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°H
- 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

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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***
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Campylobacter

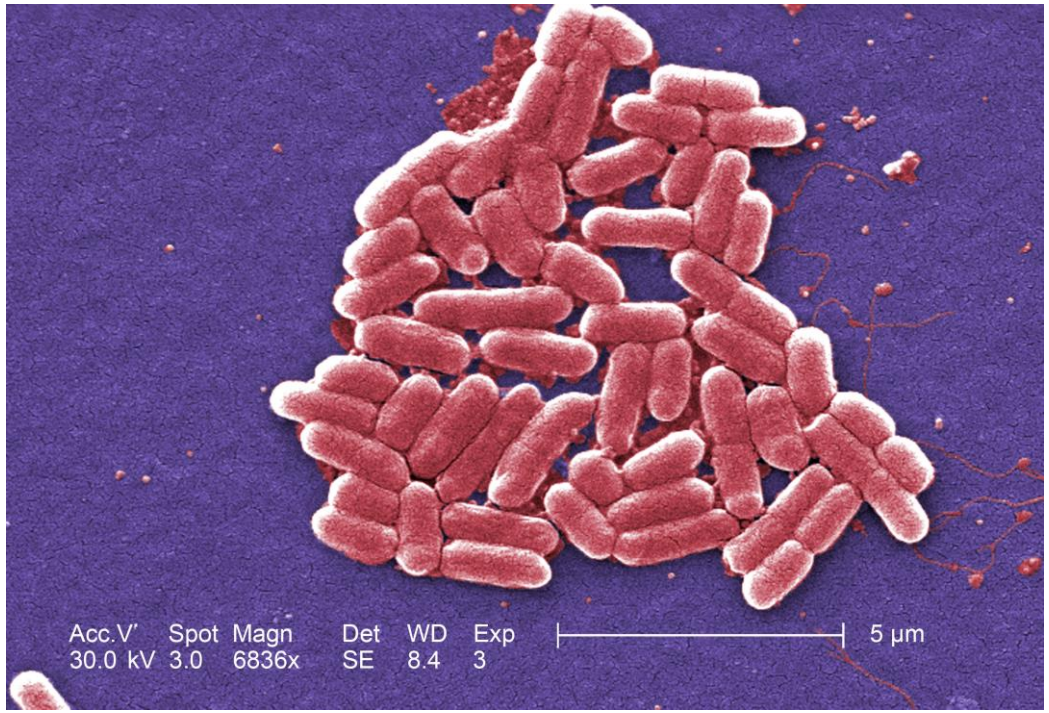
- Non-sporeforming, microaerophilic, Gram-negative rod
- Susceptible to drying, heating, freezing, disinfectants and pH
- ~76 deaths per year in the US attributable to *Campylobacter*

