Quantitative risk assessment of *Listeria monocytogenes* in milk and milk products

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Pasteurized milk


Hazard assessment of *Listeria monocytogenes* in processing of bovine milk.

Peeler & Bunning (1994)

Aim

- Product aspect of exposure assessment
- *L. monocytogenes* in pasteurized milk placed onto the market
Peeler & Bunning (1994)

- Milking
- Pipeline transport
- Bulktank storage
- Bulktank transport
- Silo storage
- Pasteurization
- Packaging
Peeler & Bunning (1994)

« The calculations were performed using conservative estimates of each variable. »
- 95<sup>th</sup> percentiles, except one median

« The calculated results, based on the above assumptions, showed that even under a system breakdown, low levels of *L. monocytogenes* would occur infrequently. »

« Probability is <2 in 100 that one *Listeria* cell would occur in 5.9 x 10<sup>10</sup> gallons »
- 4.5 x 10<sup>-15</sup> cell/ml


Response

Cassin et al. (1996)

Three sources of errors

- Estimation of the 95\textsuperscript{th} percentile of random variables as values which were 2 standard deviations from the mean
- Compounding conservatism \textsuperscript{1}
- Compounding scenario exclusion \textsuperscript{2}

1. « prudence excessive »
2. « exclusion des cas les plus graves »
Cassin et al. (1996)

<table>
<thead>
<tr>
<th>Concentration/ml</th>
<th>Peeler &amp; Bunning estimate of risk</th>
<th>Monte Carlo (Cassin et al.) estimate of risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>$4.5 \times 10^{-15}$</td>
<td>0.016</td>
<td>0.447</td>
</tr>
<tr>
<td>$2.8 \times 10^{-8}$</td>
<td>$1.6 \times 10^{-8}$</td>
<td>$8.3 \times 10^{-5}$</td>
</tr>
</tbody>
</table>
Raw milk soft cheese


Quantitative risk assessment of *Listeria monocytogenes* in soft cheeses made from raw milk.

*Preventive Veterinary Medicine* 37 129-145.
Aim

- Assessment of the risk of listeriosis from consumption of Camembert type cheeses made from raw milk in France in 1990 - 1992
- According to the Codex Alimentarius framework (1995)
Instantaneous prevalence of milk contamination

Milk production
- Herd size
- Milk-contamination status
- Presence of cow with *L. monocytogenes* mastitis
- Concentration in bulk-tank milk, environmental origin
- Concentration in milk, intramammary source

Storage before collection
- Storage temperature before collection
- Storage time before collection
- *Increase in concentration before transport*
- *Concentration in milk before collection*

Transport
- Temperature during transport
- Collection time
- *Increase in concentration during transport*

Storage in manufacture
- Storage temperature
- Storage time in manufacture
- *Increase in concentration in manufacture*

Concentration in the tanker truck before transport

Fraction of farms with *L. monocytogenes* mastitis

Final concentration in milk before cheese processing

Number of *L. monocytogenes* in one vat of 1000 l

Number of *L. monocytogenes* in 2.2 l of milk

Number of *L. monocytogenes* in 250 g of cheese

Concentration in the tanker truck before transport

Final concentration in milk before cheese processing

Average consumption of soft cheese

Size of a typical serving

Number of servings consumed

Proportion of virulent strains

Probability of illness from a single exposure

High-risk subpopulation

Low-risk subpopulation

Individual Annual Cumulative Risk
Instantaneous prevalence of milk contamination: Fraction of farms with L. monocytogenes mastitis

Milk production
Herd size
Milk-contamination status
Presence of cow with L. monocytogenes mastitis
Concentration in bulk-tank milk, environmental origin
Concentration in milk, intramammry source
Storage before collection
Storage temperature before collection
Storage time before collection
Increase in concentration before transport
Concentration in milk before collection
Transport temperature during transport
Collection time
Increase in concentration during transport
Storage in manufacture
Storage temperature
Storage time in manufacture
Increase in concentration in manufacture
Cheese processing
Number of L. monocytogenes in one vat of 1000 l
Number of L. monocytogenes in 2.2 l of milk
Number of L. monocytogenes in 250 g of cheese
Number of L. monocytogenes in a typical serving of 31 g

