In the Raw: Pathogens and Milk Quality

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Outline

• Raw milk quality parameters

• Prevalence of pathogens in raw milk

• The impact of raw milk consumption on public health
High Quality Raw Milk - Sedimentation

• High levels of sedimentation due to poor pre-milking hygiene
High Quality Raw Milk – Added Water

• Added water dilutes the components of milk (i.e., protein) and can lead to sensory defects
• Raw milk has a freezing point of ~-0.542°C
• Added water is detected via freezing point depression
High Quality Raw Milk – Farm Related Off-Flavors

- Farm practices may lead to off-flavors and odors
  - Absorbed
  - Bacterial
  - Chemical

- Most raw milk flavor/odor defects will be carried over to finished products
High Quality Raw Milk – Antibiotic Residues

- Antibiotics are used to treat cows with mastitis or other infections
- Residual antibiotics
  - Inhibit starter cultures
  - Induce allergic reactions
High Quality Raw Milk – Somatic Cells

• Indicator of animal health
  • Mastitis increases SCC

• Enzymes from high SCC can result in deteriorated quality of various dairy products
  • Reduced cheese yields
  • Sensory defects
High Quality Raw Milk – Microbial Contamination
Raw Milk Quality – Microbiological Contamination

• “Normal” flora of milk
  • Beneficial/Benign
  • Spoilage
  • Pathogenic
Raw Milk Quality – Microbiological Contamination

• “Normal” flora of milk

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Raw Milk Quality – Microbiological Contamination

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Spoilage Raw Milk Flora

• Psychrotolerant Gram-negative bacteria
  • *Pseudomonas* and other psychrotolerant bacteria (e.g., *Aeromonas, Serratia, Citrobacter* and other psychrotolerant coliform bacteria) are commonly found in raw milk
  • Some strains produce heat stable enzymes that can degrade the quality of processed dairy products
  • High levels can indicate improper cooling or sanitation
Spoilage Raw Milk Flora

• Sporeforming bacteria
  • Found ubiquitously in natural environments including on dairy farms
  • Spores are capable of surviving various environmental stresses, including heat, pressure, acid and others
  • Psychrotolerant, Mesophilic, Thermophilic, Highly Heat Resistant and Butyric Acid Bacteria (Anaerobic) have implications on various processed dairy products
Raw Milk Quality – Microbiological Contamination

• “Normal” flora of milk
  • Beneficial/Benign
  • Spoilage
  • Pathogenic
Pathogenic Raw Milk Flora

- Brucella
- Campylobacter
- Listeria monocytogenes
- Mycobacterium bovis
- Salmonella
- Escherichia coli
- Shigella
- Streptococcus pyogenes
- Yersinia enterocolitica
Pathogenic Raw Milk Flora

- Brucella
- *Campylobacter*
- *Listeria monocytogenes*
- *Mycobacterium bovis*
- *Salmonella*
- *Escherichia coli*
- *Shigella*
- *Streptococcus pyogenes*
- *Yersinia enterocolitica*
Campylobacter

- Non-sporeforming, microaerophilic, Gram-negative rod
- Susceptible to drying, heating, freezing, disinfectants and pH
- ~76 deaths per year in the US attributable to Campylobacter
Campylobacter

• Third leading cause of bacterial foodborne disease in the US

• Campylobacteriosis onset 2 to 5 days
  • Fever, diarrhea, abdominal cramps, vomiting
  • Infrequent severe complications can occur

• Populations at a higher risk of contracting campylobacteriosis are infants, children, young adults, pregnant women and immunocompromised individuals
Escherichia coli

• Diversity of E. coli causing human disease
  • ETEC – Enterotoxigenic *E. coli*
  • EIEC – Enteroinvasive *E. coli*
  • EAEC – Enteroaggregative *E. coli*
  • EPEC – Enteropathogenic *E. coli*
  • STEC – Shiga toxin producing *E. coli*
  • EHEC – Enterohemorrhagic *E. coli*
Shiga toxin producing *Escherichia coli* (STEC)

- Gram-negative, rod shaped bacteria
- Notable member – *E. coli* O157:H7
- Infective dose estimated to be low – 10 to 100 cells
Shiga toxin producing *Escherichia coli* (STEC)

- Onset of symptoms may range from 1-9 days
  - Mild forms include diarrhea
  - Severe disease leads to hemorrhagic colitis (HC) potentially leading to hemolytic uremic syndrome (HUS) or thrombotic thrombocytopenia purpura (TTP)
  - 3-7% of HC cases progress to HUS or TTP
**Salmonella**