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

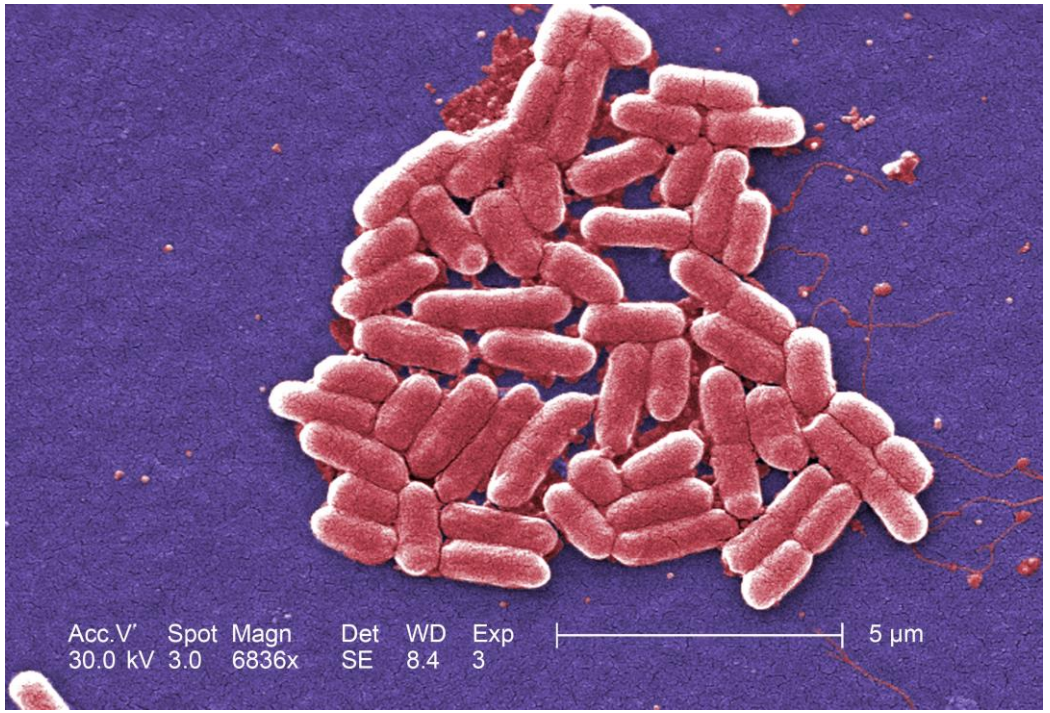
Escherichia coli

- 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 – Enterohemorhagic *E. coli*



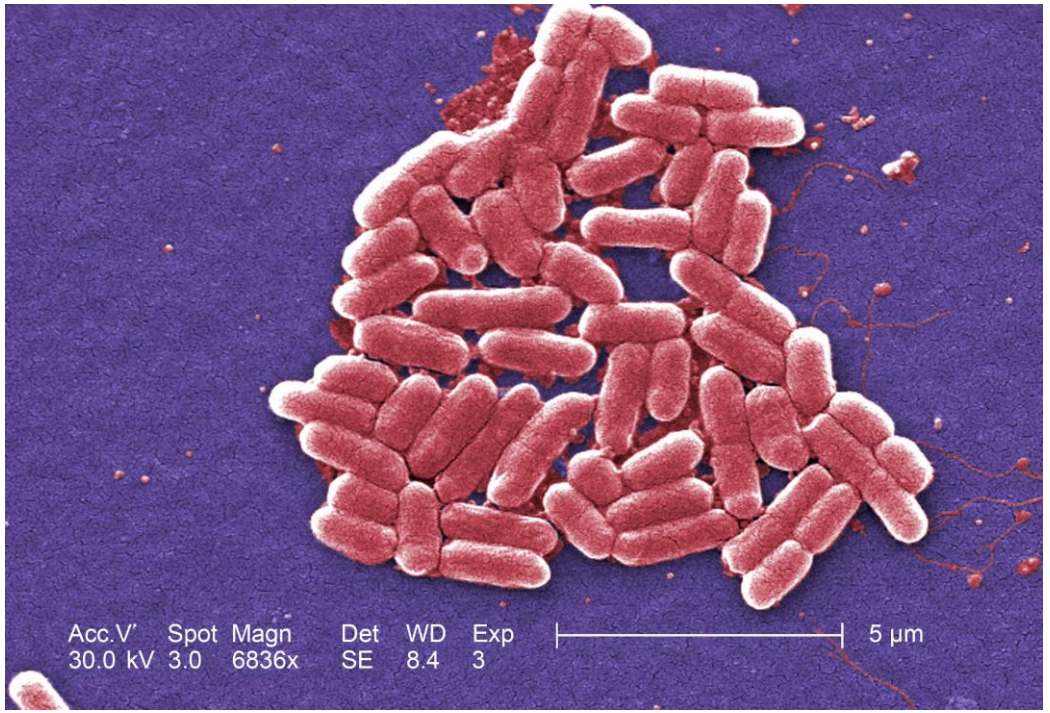
Shiga toxin producing *Escherichia coli* (STEC)

- Gram-negative, rod shaped bacteria
- Notable member – *E. coli* O157:H7
- Infective dose estimated to be low – 10 to 100 cells



