Raw Milk: Political Football or Food Safety Issue?

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Global Milk Production

Milk output in 2005 shown as a percentage of the top producer (India – 91,940,000 tonnes)
How Many People Drink Raw Milk?

• Large knowledge gap

• US: 42% of dairy farmers consume raw milk (Jayarao et al., 2006)

• EU: Widespread esp cheese sector
Milk Sources
Raw Milk Products
Pre-Industrial Revolution

Farm Based Economy
Local Distribution

- No temp control
- Short distribution chain
- Industrialization
  Rural to urban centers
  Migration
- No change in milk supply chain
New York Slums

- Slums
- Crowding
- Contaminated water
- Basic sewage facilities
Distillery (Swill) Dairies 1812-1930

- Original factory farm
- Cattle housed in basement, fed spent grains
- Poor sanitation
- Poor worker and animal health
- Profit driven
- Adulteration common
- New York: 18,000 cows, 5 million gallons
Infant Mortality

• NY 1850: 1 in 2 children dead by 5yrs old

• Typhoid
• Tuberculosis
• Scarlet fever
• Cholera
• Undulant fever
• Infant diarrhea
Infant Deaths 1900

Typhoid classed under other
Certified Raw Milk

- Dr Henry Colt
- Lost child to raw milk
- Certified production
- Sanitation
- Herd Health
- Transportation

- 6 times the cost of conventional
Milk Depot

- Nathan Straus
- Lost child to raw milk
- Low cost pasteurized milk
Industrial Revolution

- Infant mortality
- Industrial growth

% rate of growth of industrial production

Infant mortality per 1000 live births

1810 1830 1850 1870 1890 1910
Water Chlorination

Filtration becomes available

Chlorination first used in some cities
Milk Related Deaths

- NYC announces its intent to require milk pasteurization
- Milk supply is pasteurized in the majority of cities
Mandatory Pasteurization

• 1944

• Conspiracy: Industry increase profits, increased shelf-life, remove cream (fat) for high value products

• Reality: Decrease in infant mortality was due to a combination of factors, milk pasteurization being one of them
## Milk Pasteurization

<table>
<thead>
<tr>
<th>Process</th>
<th>Time/Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Temp Short Time (HTST)</td>
<td>71.7°C 15-20s</td>
</tr>
<tr>
<td>Ultra High Temperature</td>
<td>135°C 1s</td>
</tr>
<tr>
<td>LTLT</td>
<td>63°C for 30mins</td>
</tr>
<tr>
<td>Extended Shelf Life Milk (filtration)</td>
<td>73.5°C for 20s</td>
</tr>
</tbody>
</table>

**Shelf-life**

- ESL 21 days <8°C
- HTST 6 -12 days <8°C
Casein Micelle
Casein micelle contains hydrophobic $\alpha_{S1}$-, $\alpha_{S2}$-, $\beta$- and $\gamma$-casein

Unfolded denatured whey proteins

Hydrophilic CMP

Covalent bonding of unfolded whey proteins and para-$\kappa$-casein

$\kappa$-casein enriched surface submicelle

Covalently bonded denatured whey protein

Hydrodynamic radius of 7 nm

100 nm

Heating $> 80^\circ$C

$\beta$-LG

$\alpha$-LA

IgG

BSA
Figure 6. Coagulation of casein micelles by chymosin and cleavage of CMP. CMP = caseinomacropeptide.
Milk Processing

Raw Side
- Hauling
- Receiving
- Storage

Processing
- Clarification
- Separation
- Standardization
- Pasteurization
- Homogenization
- Vitamin Fortification

Packaging
- Filling Machines
- Storage
- Delivery
- Markets
- Home Refrigerators

Distribution
The Microbiological Hazards
# Raw Milk Related Foodborne Illness Outbreaks

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Year</th>
<th>Confirmed Cases</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Campylobacter and Cryptosporidium</strong></td>
<td>2010</td>
<td>7</td>
<td>Minnesota</td>
</tr>
<tr>
<td><strong>Campylobacter and E. coli O157:H7</strong></td>
<td>2010</td>
<td>30</td>
<td>Denver</td>
</tr>
<tr>
<td><strong>E. coli O157:H7</strong></td>
<td>2010</td>
<td>8</td>
<td>Washington State</td>
</tr>
<tr>
<td><strong>E. Coli O157:H7</strong></td>
<td>2010</td>
<td>12</td>
<td>Minnesota</td>
</tr>
<tr>
<td><strong>Salmonella Newport</strong></td>
<td>2010</td>
<td>10</td>
<td>Utah</td>
</tr>
<tr>
<td><strong>Campylobacter</strong></td>
<td>2010</td>
<td>12</td>
<td>Multistate</td>
</tr>
<tr>
<td><strong>Campylobacter</strong></td>
<td>2009</td>
<td>35</td>
<td>Wisconsin</td>
</tr>
<tr>
<td><strong>Campylobacter</strong></td>
<td>2009</td>
<td>68</td>
<td>Pennsylvania</td>
</tr>
<tr>
<td><strong>Campylobacter</strong></td>
<td>2007</td>
<td>25</td>
<td>Kansas</td>
</tr>
</tbody>
</table>
# Outbreaks Linked to Pasteurized Milk