Probability of illness from a single exposure
high-risk subpopulation
low-risk subpopulation

Consumption
Average consumption of soft cheese
Size of a typical serving
Number of servings consumed
Proportion of virulent strains

Individual Annual Cumulative Risk
Final concentration in milk before cheese processing

Log_{10}(dose) vs. Probability

WG (PR) and WG (PN) curves
Risk of illness associated with the consumption of one serving of cheese by people in high-risk (a) and typical healthy (b) populations.
### Bemrah et al. (1998)

<table>
<thead>
<tr>
<th>Number of servings/capita.year</th>
<th>Mean</th>
<th>99 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>57 (0.5)</td>
<td>74 (3)</td>
</tr>
<tr>
<td>50 (no mastitis)</td>
<td>11 (0.1)</td>
<td>20 (1)</td>
</tr>
<tr>
<td>Triangular(10,20,50)</td>
<td>31 (0.2)</td>
<td>44 (2)</td>
</tr>
<tr>
<td>20</td>
<td>23 (0.2)</td>
<td>33 (2)</td>
</tr>
</tbody>
</table>
Ready-to-eat foods


- FAO: Rome, WHO: Geneva
Three questions:

- Estimate the risk for consumers in different susceptible population groups relative to the general population.
- Estimate the risk from *L. monocytogenes* in foods that support growth and foods that do not support growth under specific storage and shelf-life conditions.
- Estimate the risk from *L. monocytogenes* in food when the number of organisms ranges from absence in 25 grams to 1000 colony forming units (CFU) per gram, or does not exceed specified levels at the point of consumption.
### Present situation

<table>
<thead>
<tr>
<th>Maximum number of <em>L. monocytogenes</em> cells per serving at consumption</th>
<th>Predicted number of cases/number of years, USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present situation</td>
<td>&lt;100<em>Lm</em>/g + analytical tolerance</td>
</tr>
<tr>
<td>31 600</td>
<td>2130 / 1</td>
</tr>
<tr>
<td>3 160</td>
<td>25 / 1</td>
</tr>
<tr>
<td>316</td>
<td>5 / 1</td>
</tr>
<tr>
<td>32</td>
<td>1 / 1</td>
</tr>
<tr>
<td>3</td>
<td>1 / 5</td>
</tr>
<tr>
<td>0.3</td>
<td>1 / 17</td>
</tr>
<tr>
<td>0.03</td>
<td>1 / 50</td>
</tr>
<tr>
<td>1 / 100</td>
<td></td>
</tr>
</tbody>
</table>
Relative risk ranking


Quantitative assessment of relative risk to public health from foodborne *Listeria monocytogenes* among selected categories of ready-to-eat foods.

- FDA - Center for food safety and applied nutrition, USDA - Food safety and inspection service, Center for disease control and prevention.
Relative risk ranking (USA)

- Overall burden of listeriosis (severe illness) on public health
- Use as a tool
  - to evaluate the effectiveness of current policies and programs
  - to guide in reducing *L. monocytogenes* contamination of foods
  - to identify specific areas on which to focus future initiatives
Relative risk ranking (USA)

<table>
<thead>
<tr>
<th>Relative Risk Ranking</th>
<th>Per Serving Basis</th>
<th>Cases (median)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>High Risk, Unpasteurized Milk</td>
<td>7.1x10⁻⁹</td>
</tr>
<tr>
<td>7</td>
<td>Moderate Risk, Other Dairy Products</td>
<td>2.7x10⁻⁸</td>
</tr>
<tr>
<td>8</td>
<td>Low Risk, Soft Unripened Cheese</td>
<td>1.8x10⁻⁹</td>
</tr>
<tr>
<td>9</td>
<td>Low Risk, Pasteurized Milk</td>
<td>1.0x10⁻⁹</td>
</tr>
<tr>
<td>10</td>
<td>Low Risk, Fresh Soft Cheese</td>
<td>1.7x10⁻¹⁰</td>
</tr>
<tr>
<td>16</td>
<td>Low Risk, Semi – soft Cheese</td>
<td>6.5x10⁻¹²</td>
</tr>
<tr>
<td>17</td>
<td>Low Risk, Soft Ripened Cheese</td>
<td>5.1x10⁻¹²</td>
</tr>
<tr>
<td>22</td>
<td>Low Risk, Cultured Milk Products</td>
<td>3.2x10⁻¹⁴</td>
</tr>
<tr>
<td>23</td>
<td>Low Risk, Hard Cheese</td>
<td>4.5x10⁻¹⁵</td>
</tr>
</tbody>
</table>
# Relative risk ranking (USA)