- Motile, non-sporeforming, Gram-negative bacteria
- Mortality rates for gastrointestinal or nontyphoidal salmonellosis is estimated to be <1%
- CDC estimates >1 million US cases annually
Salmonella

• Onset of symptoms may be 6-72 hours after exposure
  • High fever, lethargy, diarrhea or constipation, headache, achiness
  • Septicemia with possible endocarditis and chronic infection
Listeria monocytogenes

- Gram-positive, rod-shaped, facultatively aerobic bacteria
- Leading cause of foodborne illness deaths in the US
  - Mortality rate 15-30% overall, up to 80% in neonatal infections
- Capable of persistence in food processing environments
- Growth at refrigeration temperatures
Listeria monocytogenes

- Incubation period can range from a few days for the non-invasive gastrointestinal form to 3 months for the invasive form
- Symptoms include fever, nausea, vomiting, headache, stiff neck, confusion, convulsions and abortion/stillbirth
Sources of Pathogens

- **Feces**
  - Campylobacter
  - E. coli
  - Salmonella

- **Environment**
  - *Listeria monocytogenes*
Prevalence of pathogenic bacteria in raw milk

<table>
<thead>
<tr>
<th>Foodborne pathogen</th>
<th>Isolation rate (%)</th>
<th>Reference</th>
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<tbody>
<tr>
<td><em>Campylobacter jejuni</em></td>
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<td>Doyle and Roman (1982)</td>
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<td></td>
<td>0.9</td>
<td>Lovett et al. (1983)</td>
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<td>McManus and Lanier (1987)</td>
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<td>Davidson et al. (1989)</td>
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<td>Steele et al. (1997)</td>
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<td>Jayarao and Henning (2001)</td>
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<td><em>Shiga toxin–producing Escherichia coli</em></td>
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<td>Steele et al. (1997)</td>
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<td>Jayarao and Henning (2001)</td>
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<td></td>
<td>3.8</td>
<td>Murinda et al. (2002b)</td>
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<td>Listeria monocytogenes</td>
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<td>Farber et al. (1988)</td>
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<td>Slade et al. (1988)</td>
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<td>Liewen and Plautz (1988)</td>
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<td>Davidson et al. (1989)</td>
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<td>Fedio and Jackson (1990)</td>
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<td>Rohrbach et al. (1992)</td>
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<td>2.7</td>
<td>Steele et al. (1997)</td>
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<td>Jayaraao and Henning (2001)</td>
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<td>Hassan et al. (2000)</td>
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<td>1.0</td>
<td>Waak et al. (2002)</td>
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<td>4.9 to 7.0</td>
<td>Muraoka et al. (2003)</td>
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<td>Van Kessel et al. (2004)</td>
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<tr>
<td>Salmonella spp.</td>
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<td>McManus and Lanier (1987)</td>
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<td>McEwen et al. (1988)</td>
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<td>Murinda et al. (2002a)</td>
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<td>2.6</td>
<td>Van Kessel et al. (2004)</td>
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</tbody>
</table>
Associations between raw milk quality and incidence of pathogens

FIGURE 4. Average log values for each quality indicating organism in samples containing zero ( ), one ( ), two ( ), or three ( ) pathogens.
Foodborne disease associated with raw milk consumption

• Between the years of 1993 to 2006 in the US
  • 73 outbreaks caused by raw milk and milk products
  • 48 outbreaks caused by pasteurized milk and milk products
• Risk of foodborne outbreak from raw milk products >150 times greater than for pasteurized milk products
• Hospitalization rate for patients from raw milk outbreaks >13 times higher than for those associated with pasteurized products
Foodborne disease associated with raw milk consumption, cont.

- Between the years 2007 and 2012 in the US
  - 81 outbreaks associated with raw milk resulting in 979 illnesses
  - 81% of outbreaks from states where sale of raw milk was legal

Mungai et al., 2015
Foodborne disease associated with raw milk consumption, cont.
Raw milk consumption: A case study

- July 2008, two unrelated Connecticut children with HUS identified through routine surveillance
- Epidemiological investigation identified 14 confirmed and probable cases
  - 71% of those affected were children (mean age of 5)
  - 5 required hospitalization
Raw milk consumption: A case study

- Raw milk from Farm X was implicated in the outbreak
- E. coli O157:NM isolated from patients as well as an asymptomatic cow from Farm X
- Practices on Farm X reflected industry standards
  - Some deficiencies were noted
- Total estimated cost for outbreak was $413,402

