intensified sampling &amp; testing</td>
<td>• Intensified sampling &amp; testing</td>
</tr>
<tr>
<td></td>
<td>• Hold &amp; test product</td>
<td>• Consider hold and test food</td>
</tr>
<tr>
<td></td>
<td>• Reprocess, divert or destroy product on hold if there is positive product</td>
<td>• Comprehensive investigation</td>
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</table>
## FDA recommended corrective actions – *Listeria* spp.

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<tr>
<th></th>
<th>FCS &amp; With growth</th>
<th>FCS &amp; No growth</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Follow-up sampling</strong></td>
<td>• Stop production and consult experts for comprehensive investigation</td>
<td>• Intensified cleaning &amp; sanitizing; equipment disassembly</td>
</tr>
<tr>
<td>positive #3</td>
<td>• Intensified cleaning &amp; sanitizing</td>
<td>• Intensified sampling &amp; testing</td>
</tr>
<tr>
<td></td>
<td>• Intensified sampling &amp; testing</td>
<td>• Expand comprehensive investigation</td>
</tr>
<tr>
<td></td>
<td>• Resume production with product hold &amp; test until 3 consecutive days of product and FCSs are negative</td>
<td>• Hold &amp; test product</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reprocess, divert or destroy positive product lots</td>
</tr>
</tbody>
</table>

**Follow-up sampling positive #4**
## FDA recommended corrective actions – *Listeria* spp.

<table>
<thead>
<tr>
<th>Follow-up sampling positive #3</th>
<th>FCS &amp; With growth</th>
<th>FCS &amp; No growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Stop production and consult experts for comprehensive investigation</td>
<td>• Intensified cleaning &amp; sanitizing; equipment disassembly</td>
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<tr>
<td>• Intensified cleaning &amp; sanitizing</td>
<td>• Intensified sampling &amp; testing</td>
<td></td>
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<td>• Expand comprehensive investigation</td>
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</tr>
</tbody>
</table>

| Follow-up sampling positive #4 | |
|-------------------------------| • Stop production & consult experts for comprehensive investigation |
What if FCS are positive?

Or

RTE food?

Scenario 3: 
*Listeria* spp. on a FCS

Scenario 4: 
*Lm* on a FCS

Scenario 5: 
*Listeria* spp. in food
FDA Draft Guidance recommends

- Reprocess food with a validated listericidal control measure; divert or destroy *Lm* positive lot(s)
- Determine whether other lot(s) are potentially contaminated & segregate and hold these lots
- Review environmental monitoring results
- Intensify sampling and testing of FCSs and non-FCSs
- Follow corrective actions for any positives
- Determine whether food in commerce would be subject to recall

EML Program – Other important factors to consider

- Management commitment
- Risk consideration
  - Likelihood of occurrence [in your product]
  - Severity of consequences if contaminated product consumed [healthy vs. immune-compromised consumer]
  - Special circumstances
    - Complexity of production process
    - Likelihood of harborage sites and equipment design
    - Product made for high-risk groups [hospitals, daycares etc.]
  - Probability of RTE contamination
    - Proximity of microbial harborage sites to RTE product
    - Number of harborage sites
    - Spatial relationship of harborage sites to product stream
    - Microbial populations in harborage sites
    - Extent of harborage site disruption
    - Exposure of product stream to the environment

EML Program – Important considerations

➢ Routine monitoring
  o Detecting niches, harborage sites and potential transfer points
  o Typically zones 1, 2, 3

➢ Investigative monitoring
  o Follow-up to a positive result, complaint, illness
  o Identifying the root cause
  o Eliminate the condition
Understand if *Lm* is transient vs. persistent

Table 2. Examples demonstrating that certain strains of *L. monocytogenes* can become established and persist in the food-processing environment. From Tompkin, 2002. J Food Prot. 65:709-725.