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Year</th>
<th>Number of cases</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Yersinia</em></td>
<td>2011</td>
<td>5</td>
<td>Pennsylvania</td>
</tr>
<tr>
<td><em>Listeria monocytogenes</em></td>
<td>2007</td>
<td>3</td>
<td>MA</td>
</tr>
<tr>
<td><em>Campylobacter</em></td>
<td>2006</td>
<td>1592</td>
<td>CA</td>
</tr>
<tr>
<td><em>Salmonella</em></td>
<td>2000</td>
<td>98</td>
<td>Multistate</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>1995</td>
<td>13420</td>
<td>Japan</td>
</tr>
<tr>
<td><em>Yersinia</em></td>
<td>1995</td>
<td>10</td>
<td>Multistate</td>
</tr>
<tr>
<td><em>Salmonella</em></td>
<td>1994</td>
<td>2010</td>
<td>Multistate</td>
</tr>
<tr>
<td><em>Salmonella</em></td>
<td>1984</td>
<td>16, 254</td>
<td>Multistate</td>
</tr>
</tbody>
</table>
Raw Milk Contaminated from Multiple Pathogens and Multiple Sources

1) *Bacillus* spp
2) Brucellosis
3) *Campylobacter jejuni*
4) *Clostridium botulinum*
5) *Escherichia coli* O157
6) *Listeria monocytogenes*
7) *Mycobacterium tuberculosis*
8) *Salmonella*
9) *Staphylococcus aureus*
10) Q fever (*Coxiella burnetti*)
11) *Yersinia enterocolitica*

Figure 1: Sources of contamination in raw milk. The numbers refer to the pathogen listed on the left.
**Step**

**Milk Production**
- Animal production strategies including health status, housing and herd size
- Supplementary feed e.g. silage and water source
- Waste management

**Milk Collection**
- Milking practices including teat washing and drying, stripping foremilk, etc
- Mastitis control measures
- Equipment cleaning and maintenance

**Milk Chilling and Storage**
- Rate and efficiency of chilling practices
- Equipment and personnel hygiene and sanitation

**Milk Packaging**
- Equipment and personnel hygiene and sanitation
- Maintenance of chill temperatures

**Transport**
- Maintenance of chill temperatures

**Consumer Practices**
- Maintenance of chill temperatures during home storage
- Adherence to use-by-dates
- Time before consumption
**Escherichia coli O157:H7**

- Gram negative
- Carriage in cattle: 11%
- Infectious dose: 10-100 cells
- Gastroenteritis; Possible HUS
Salmonella

• Gram negative

• Fecal material and processing environments

• Infectious dose: 100 – 100,000 (strain and host susceptibility)

• Gastroenteritis (multi-drug resistant strains key issue)
Campylobacter

- *C. coli* and *C. jejuni* Microaerophilic
- Animal GI tract
- Infectious dose: 500 cells
- Gastroenteritis: Explosive diarrhea
Listeria monocytogenes

• Psychrotrophic

• Endemic with dairies

• Infectious dose: 100 – 1e8 cfu (strain and host)

• Listeriosis: Abortion, Septicemia, meningitis
Coxiella burnetii

• Intracellular pathogen (cannot be cultured in the lab)
• High thermal and UV resistance
• Infectious dose: low
• Q Fever; Flu-like
• 0.6 cases per million population
Mycobacterium

- Obligate aerobic; slow growth (Generation Time 15-20 h)
- Respiratory system man and animals
- Infectious dose: 1-10 cells for
- 10% expose contract tuberculosis.
- Tuberculosis: Fever, weakness and respiratory failure
Mycobacterium tuberculosis complex (MTBC)

- Tuberculosis in man and animals
  - M. tuberculosis
  - M. bovis
  - M. africanum
  - M. canetti
  - M. caprae
TB Eradication Program in Cattle

% Positive for TB vs. Year

- % Positive for TB: 5, 1, 0.5, 0.1, 0.01, 0.01, 0.01
Brucella

- Brucellosis (Undulant fever): Fever, flu-symptoms
- Invasive pathogen
- Symptoms persist for months and can re-occur
- Rare (200-400 cases per year; 1 death)
- Almost eradicated in most developed countries
Brucellosis

• 1934 11% Cattle

• 1950: 4% Cattle

• 1977: 0.4%
Cryptosporidium

- Protozoan: Intestinal parasite
- Cattle, Sheep
- Infectious dose: Low
- Cryptosporidiosis: Abdominal cramp, Perfuse diarrhea (2-4 day duration)
## Summary of Microbiological Hazards

<table>
<thead>
<tr>
<th>Organism</th>
<th>Shed directly in milk</th>
<th>Severity of illness</th>
<th>Implicated in foodborne illness</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Bacillus cereus</em></td>
<td>x</td>
<td>Moderate</td>
<td>++</td>
</tr>
<tr>
<td><em>Campylobacter jejuni/coli</em></td>
<td>✓</td>
<td>Severe(^A)</td>
<td>++</td>
</tr>
<tr>
<td><em>Clostridium perfringens</em></td>
<td>x</td>
<td>Severe(^A)</td>
<td>+</td>
</tr>
<tr>
<td><em>Coxiella burnetii</em></td>
<td>✓</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td><em>Cryptosporidium parvum</em></td>
<td>x</td>
<td>Severe(^A)</td>
<td>+</td>
</tr>
<tr>
<td><em>Enterohaemorrhagic E. coli</em></td>
<td>✓</td>
<td>Severe</td>
<td>++</td>
</tr>
<tr>
<td><em>Listeria monocytogenes</em></td>
<td>✓</td>
<td>Severe(^A)</td>
<td>++</td>
</tr>
<tr>
<td><em>Salmonella</em> spp.</td>
<td>✓</td>
<td>Serious</td>
<td>++</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>✓</td>
<td>Moderate</td>
<td>++</td>
</tr>
<tr>
<td><em>Streptococcus</em> spp.</td>
<td>✓</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td><em>Toxoplasma gondii</em></td>
<td>✓</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td><em>Yersinia enterocolitica</em></td>
<td>✓</td>
<td>Serious</td>
<td>+</td>
</tr>
</tbody>
</table>