Table 1. Number and Percentage of Exposures to E. coli O157 Among Case Patients and Controls, by Food Item/Exposure, Connecticut, 2008

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Cases</th>
<th>Controls</th>
<th>OR</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>No. (%)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Raw milk</td>
<td>5/5</td>
<td>0/10 (0)</td>
<td>231.0*</td>
<td>(4.0 - 13304.1)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Raw cheese</td>
<td>2/5</td>
<td>0/10 (0)</td>
<td>15.0*</td>
<td>(0.6 - 394.1)</td>
<td>0.0952</td>
</tr>
<tr>
<td>Ground beef</td>
<td>1/5</td>
<td>8/9 (89)</td>
<td>0.03</td>
<td>(0.01 - 0.6)</td>
<td>0.0230</td>
</tr>
<tr>
<td>Bagged lettuce</td>
<td>1/5</td>
<td>5/9 (56)</td>
<td>0.2</td>
<td>(0.02 - 2.6)</td>
<td>0.3007</td>
</tr>
<tr>
<td>Whole head lettuce</td>
<td>2/4</td>
<td>2/9 (22)</td>
<td>3.5</td>
<td>(0.3 - 43.2)</td>
<td>0.5301</td>
</tr>
<tr>
<td>Spinach</td>
<td>1/3</td>
<td>2/9 (22)</td>
<td>1.6</td>
<td>(0.9 - 30.8)</td>
<td>1.0000</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>3/5</td>
<td>5/9 (56)</td>
<td>1.2</td>
<td>(0.1 - 11.1)</td>
<td>1.0000</td>
</tr>
<tr>
<td>Jalapenos</td>
<td>0/4</td>
<td>0/9 (0)</td>
<td>n/a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swimming</td>
<td>3/5</td>
<td>8/9 (89)</td>
<td>0.2</td>
<td>(0.01 - 2.9)</td>
<td>0.5055</td>
</tr>
<tr>
<td>Visit farm</td>
<td>2/5</td>
<td>0/9 (0)</td>
<td>13.6*</td>
<td>(0.5 - 358.5)</td>
<td>0.1099</td>
</tr>
<tr>
<td>Contact w/ farm animals</td>
<td>1/5</td>
<td>0/6 (0)</td>
<td>5.7*</td>
<td>(0.2 - 169.5)</td>
<td>0.3846</td>
</tr>
</tbody>
</table>
Raw milk consumption: A case study

- Total estimated cost for outbreak was $413,402
- Farm X was sued by two families whose children were involved in the outbreak
- Farm X [Town Farm Dairy] closed in September, 2008
Raw milk consumption: A case study

• Take home message:
  • Children bear the burden of many foodborne disease outbreaks
  • Raw milk safety can not be determined by traditional raw milk quality parameters or symptomatic animals
  • High financial, business and public health costs associated with raw milk foodborne disease outbreaks
Raw milk consumption: A second case study

- Outbreak involving *Campylobacter jejuni/coli* in May and June, 2008 in California

- Investigation prompted by a patient with campylobacteriosis triggered Guillain-Barre Syndrome
  - Onset of GBS is a rare but well-known risk of campylobacteriosis
  - Patient was hospitalized for six months incurring >$1 million in medical expenses

- 16 individuals involved in the outbreak
  - Aged 4-70 years old, median age of 48
Raw milk consumption: A second case study, cont.

- A “cow-leasing” program from Dairy A, an organic dairy farm was implicated in the Campylobacteriosis outbreak

- 4 patients were first time consumers of raw milk while 7 patients had consumed raw milk daily for months or even years
Raw milk consumption: A second case study, cont.

• Take away message:
  • Raw milk consumption leads to risk of rare, but life altering diseases caused by bacteria commonly found in raw milk
  • Frequent consumption of raw milk does not prevent foodborne illness
  • Pathogens are found in conventionally produced and organically produced raw milk
Summary

• Pathogenic bacteria associated with raw milk are found in dairy farm environments and colonize the intestinal tract of dairy producing animals

• Transmission of these bacteria from the environment and feces results in <1% to >10% prevalence of common raw milk associated bacteria

• Traditional measures of raw milk quality are insufficient for indicating the presence of pathogenic bacteria
Summary

• Outbreaks associated with raw milk consumption have increased in the US, primarily in states where the sale of raw milk is legal

• Children, the elderly and immunocompromised individuals are at particular risk of developing foodborne disease from consuming raw milk

• *New estimates indicate that non-outbreak, sporadic cases may outnumber outbreaks by 25 to 1*