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**Review**

# Food Safety Hazards Associated with Consumption of Raw Milk

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**Abstract**

An increasing number of people are consuming raw unpasteurized milk. Enhanced nutritional qualities, taste, and health benefits have all been advocated as reasons for increased interest in raw milk consumption. However, science-based data to substantiate these claims are limited. People continue to consume raw milk even though numerous epidemiological studies have shown clearly that raw milk can be contaminated by a variety of pathogens, some of which are associated with human illness and disease. Several documented milkborne disease outbreaks occurred from 2000–2008 and were traced back to consumption of raw unpasteurized milk. Numerous people were found to have infections, some were hospitalized, and a few died. In the majority of these outbreaks, the organism associated with the milkborne outbreak was isolated from the implicated product(s) or from subsequent products made at the suspected dairy or source. In contrast, fewer milkborne disease outbreaks were associated with consumption of pasteurized milk during this same time period. Twenty nine states allow the sale of raw milk by some means. Direct purchase, cow-share or leasing programs, and the sale of raw milk as pet food have been used as means for consumers to obtain raw milk. Where raw milk is offered for sale, strategies to reduce risks associated with raw milk and products made from raw milk are needed. Developing uniform regulations including microbial standards for raw milk to be sold for human consumption, labeling of raw milk, improving sanitation during milking, and enhancing and targeting educational efforts are potential approaches to this issue. Development of pre- and postharvest control measures to effectively reduce contamination is critical to the control of pathogens in raw milk. One sure way to prevent raw milk–associated foodborne illness is for consumers to refrain from drinking raw milk and from consuming dairy products manufactured using raw milk.

## Introduction

Milk quality continues to be a topic of intense debate in the dairy industry and in the medical and public health communities. Production of maximum quantities of high-quality milk is an important goal of every dairy operation. High-quality milk contains a low number of somatic cells and a low bacteria count, and is free of human pathogens and antibiotic residues (Fig. 1). Several different methods are used to assess milk quality. Some methods such as the somatic cell count (SCC) and standard plate count (SPC) are mandated by the Pasteurized Milk Ordinance (PMO), which is a document that specifies public health and sanitation standards for Grade A milk (Grade "A" Pasteurized Milk Ordinance, 2007 Revision). Other methods, while not mandated, are useful to help diagnose potential on-farm problems/deficiencies associated with high bacterial numbers and poor-quality milk.

The number of somatic cells in milk is used throughout the world as an indicator of milk quality. In the United States, the current regulatory limit for somatic cells in milk defined in the PMO is 750,000/mL (Grade "A" Pasteurized Milk Ordinance, 2007 Revision). There is continuing interest by various advocacy groups to reduce the SCC limit of the PMO to 400,000 cells/mL or less. The scientific literature shows very clearly that a high milk SCC is associated with a higher incidence of antibiotic residues in milk (Ruegg and Tabone, 2000), and the presence of pathogenic organisms and toxins in milk (Oliver *et al.*, 2005). It is clear that, indirectly, milk with a high number of somatic cells is associated with health risks to the consumer, and ultimately results in milk with decreased

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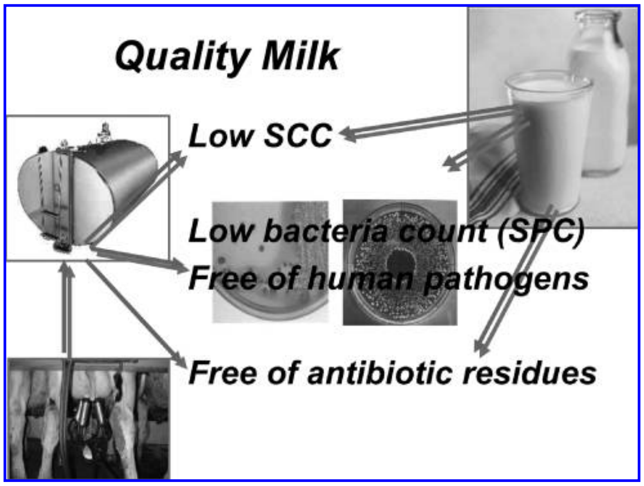


**FIG. 1.** High-quality raw milk produced by dairy cows contains a low somatic cell count (SCC), a low standard plate count (SPC), no human pathogens, and no antibiotic residues.

manufacturing properties and dairy products with reduced shelf-life (Ma *et al.*, 2000).

The SPC is an estimate of the total number of viable aerobic bacteria present in raw milk. This test can also be used to monitor herd health and production sanitation since consistent application of proper milking practices, udder hygiene and good mastitis prevention and control practices should allow dairy producers to routinely produce milk with a low SPC (<5000 colony forming units [cfu] of bacteria/mL). Most farms can produce milk with counts of <10,000 cfu/mL. High bacterial counts (>10,000 cfu/mL) suggest that bacteria are entering milk from a variety of possible sources. The most frequent cause of high SPC is poor cleaning of milking systems (Hayes *et al.*, 2001; Jayarao *et al.*, 2004). Milk residues on equipment surfaces provide nutrients for growth and multiplication of bacteria that contaminate milk of subsequent milkings. Cows with mastitis (streptococcal and coliform), soiled cows, unclean milking practices, and failure to cool milk rapidly to <4.4°C can also contribute to high SPCs in raw milk (Hayes *et al.*, 2001; Jayarao *et al.*, 2004; Zadoks *et al.*, 2004). Federal regulations defined in the PMO mandate that the milk SPC should not exceed 100,000 cfu/mL (Grade "A" Pasteurized Milk Ordinance, 2007 Revision). However, most segments of the dairy industry feel that more stringent standards will result in higher quality milk. Although it is impossible to eliminate all sources of bacterial contamination of milk, milk from clean, healthy cows that has been properly collected generally has an SPC <1000 cfu/mL.

High-quality milk should also be free of foodborne pathogens. Several surveys have detected foodborne pathogens in bulk tank milk, including *Campylobacter jejuni*, Shiga-toxin-producing *Escherichia coli* (STEC), *Listeria monocytogenes*, *Salmonella* spp., enterotoxigenic *Staphylococcus aureus*, *Yersinia enterocolitica*, *Mycobacterium bovis*, *Brucella* spp., *Coxiella burnetti*, and others (see review by Oliver *et al.*, 2005). Some of these foodborne pathogens have habitats in food-producing animals, such as skin and gastrointestinal tracts, and in the farm environment (see reviews by Oliver *et al.*, 2005, 2009). These pathogens can enter meat and milk products during slaughter, at milking, or contaminate raw vegetables when soil is fertilized with improperly (or not) composted animal manure (McEwen and Fedorka-Cray, 2002).

