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Salmonella, Campylobacter, and *Escherichia Coli*: Farm Trends and Implications for Raw Dairy Products Consumption

Alvaro Garcia DVM PHD
Professor Extension Dairy Specialist
South Dakota State University
USA

Athens Institute for Education and Research
8 Valaoritou Street, Kolonaki, 10671 Athens, Greece
Tel: + 30 210 3634210 Fax: + 30 210 3634209
Email: info@atiner.gr URL: www.atiner.gr
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Alvaro Garcia DVM PHD
Professor Extension Dairy Specialist
South Dakota State University
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Abstract

In 1938 raw milk was responsible for 25% of all foodborne outbreaks in the U.S. Chicago passed the first milk pasteurization law in 1908. Between 1973 and 1992 raw milk-originated outbreaks were 2.4 yearly whereas between 1993 and 2006 they more than doubled (5.2). One of the largest raw milk-originated outbreaks of recent times happened in Pennsylvania in 2012. More than 71 cases of Campylobacter were confirmed in a four-state area. Ironically, the milk came from a farm called "The Family Cow" and was sold by a store named the "Healthy Grocer". Campylobacter is a common inhabitant of the intestine of the cow and other animal species, not a haphazard event. The U.S. Animal Health Monitoring System has determined that 92.6% of the dairies and 33.7% of the cows are positive to this pathogen. Producers unaware of milk pathogens are two-fold more likely to drink raw milk. Primary factors cited were taste (72%) and convenience (60%). A European Union Commission Regulation of July 2010 laid down the particular veterinary certification requirements for raw milk and dairy products destined for human consumption. Regulations and policies have protected the consumers' from diseases that can be transmitted through raw dairy products. This fact has created a partnership of trust among producers, industry, and consumers, that if broken can take a long time to be reinstated. This presentation will address the current raw milk bacteriological status with special emphasis place on Salmonella, E. coli, and Campylobacter and its implications for raw dairy products consumption.

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Corresponding Author:

The history of milk and dairy products processing would not be complete without mentioning the French researcher Louis Pasteur. Pasteur conducted his first experiments in microbiology around 1856. His early work led to the development of the first commercial pasteurizers in the late 1800's. At that time milk-borne disease outbreaks among infants were close to 29 cases per year. Later in that decade, another visionary, Nathan Straus (owner of Macy's stores) followed on Pasteur's findings and decided to supply free "purified" milk to indigent mothers (Habstritt.2013). In 1893 Straus opens the first depot that supplies milk treated with this "new" method. The first commercial pasteurizers open in 1895 and in just nine years infant mortality had dropped to 59 deaths per 1,000 infants. As a first outcome of this successful public health measure Chicago passes in 1908 the first compulsory milk pasteurization law.

With mandatory pasteurization, the incidence of milk-borne diseases dropped dramatically. In recent times, however, there has been a new trend in the general public that looks to more organic, "natural", unprocessed foods including milk. In the two decades between 1973 and 1992 there were only 2.4 cases of milk-borne outbreaks per year, from 1993 to 2006 they more than doubled reaching 5.2 per year. During this period there were 121 dairy-related disease outbreaks, resulting in 4413 illnesses, 239 hospitalizations, and 3 deaths (APHIS 2009). Raw milk products were responsible for 60% of the outbreaks and 84% of the hospitalizations. What is also of concern is that 60% of the outbreaks associated with non-pasteurized dairy products involved minors. The U.S. Centers for Disease Control have reported that 3.5% of the population had consumed unpasteurized milk in the past 7 days before a survey (CDC. 2004).

Best management practices developed in farms over time have made milk safer compared to a century ago. Milk produced in the udder of a healthy dairy cow is nowadays safer than in the past. However, cows live in an environment that, even when maintained scrupulously clean, is laden with microorganisms some of which can be dangerous and even deadly to humans. The increasing popularity of raw milk during recent times has alarmed health professionals who deem raw milk unsafe to drink. Ironically, this also comes at a time when nearly one out of three large dairy farms in the U.S. pasteurize the milk they feed to their calves with the number growing yearly.

There is the misconception that pasteurized milk does not have the same wholesomeness when compared to raw milk. This emotion-based perception has been utilized in marketing the latter. One such example resulted in the largest milk-borne Campylobacter outbreak of recent times which occurred in 2012 in Pennsylvania. The milk came from "The Family Cow" dairy, and was sold by a store named the "Healthy Grocer" (Penn State Food Safety. 2012).