**Key:**

- # Transmission through udder, mastitis etc
- ✓ Shedding
- x Not shedded
- \(^A\) Susceptible sub-populations
- ¥ No data/unknown
- - No
- ++ More common
- + Rare
### Prevalence of Pathogens in Raw Milk

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Prevalence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Campylobacter jejuni</strong></td>
<td>9.2</td>
</tr>
<tr>
<td>VTEC</td>
<td>3.8</td>
</tr>
<tr>
<td><strong>Listeria monocytogenes</strong></td>
<td>4.6</td>
</tr>
<tr>
<td><strong>Salmonella</strong></td>
<td>6.1</td>
</tr>
<tr>
<td><strong>Yersinia</strong></td>
<td>6.1</td>
</tr>
</tbody>
</table>

Jayarao and Henning, 2001  United States
# Prevalence of Pathogens in Raw Milk

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Prevalence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Salmonella</em></td>
<td>28.1</td>
</tr>
<tr>
<td>STEC</td>
<td>15.2</td>
</tr>
<tr>
<td><em>L. monocytogenes</em></td>
<td>7.2</td>
</tr>
</tbody>
</table>

US
Kessel et al., 2011
## Raw Goat and Sheep Milk

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Prevalence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Listeria monocytogenes</em></td>
<td>2.3</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>34</td>
</tr>
<tr>
<td><em>E. coli O157</em></td>
<td>0.7</td>
</tr>
<tr>
<td><em>Salmonella</em></td>
<td>0.7</td>
</tr>
</tbody>
</table>

US
D’Amico et al, 2008
## Summary of Prevalence Data

<table>
<thead>
<tr>
<th>Organism</th>
<th>International data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campylobacter jejuni</td>
<td>0 – 40%</td>
</tr>
<tr>
<td>Enterohaemorrhagic Escherichia coli (EHEC)</td>
<td>0 – 33.5%</td>
</tr>
<tr>
<td>Listeria monocytogenes</td>
<td>1 – 60%</td>
</tr>
<tr>
<td>Salmonella spp.</td>
<td>0 – 11.8%</td>
</tr>
</tbody>
</table>

FSANZ, 2009
Raw Milk is Produced under a Higher Sanitary Environment

• Ingham et al., 2011

• Wisconsin farms
• Small <118 cows
• Large 119-713 cows
• Confined animal feeding >714 cows

• Standard Plate Count of bulk tank milk
• Somatic Cell Count
Confinement Dairy System

Cows never leave stalls; life span averages 42 months.
Confinement Dairy System

Cows bred to have large udders; they are typically milked three times per day.

NOTE: We do NOT recommend raw milk from cows in the conventional dairy system!
# Feed Given to Confinement Cows

<table>
<thead>
<tr>
<th>Feed</th>
<th>Result in Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soy</td>
<td>Not digested. Soy needs to be fermented for it to become digestible. Allergenic soy protein and estrogenic isoflavones</td>
</tr>
<tr>
<td>GMO grains</td>
<td>Aflatoxins (liver poisons)</td>
</tr>
<tr>
<td>Bakery waste</td>
<td><em>Trans</em> fatty acids</td>
</tr>
<tr>
<td>Citrus peel cake</td>
<td>Cholinesterase inhibitors (pesticides that act as nerve poisons)</td>
</tr>
<tr>
<td>Hormones and antibiotics</td>
<td>Hormones and antibiotics</td>
</tr>
<tr>
<td>Pellets from ethanol production!</td>
<td>Chemicals used in ethanol production.</td>
</tr>
</tbody>
</table>
**SPC and SCC of Bulk Tank Milk Produced on Different Size Farms**

Table 1. Group mean values for minimum, median, mean 90th percentile, and SPC and SCC for small (≤118 cows), large (119–713 cattle), and confined animal feeding operations (CAFO; ≥714 cattle) farm size categories