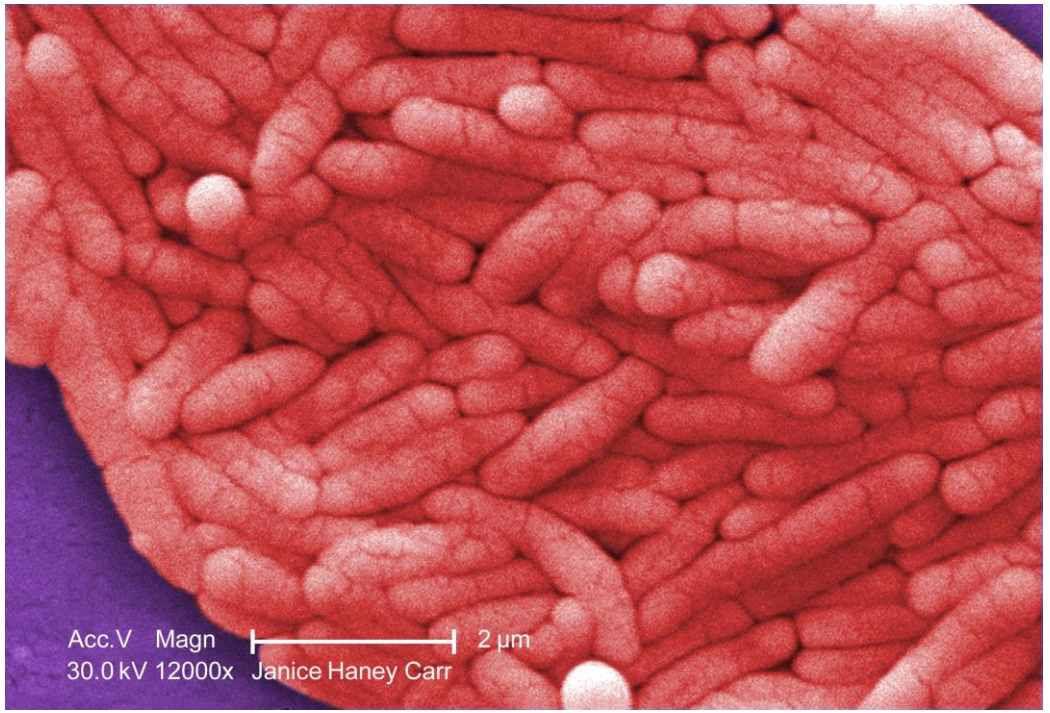
Shiga toxin producing *Escherichia coli* (STEC)