Campylobacter is a common inhabitant of the intestine of the cow and other animal species, and not a haphazard event. The Animal Health Monitoring System has determined that 92.6 percent of the dairy farms and 33.7 percent of the cows were positive to this microorganism (NAHMS Dairy 2007). Pasteurization is a heat by time treatment combination applied to milk to eliminate pathogens with negligible effects on its nutritive value. The Food and

Drug Administration (USFDA. 2005) has approved six procedures as detailed in table 1.

These temperature*time treatments have demonstrated that while killing pathogenic bacteria, they do not significantly alter milk nutritional value.

LeJeune and J. Rajala-Schultz (2009) tested the activity after pasteurization of some important milk components. Some enzymes are considered important because of their bactericidal properties, and their denaturation by heating is among the main reasons used by raw milk consumption proponents. Lactoferrin in milk for example is an iron scavenger, and its antibacterial effects are mediated by limiting available free iron that is required for bacterial growth. In LeJeune and J. Rajala-Schultz (2009) work both unheated and pasteurized lactoferrin had similar antibacterial properties and only UH-temperature denatured it. Another enzyme is lacto-peroxidase which contributes to milk's bacteriostatic properties. Hydrogen peroxide and thiocyanate ions must be present for this enzyme to be effective and while both chemicals are not endogenous to milk they are by-products of bacterial activity. When milk was heated at 72°C for 15 seconds, it retained 70% of its activity and it decreased its activity only when heated further. Another milk enzyme, lysozyme, is known for its bactericidal effect when in conjunction with lactoferrin. This enzyme survived 80°C for 15 s. Bovine immunoglobulin did not lose activity when held for 30 min at 62.7°C, and it retained 59% to 76% of its activity after ultra-high short temperature (UHST) pasteurization. Bacteriocins have narrow-spectrum antimicrobial activity and are often produced by other bacteria that contaminate milk. They are heat-stable and retain their activity after pasteurization. Oligosaccharides competitively bind pathogens to prevent their adherence to target mucosal receptors; they are not affected by heat. Xanthine oxidase is an enzyme linked with flavor which changes in milk during storage. It retained its enzymatic activity after 7 min at 73°C, or 50 s at 80°C.The effects of temperature treatment on lactose were also measured. This disaccharide destroys lactase- producing bacteria that might aid in the tolerance to dairy products among lactase-deficient persons. Upon heating lactose is degraded to lactulose and epilactose and then galactose and tagatose. Pasteurization did not lead to detectable levels of lactulose in milk.

Milk is considered a good source of vitamins both some from the B complex (i.e. thiamine, folate, and riboflavin) as well as vitamins A, D, E, and K. The relative short heat treatment during pasteurization does not significantly alter vitamin activity. Vitamin C for example of which milk is not a good dietary source anyways loses between 0 and 10% of its activity (LeJeune and J. Rajala-Schultz . 2009).

If there are no significant differences between the nutritional properties of pasteurized and raw milk, then why is it preferred by some? Jayarao et al. (2006) researched the reasons for preferring raw milk among dairy producers. The authors found out that 42.3% of the producers drank raw milk even when 68.5% were aware of foodborne pathogens. However, dairy producers not aware of pathogens were 2-fold more likely to drink raw milk. Among the main reasons were taste (72%) and convenience (60%). Those individuals who resided on the dairy farm were nearly 3-fold more likely to drink it. In spite of this documented preference, there is a national trend for larger dairy producers for on-farm pasteurization of the milk they feed to their calves (NAHMS. Dairy 2007). The main reason behind this is that nowadays 87.2% of dairies in the U.S. feed waste milk to calves which have led to increased morbidity and mortality. Stabel et al. (2004) reported that high temperature short time (HTST; 71.7°C for 15 s) was effective to generate safer product for calves as it destroyed *Mycobacterium paratuberculosis*, *Salmonella* (*derby, dublin, typhimurium*), and *Mycoplasma* (*bovis, californicum, canadense, serogroup* 7). Godden et al (2005) also reported that calves fed pasteurized milk gained more weight, had higher weights at weaning, lower morbidity in the summer, and lower morbidity and mortality in winter than calves fed an equal volume of milk replacer. Table 2 shows the calf feeding practices in the U.S. by herd size. The preference or not to feed pasteurized milk to calves depends on the size of the dairies. Milk replacer (medicated and non-medicated) is the preferred feeding approach by larger (more than 500 cows) dairies (64.3%). The second method by preference in these dairies is to feed pasteurized waste milk (31.5%). When all sizes are considered 69% of the dairies in the U.S. feed milk replacer (medicated + non-medicated), the second choice going to non-pasteurized waste milk (20.9%) followed by pasteurized waste milk (15%). In addition larger dairies are twice more likely to feed their calves pasteurized saleable milk than smaller dairies.