<table>
<thead>
<tr>
<th>Item</th>
<th>Small farms (n = 12,866)</th>
<th>Large farms (n = 1,565)</th>
<th>CAFO farms (n = 160)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SPC (× 10⁴ cfu/mL)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>25,700&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25,100&lt;sup&gt;b&lt;/sup&gt;</td>
<td>25,000&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Median</td>
<td>31,300&lt;sup&gt;a&lt;/sup&gt;</td>
<td>26,000&lt;sup&gt;b&lt;/sup&gt;</td>
<td>25,400&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean</td>
<td>58,700&lt;sup&gt;a&lt;/sup&gt;</td>
<td>36,300&lt;sup&gt;b&lt;/sup&gt;</td>
<td>35,000&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>90th percentile</td>
<td>100,100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>46,800&lt;sup&gt;b&lt;/sup&gt;</td>
<td>40,500&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Maximum</td>
<td>250,200&lt;sup&gt;a&lt;/sup&gt;</td>
<td>110,500&lt;sup&gt;b&lt;/sup&gt;</td>
<td>113,600&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>SCC (× 10⁵ cells/mL)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>209,000&lt;sup&gt;a&lt;/sup&gt;</td>
<td>183,000&lt;sup&gt;b&lt;/sup&gt;</td>
<td>179,000&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Median</td>
<td>348,000&lt;sup&gt;a&lt;/sup&gt;</td>
<td>266,000&lt;sup&gt;b&lt;/sup&gt;</td>
<td>239,000&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean</td>
<td>369,000&lt;sup&gt;a&lt;/sup&gt;</td>
<td>273,000&lt;sup&gt;b&lt;/sup&gt;</td>
<td>240,000&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>90th percentile</td>
<td>511,000&lt;sup&gt;a&lt;/sup&gt;</td>
<td>344,000&lt;sup&gt;b&lt;/sup&gt;</td>
<td>283,000&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Maximum</td>
<td>625,000&lt;sup&gt;a&lt;/sup&gt;</td>
<td>394,000&lt;sup&gt;b&lt;/sup&gt;</td>
<td>313,000&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a,b</sup>Different superscript letters within a row indicate that P < 0.017 for pairwise comparison of group means using the Wilcoxon rank sum test.
### Food-Borne Illnesses Associated with Milk: A Comparison with Other Foods - 1997

<table>
<thead>
<tr>
<th>Food</th>
<th>No. of Outbreaks</th>
<th>%</th>
<th>No. of Cases</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>2</td>
<td>0.4</td>
<td>23</td>
<td>0.2</td>
</tr>
<tr>
<td>Salads</td>
<td>21</td>
<td>4.2</td>
<td>1104</td>
<td>9.2</td>
</tr>
<tr>
<td>Fruits and Vegetables</td>
<td>15</td>
<td>3.0</td>
<td>719</td>
<td>6.0</td>
</tr>
<tr>
<td>Eggs</td>
<td>3</td>
<td>0.6</td>
<td>91</td>
<td>0.8</td>
</tr>
<tr>
<td>Chicken</td>
<td>9</td>
<td>1.8</td>
<td>256</td>
<td>2.1</td>
</tr>
</tbody>
</table>

*MMWR Vol 45, No SS-5*
Of All Foods, Milk has the Lowest Incidence of Reported Food-Borne Illnesses (0.2%)

On a case-by-case basis, persons consuming milk from ANY source (raw or pasteurized) are:

- 30 times more likely to become ill from fruits and vegetables
- 13 times more likely to become ill from beef
- 11 times more likely to become ill from chicken
- 10 times more likely to become ill from potato salad
- 2.7 times more likely to become ill from non-dairy beverages

MMWR Vol 45, No SS-5
<table>
<thead>
<tr>
<th>Point in Chain</th>
<th>Cases per 100,000 servings of 540ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-retail</td>
<td></td>
</tr>
<tr>
<td>Campylobacter</td>
<td>1</td>
</tr>
<tr>
<td>EHEC</td>
<td>97</td>
</tr>
<tr>
<td>Salmonella</td>
<td>153</td>
</tr>
<tr>
<td><em>Listeria monocytogenes</em></td>
<td>170</td>
</tr>
<tr>
<td>From Bulk Tank</td>
<td></td>
</tr>
<tr>
<td>Campylobacter</td>
<td>19</td>
</tr>
<tr>
<td>EHEC</td>
<td>16</td>
</tr>
<tr>
<td>Salmonella</td>
<td>17</td>
</tr>
<tr>
<td><em>Listeria monocytogenes</em></td>
<td>1</td>
</tr>
</tbody>
</table>

FSANZ, 2006
Activities of Greater Risk than Consuming Raw Milk

• Downhill skiing
• Gymnastics
• Driving
• Mercury in Fish
• Driving whilst using mobile phones
• Vaccines
• Ridding in a shopping cart
## Carriage of *Salmonella*

<table>
<thead>
<tr>
<th>Class</th>
<th>% Positive for <em>Salmonella</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Broilers</td>
<td>7.2</td>
</tr>
<tr>
<td>Market Hog</td>
<td>2.3</td>
</tr>
<tr>
<td>Cows/Bulls</td>
<td>0.6</td>
</tr>
<tr>
<td>Steers</td>
<td>0.2</td>
</tr>
<tr>
<td>Ground Beef</td>
<td>10.1</td>
</tr>
<tr>
<td>Ground Chicken</td>
<td>18.2</td>
</tr>
<tr>
<td>Ground Turkey</td>
<td>10.7</td>
</tr>
<tr>
<td>Turkey</td>
<td>3.8</td>
</tr>
<tr>
<td>Eggs</td>
<td>0.05</td>
</tr>
<tr>
<td>Fresh Produce</td>
<td>0.6</td>
</tr>
</tbody>
</table>
EU Carriage of *Listeria* on RTE Meat

- EU Average <1%
- Germany 11%
- Greece 20.7%
- Italy 13.6%
- Poland 62.9%
- Slovenia 16.7%