- 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



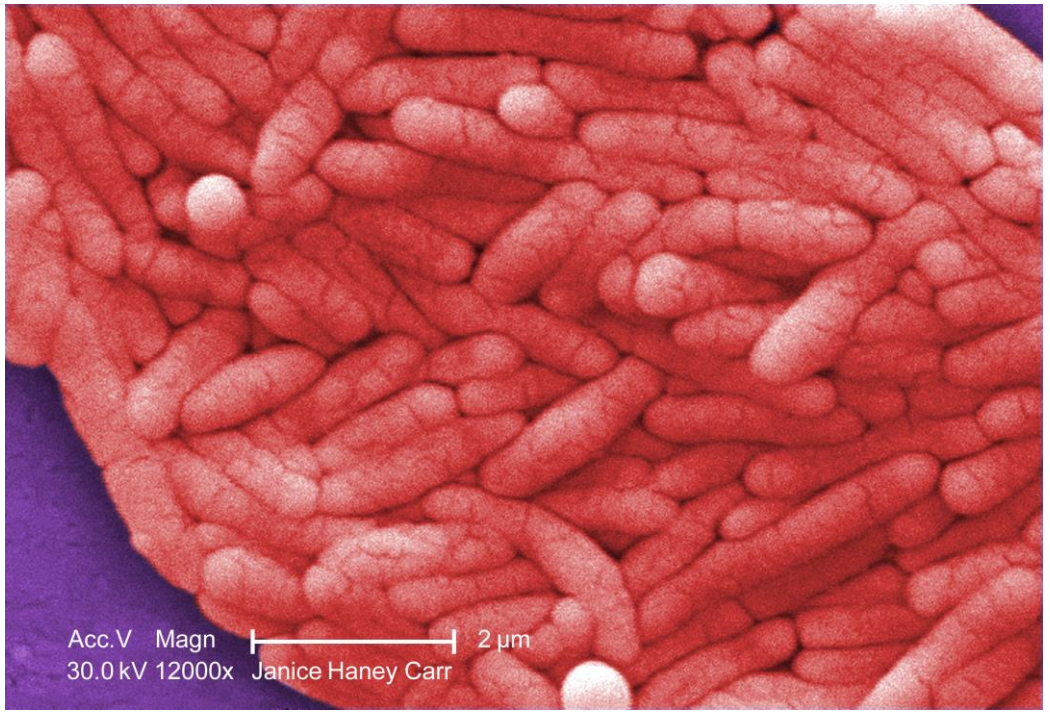
Salmonella

- 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



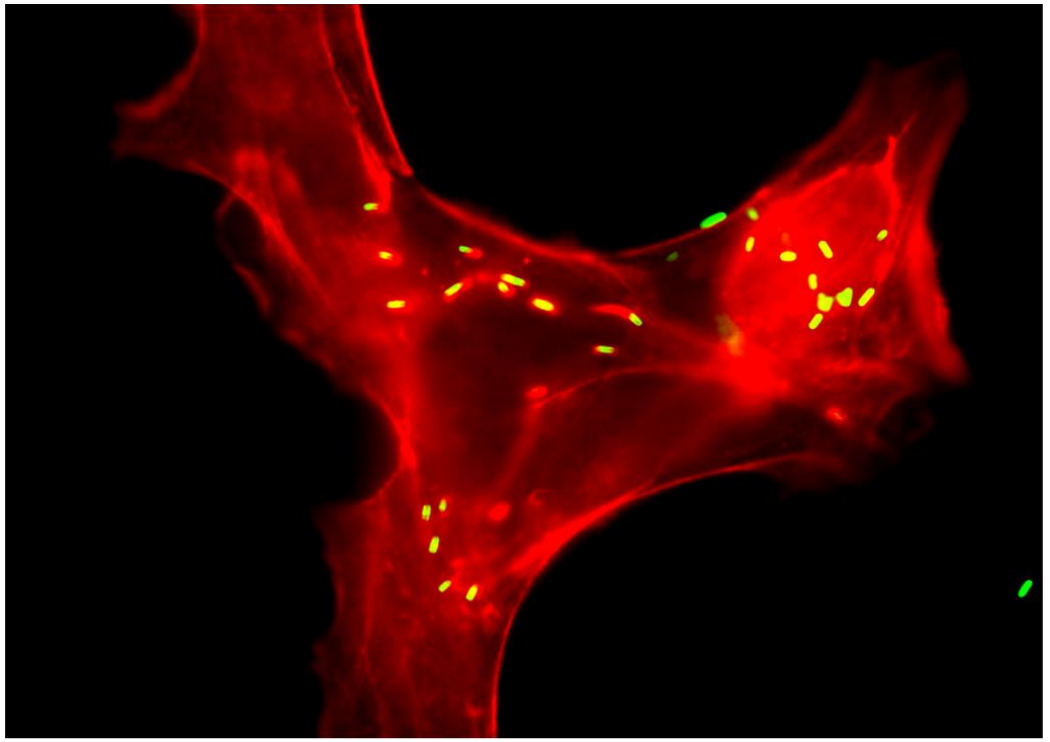
Salmonella

- 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



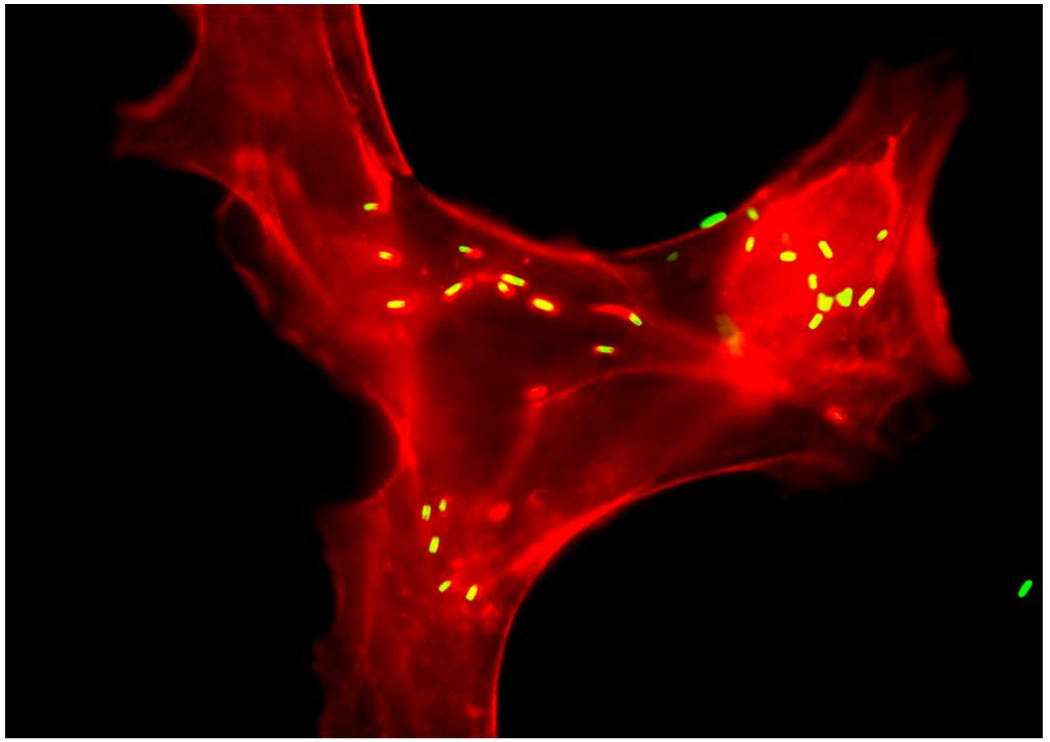
Listeria monocytogenes

- 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




Environment
• Listeria monocytogenes
Feces
• Campylobacter
• E. coli
• Salmonella