Approximately 35–60% of farm families and farm employees consume raw milk (Rohrbach *et al.*, 1992; Jayarao and Henning, 2001; Jayarao *et al.*, 2006) probably because it is a traditional practice and it is less expensive to take milk from the bulk tank than buying pasteurized retail milk (Hegarty *et al.*, 2002). Consumption of raw milk by the urban community is more difficult to estimate. Headrick *et al.* (1998), in a study on the epidemiology of raw milk–associated foodborne disease outbreaks reported in the United States from 1973 to 1992, indicated that raw milk accounted for <1% of the total milk sold in states that permit the sale of raw milk. Headrick *et al.* (1997) conducted another study to determine the prevalence of raw milk consumption in California, which at the time of the study was the largest producer of certified raw milk in the United States. Among 3999 survey respondents, 3.2% reported drinking raw milk in the previous year. Raw milk drinkers were more likely than nondrinkers to be younger than age 40, male, and Hispanic and to have less than a high school education. A more recent estimate reported that 3.5% of people who participated in a survey conducted in 2002 consumed unpasteurized milk within a 7-day period before the survey was taken (Centers for Disease Control and Prevention [CDC], 2004). Thus, it appears that an increasing number of people are drinking raw unpasteurized milk and/or consuming products made from raw unpasteurized milk despite the well-documented hazards associated with this practice. Increased interest in raw milk consumption is likely associated with some people's desire to purchase locally and consume natural, unprocessed foods as well as the promotion of raw milk consumption by certain groups.

The increased demand for raw milk has intensified the raw milk debate. Much information is available on the Internet on this issue (Westin A. Price Foundation, www.westonprice.org; Marler Blog, www.marlerblog.com). Groups that support the consumption of raw milk such as the Westin A. Price Foundation are vocal and very passionate about this issue. Enhanced nutritional qualities, taste, and health benefits have all been advocated as reasons for increased interest in raw milk consumption. Science-based data to substantiate these claims are limited or lacking. The pasteurized versus unpasteurized milk debate is certainly not new. About 25 years ago, Potter *et al.* (1984) stated that "Meaningful differences in nutritional value between pasteurized and unpasteurized milk have not been demonstrated, and other purported benefits of raw milk consumption have not been substantiated. Conversely, the role of unpasteurized dairy products in the transmission of infectious diseases has been established repeatedly. To effectively counsel patients attracted by the health claims made for raw milk, practicing physicians must understand both the rationale used by proponents of raw milk and the magnitude of the risk involved in drinking raw milk." Those opposed to the consumption of raw milk argue that any potential benefits associated with raw milk are negated by potential health hazards due to possible contamination with pathogenic bacteria, so the debate continues.

The purpose of this communication is to review the literature on food safety hazards associated with the consumption of raw milk. The prevalence of foodborne pathogens in raw milk, raw milkborne disease outbreaks that have occurred

Table 1. Prevalence of Foodborne Pathogens Isolated from Bulk Tank Milk and Milk Filters

| *Pathogen* | *Prevalence rates (%)*[a] | *Reference* |
|---|---|---|
| *Listeria monocytogenes* | 12.6 (filters) | Hassan *et al.* (2000) |
| | 2.8 | Jayarao *et al.* (2006) |
| | 4.6 | Jayarao and Henning (2001) |
| | 6.5 | Van Kessel *et al.* (2004) |
| | 4.9 and 7.0[b] | Muraoka *et al.* (2003) |
| | 4.8 | D'Amico *et al.* (2008) |
| *Salmonella* spp. | 6.1 | Jayarao and Henning (2001) |
| | 6.0 | Jayarao *et al.* (2006) |
| | 1.5[c] (filters) | Hassan *et al.* (2000) |
| | 2.2 | Murinda *et al.* (2002a) |
| | 1.1/12.6 (milk/filters) | Warnick *et al.* (2003) |
| | 2.6 | Van Kessel *et al.* (2004) |
| | 2.6/11.8[d] | Karns *et al.* (2005) |
| | 11.0/66.0 (milk/filters) | Van Kessel *et al.* (2008) |
| | 15.0[e] | Houser *et al.* (2008) |
| | 0.0 | D'Amico *et al.* (2008) |
| *Campylobacter jejuni* | 9.2 | Jayarao and Henning (2001) |
| | 2.0 | Jayarao *et al.* (2006) |
| *Yersinia enterocolitica* | 6.1 | Jayarao and Henning (2001) |
| | 1.2 | Jayarao *et al.* (2006) |
| *Escherichia coli* O157:H7 | 0.23 | Karns *et al.* (2007) |
| | 0 | Jayarao and Henning (2001) |
| | 0.75 | Murinda *et al.* (2002b) |
| | 0 | D'Amico *et al.* (2008) |
| Shiga-toxin *E. coli* | 2.4 | Jayarao *et al.* (2006) |
| | 3.8 | Jayarao and Henning (2001) |
| | 3.96 | Karns *et al.* (2007) |
| | 3.5[f] | Cobbold *et al.* (2008) |

[a]Prevalence based on isolation of pathogens from bulk tank milk samples unless otherwise noted.
[b]November and June, respectively.
[c]One of six isolates was *Salmonella* Typhimurium DT104.
[d]Conventional versus real-time polymerase chain reaction method.
[e]Colostrum.
[f]Includes *E. coli* positive for $stx_1$ and/or $stx_2$, and those that in addition had *eae* and *ehx* genes.

since 2000, and the number of states in the United States where the sale of raw milk is legal are described.

## Prevalence of Milkborne Pathogens in Raw Milk in the United States

Prevalence data for milkborne pathogens were obtained from peer-reviewed literature published from January 2000 to January 2009. Prevalence rates for the common pathogens that were isolated from at least 20 states representing diverse geographic areas and agroecological regions of the United States are summarized in Table 1. Oliver *et al.* (2005) recently reviewed the prevalence of pathogens from bulk tank milk and dairy farm environments, specifically, *C. jejuni*, STEC, *L. monocytogenes*, and *Salmonella* species.

*L. monocytogenes* and *Salmonella* spp. were the most commonly reported foodborne pathogens isolated from bulk tank milk (Table 1). Isolation rates for *L. monocytogenes* ranged from 2.8 to 7.0% (Jayarao and Henning, 2001; Muraoka *et al.*, 2003; Van Kessel *et al.*, 2004; Jayarao *et al.*, 2006; D'Amico *et al.*, 2008) and were highest (12.6%) in in-line milk filters (Hassan *et al.*, 2000). *Salmonella* isolation rates ranged from 0 to 11% in normal bulk tank milk (Jayarao and Henning, 2001; Murinda *et al.*, 2002a; Warnick *et al.*, 2003; Van Kessel *et al.*, 2004, 2008; Karns *et al.*, 2005; Jayarao *et al.*, 2006; D'Amico *et al.*, 2008) and 1.5 to 66.0% in in-line milk filters (Hassan *et al.*, 2000; Warnick *et al.*, 2003; Van Kessel *et al.*, 2008), with higher isolation rates (15%) in colostrum samples (Houser *et al.*, 2008). The latter finding indicates that raw colostrum could be a potential health hazard. A strain of *Salmonella* Typhimurium DT104 was isolated from one of six ($n = 404$) *Salmonella*-positive milk filter samples (Hassan *et al.*, 2000). In general, isolation rates of pathogens were higher on in-line milk filter samples than in bulk tank milk. Warnick *et al.* (2003) reported prevalence rates of 1.1% versus 12.6% (bulk tank milk vs. in-line filters), whereas Van Kessel *et al.* (2008) reported higher rates of 11% versus 66%, respectively. From these two reports, evaluation of the microbiological status of in-line milk filters may provide a reasonable reflection of herd contamination status by *Salmonella* (and most likely, other pathogens).