## Selected Outbreaks Linked to Sprouts

<table>
<thead>
<tr>
<th>Year</th>
<th>Pathogen</th>
<th>Source</th>
<th>Number of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>E. coli O104:H4</td>
<td>Bean Sprouts</td>
<td>&gt;3000</td>
</tr>
<tr>
<td>2011</td>
<td>Salmonella</td>
<td>Clover Sprouts</td>
<td>7</td>
</tr>
<tr>
<td>2010</td>
<td>Salmonella</td>
<td>Alfalfa</td>
<td>125</td>
</tr>
<tr>
<td>2010</td>
<td>Salmonella</td>
<td>Alfalfa</td>
<td>28</td>
</tr>
<tr>
<td>2010</td>
<td>Salmonella</td>
<td>Bean Sprouts</td>
<td>190</td>
</tr>
<tr>
<td>2009</td>
<td>Salmonella</td>
<td>Alfalfa</td>
<td>78</td>
</tr>
<tr>
<td>2005</td>
<td>Salmonella</td>
<td>Bean Sprouts</td>
<td>648</td>
</tr>
<tr>
<td>1996</td>
<td>E. coli O157</td>
<td>Radish</td>
<td>&gt;6000</td>
</tr>
</tbody>
</table>
It is all Relative

• Consumption raw milk only a fraction of fresh produce and deli meat

• Raw milk accounts for <1% of total dairy products but responsible for >85% of outbreaks.

• There is risk in everything, individuals constantly evaluate risk vs benefits
Anti-Microbial Components and Nutrients in Raw Milk
Health Benefits of Raw Milk

• Antimicrobial agents
  – Lactoperoxidase
  – Xanthine oxidase
  – Lysozyme
  – IgA
• Endogenous microflora (lactic acid bacteria)
• Lactoferrin (iron binding)
• Low levels of pathogens can boost the immune system

• Cowpox and dairy maids
  – Vaccination discovered for smallpox
Lactoperoxidase (LPO) and myeloperoxidase (MPO) catalyzed oxidation reactions.

A

\[ \text{SCN}^- \xrightarrow{\text{LPO}} \text{OSCN}^- \]

\[ \text{H}_2\text{O}_2 \quad \text{H}_2\text{O} \]

Thiocyanate and hydrogen peroxide addition

B

\[ \text{Cl}^- \xrightarrow{\text{MPO}} \text{OCl}^- \]

\[ \text{H}_2\text{O}_2 \quad \text{H}_2\text{O} \]

C

\[ \text{OCl}^- \xrightarrow{\text{non-enzymatic}} \text{Cl}^- \]

\[ \text{SCN}^- \quad \text{OSCN}^- \]

Xu Y et al. PNAS 2009;106:20515-20519
Lactoferrin

- Iron binding protein
- Binds to LPS, DNA
- Degrades RNA
- Anti-bacterial
- Anti-fungal
- Anti-virus
Lysozyme

- Hydrolyze bacterial cell walls
- Gram positive more sensitive
- Anti-bacterial activity
Immunoglobulin (IgA)

- Antibodies
- Bind to pathogens to enhance response of the immune system
- Overcome pathogen stealth tactics
Raw Milk Benefits

- Lower incidence
- Allergy/asthma
- Autism
- Cancer
- Crohn’s disease
- Lactose intolerance
- Tooth decay
Breast Milk vs Formula

- Reduced infections
- Diarrhea
- Ear
- Urinary tract
- Respiratory tract
- Less risk of diabetes
- Reduced obesity
- Reduced allergens

Reality: Minor effect; little scientific evidence of benefits
Breast is Best

• Health agencies promote breast feeding

• Nutrition and health

• Key difference between breast and raw milk: Post-collection storage conditions
## Destruction of Built-In Safety Systems by Pasteurization

<table>
<thead>
<tr>
<th>Component</th>
<th>Breast Milk</th>
<th>Raw Milk</th>
<th>Pasteurized Milk</th>
<th>Infant Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-lymphocytes</td>
<td>X</td>
<td>X</td>
<td>inactivated</td>
<td>inactivated</td>
</tr>
<tr>
<td>Macrophages</td>
<td>X</td>
<td>X</td>
<td>inactivated</td>
<td>inactivated</td>
</tr>
<tr>
<td>Neutrophils</td>
<td>X</td>
<td>X</td>
<td>inactivated</td>
<td>inactivated</td>
</tr>
<tr>
<td>Lymphocytes</td>
<td>X</td>
<td>X</td>
<td>inactivated</td>
<td>inactivated</td>
</tr>
<tr>
<td>IgA/IgG Antibodies</td>
<td>X</td>
<td>X</td>
<td>inactivated</td>
<td>inactivated</td>
</tr>
<tr>
<td>B12 Binding Protein</td>
<td>X</td>
<td>X</td>
<td>inactivated</td>
<td>inactivated</td>
</tr>
<tr>
<td>Bifidus Factor</td>
<td>X</td>
<td>X</td>
<td>inactivated</td>
<td>inactivated</td>
</tr>
<tr>
<td>Medium-Chain Fatty Acids</td>
<td>X</td>
<td>X</td>
<td>reduced</td>
<td>reduced</td>
</tr>
<tr>
<td>Fibronectin</td>
<td>X</td>
<td>X</td>
<td>inactivated</td>
<td>inactivated</td>
</tr>
<tr>
<td>Gamma-Interferon</td>
<td>X</td>
<td>X</td>
<td>inactivated</td>
<td>inactivated</td>
</tr>
<tr>
<td>Lactoferrin</td>
<td>X</td>
<td>X</td>
<td>inactivated</td>
<td>inactivated</td>
</tr>
<tr>
<td>Lysozyme</td>
<td>X</td>
<td>X</td>
<td>inactivated</td>
<td>inactivated</td>
</tr>
<tr>
<td>Mucin A/Oligosaccharides</td>
<td>X</td>
<td>X</td>
<td>reduced</td>
<td>inactivated</td>
</tr>
<tr>
<td>Hormones &amp; Growth Factors</td>
<td>X</td>
<td>X</td>
<td>reduced</td>
<td>inactivated</td>
</tr>
</tbody>
</table>