Prevalence of pathogenic bacteria in raw milk

TABLE 1. SURVEYS ON THE ISOLATION OF *CAMPYLOBACTER JEJUNI* AND SHIGA TOXIN–PRODUCING *ESCHERICHIA COLI* FROM BULK TANK MILK

Foodborne pathogen	*Isolation rate (%)*	*Reference*
Campylobacter jejuni	0.9	Doyle and Roman (1982)
	1.5	Lovett et al. (1983)
	0.4	McManus and Lanier (1987)
	1.2	Davidson et al. (1989)
	12.3	Rohrbach et al. (1992)
	0.5	Steele et al. (1997)
	9.2	Jayarao and Henning (2001)
Shiga toxin–producing *Escherichia coli*	0.9	Steele et al. (1997)
	3.8	Jayarao and Henning (2001)
	0.8	Murinda et al. (2002b)

Oliver at al., 2005

TABLE 2. SURVEYS ON THE ISOLATION OF *LISTERIA MONOCYTOGENES* AND *SALMONELLA* SPP. FROM BULK TANK MILK

Foodborne pathogen	*Isolation rate (%)*	*Reference*
Listeria monocytogenes	4.2	Lovett et al. (1987)
	1.3	Farber et al. (1988)
	5.4	Slade et al. (1988)
	4.0	Liewen and Plautz (1988)
	1.6	Davidson et al. (1989)
	1.9	Fedio and Jackson (1990)
	4.1	Rohrbach et al. (1992)
	2.7	Steele et al. (1997)
	4.6	Jayarao and Henning (2001)
	12.6	Hassan et al. (2000)
	1.0	Waak et al. (2002)
	4.9 to 7.0	Muraoka et al. (2003)
	6.5	Van Kessel et al. (2004)
Salmonella spp.	4.7	McManus and Lanier (1987)
	2.9	McEwen et al. (1988)
	8.9	Rohrbach et al. (1992)
	0.2	Steele et al. (1997)
	6.1	Jayarao and Henning (2001)
	1.5	Hassan et al. (2000)
	2.2	Murinda et al. (2002a)
	2.6	Van Kessel et al. (2004)