Jayarao and coworkers reported on the occurrence of *C. jejuni* and *Y. enterocolitica* in bulk tank milk (Table 1). Isolation rates for *C. jejuni* were 2.0% (Jayarao *et al.*, 2006) and 9.2% (Jayarao and Henning, 2001). Corresponding prevalence rates for *Y. enterocolitica* were 1.2% (Jayarao *et al.*, 2006) and 6.1% (Jayarao and Henning, 2001). Prevalence of STEC in bulk tank milk was investigated in a number of studies. A low prevalence rate of 0–0.75% (Table 1) was established (Jayarao and Henning, 2001; Murinda *et al.*, 2002b; Karns *et al.*, 2007; D'Amico *et al.*, 2008). Further, other researchers have indicated low prevalence rates (2.4–3.96%) for non-O157 STEC in bulk tank milk (Jayarao and Henning, 2001; Jayarao *et al.*, 2006; Karns *et al.*, 2007; Cobbold *et al.*, 2008).

Hassan *et al.* (2000) conducted a cross-sectional study to determine the prevalence of *L. monocytogenes* and *Salmonella* spp. in dairy herds (Table 1). In-line milk filters were collected from each farm ($n = 404$) and were evaluated for the presence of the two pathogens. *L. monocytogenes* was isolated from 51 (12.6%) of milk filters. Region-specific differences in prevalence rates of farms with positive milk filters for this pathogen were noted. *Salmonella* spp. were isolated from 6 (1.5%) milk filters. One of the six isolates was confirmed as *Salmonella enterica* serotype Typhimurium DT 104. The prevalence of *L. monocytogenes* in bulk milk from three Pacific Northwest states was assessed for 474 herds (Muraoka *et al.*, 2003). The respective isolation rates for samples collected in November 2000 and June 2001 were 4.9% and 7.0%. Isolates were subtyped serologically and by pulsed-field gel electrophoresis (PFGE). Forty-nine of the 55 *Listeria* isolates belonged to serogroup 1/2a, while six belonged to serogroup 4. Isolation rate for *L. monocytogenes* reported by D'Amico *et al.* (2008) was 4.8%, and isolation rate for *Salmonella* and STEC O157 was 0%.

Jayarao and Henning (2001) examined bulk tank milk from 131 dairy herds in eastern South Dakota and western Minnesota for the presence of foodborne pathogens. *L. monocytogenes*, *Salmonella* spp., *C. jejuni*, STEC, and *Y. enterocolitica* were detected in 4.6%, 6.1%, 9.2%, 3.8%, and 6.1% of bulk tank milk samples, respectively. Thirty-five of 131 (26.7%) bulk tank milk samples contained one or more species of pathogenic bacteria. *Salmonella* isolates belonged to group D, B, C and E "O" serogroups. All six isolates of *L. monocytogenes* were identified as O antigen type 1. Four of five isolates of *E. coli* were positive for the Shiga-toxin 2 gene, *stx2*, whereas one strain was positive for the Shiga-toxin 1 gene, *stx1*. None of the bulk tank milk samples were *E. coli* O157:H7 positive. Nongrade A (manufacturing grade) raw milk producers were at a higher risk (odds ratio, 4.98; confidence interval, 1.96–12.22) of having one or more pathogens in their bulk tank milk than Grade A producers. It was observed that 21 of 79 (26.6%) dairy producers who consumed raw milk had one or more pathogenic bacteria in their bulk tank milk. In another study, Jayarao *et al.* (2006) examined bulk tank milk from 248 participating dairy herds for foodborne pathogens. *L. monocytogenes* (2.8%), *Salmonella* (6%), *C. jejuni* (2%), STEC (2.4%), and *Y. enterocolitica* (1.2%) were isolated. *Salmonella* isolates were identified as *S. enterica* serotype Typhimurium ($n = 10$) and *S. enterica* serotype Newport ($n = 5$). Thirty-two of 248 bulk tank milk samples (13%) contained at least one or more pathogens.

Van Kessel *et al.* (2008) isolated *Salmonella* from 11% ($n = 183$) of milk samples and 66% ($n = 152$) of milk filters. When observed over time, the average prevalence of *Salmonella* in milk filters closely paralleled fecal prevalence of *Salmonella* in the herd. In-line filter testing was found to be a more sensitive measure of *Salmonella* prevalence than tests on bulk tank milk. Murinda *et al.* (2002b) conducted a survey to establish the prevalence of *Salmonella* in cull dairy cow fecal samples and bulk tank milk and to determine the proportion of *Salmonella*-positive dairy farms ($n = 30$) in east Tennessee. Six of 268 (2.24%) bulk tank milk samples were *Salmonella* positive. Most isolates were obtained between September and December. *Salmonella* isolates were further characterized using polyvalent somatic O Salmonella antiserum, and biochemical tests and PFGE were used to subtype isolates. Warnick *et al.* (2003) evaluated the effect of sampling frequency on *Salmonella* isolation and compared *Salmonella* isolation and serogroup classification among sample sources on 12 U.S. dairy farms sampled weekly for 7–8 weeks. Three herds per state were enrolled from Michigan, Minnesota, New York, and Wisconsin based upon predefined herd-size criteria. Weekly samples of bulk tank milk, milk filters, and other sample types were collected. A total of 1.1% of bulk tank milk samples ($n = 91$) and 12.6% of in-line milk filters ($n = 87$) were *Salmonella* positive.

Samples of bulk tank milk ($n = 861$) collected from dairies from 21 states and 854 farms across the U.S. as part of the National Animal Health Monitoring System Dairy 2002 survey were tested for prevalence of foodborne pathogens and other parameters (Van Kessel *et al.*, 2004; Karns *et al.*, 2005). *L. monocytogenes*, serotypes 1/2a, 1/2b, 3b, 4b, and 4c, the most common human clinical serotypes, were isolated from 56 (6.5%) samples. Samples were analyzed for the presence of *Salmonella enterica* using real-time polymerase chain reaction (PCR), and 101 of the samples (11.8%) were shown to contain *Salmonella enterica.* In comparison, conventional culture techniques detected the pathogen in only 22 (2.6%) of samples (Karns *et al.*, 2005). Use of conventional PCR that targeted a different gene from *Salmonella enterica* confirmed the presence of the organism in 94 (93.1%) of the real-time PCR-positive samples. Regional differences in *L. monocytogenes* and *Salmonella* prevalence were observed; however, to establish the validity of the observed differences more studies were suggested.

