

The Effect of Milking Management on Microbial Quality

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Take Home Message

- Microbial quality of milk is an important measure and is associated with a number of farm management practices
- Microbial quality is measured using standard plate counts and investigation of problems with microbial quality requires the use of a variety of diagnostic bacterial counts such as laboratory pasteurized counts and coliform counts
- Several milking practices such as use of manual detachers, defecation in the milking parlor and the failure to use a complete milking routine are associated with increased bacterial counts in milk

Introduction

Bacterial and somatic cell counts (SCC) are reference methods commonly used to evaluate raw milk quality (Costello et al., 2003). Total bacterial count (often referred to as the standard plate count or SPC) indicates on-farm general hygienic conditions, herd health status, milking equipment sanitation and milk storage temperatures (Hayes et al., 2001). Although most bacteria found in raw milk are nonpathogenic and are mostly destroyed by pasteurization, close monitoring of SPC is crucial to establish consumer confidence in the quality of milk produced and is of increasing interest to milk purchasers (Berry et al., 2006). Successful milk quality assurance programs focus on producing of milk free of antibiotic residues and with low somatic cell and bacterial counts, resulting in better quality products with longer shelf life. Many dairy producers in the United States also receive premiums from their milk cooperative for producing milk with low somatic cell and bacterial counts (Jayarao et al., 2004) and in most countries, bacterial content is one of the factors considered in determining the level of payment for raw milk (Costello et al., 2003).

Bacteriological contamination of raw milk can occur from 2 basic sources: 1) organisms can contaminate milk from environmental sources (especially contamination during the milking process) or 2) from shedding of mastitis organisms from within the udder (Reinemann et al., 1997). Bacterial numbers in bulk milk will not typically increase from the contribution of non-pathogenic bacteria in the gland or teat duct in a healthy mammary gland. Normally, raw milk from healthy udders contains < 1,000 total bacteria per ml; and therefore do not have a significant contribution to the total numbers of microorganisms in the bulk milk, or to a potential increase in bacterial numbers during refrigerated storage (Murphy and Boor, 2006). It is unusual for mastitis to contribute to SPC but cows with mastitis can occasionally shed large numbers of microorganisms in milk; this is most commonly associated with subclinical infections caused by Streptococci (especially *Streptococcus agalactiae*). At the cow level, the influence of mastitis on the total bacteria count in milk mostly depends on pathogen type and stage of infection (Murphy and Boor, 2006). Occasionally, infected cows can shed more than 10,000,000 bacteria per ml (Bramley and McKinnon, 1990). At herd level, the effect of shedding on the bulk tank bacterial count depends on the size of the herd, number of mastitic cows, and ratio of mastitic to nonmastitic milk (Hayes et al., 2001). The objective of this paper is to review tests of milk quality and highlight new research describing management practices that may influence microbial quality of milk.

Testing Microbial Quality of Milk

Standard Plate Count

Throughout the world, official regulatory standards for milk are based on determination of bacterial numbers present in raw milk. The SPC is the official regulatory test used for estimating bacterial populations of raw milk and milk products and is the official reference method specified in the U.S. standards for milk production (the Grade A Pasteurized Milk Ordinance (PMO)) (Houghtby, et al., 1993). The PMO requires the SPC to be less than 100,000 cfu/ml for Grade A

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farms. Few dairy producers consistently exceed the regulatory limit. Of 804,575 monthly SPC values examined for WI grade A farms between 1994 and 1998, 90% were <34,000 cfu/ml (Ruegg and Tabone, 2001). The SPC is a critical control point for milk quality and many milk purchasers have standards that are more rigorous than the official regulations. A reasonable goal for SPC is $\leq 5,000$ cfu/ml and a count of $>10,000$ cfu/ml is usually indicative of a problem (Jayarao et al., 1998; Reinemann et al., 1999). The SPC is an overall measure of milk quality but a single SPC value is not very useful diagnostically. A high SPC is an indication of a milk quality problem usually caused by errors in cooling milk or cleaning milking equipment. Rarely, a high bacterial count can be associated with subclinical mastitis (especially mastitis caused by *Streptococcus* spp.) (Hayes et al., 2001). In many of these instances the SCC and the SPC are both high and the causative organism should be apparent from a bulk tank milk culture.

The SPC is performed following prescribed methods and because of differences in methodology the results should not be compared to qualitative bulk tank cultures. In brief, the procedure is performed by pipetting standard dilutions of milk into petri dishes, adding standard methods agar and incubating the plates at 32C for 48 hours. Bacterial colonies are then counted using a variety of methods depending. There are a number of alternatives to the SPC and the use of the Bactoscan™ method is a recent technological advance that uses continuous epifluorescent microscopy to count bacterial cells stained with acridine orange. Bactoscan™ has compared favorably to traditional bacteriologic methods and is considered to be less variable and more reproducible (Cunningham et al., 1988; Lachowsky et al., 1997) Bactoscan™ is now used as the official reference method for several countries and the Canadian province of Ontario.