Oliver at al., 2005

Associations between raw milk quality and incidence of pathogens

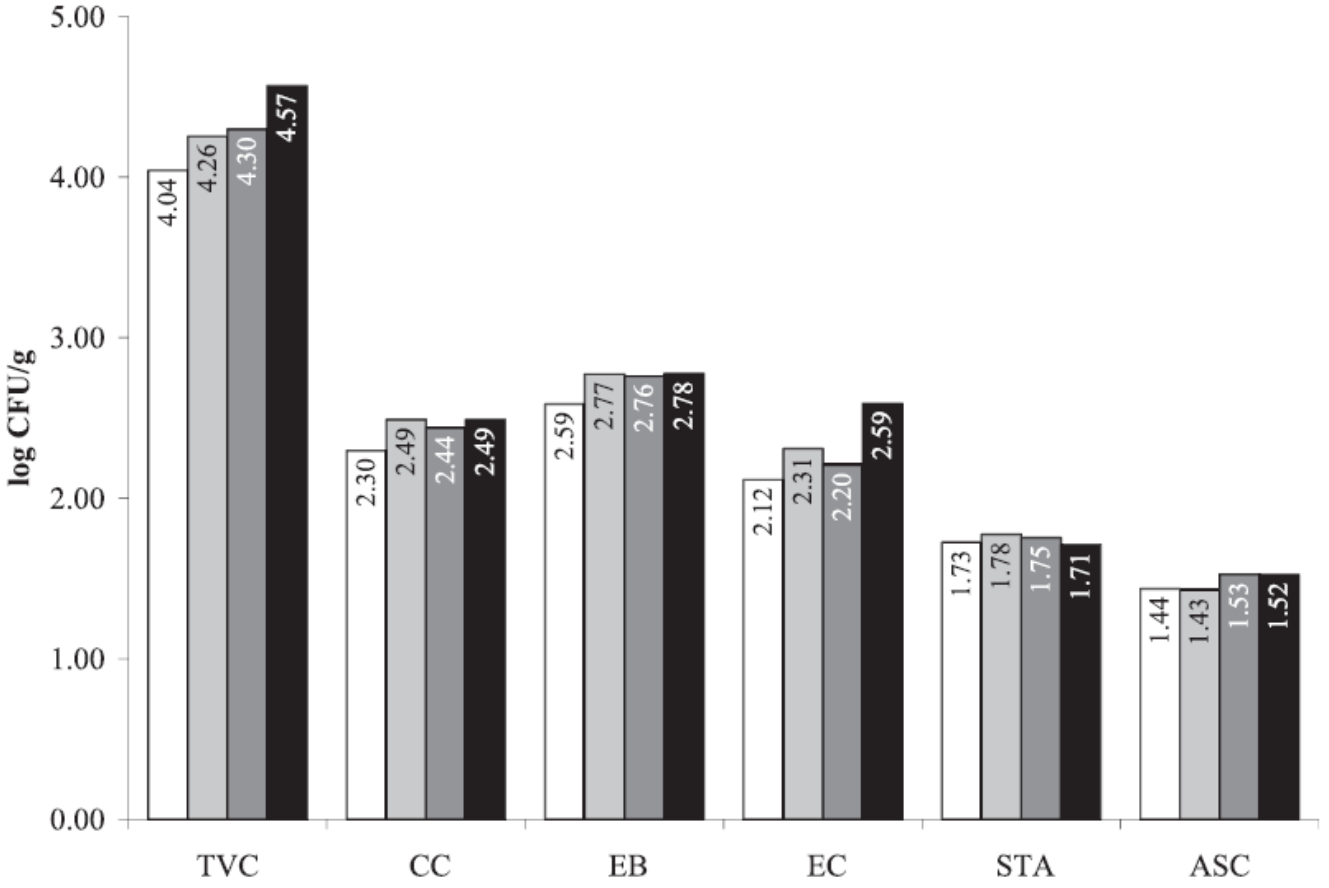


FIGURE 4. *Average log values for each quality indicating organism in samples containing zero (□), one (▒), two (▓), or three (■) pathogens.*