<table>
<thead>
<tr>
<th>Relative Risk Ranking</th>
<th>Per Annum Basis</th>
<th>Cases (median)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>High Risk</td>
<td>Pasteurized Milk</td>
</tr>
<tr>
<td>3</td>
<td>Moderate Risk</td>
<td>Other Dairy Products</td>
</tr>
<tr>
<td>5</td>
<td>Soft Unripened Cheese</td>
<td>7.7</td>
</tr>
<tr>
<td>7</td>
<td>Unpasteurized Milk</td>
<td>3.1</td>
</tr>
<tr>
<td>14</td>
<td>Low Risk</td>
<td>Fresh Soft Cheese</td>
</tr>
<tr>
<td>15</td>
<td>Semi – soft Cheese</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>16</td>
<td>Soft Ripened Cheese</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>22</td>
<td>Cultured Milk Products</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>23</td>
<td>Hard Cheese</td>
<td>&lt;0.1</td>
</tr>
</tbody>
</table>
Pasteurized Milk (USA)

Contamination frequency at retail for this category is low (average of 0.4%) due to pathogen inactivation during pasteurization. However, this is offset somewhat by the large serving sizes associated with this product and high potential for growth of *Listeria monocytogenes* in the product during storage. The median amount consumed per serving is 244 g which is substantially larger than the serving sizes of most other foods considered in this risk assessment. The frequency of serving (8.7x10^{10}) is also the highest among the food categories."
High moisture (>50%), ripened cheeses such as mold surface-ripened cheeses (Brie, Camembert), pickled (white brined) cheeses, feta, and soft Italian-style cheeses (mozzarella).

Median size of serving is 28 g, annual number of servings is $1.9 \times 10^9$.

50% of the Camembert and Brie Cheese and 20% of the feta cheese sold in the United States are imported.

Data not available on the proportion of United States or imported cheese that is made from unpasteurized fluid milk.
Figure V-12b. Rankings of Total Predicted Listeriosis Cases per Annum for Soft Ripened Cheese
Raw milk hard cheese


Quantification of the probability of milk contamination by *Listeria monocytogenes* during manufacture of hard cheese

- Rev. Epidemiol. Santé Publique **51** 493 - 503
Proba. of milk being contaminated: 0.07
- Resulting *Listeria monocytogenes* concentration in green cheese: 4.6 cfu/kg

Discussion:
- not found in ripened cheese at the time of consumption;
- due to recontamination during packaging, distribution or preparation by the consumer, expert evaluation: 1 to 10 cells/portion

« Extremely low but existent risk, especially for people with deficient or diminished immune system »
Raw milk soft cheese


Risk assessment of listeriosis linked to the consumption of two soft cheeses made from raw milk: Camembert of Normandy and Brie of Meaux.

Risk Analysis (April 2004).

- Data purposely collected in 2000 – 2001
- Modeling of growth accounting for temperature – pH interaction
- Lag – time based on *in vivo* and *in vitro* studies
- Growth in colonies (no spread of daughter cells)
In the 12% of servings that are *Lm* positive

- Lm conc. in selected raw milk divided by $10^4$ since 1992
- Assuming no contamination during ripening, transport, distribution and consumption stages
  - No L. monocytogenes in 88% of servings
  - Estimated median number of cases of listeriosis per year $\approx 10^{-3}$
Future

Skill is available to estimate risks
- Of listeriosis from any milk products
- Of other microbial diseases communicable by milk and milk products
- USA, France, Switzerland

Example of software
- AnaRisk (CNIEL, Paris:France)