Bulk tank milk samples from the National Animal Health Monitoring Dairy 2002 survey were also analyzed for the presence of several genes encoding virulence factors associated with enterohemorrhagic *E. coli* (EHEC) using real-time and conventional PCR assays (Karns *et al.*, 2007). Samples from 859 farms in 21 states were collected and evaluated. Various combinations of genes associated with STEC and other pathogenic *E. coli* were found. Two samples (0.23%) were *E. coli* O157:H7 positive. Thirty-four *eaeA*-positive samples did not contain detectable gamma-*tir* (an intimin variant) but contained one or both of the *stx* genes, suggesting the presence of non-O157:H7 EHEC strains. These results indicate a low incidence of O157:H7 in bulk tank milk and that a risk from other enteropathogenic and EHEC forms of *E. coli* may be present. A study on the prevalence of *E. coli* O157:H7 was conducted on 30 dairy farms in east Tennessee between May 2000 and April 2001 (Murinda *et al.*, 2002b). The pathogen was isolated from eight of 30 (26.7%) dairy farms at various sampling times. A total of 268 bulk tank milk samples were analyzed. Overall, two of 268 (0.75%) milk samples were *E. coli* O157:H7 positive. Multiplex PCR profiles of *E. coli* O157:H7 isolates indicated the presence of common virulence factors (i.e., Shiga-toxin, enterohemolysin, and intimin) of STEC, suggesting the potential human pathogenicity of the bacterial isolates. PFGE was used to establish relatedness among bacterial isolates. A survey for STEC in raw milk (and other samples) was conducted in the Pacific northwest region of the United States (Cobbold *et al.*, 2008). Prevalence rates based on detection of *stx* were 21% for raw milk samples, which were significantly higher than the STEC isolation rate of 3.5%. *stx1* was the predominant genotype in milk. Seasonal prevalence differences were significant. In addition, STEC-associated virulence markers, that is, *eae* and *ehx*, were detected.

### Mastitis Pathogens in Raw Milk

The percent of bulk tank milk samples that were positive for *S. aureus* (the major pathogen associated with contagious mastitis) was 27.4–37%, whereas, colostrum was associated with higher prevalence rates (42%). Contamination of bulk tank milk and colostrum with coagulase-negative *Staphylococcus* (CNS) spp. and *Streptococcus* spp. has also been reported (Table 2). Khaitsa *et al.* (2000) investigated herd characteristics and management practices associated with bulk tank SCCs in 186 dairy herds in Ohio. *Streptococcus agalactiae* and *Mycoplasma* spp. were not isolated from bulk tank milk samples. *S. aureus* was isolated from 64 of 172 (37%) of herds. Jayarao *et al.* (2004) reported an increase in the frequency of isolation of *S. aureus* and *S. agalactiae*, which significantly associated with increased bulk tank SCCs. Prevalence rates for the isolation of these two contagious mastitis pathogens were 31% and 10%, respectively. *S. aureus* isolation rates reported by D'Amico *et al.* (2008) were slightly lower at 27.4% (Table 2).

*S. aureus* isolated from milk of cows with mastitis were evaluated for the prevalence of sequences of 16 enterotoxin genes, *sea-see* and *seg-seq*, and toxic shock syndrome toxin (*tsst*-1) gene (Srinivasan *et al.*, 2006). Of 78 *S. aureus* isolates examined, 73 (93.6%) were positive for one or more of the enterotoxin genes. Enterotoxin genes *sen* (84.6%), *sem* (71.8%), *sei* (60.3%), and *sed* (52.6%) were found frequently, whereas *seg* (24.4%), *seq* (16.7%), *seo* (12.8%), and *seb* (1.3%) were found at lower frequencies. The *tsst*-1 gene was detected in 20 (25.6%) isolates and was always found in combination with other enterotoxin genes. The majority of *S. aureus* (88.5%) harbored more than one enterotoxin gene in different combinations. Most *S. aureus* strains isolated from milk of cows with mastitis carried the newly described *Staphylococcus* enterotoxin genes *sem*, *sen*, and *sei* along with the classical enterotoxin genes, *sed* and *tsst*-1. The high prevalence of enterotoxin and *tsst*-1 genes in *S. aureus* may be a concern of epidemiological significance to raw milk consumers since *S. aureus* is a common foodborne pathogen isolated from bulk tank milk.

Table 2. Prevalence Rates for Isolation of *Staphylococcus aureus* and Other Mastitis Pathogens from Bulk Tank Milk

| *Pathogen* | *Prevalence rates (%)* | *Reference* |
|---|---|---|
| *S. aureus* | 42[a] | Houser *et al.* (2008) |
| | 31 | Jayarao *et al.* (2004) |
| | 37 | Khaitsa *et al.* (2000) |
| | 27.4 | D'Amico *et al.* (2008) |
| Coagulase-negative *Staphylococcus* spp. | >74[a] | Houser *et al.* (2008) |
| Streptococci | >71[a] | Houser *et al.* (2008) |
| *Streptococcus agalactiae* | 10 | Jayarao *et al.* (2004) |

[a]Colostrum.

Gillespie *et al.* (2009) isolated CNS from 11.4% (1407 of 12,412) of mammary quarter samples obtained from cows in three dairy research herds in 2005. These pathogens likely end up in bulk tank milk. Approximately 27% (383/1407) of CNS were identified to the species level. The dominant CNS species isolated were *Staphylococcus chromogenes* (48%), *Staphylococcus hyicus* (26%), and *Staphylococcus epidermidis* (10%). A majority of the CNS isolates were susceptible to ampicillin, oxacillin, cephalothin, ceftiofur, erythromycin, and pirlimycin (Sawant *et al.*, 2009). The only exception was observed with *S. epidermidis* where some strains exhibited efflux-based resistance to erythromycin encoded by *msr*A and one isolate carried *erm*C encoding ribosomal methylase-based resistance to both erythromycin and pirlimycin. Methicillin-resistant *S. epidermidis* carried low-affinity penicillin-binding protein encoded by *mec*A. Most multi-drug resistant *S. epidermidis* ($\geq$2 resistance genes) were resistant to ampicillin, erythromycin, and methicillin. Based on PFGE typing, multi-drug-resistant *S. epidermidis* were closely related genotypically, and were isolated from different cows on the same farm, suggesting clonal dissemination. Bovine *S. epidermidis* share antimicrobial resistance patterns and virulence determinants of strains observed in human infections (Sawant *et al.*, 2009). Antimicrobial resistance of *S. epidermidis* may be important to those who consume raw milk because this organism is isolated frequently from bulk tank milk. In addition, the average milk SCC (5.32 $\log_{10}$/mL) for cows where CNS were the only bacteria isolated was significantly higher than for cows with quarter milk samples that were CNS negative (4.90 $\log_{10}$/mL).

Bovine colostrum has gained popularity as a human food because it is an excellent source of bioactive proteins, which have been claimed to inhibit viral and bacterial pathogens, improve gastrointestinal health, and enhance body condition (Houser *et al.*, 2008). In a study that was conducted to determine bacteriological quality and occurrence of *S. aureus*, *S. agalactiae*, CNS, streptococci, and other parameters (Houser *et al.*, 2008), colostrum was associated with high contamination rates with milkborne pathogens, that is, *S. aureus* (42%), CNS (>74%), and *Streptococcus* spp. (>71%).