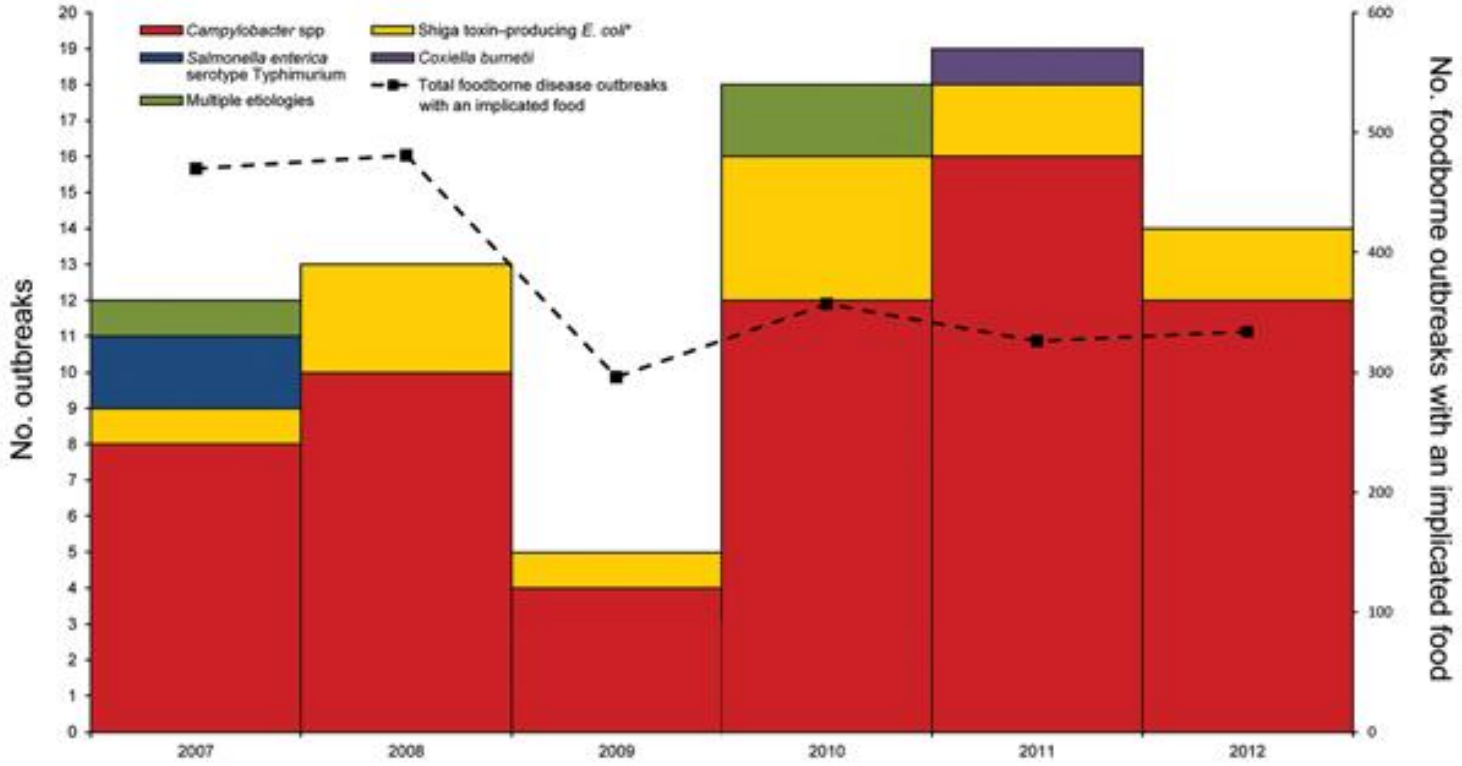
Jackson et al., 2012

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

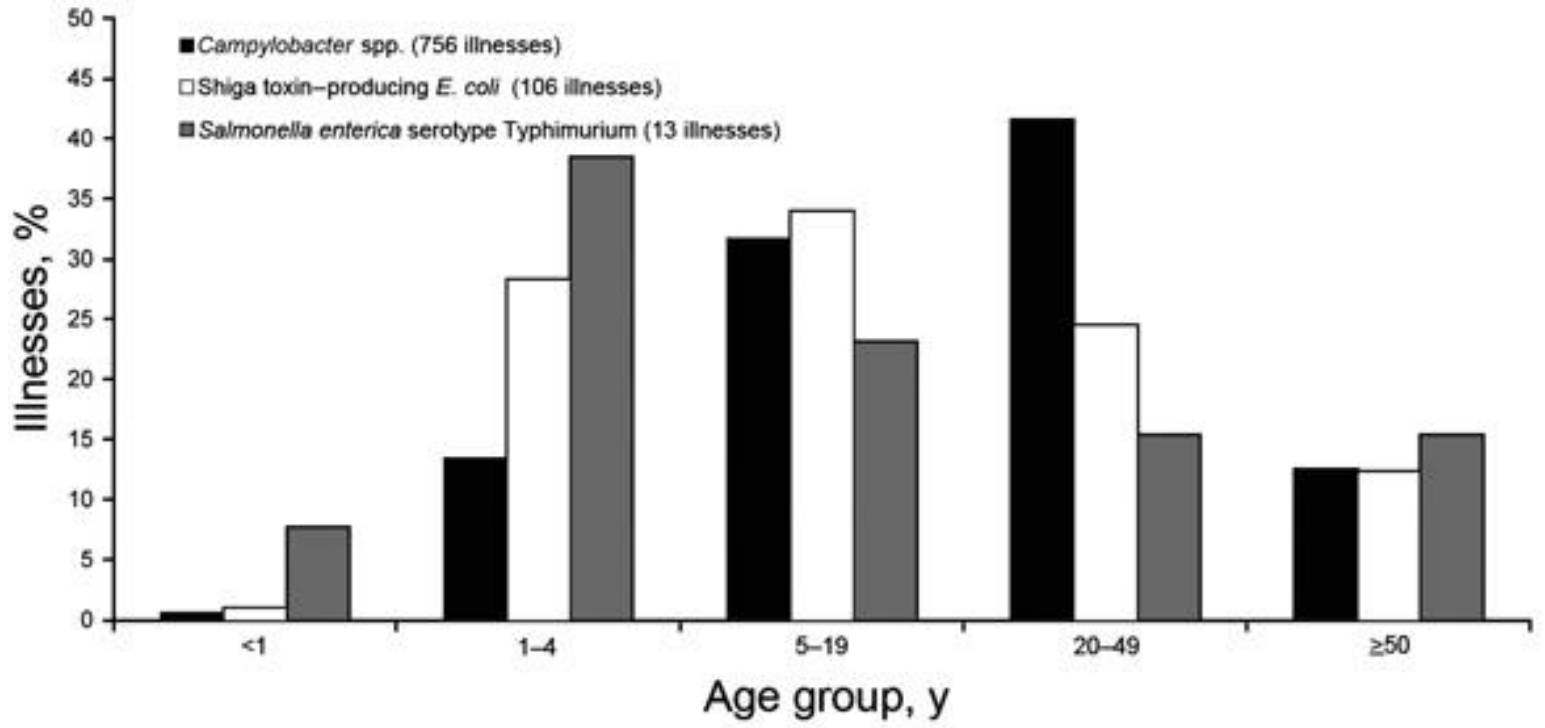
Foodborne disease associated with raw milk consumption, cont.