<table>
<thead>
<tr>
<th>Type of food produced at plant</th>
<th>Time of persistence</th>
<th>Country</th>
<th>Implicated in illness?</th>
<th>Serotype(s)</th>
<th>Reference(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheese</td>
<td>4 years</td>
<td>Switzerland</td>
<td>Yes</td>
<td>4b</td>
<td>5</td>
</tr>
<tr>
<td>Cheese, blue veined</td>
<td>7 years</td>
<td>Sweden</td>
<td>No</td>
<td>3b</td>
<td>94</td>
</tr>
<tr>
<td>Cheese, goat</td>
<td>11 months</td>
<td>United Kingdom</td>
<td>Yes</td>
<td>4b</td>
<td>3, 63</td>
</tr>
<tr>
<td>Fish, smoked</td>
<td>Months</td>
<td>Switzerland</td>
<td>No</td>
<td>Several</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>14 months</td>
<td>Finland</td>
<td>No</td>
<td>1/2a (86%), 4b (14%)</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Months</td>
<td>United States</td>
<td>No</td>
<td>ND</td>
<td>70</td>
</tr>
<tr>
<td>Frankfurters</td>
<td>4 months</td>
<td>United States</td>
<td>Yes</td>
<td>1/2a</td>
<td>16, 95</td>
</tr>
<tr>
<td>Frankfurters (outbreak strain was not isolated from the plant)</td>
<td>Months</td>
<td>United States</td>
<td>Yes</td>
<td>4b</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Finland</td>
<td>No</td>
<td>1/2</td>
<td>66</td>
</tr>
<tr>
<td>Ice cream</td>
<td>7 years</td>
<td>United States</td>
<td>Yes</td>
<td>4b</td>
<td>17</td>
</tr>
<tr>
<td>Meat, sliced lunch</td>
<td>4 years</td>
<td>Norway</td>
<td>No</td>
<td>ND</td>
<td>69</td>
</tr>
<tr>
<td>Mussels, smoked</td>
<td>3 years</td>
<td>New Zealand</td>
<td>Yes</td>
<td>1/2</td>
<td>7</td>
</tr>
<tr>
<td>Pâté (product from one plant was the source of an outbreak from 1987 to mid-1989)</td>
<td>2 years</td>
<td>United Kingdom</td>
<td>Yes</td>
<td>4b(x), 4b</td>
<td>64, 72</td>
</tr>
<tr>
<td>Pork tongue in aspic (outbreak strain recovered from the implicated plant)</td>
<td>Months</td>
<td>France</td>
<td>Yes</td>
<td>4b</td>
<td>50, 86</td>
</tr>
<tr>
<td>Poultry, cooked</td>
<td>1 year</td>
<td>Ireland</td>
<td>No</td>
<td>1/2</td>
<td>57</td>
</tr>
<tr>
<td>Poultry, cooked deli products (outbreak strain matched a strain previously isolated from the same plant (95))</td>
<td>12 years</td>
<td>United States</td>
<td>Yes</td>
<td>4b</td>
<td>89</td>
</tr>
<tr>
<td>Salmon, cold smoked</td>
<td>4 years</td>
<td>Denmark</td>
<td>No</td>
<td>ND</td>
<td>31</td>
</tr>
<tr>
<td>Salmon, smoked</td>
<td>8 months</td>
<td>Norway</td>
<td>No</td>
<td>ND</td>
<td>82</td>
</tr>
<tr>
<td>Seafood, smoked salmon</td>
<td>Months–2 years</td>
<td>Norway</td>
<td>Possibly</td>
<td>4, 1</td>
<td>81</td>
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<tr>
<td>Shrimp, raw shelled frozen</td>
<td>NS</td>
<td>Brazil</td>
<td>No</td>
<td>1, 4b</td>
<td>25</td>
</tr>
<tr>
<td>Trout/salmon, gravad</td>
<td>1 month</td>
<td>Sweden</td>
<td>No</td>
<td>4b</td>
<td>60</td>
</tr>
<tr>
<td>Trout, gravad and cold smoked</td>
<td>11 months</td>
<td>Sweden</td>
<td>Yes (gravad)</td>
<td>4b</td>
<td>28</td>
</tr>
<tr>
<td>Trout, smoked/salmon, gravad</td>
<td>&gt;4 years</td>
<td>Sweden</td>
<td>Possibly</td>
<td>1/2a</td>
<td>59</td>
</tr>
<tr>
<td>Trout, cold smoked</td>
<td>NS</td>
<td>Finland</td>
<td>No</td>
<td>1/2</td>
<td>2</td>
</tr>
</tbody>
</table>
Take home messages

➢ Prevent harborage sites

➢ Address each positive sample promptly and effectively
  - Verify whether problem is corrected

➢ Perform short term assessments
  - Daily and weekly

➢ Perform trend analysis

➢ Be diligent
  - SEEK and DESTROY

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Got a positive environmental sample?

Your environmental monitoring program is working!

Now what?

Put your investigator hat on, find the source and get rid of it!
Good Resources on EML


NEW Food Safety Program & Research Lab at the Food Innovation Center

- Contamination troubleshooting
- Sanitizer efficacy & resistance
- Molecular typing
- Whole genome sequencing
- Workshops on EML; FSMA

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