### Contamination of Non-bovine Milk Samples by Foodborne Pathogens

With regard to carriage of foodborne pathogens, alternative sources of raw milk for consumers in the United States, for example, goat or sheep, present similar risks as bovine milk. Abou-Eleinin *et al.* (2000) isolated *L. monocytogenes* from 17% of goat bulk milk samples that were tested ($n = 450$). The authors also noted that the method employed for microbiological detection could greatly influence the prevalence rate. For example, a modified U.S. Department of Agriculture–Food Safety and Inspection Service (FSIS) method yielded more *Listeria*-positive samples than a U.S. Department of Agriculture method, 77.1% versus 51.4%. D'Amico *et al.* (2008) isolated *E. coli* O157:H7 from one goat milk sample (prevalence rate, 0.75%; $n = 49$), where milk samples from cows ($n = 62$) and sheep ($n = 22$) were negative for the pathogen.

### Outbreaks of Foodborne Illnesses Associated with Dairy Products

Raw milk has long been recognized as a vehicle for the transmission of a wide variety of microbial pathogens.

Approximately 29 outbreaks of milkborne disease were reported each year in the United States between 1880 and 1907 (Chin, 1982). Milkborne disease outbreaks caused approximately 25% of all reported disease outbreaks from contaminated food and water in 1938; since then milkborne disease outbreaks decreased significantly (Grade "A" Pasteurized Milk Ordinance, 2007 Revision). From 1973 to 1992, 46 milkborne disease outbreaks, an average of 2.4/year, were reported (Headrick *et al.*, 1998). Between 1993 and 2006, 68 outbreaks (average of 5.2/year) associated with unpasteurized milk or milk products made from unpasteurized milk were reported (CDC, 2008d).

In recent years, bacteria from four genera, *Campylobacter* spp., EHEC, *Salmonella* spp., and *L. monocytogenes*, are the organisms that have been associated most frequently with foodborne illness outbreaks (Headrick *et al.*, 1998; LeJeune and Rajala-Schultz, 2009; Yilmaz *et al.*, 2009). Documented outbreaks associated with raw milk consumption that occurred between 2000 and 2008 are summarized in Table 3. In all of the outbreaks listed, raw milk or raw milk products were implicated initially by epidemiological evidence. In the majority of the outbreaks listed, the organism associated with the outbreak was isolated from the implicated product(s) or from subsequent products made at the suspected dairy or source. For many of the cases, strains that had been isolated from patients and from raw milk products or from environmental samples were indistinguishable by PFGE, providing evidence of a causal association between the producer/processor, products, and illnesses. From the 12 outbreaks, 435 persons were found to have infections, with over 60 people hospitalized and five deaths (all stillbirths due to listeriosis). Corresponding outbreaks associated with pasteurized milk product consumption that occurred between 2000 and 2008 are provided in Table 4. Pasteurization is the process where milk is heated for a short time to destroy pathogens that may be present in raw milk. Two outbreaks were documented during this period: one involved *L. monocytogenes*; the other, *Salmonella* Typhimurium. Postpasteurization contamination was implicated in both of these outbreaks although the specific mode of contamination was not identified. Lower morbidity and mortality associated with pasteurized milk attest to the value of pasteurizing raw milk.

Additional information on milk- and cheese-associated outbreaks reported between 2000 and 2006 (Table 5) was obtained from CDC line listings (CDC, 2008d) and a searchable database maintained by the Center for Science in the Public Interest (CSPI, 2008). The CDC listings reflect a compilation of all food-related illness outbreaks that were reported to the CDC by state health agencies or that were investigated by CDC. The CSPI data are based on CDC listings as well as on additional data obtained from published scientific papers, federal government and state health department reports, and general media articles that were verified by public health officials (Smith DeWaal *et al.*, 2006). The available information included 40 outbreaks in which raw milk was implicated (639 reported ill), 4 outbreaks where pasteurized milk was implicated (454 reported ill), 10 outbreaks where raw milk cheese was implicated (262 reported ill), 1 outbreak associated with cheese made from pasteurized milk (3 reported ill), and 6 outbreaks involving cheese not specified as raw or pasteurized (75 reported ill). *Campylobacter* was the most common causative agent associated with raw milk product consumption, followed by EHEC. *L. monocytogenes* was implicated in consumption of cheese made from raw milk (Queso fresco) in three reported outbreaks (two in Texas and one in N. Carolina). Illnesses caused by *Brucella* spp. were also reported in three separate outbreaks in which raw milk and homemade and imported cheeses were implicated. *Shigella* was the cause of one outbreak in California with two reported illnesses. In the New York City area, 35 cases of tuberculosis caused by *M. bovis* were reported, where consumption of fresh cheese illegally imported from Mexico was implicated as the possible cause in a large percentage of the cases (CDC, 2005). Similar cases suspected to be associated with illegally imported cheese were also reported in California.

Outbreak summaries described in Tables 3–5 provide an overview of illnesses associated with dairy product consumption in the United States since 2000. However, these data should be interpreted with caution, as states vary in their reporting frequencies or consistencies. All outbreaks listed in Tables 3 and 4 that occurred between 2000 and 2006 appeared in the CDC/CSPI data summaries used to create Table 5 with the exception of the 2000 *Salmonella* outbreak that involved pasteurized milk, as reported by Olsen *et al.* (2004). In three raw milk–associated outbreaks, the number of reported cases in the CDC/CSPI data summaries differed from the corresponding published reports cited in Table 3, which may be due to further interpretation of epidemiological data after the outbreak was reported to CDC and entered into the line listing. The discrepancies include the 2001 Connecticut *Salmonella* cheese outbreak, which had 26 cases in the published report (McCarthy *et al.*, 2002) and 15 in the CSPI's data base; the 2002 Ohio *Salmonella* raw milk outbreak, which had 62 in the published report (CDC, 2003) and 107 in the CDC line listing; and the 2006 Illinois *Salmonella* cheese outbreak, which had 85 in the published report (CDC, 2008b) and 96 in the CDC listing. Specific details were sparse for several of the outbreaks in the CDC listings. In addition, a major *Campylobacter* outbreak associated with pasteurized milk that occurred in May 2006 in the California prison system (personal communication with M. Jay-Russell, 12-10-08; Jay *et al.*, 2007), where over 1600 became ill, was not listed in either database.