- 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.

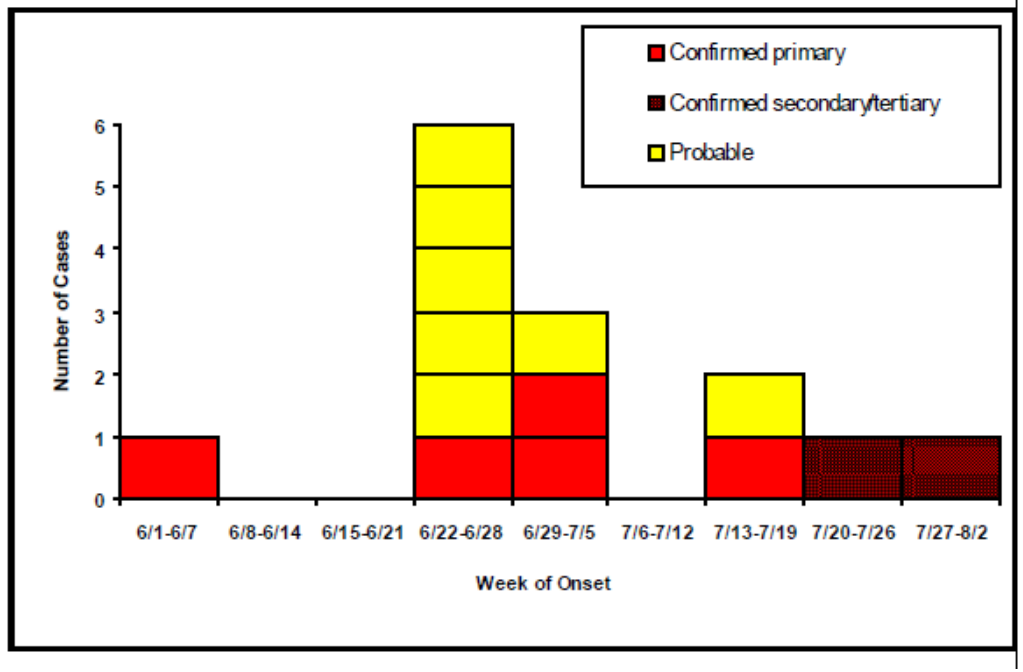


Mungai et al., 2015

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

Figure 1. Number of Confirmed and Probable Cases of *E. coli* O157 Infection by Week of Illness Onset, Connecticut, 2008



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

	Cases		Controls				
Exposure	**No.**	**(%)**	**No.**	**(%)**	**OR**	**95% CI**	**p-value**
Raw milk	**5/5**	**(100)**	**0/10**	**(0)**	**231.0***	**(4.0 - 13304.1)**	**<0.0001**
Raw cheese	2/5	(40)	0/10	(0)	15.0*	(0.6 - 394.1)	0.0952
Ground beef	1/5	(20)	8/9	(89)	0.03	(0.01 - 0.6)	0.0230
Bagged lettuce	1/5	(20)	5/9	(56)	0.2	(0.02 - 2.6)	0.3007
Whole head lettuce	2/4	(50)	2/9	(22)	3.5	(0.3 - 43.2)	0.5301
Spinach	1/3	(33)	2/9	(22)	1.8	(0.9 - 30.8)	1.0000
Tomatoes	3/5	(60)	5/9	(56)	1.2	(0.1 - 11.1)	1.0000
Jalapenos	0/4	(0)	0/9	(0)	n/a		
Swimming	3/5	(60)	8/9	(89)	0.2	(0.01 - 2.9)	0.5055
Visit farm	2/5	(40)	0/9	(0)	13.6*	(0.5 - 358.6)	0.1099
Contact w/ farm animals	1/5	(20)	0/8	(0)	5.7*	(0.2 - 169.5)	0.3846

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

HEALTH

Making Their Case for Raw Milk

George Ruhe for The New York Times

A MATTER OF TASTE The raw-milk cooler at Town Farm Dairy in Simsbury, Connecticut is one of a handful of states that permit the sale of raw milk wherever milk is sold.

By JAN ELLEN SPIEGEL
Published: February 24, 2008

TWITTER

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***