In spite of well-documented positive effects of pasteurization on calves' health and the resultant preference of large dairies to pasteurize their milk there are still those who claim raw milk has health benefits to humans. These bacteria that affect calves also affect humans and are not a haphazard event as they are frequently found in today's dairy operations. Among those that are of most concern are *Salmonella and Campylobacter* which in the U.S. cause the most foodborne illness in humans. In the U.S. *Salmonella spp.* causes 1.4 million cases with 500 deaths *Campylobacter spp.* causes 2.5 million cases with 100 deaths (APHIS 2009). In 2001 Jayarao and Henning evaluated the milk from 131 commercial dairy farms in eastern South Dakota and western Minnesota. The foodborne pathogens detected were *Campylobacter jejuni*, shiga-toxin producing *E. coli*, *Lysteria monocytogenes*, *Salmonella* spp., and *Yersinia enterocolitica*, which were detected in 9.2, 3.8, 4.6, 6.1, and 6.1% of bulk tank milk samples, respectively. Non A-grade milk producers were at higher risk of having one or more pathogens in their milk. Of the dairy producers who consumed raw milk 26.6% had one or more pathogenic bacteria in their bulk tank milk. *Campylobacter jejuni*, is a common inhabitant of the intestine, and oral cavity of humans and animals, and is excreted in large numbers in feces. Table 3 shows the incidence of *C. jejuni* in dairy farms and cows present in those farms. The results of this survey show that Campylobacter is endemic to almost all dairies and that in 2007 at least one in three cows is a carrier.

The incidence of Salmonella found in the NAHMS study shows that this microorganism is not as prevalent as Campylobacter both in farms as well as cows in those farms (table 4). Regardless their presence in dairy almost doubled since 1996 and their presence in cows increased 2.5 times. Similarly the presence of *E. coli* 0157 has increased both in farms and cows in those farms (Figure 2). One could make the case for cows being more in contact with manure in freestalls compared to stanchion systems as there has been an increase of the former over time (figures 3 and 4).

It is more likely however that a higher incidence of coliform bacteria in adult cows is a result of either faulty colostrum management or feeding of unpasteurized waste milk to calves. Adequate colostrum intake influences the way *E. coli* attaches to intestinal cells in the newborn calf. In an older experiment (albeit good!), Corley et al. (1977) exposed colostrum-deprived newborn calves to three different *E. coli* contaminated fluids. Calves (2 to 6 hours old) were given *E. coli* suspended in saline, *E. coli* suspended in colostrum, or *E. coli* in saline, 1 h after colostrum. Twenty-four hours after exposure, tissues were collected for examination. *Escherichia coli* were numerous in mesenteric lymph nodes of calves given this organism in saline. Fewer were recovered from lymph nodes of calves that received the bacteria in colostrum. *Escherichia coli* were not recovered from mesenteric lymph nodes of calves given colostrum before dosage with the organism. The conclusions of this trial were basically that fecal contamination of colostrum in calves that did not receive adequate colostrum could be found in the gut tissue and the lymph nodes. In colostrum contaminated with *E. coli* the bacterium was recovered from the lymph nodes in lower numbers however, than with the saline treatment alone. When calves received colostrum before being challenged with *E. coli,* no bacteria were found in the lymph nodes. This clearly reinforces the concept that fecal contamination of colostrum will result in the presence of coliform bacteria in the lymph nodes. The presence of higher concentrations of *E. coli* bacteria in cows housed in modern freestall systems is probably not acquired at an older age but more than likely can be traced back to colostrum management of the calf. Make sure calves receive adequate amounts of high quality colostrum right after birth.

Today's consumers look for wholesome dairy products that are at the same time minimally processed and with reduced carbon footprint on the environment. Management practices have improved through the years reducing the load of pathogens in farms and cows. However, the standards for milk quality in the U.S. (750,000 somatic cell counts per ml; SCC) still lag behind those of the EU (400,000 SCC) and Canada (500,000 SCC). This implies that unpasteurized milk in the U.S. has a greater potential to be contaminated with milk pathogens. Throughout the years rules that regulate processing and marketing of milk and dairy products have also resulted in them being safe and reliable. This created a partnership of trust between producers, industry, and consumers, which can be broken at any time by a higher incidence of milk-borne disease outbreaks. The loss of this trust about fluid milk safeness will negatively affect dairy producers and the industry resulting in further retractions in an already reduced market for fluid milk. Anyone should be able to choose freely what to eat or drink. However, in light of the risks described we should carefully ponder the decisions we make concerning ourselves, our children, and the dairy producers.