## Raw Milk Sales Regulations in the United States

Currently, it is a violation of federal law to sell raw milk packaged for consumer use across state lines. However, intrastate sale of raw milk is legal in many states. According to results from a recent survey conducted by the National Association of State Departments of Agriculture (NASDA, 2008), 29 states allow the sale of raw milk by some means (Table 6). Seven of these states restrict raw milk sales in some manner, including sale of only raw goat milk, or of prescription goat milk. Limitations are also based on farm size or on sales volume (incidental sales only are allowed). Of the states where raw milk sales are legal in some form, 17 states allow sales on the farm only, while 13 allow retail sales; Oregon allows limited cow milk sales on the farm only, but allows retail sale of raw goat milk. Cow-share or leasing programs have been used as a means for consumers to obtain raw milk by owning a share of a cow or the herd, thus allowing the shareholder to "drink raw milk from their own cow." This strategy is specifically allowed in some states but has also been used in other

Table 3. Summary of Foodborne Illness Outbreaks Associated with Raw Milk and Raw Milk Products from Available Epidemiological Reports from 2000 to 2008

| *Year* | *Organism* | *State/vehicle* | *Outbreak details*[a] | *Reference* |
|---|---|---|---|---|
| 2008 | *Campylobacter* spp. | California/raw milk from a cow-leasing program | 16 cases, age: 4–70 years<br>4 cases CC for *Campylobacter*; 3/4 drank raw milk, other was employee<br>2 hospitalized, one with form of Guillain–Barré Syndrome<br>15/16 consumed raw milk from a cow-leasing program; other was employee<br>Milk from patients home positive for *C. jejuni* DNA after 6 wks refrig<br>Cow-lease programs were allowed, currently under review | CDPH (2008) |
| 2007 | *C. jejuni* | Kansas/raw milk from licensed dairy | 25 cases, age: 1–46 years<br>7 cases CC, 18 probable<br>Occurred over several months 16/28 persons who consumed raw milk at a gathering became ill<br>Milk samples from the implicated dairy were not tested | KDHE (2007b) |
| 2007 | *Salmonella* Typhimurium | Pennsylvania/raw milk from licensed dealer before and after suspension and cheese made illegally from dealers milk | 29 cases, age: 5 months–76 years; 16/29 were <7 years<br>29 cases CC, identical PFGE patterns<br>2 hospitalized<br>Three case clusters (periods):<br>(a) 15 cases (2/3–3/5); raw milk was implicated; permit suspended, but reinstated<br>(b) 3 cases (3/19–3/22); raw milk and cheese made from the raw milk were implicated; permit suspended<br>(c) 11 cases (June/July); raw milk was implicated; permit revoked<br>Exposure source not identified in 7 cases<br>Outbreak strain and isolates from implicated raw milk samples had same PFGE pattern; pathogens were not isolated from the cheese<br>Initial raw milk sales were legal; selling raw milk for and manufacture of raw milk cheese were not legal | CDC (2007b) |
| 2007 | *C. jejuni* | Kansas/cheese made from raw milk prepared and consumed at a community event | 68 cases, age: 1–75 years<br>4 cases CC for *C. jejuni*<br>2 hospitalized<br>Case defined based on symptoms and presence at event; consuming cheese was associated statistically with illness<br>Campylobacter was not isolated from the cheese or raw milk from the dairy | KDHE (2007a) |

*(continued)*

Table 3. (Continued)

| *Year* | *Organism* | *State/vehicle* | *Outbreak details*[a] | *Reference* |
|---|---|---|---|---|
| 2006 2007 | *Salmonella* Newport | Illinois/Latin-style aged cheese made in unlicensed operation | 85 cases, age: 9 days–85 years, mostly Hispanic<br>85 CC, identical PFGE patterns<br>36 hospitalized<br>Improperly labeled Cotija cheese and grocery store A suspected, but no statistical association found<br>Outbreak strain was isolated from a Cotija cheese sample from store A<br>Outbreak strain was isolated from raw milk from farm supplying store A<br>Raw milk sale for cheese manufacture and the cheese were not legal | CDC (2008b) |
| 2006 | *E. coli* O157:H7 | California/raw milk from certified supplier | 6 cases, age: 6–18 years<br>5 CC, identical PFGE patterns<br>1 Non-CC, HUS<br>3 hospitalized<br>5/6 drank raw milk or colostrum from implicated dairy; other purchased raw milk from implicated dairy<br>Outbreak strain was not found in milk products or farm environment; non-outbreak strains isolated from cows<br>Sale of raw milk legal; colostrum sold as "dietary supplement" | CDC (2008a) |
| 2005 | *E. coli* O157:H7 | Washington and Oregon/raw milk from non-licensed farm | 18 cases, age: 1–47 years<br>8 cases CC; 7/8 identical PFGE<br>5 hospitalized, 4 with HUS<br>Outbreak strain isolated from raw milk and environmental samples<br>140 reported consuming raw milk during outbreak period; illness risk increased with amount consumed<br>Raw milk was sold through cow leasing program, but farm was not licensed | CDC (2007a) |
| 2002 2003 | *Salmonella* Typhimurium | Multi State (IL, IN, OH, TN)/raw milk and raw milk milk-shakes sold by OH's only licensed facility | 62 cases, age: 1–70 years<br>62 CC, identical PFGE patterns and epidemiologic link to implicated dairy<br>Outbreak strain isolated from milk, cream and butter samples<br>Environmental and cow samples were negative for *Salmonella* Typhimurium<br>4 barn workers involved in milk bottling had asymptomatic infections<br>Raw milk sales from dairy were legal based on a grandfathered OH law; the dairy voluntarily relinquished its license after the outbreak | CDC (2003) |
| 2002 | *C. jejuni* | Utah/raw milk served at a sporting event dinner | 13 cases, age: 11–50 years<br>5/6 cases tested CC<br>6 sought medical attention; none were hospitalized<br>All 13 drank raw milk; 2 others drank raw milk but did not become ill<br>5 others attending did not drink raw milk and did not become ill<br>Raw milk statistically associated with illness<br>Milk was not available for testing and no testing was done on the farm<br>Raw milk was donated by the farm and did not fall under UT regulation | Peterson (2003) |

*(continued)*

TABLE 3. (CONTINUED)

| *Year* | *Organism* | *State/vehicle* | *Outbreak details*[a] | *Reference* |
|---|---|---|---|---|
| 2001 | *Salmonella* Newport; multi-drug resistant (MDR-SN) | Connecticut/fresh cheese made from heated milk, not legally pasteurized | 26 cases, age: 15–88 years<br>26 cases CC for MDR-SN<br>23 were treated with antibiotics; 8 hospitalized<br>Consumption of fresh cheese strongly associated with illness<br>Outbreak strain was not isolated from cheese; was isolated from raw milk | McCarthy *et al.* (2002) |
| 2001 | *C. jejuni* | Wisconsin/raw milk sold through a cow-leasing program | 75 cases, age: 2–63 years<br>28 cases CC; PFGE of 21 tested were identical<br>70 reported drinking raw milk; of 28 CC cases, 23 drank raw milk, 4 were patient's mothers, 1 unknown<br>Outbreak strain isolated from raw milk from implicated dairy<br>Raw milk sales are illegal in WI; cow-leasing was used to circumvent law but is currently not allowed | CDC (2002) |
| 2000 2001 | *L. monocytogenes* | North Carolina/ homemade Mexican-style cheese made from raw milk | 12 defined cases, all Hispanic<br>11 cases CC, identical PFGE patterns in 9 that were tested<br>One 70-year immunocompromised man with brain abscess<br>11 women; 18–38 years with 5 still births, 3 premature deliveries and two infected newborns, 1 meningitis<br>Epidemiological link to consumption of homemade cheese from raw milk sold at local stores or from vendors<br>4 cheese samples and raw milk from 1 of 2 farms supplying cheese makers had identical PFGE patterns<br>Cheese manufacture was not legal | CDC (2001) |

[a]Cases are defined in each report based on (a) patient exhibiting specified symptoms in specified time period, (b) implicated pathogen isolated from patient sample, stool, or other sample, and/or (c) consumption of implicated product at specified time period.