*Scientific American*, December 1995  
*The Lancet*, Nov 17, 1984
Milk Composition As Per Cent Total Volume

- Water: 87.3%
- Fats: 3.9%
- Non-Fat Solids: 8.8%

Data Source: University of Guelph, Canada

---

Nutrition Facts

Serving Size 1 cup (8 fl oz/240mL)
Servings Per Container 8

<table>
<thead>
<tr>
<th>Amount Per Serving</th>
<th>% Daily Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories 160</td>
<td>Calories from Fat 80</td>
</tr>
<tr>
<td>Total Fat 9g</td>
<td>14%</td>
</tr>
<tr>
<td>Saturated Fat 6g</td>
<td>30%</td>
</tr>
<tr>
<td>Trans Fat 0g</td>
<td>0%</td>
</tr>
<tr>
<td>Cholesterol 35mg</td>
<td>12%</td>
</tr>
<tr>
<td>Sodium 120mg</td>
<td>5%</td>
</tr>
<tr>
<td>Total Carbohydrate 12g</td>
<td>4%</td>
</tr>
<tr>
<td>Dietary Fiber 0g</td>
<td>0%</td>
</tr>
<tr>
<td>Sugars 12g</td>
<td></td>
</tr>
<tr>
<td>Protein 9g</td>
<td>16%</td>
</tr>
<tr>
<td>Vitamin A 6%</td>
<td></td>
</tr>
<tr>
<td>Vitamin C 0%</td>
<td></td>
</tr>
<tr>
<td>Calcium 30%</td>
<td></td>
</tr>
<tr>
<td>Iron 0%</td>
<td></td>
</tr>
</tbody>
</table>

*Percent Daily Values are based on a 2,000 calorie diet.
Lactose Intolerance & Allergic Reactions

• All milk contains lactose

• Lactose intolerance: Low expression of galactocidase

• Pasteurization converts lactose into the β–lactose (more soluble; easily absorbed)
  – Only occurs at high temps (>95°C) over prolonged periods.
• Iodine loss during pasteurization
  • <0.02% loss

• Vit A, D, E and K
  • Negligible loss during pasteurization

• 10% loss Vit C: Milk not a significant source
Milk Proteins

- Casein
- Serum (whey)
- 50% B-lactoglobulin
- 20% a-lactoglobulin
- Blood serum albumin
- Immunoglobulins
- Lactoferin
- Enzymes
Milk Proteins

• Thermal pasteurization: B-lactoglobulin layers casein micelle to prevent curd formation

• Hard cheese can not be prepared from pasteurized milk (texture, flavor development)

• Soft cheese: Notable change in texture and flavor changes when pasturization is applied.
• Raw milk cheese must be held for 60 days prior to sale
Curds & Whey
60 Day Rule

- Based on the decrease in *E. coli* O157:H7 numbers over cheese ripening period

- Gouda and cheddar: 100 - 270 days

- Possible increase to 90 or 120 day rule
Reduced Obesity and Asthma

Supporting evidence available for positive effects of raw milk

• Protein and fat form gel in stomach: Reduce food craving

• Whey protein fraction protective effect against asthma. Lost during thermal treatment
Regulations

• Canada
• Prohibited to both supply or sell raw milk (national regulation)
• Raw milk considered to pose a hazard to the public
• Charter s.91(27) criminal law to manufacture or sell dangerous goods
• Centralized power with negligible influence of lobby groups
Regulations

• Canada
  – 63°C for not less than 30 min
  – 72°C for not less than 16 sec
Raw Milk Cheese in Quebec

- Quebec allowed the sale of raw milk cheese in 2008
- Less than 60 day holding time
- Monthly testing and vet inspection of herds
US Regulations

- Prohibited to transport interstate
- Individual states have the discretion on regulating raw milk
- More effective lobbying by interest groups
- Constitution provides power to the States
European Union

- Decision left to member states
- Wales and UK: Restrict to farm gate
- Scotland: Total ban
- Ireland: Considering ban
- Raw milk vending machines
Raw Milk Banned

- Denmark
- Norway
- Finland
- Iceland

- Historically used in other countries for cheese production
# Standards

<table>
<thead>
<tr>
<th>Product</th>
<th>Bacteria</th>
<th>PMO</th>
<th>EU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Milk</td>
<td>TAC</td>
<td>-</td>
<td>&lt;20000</td>
</tr>
<tr>
<td></td>
<td><em>S. aureus</em></td>
<td>-</td>
<td>&lt;500</td>
</tr>
<tr>
<td></td>
<td><em>Salmonella</em></td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Coliforms</td>
<td>-</td>
<td>&lt;100</td>
</tr>
<tr>
<td>Pasteurized milk</td>
<td>TAC</td>
<td>&lt;20000</td>
<td>5000/50000</td>
</tr>
<tr>
<td></td>
<td>Coliforms</td>
<td>&lt;10</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Raw milk for production</td>
<td>TAC</td>
<td>&lt;100000</td>
<td>&lt;100000</td>
</tr>
<tr>
<td></td>
<td><em>S. aureus</em></td>
<td>-</td>
<td>&lt;2000</td>
</tr>
</tbody>
</table>
European Experience