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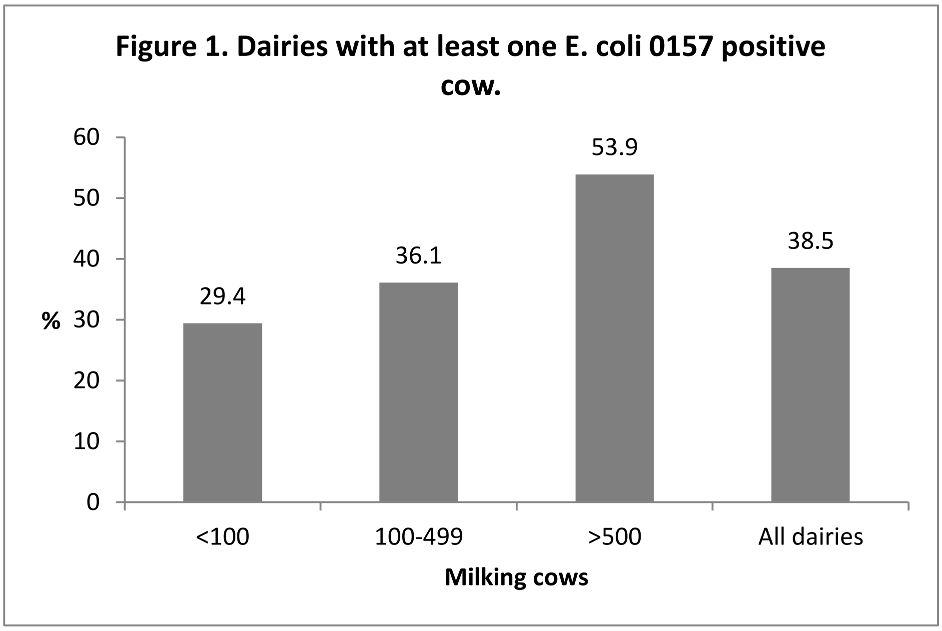


Figure 1. Dairies with at least one E. coli 0157 positive cow.

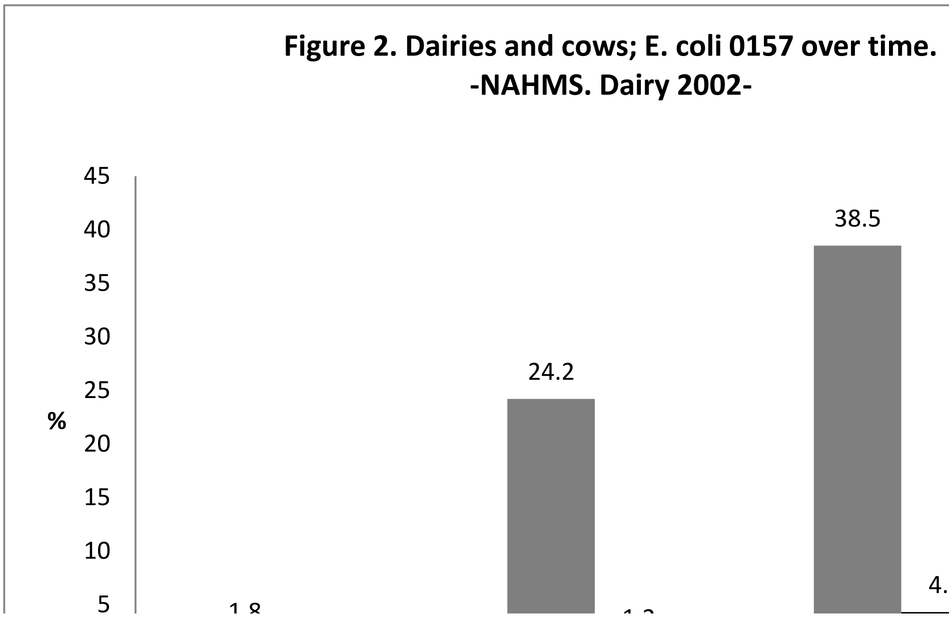


Figure 2. Dairies and cows; E. coli 0157 over time. -NAHMS. Dairy 2002-

Figure 3. Percentage of dairies (and percentage of cows on these dairies) by primary milking facility used -NAHMS. Dairy 2007-