CC, culture confirmed; CDPH, California Department of Public Health; KDHE, Kansas Department of Health and Environment; CDC, Centers for Disease Control and Prevention; PFGE, pulsed-field gel electrophoresis; HUS, hemolytic uremic syndrome.

states to circumvent laws that prohibit raw milk sales. Only nine states have specific laws that prohibit cow-share or leasing programs; several are reviewing this activity, including some states that allow raw milk sales. Another means of obtaining raw milk is through the purchase of raw milk sold as "animal or pet food" (LeJeune and Rajala-Schultz, 2009).

States vary in their microbial standards for milk that may be sold for raw consumption (Tables 7 and 8). All 13 states that allow retail sales had SPC limits for raw milk, while all but one state had coliform limits. Of states that allowed on-farm sales, only five reported SPC limits and three reported coliform limits.

Of the 40 outbreaks associated with raw milk between 2000 and 2006 listed in Table 5, 27 were from states currently allowing raw milk sales: Washington state had the most reported outbreaks with 4; Idaho, Ohio, and Oklahoma had 3; California, Kansas, New York, and Utah had 2; and Arizona, Illinois, Maine, Minnesota, Pennsylvania, and Texas all had 1 reported outbreak. Of the 13 outbreaks in states where raw milk sales are not currently allowed, Wisconsin, Wyoming, and Colorado all had 3 outbreaks reported; Iowa had 2; and Michigan and Virginia each had 1. Of the 13 reported outbreaks associated with raw milk cheese, including the *Brucella* outbreaks, 9 were in states that allow raw milk sales. Most of the cheeses implicated were Queso fresco or homemade cheeses; commercial properly aged raw milk cheese was not implicated in any of the outbreaks listed.

## Discussion

The concept of "produce, sell, and buy local" and the demand for natural and unprocessed foods are growing consumer trends that have resulted in an increased interest in raw milk. Another apparent reason is people's freedom of choice. As a result, more people are consuming raw unpasteurized milk, and to meet this increased demand more dairies are becoming involved in the sale/distribution of raw milk. This increased demand has intensified the raw milk debate. Enhanced nutritional qualities, taste, and health benefits have all been advocated as reasons for raw milk consumption. However, science-based data to substantiate these claims are lacking or do not exist. On the other hand, the evidence for

Table 4. Summary of Foodborne Illness Outbreaks Associated with Pasteurized Milk Products from Available Epidemiological Reports from 2000 to 2008

| *Year* | *Organism* | *State/product* | *Outbreak details*[a] | *Reference* |
|---|---|---|---|---|
| 2008 | *L. monocytogenes* | Massachusetts; Pasteurized fluid milk from small dairy plant presumably contaminated after pasteurization | 5 cases; 3 men aged 75–87 years<br>2 women aged 31 and 34 years<br>5 cases CC; isolates from 4 had identical unique PFGE patterns<br>All 3 men died<br>One women experienced a stillbirth, the other delivered a healthy premature baby after illness<br>3 confirmed they consumed products from implicated dairy, one did not, one could not be interviewed<br>Outbreak strain isolated from coffee-flavored milk from one patients home<br>7 additional flavored milks, one skim milk and a swab from a drain were positive for outbreak strain<br>Other *Listeria* strains were found in environmental and product samples<br>Environmental postpasteurization contamination was suspected | CDC (2008c) |
| 2000 | *Salmonella* Typhimurium | Pennsylvania Pasteurized fluid milk presumably contaminated after pasteurization | 38 cases, age: 3 months–88 years<br>38 cases CC; cases defined based on 3 PFGE patterns of isolates<br>Milk from implicated dairy was statistically associated with illness<br>*Salmonella* was not isolated from milk products or the environment of the implicated dairy<br>Three employees with GI illness at time of outbreak; all indicated that they consumed the milk from the dairy; one was positive for outbreak related strain | Olsen *et al.* (2004) |

[a]Cases are defined in each report based on (a) patient exhibiting specified symptoms in specified time period, (b) implicated pathogen isolated from patient sample, stool, or other sample, and/or (c) consumption of implicated product at specified time period.
GI, gastrointestinal.

Table 5. Number of Outbreaks (Number Ill) Associated with Milk and Cheese Products Where *Campylobacter* Spp., Enterohemorrhagic *E. coli*, *Salmonella* Spp., and *L. monocytogenes* Were Implicated as the Causative Agent as Reported by State Agencies to Centers for Disease Control and Prevention and from the Center for Science in the Public Interest Database, 2000–2006 (CDC, 2008d; CSPI, 2008)

| | | Campylobacter | | E. coli | | Salmonella | | Listeria | |
|---|---|---|---|---|---|---|---|---|---|
| Milk | Raw | 33 | (497) | 6 | (35[a]) | 1 | (107[b]) | 0 | |
| | Pasteurized | 1 | (200[c]) | 0 | | 3 | (254[d]) | 0 | |
| Cheese | Raw | 3 | (85) | 1 | (3) | 3 | (138) | 3 | (36) |
| | Pasteurized | 0 | | 0 | | 0 | | 1 | (3) |
| | Unspecified | 1 | (11) | 0 | | 5 | (64) | 0 | |

[a]An *E. coli* outbreak in 2001 in NC involving 202 cases was reported in the CDC/CSPI databases as being associated with raw milk. A 2004 NC (NCDHH, 2004) press release indicated that the outbreak was traced to butter made in an elementary school from raw milk; the associated illness then spread throughout the community.
[b]MMWR (CDC, 2003) indicated that there were 62 in the outbreak that met the case definition. Other discrepancies noted for two other reported outbreaks are discussed in the text.
[c]One outbreak occurred in a Colorado prison with 200 cases. Another prison-related *Campylobacter* outbreak with over 1600 cases was investigated in California in 2006 but was not listed in the CDC or CSPI databases.
[d]Included two reported outbreaks from CDC Listing (Wyoming, 2002—116 cases and California, 2004—100 cases). The Pennsylvania *Salmonella* (38 cases) outbreak described in Table 2 was not found in the CDC listing but included here.
CSPI, Center for Science in the Public Interest.