- 50% of listeriosis cases linked to raw milk products

**Table 1.** Prevalence of *Listeria monocytogenes* in different types of dairy products in European countries.

<table>
<thead>
<tr>
<th>Product</th>
<th>Prevalence (% of <em>Listeria monocytogenes</em>)</th>
<th>Country of origin</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw milk</td>
<td>4.4</td>
<td>The Netherlands</td>
<td>Beckers et al., 1987</td>
</tr>
<tr>
<td>Raw milk</td>
<td>3.6</td>
<td>England and Wales</td>
<td>Greenwood et al., 1991</td>
</tr>
<tr>
<td>Raw milk</td>
<td>1</td>
<td>Sweden</td>
<td>Waak et al., 2002</td>
</tr>
<tr>
<td>Soft cheese made of raw milk</td>
<td>65</td>
<td>France</td>
<td>Beckers et al., 1987</td>
</tr>
<tr>
<td>Soft ripened cheese</td>
<td>8.2</td>
<td>England and Wales</td>
<td>Greenwood et al., 1991</td>
</tr>
<tr>
<td>Soft unripened cheese</td>
<td>1.1</td>
<td>England and Wales</td>
<td>Greenwood et al., 1991</td>
</tr>
<tr>
<td>Soft cheese</td>
<td>6</td>
<td>Italy, Germany, Austria, and France</td>
<td>Rudolf and Scherer, 2001</td>
</tr>
<tr>
<td>Soft or semi soft cheese</td>
<td>6</td>
<td>France, Germany, and Italy</td>
<td>Loncarevic et al., 1995</td>
</tr>
<tr>
<td>Semi soft cheese</td>
<td>8</td>
<td>Italy, Germany, Austria, and France</td>
<td>Rudolf and Scherer, 2001</td>
</tr>
<tr>
<td>Hard cheese</td>
<td>1.5</td>
<td>England and Wales</td>
<td>Greenwood et al., 1991</td>
</tr>
<tr>
<td>Hard cheese</td>
<td>4</td>
<td>Italy, Germany, Austria, and France</td>
<td>Rudolf and Scherer, 2001</td>
</tr>
<tr>
<td>Ice cream</td>
<td>0.5</td>
<td>Finland</td>
<td>Miettinen et al., 1999a</td>
</tr>
</tbody>
</table>
Table 1  *Food-borne disease outbreaks recorded and implication of milk products in different countries* (De Buyser et al., 2001)

<table>
<thead>
<tr>
<th>Country</th>
<th>No. of years (years)</th>
<th>No. of outbreaks with known food vehicle</th>
<th>No. (%) of outbreaks implicating milk and milk products</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>5 (1988—1992)</td>
<td>465&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10 (2.2%)</td>
</tr>
<tr>
<td>Finland</td>
<td>8 (1983—1990)</td>
<td>279</td>
<td>8 (3%)</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>4 (1991—1994)</td>
<td>122&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7 (5.7%)</td>
</tr>
<tr>
<td>England and Wales</td>
<td>2 (1992—1993)</td>
<td>204</td>
<td>9 (4.4%)</td>
</tr>
<tr>
<td>Germany</td>
<td>4 (1993—1996)</td>
<td>547</td>
<td>30 (5.5%)</td>
</tr>
<tr>
<td>Poland</td>
<td>5 (1992—1996)</td>
<td>2435</td>
<td>86 (3.5%)</td>
</tr>
<tr>
<td>France</td>
<td>10 (1988—1997)</td>
<td>2861</td>
<td>177 (6.1%)</td>
</tr>
</tbody>
</table>

<sup>a</sup> of bacterial aetiology only, the 990 outbreaks of unknown aetiology (chemicals + others) were excluded.

<sup>b</sup> incidents = outbreaks + single cases
New Zealand and Australia

• NZ: Permitted to sell 5 liters per transaction at the farm gate

• Must comply with Animal Products Act 1999; Standards for sanitation and herd health

• Unpasteurized cheese can be produced and imported from EU

• Australian: All dairy products required to be pasteurized
FSANZ

• Proposal 1007: Public comment on the sale of raw milk dairy products in Australia

• Identify standards in production and processing to enhance safety

• Permission to sell soft, hard and very hard cheeses (intrinsic and extrinsic factors)

• Raw milk will not be considered due to high risk
A Different Age

1940’s
• Tuberculosis
• Typhoid
• Inadequate sanitation
• Waterborne disease
• Poor herd health surveillance
• Poor temperature control

Present Day
• Improved sanitation and equipment
• Close monitoring of herd health
• Pathogen reduction programs
• Carriage of virulent pathogens including antibiotic resistance
Alternative Pasteurization Technologies (Non-thermal)

- Ultraviolet
- Filtration
- Pulsed electric fields
- Ultrasound
- Cold plasma
- High Hydrostatic Pressure (HHP)
ULTRAVIOLET