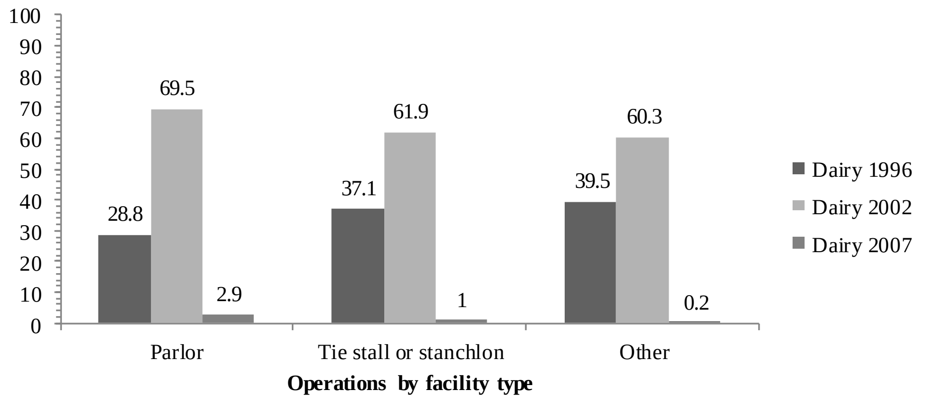
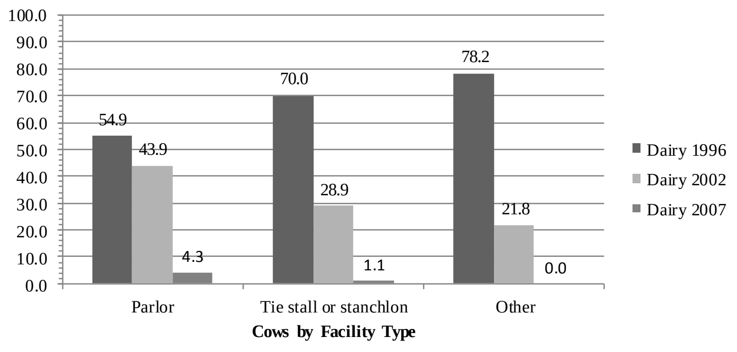


Fig. 4. Percentage of Operations (and Percetage of Cows on These Operations) by Primary Milking Facility Used



NAHMS. Dairy 2007-

Table 1. Temperatures and times accepted for pasteurization by the FDA.

63°C	30.0 minutes
72°C	15.0 seconds
89°C	1.0 second
90°C	0.5 second
94°C	0.1 second
96°C	0.05 second
100°C	0.05 second

Source: USFDA. 2005

Table 2. Calf feeding practices by herd size

	Heifers, % Herd size (number of cows)							
	Small < than 100		**Medium 100-499**		**Large >500**		**All farms**	
	%	**SE**	**%**	**SE**	**%**	**SE**	**%**	**SE**
Replacer, non-medicated	10.4	1.1	13.7	1.7	27.9	2.6	19.1	1.3
Replacer, medicated	57.9	1.8	63	2.2	36.4	3.0	49.9	1.5
Non-past. waste milk	23.2	1.5	20.3	1.8	19.9	2.5	20.9	1.3
Past. waste milk	1.2	0.3	2.6	0.6	31.5	2.6	15	1.2
Non-past. saleable milk	25.5	1.6	13.3	1.5	6.9	1.3	13.8	0.8
Past. saleable milk	0.9	0.3	0.6	0.3	1.4	0.6	1.0	0.3

Source NAHMS 2007

Table 3. Campylobacter cultures from three NAHMS dairy studies1

Year	**Positive for Campylobacter / Total Sampled**	
	Farms	**Cows**
1996	31/31 (100%)	Not available
2002	95/97 (97.9%)	730/1,424 (51.3%)
2007	112/121 (92.6%)	635/1,885 (33.7%)

1Only cows healthy at the time of collection are included; 2Operations with at least one positive cow were considered positive.

Source NAHMS 2007

Table 4. Salmonella cultures from three NAHMS dairy studies1

	Positive for Salmonella / Total Sampled	
Year	**Farms**	**Cows**
1996	19/90 (21.1%)	198/3,640 (5.4%)
2002	30/97 (30.9%)	259/3,645 (7.1%)
2007	48/121 (39.7%)	523/3,804 (13.7%)

Source NAHMS 2007