Table 6. Summary of a Survey on Raw Milk Regulations Sent to 50 U.S. States (NASDA, 2008)

| | No. of states | | |
|---|---|---|---|
| | *Yes*[a] | *No* | *Conditional comments* |
| Is the sale of raw milk for human consumption legal? | 29 | 21 | 2 allow sale of goat milk only<br>1 allows goat only or cow milk if less than 3 in herd and 2 milked<br>2 allow sale of goat milk by Rx<br>2 allow "incidental" sales |
| Are animal share operations explicitly prohibited? | 9 | 33 | 7 states reviewing policy<br>1 state undetermined<br>23/29 that allow raw milk sales answered No; 1 answered Yes<br>10/21 that do not allow raw milk sales answered No; 8 answered Yes |
| Are raw milk sales allowed only on the farm?[b] | 17[c] | NA | 2 allow sales of goat milk only<br>2 allow sales of goat milk with Rx<br>2 allow only "incidental" sales<br>1 allows cows milk if less than 3 in herd and only 2 milked<br>1 allows farmers to deliver direct to consumers |
| Are raw milk sales at retail stores, separate from farm, legal?[b] | 13[d] | NA | 1 allows sales of goat milk at retail, while cow milk only from herd less than 3 and only 2 milked can be sold on the farm only<br>1 allows retail sales only if store is farmer owned |

[a]Numbers under "Yes" include those states listed under conditional comments where applicable (e.g., sales are allowed).
[b]Question applies only to those who answered yes to the first question.
[c]States that allow raw milk sales on the farm include only IL, KS, MA, NB, NY, OK, SC, SD, TX, and VT; goat milk only AR, KY (Rx-prescription), MS, OR (2/3 cows milk), and RI (Rx); and incidental MI and WI.
[d]States that allow retail sales include AZ, CA, CT, ID, ME, MO, NH, NM, NV, OR (goat only; 2/3 cows milk allowed on farm only), PA, UT, and WA. Although not specifically asked in this survey, a 2005 survey indicated that all states that allowed retail sales of raw milk also allowed sales on the farm (Virginia Department of Agriculture and Consumer Services, 2005).
NA, not applicable.

the risks associated with raw milk consumption is clear. Disease outbreaks associated with consumption of raw milk are considerably higher than outbreaks associated with the consumption of pasteurized milk. Twelve documented disease outbreaks in humans traced back to consumption of raw unpasteurized milk occurred from 2000 to 2008. During this same time period, two documented outbreaks were associated with pasteurized milk product consumption. Based on recent and historical illnesses associated with consumption of raw milk, organizations, agencies, and associations, including the U.S. Food and Drug Administration, the U.S. CDC, the American Medical Association, the American Academy of Pediatrics, the American Public Health Association, NMC (formerly the National Mastitis Council), the American Veterinary Medical Association, the U.S. Animal Health Association, the U.S. Department of Agriculture, the National Environmental Health Association, the International Association for Food Protection, and the World Health Organization, all have formal statements regarding the hazards of consumption of raw unpasteurized milk and advocate that milk be pasteurized.

Table 7. Summary of Coliform Standards for Raw Milk Sold for Human Consumption from the Farm and at Retail Based on a Survey Sent to 50 U.S. States (NASDA, 2008)

| | No. of states with coliform standard | |
|---|---|---|
| *Coliform standard* | *On-farm only* | *Retail milk* |
| No limit | 14 | 2 |
| ≤10 cfu/mL | 2 | 7 |
| ≤30 cfu/mL | 1 | 0 |
| ≤50 cfu/mL | 0 | 3 |
| ≤100 cfu/mL | 0 | 1 |
| Total | 17 | 13 |

cfu, colony forming units.

In the United States, it is a violation of federal law to sell raw milk packaged for consumer use across state lines. However, intrastate sale of raw milk is legal in many states. Standards for raw milk that may be sold for human consumption vary considerably by state. A 2008 survey conducted by the National Association of State Departments of Agriculture indicated that 29 states allow the sale of raw milk by some means. Regulations and microbial standards for milk that may be sold for raw consumption vary considerably by state. Cow-share or leasing programs have also been used as a means for consumers to obtain raw milk by owning a share of a cow or the herd, thus allowing the shareholder to "drink raw milk from their own cow."

Despite numerous studies that clearly show that raw milk can be contaminated by a variety of pathogens of known risk for human illness, people continue to consume raw milk. It is unlikely that states that allow raw milk sales will change their regulations in the near future to prevent raw milk sales,

Table 8. Summary of Microbial Standards (Standard Plate Count and Coliform Bacteria Count Limits) for Raw Milk Sold for Human Consumption Reported by 18 States[a] Based on Responses to a Survey Sent to 50 U.S. States (NASDA, 2008)

| *SPC limit* | *No. of states* | *Coliform limit* | *No. of states* |
|---|---|---|---|
| ≤10,000 cfu/mL | 1 | No limit | 4[b] |
| ≤15,000 cfu/mL | 2 | ≤10 cfu/mL | 9 |
| ≤20,000 cfu/mL | 9 | ≤30 cfu/mL | 1 |
| ≤30–35,000 cfu/mL | 4 | ≤50 cfu/mL | 3 |
| ≤50,000 cfu/mL | 2 | ≤100 cfu/mL | 1 |
| Total | 18 | Total | 18 |

[a]All 13 states that allow retail sales had SPC limits; all but one state had coliform limits. Of states that allow on-farm sales only, five reported SPC limits and three reported coliform limits.
[b]New York State has a limit of 10 for generic *E. coli* for on-farm milk sales.
SPC, standard plate count.

and if they did, underground sales or other means to obtain raw milk would likely occur. Where raw milk is offered for sale, strategies to reduce risks associated with raw milk and products made from raw milk are needed. Developing uniform regulations including microbial standards for raw milk to be sold for human consumption, labeling of raw milk, improving sanitation during milking, and enhancing and targeting educational efforts are potential approaches to this issue. While many are opposed to regulatory intervention, regulations requiring that unpasteurized milk products meet process hygiene, food safety, and microbiological standards have worked effectively in other countries (Yilmaz *et al.*, 2009). Development of microbiological standards for raw milk would appear to have merit. However, this will not be easy. Testing of raw milk and raw milk products cannot be used as an effective alternative to pasteurization since the inability of a method to detect a pathogen does not indicate absence of the pathogen. Thus, methods of detecting a variety of different pathogens in milk would be necessary and likely cost prohibitive. Labeling of raw milk and products made from raw milk warning consumers of the inherent risks associated with consumption of raw milk is another means. Some states in the United States already require warning labels to inform consumers about the potential hazards of consuming raw milk. In Europe, products made from raw unpasteurized milk must have a label stating that they were made from unpasteurized raw milk. From the standpoint of reducing risks at the farm level, development of pre- and postharvest control measures to effectively minimize contamination is critical to the control of pathogens in raw milk (LeJeune and Rajala-Schultz, 2009). Further research efforts to identify on-farm risk factors are needed. Some foodborne pathogens have habitats in food-producing animals and in the farm environment. A primary route of pathogen transmission in milk is fecal contamination during milking. Potential contamination levels could be reduced by improving sanitation and hygiene during milking, although completely eliminating these risks would be difficult.

Of primary importance is the need for providing educational programs and materials that bring awareness of microbial safety hazards to dairy farmers, dairy workers, milk processors, and consumers. Dairy producers supplying raw milk must be well informed on the risks and liabilities associated with the milk they sell. Enhanced educational efforts targeting consumers is essential for protecting them from the potential hazards associated with the consumption of raw milk. Efforts to educate policy makers/regulators/legislators are also necessary so that appropriate and necessary regulations and microbial standards for raw milk to be sold for human consumption can be established. While all these efforts may be able to reduce the risks associated with raw milk consumption, the only sure way to prevent raw milk–associated foodborne illness is for consumers to refrain from drinking raw milk and from consuming certain dairy products manufactured using raw milk.

## Disclosure Statement

No competing financial interests exist.

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