Before

Incoming UV Photon

After

Denaturation

Normal protein

Renaturation

Denatured protein

Percentage of Activity

UV Dose

Scrapie

Gene

Bacterium

Bacteriophage
Turbulent Flow Reactors

Fluid Enters → 1 m → Fluid Exits

UVX-25 Sensors

Quartz Tube

UV Light

A

B
CiderSure Raw Goat Milk

![Graph showing survivors (log CFU/ml) vs. total UV dose (mJ/cm²) for different capacities.](image)
Shockwave Reactor

- High flow rates
- Rotating cylinder
- Cavitation
- Turbulent Flow
ShockWave Reactor

Inactivation of *E. coli* in Skimmed Milk

- Log Count Reduction
- Rotation Speed (rpm)
- H Dose (J/m²)
Dean Flow Reactor
Taylor-Couttee Reactor

- UV Treatment of opaque fluids
- Generation of vortices to enhance mixing
- Alternative to thermal pasteurization
Bacteriophage in Milk

Wavy Vortices

Turbulent Vortices

Log Count Reduction PFU/ml

Taylor number
Pulsed Electric Fields

• High voltage (20-80 kVcm$^{-1}$) across electrodes separated by a narrow gap.

• Critical membrane potential: Pore formation in the cell membrane

• Batch or continuous
PEF
Jaeger et al., 2009
Effect of Whey Protein Concentration
Ultrasonics

- Acoustic energy
- Formation and destruction of bubbles (cavitation)
- Cavitation release energy & heat
Figure 1—Inactivation kinetics of mid-stationary phase cells of *Escherichia coli* ATCC 25922 (●) and *Listeria monocytogenes* ATCC 19115 (▲) in phosphate buffer (pH 7.2) upon sonication with ultrasound waves (24 kHz, 80% pulse/s, 100 μm, 85 W/cm²).

Phosphate Buffer
Gera and Doore, 2011
Figure 2—Survival curves of *E. coli* ATCC 25922 (closed symbols) and *L. monocytogenes* ATCC 19115 (open symbols) on selective and nonselective media upon treatment with ultrasound waves (24 kHz, 80% pulse/s, 100 μm, 85 W/cm²) in whole milk.
High Hydrostatic Pressure

- Non-compressible liquid (water)
- Apply 500 – 600MPa
- Loss of cell integrity
- Die-off over 24 h
HHP *Listeria* inoculated into milk

![Graph showing viability loss (log No/N) at different pressures.](image)

**FIG. 3.** Comparison of inactivation of *E. coli* MG1655 (A) and *L. innocua* LMG 11387 (B) in skim milk (SM) versus 100 mM phosphate buffer (pH 6.7) (PB) by high pressure (black), by high pressure and H₂O₂ (white), or by high pressure and the full LP system (grey). Data with error bars are means ± standard deviations.

Garcia-Graells et al., 2000
FIG. 4. Evolution of viable counts during storage at 20°C after pressure treatment (15 min, 20°C) of *E. coli* MG1655 (600 MPa) and *L. innocua* LMG 11387 (350 MPa) in milk without any additives (●), supplemented with H₂O₂ (□), or supplemented with the full LP system (▲).
### HHP Treated Cheese

<table>
<thead>
<tr>
<th>Product</th>
<th>Pathogen/Bacterium</th>
<th>Treatment</th>
<th>Log Count Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mato</td>
<td><em>E. coli</em> O157:H7</td>
<td>400-500 MPa 15 min</td>
<td>7</td>
</tr>
<tr>
<td>Goat milk cheese</td>
<td><em>L. monocytogenes</em></td>
<td>450 MPa 10 min</td>
<td>5.6</td>
</tr>
<tr>
<td>Full-fat Cheese</td>
<td><em>Lactobacillus</em></td>
<td>400MPa 10 min</td>
<td>1.5</td>
</tr>
</tbody>
</table>

No reported negative effects of sensory properties

Cost: 10 cents per kg
Microfiltration

Cross-flow filtration

0.2μm pore size

>5 log cfu reduction: Spores and vegetative cells

No reliable method to detect membrane damage
Microfiltration
Non-thermal Technologies

• Not accepted by pro-raw milk groups

• Expensive

• Clear demand by industry

• Thermal processing is still required
Conclusions

• Microbiological safety of raw milk compromised large scale production and long supply chains.
• Impact of pasteurization likely over-estimated
• Hazards associated with raw milk have changed through the years.
• High risk of multi-drug resistant, virulent, pathogens
• No conclusive evidence promoting the majority of perceived health benefits of raw milk.
• Some evidence for controlling allergies and obesity
• Pro-raw milk groups justify choice based on nutritional attributes
• Reality: Anti-establishment and Taste
• Food safety risks linked to raw milk greater than other RTE foods
• Freedom of choice
• Regulations reducing availability of raw milk
• Non-thermal technologies are available
• Potential screening of raw milk prior to distribution.
Verdict

• Raw milk does not bring any tangible benefits except for taste

• Freedom of choice but need to educate on risks

• Protect vulnerable groups

• Non-thermal techniques should be considered as alternatives to thermal pasteurization.
Where to go?

- Consumer Safety
- Animal hygiene
- Special animal hygiene
- Production hygiene
- Routine Checks
- Advanced production hygiene
- Pasteurisation, Standardisation

1. Direction „High Quality Native Milk“ (Vorzugsmilch)
   - NATIVE, SHORT SHELF-LIFE

2. Direction „Conventional Dairy Milk“
   - NO MORE NATIVE, VARYING SHELF-LIFE