Laboratory Pasteurized Count

The laboratory pasteurized count (LPC) is usually performed when SPC values are high. The LPC is a SPC performed on milk that has been heated to 62.8C and held for 30 minutes (low temperature-long time pasteurization). The objective of the LPC is to identify organisms that survive pasteurization (thermoduric bacteria). High LPC are associated with unclean equipment, improper sanitizing practices and milkstone deposits (Murphy, 1997). Typical mastitis causing organisms do not survive pasteurization. Thermoduric bacteria may include *Micrococcus*, *Microbacterium*, *Lactobacillus*, *Bacillus*, *Clostridium* and occasional *Streptococci* and are often related to spoilage of pasteurized milk. Poor milking hygiene can result in an elevation of coliform counts and SPC with near normal LPC. The LPC should be below 100 to 200 cfu/ml and a LPC below 10 cfu/ml indicates excellent equipment hygiene (Reinemann et al., 1999).

Coliform Count

Coliform counts are performed by culturing dilutions of raw milk on selective media such as violet red bile agar. The source of coliform bacteria in bulk tank milk is the udders of cows or unsanitary milking practices. The coliform count is an indication of the effectiveness of cow preparation procedures during milking and the cleanliness of the cows' environment (Reinemann, et al., 1999). Coliforms can also incubate on residual films of milking equipment. The coliform count should be less than 10 cfu/ml (Reinemann, et al., 1999). A coliform count between 100 and 1000 usually indicates poor milking hygiene and a coliform count >1000 suggests that bacterial growth is occurring on milk handling equipment.

Microbial Quality and Farm Management Practices

We recently evaluated the relationship between milking management and microbiological status of bulk tank milk by collecting data during milking time on commercial dairy farms ($n = 75$) in Wisconsin (Hohmann and Ruegg, 2007). Data were collected during a farm visit (1-3 hours per farm) and included: timing of the work routine during milking, milk flow data obtained using a Lactocorder,™ teat end vacuum, teat cleanliness and condition scores and udder hygiene scores. Microbiological status of bulk tank milk samples from each farm were determined and one-way ANOVA was used to screen for potential relationships between selected milking practices and bacterial counts. Separate models were produced for larger farms that milked cows in parlors ($n = 56$) or small farms that milked cows in tie-stall barns ($n = 19$). After initial analysis, all variables that showed a potential relationship ($P < 0.15$ on ANOVA) were included in multivariate models

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that were used to determine the effect of milking practices on microbiological counts of bulk tank milk. A number of initial variables were considered for the models (Table 1).

Table 1. Univariate relationships between milking practices and microbial counts of bulk tank milk for all farms (\log_{10} transformed, for example: $10^1 = 10\text{cfu/ml}$, $10^2 = 100\text{ cfu/ml}$)

Practice	Coliform Count	SPC	Staphylococcus aureus count
Bimodal milk flow			
Yes (n = 45)	1.7	2.7	1.4 ^(TS)
No (n = 26)	1.5	2.8	1.1
Milking Unit fall-off per 100 units per hour			
None (n = 36)	1.4	2.7	1.2
Some (n = 36)	1.8	2.8	1.5
Use of manual mode of milking per 100 units per hour (for herds using automatic take-offs)			
No use of manual (n = 36)	1.5 ^(P)	2.7 ^(TS)	1.3
1 -10 % of units (n = 12)	1.9	2.6	1.6
> 10 % of units (n = 14)	2.0	3.1	1.4
Cow defecation observed in milking parlor per 100 cows per hour			
None observed (n = 16)	1.2 ^(P)	2.7	1.5
Defecation observed (n = 37)	1.9	2.8	1.4
Herds size			
< 100 milking cows (n = 24)	1.2 ^(P)	2.7	1.1 ^(TS)
100-200 milking cows (n = 12)	1.6	3.1	1.7
>200 milking cows (n = 39)	1.8	2.7	1.4
Udder Hygiene score			
< 10% of scores 3 & 4 (dirty) (n = 12)	2.0 ^(P)	2.6	1.3
10-30% of scores 3 & 4 (n = 35)	1.4	2.8	1.4
>30% of scores 3 & 4 (n = 25)	1.6	2.8	1.3
Teat condition score			
< 20% scores 3 (R) & 4 (VR) (n = 30)	1.5	2.7 ^(TS)	1.2 ^(TS)
≥20% score 3 & 4 (n = 42)	1.6	2.8	1.4
Teat cleanliness score			
< 20% dirty (scores 3 and 4) (n = 37)	1.6	2.7	1.3
>20% dirty (n = 35)	1.5	2.8	1.4
Milking Frequency			
2 (n = 43)	1.3 ^(P)	2.8	1.3
3+ (n = 32)	1.9	2.7	1.4
Use of a Complete milking routine			
No (n = 7)	1.8	3.3	2.0 ^(TS)
Yes (n = 68)	1.5	2.7	1.3
Use of Automatic take-offs			
No (n = 10)	0.8 ^(TS)	2.6 ^(TS)	1.4
Yes (n = 65)	1.7	2.8	1.4
Number of milking technicians working each month			
1 - 2 (n = 15)	1.1 ^(TS)	2.7	1.4
3 - 6 (n = 40)	1.6	2.8	1.3
>6 (n = 19)	1.8	2.7	1.4
Number of cows milked per hour per milking technician			
10-21 (n = 17)	1.3	2.8	1.3 ^(TS)
22-45 (n = 39)	1.5	2.8	1.4
>45 (n = 19)	2.0	2.7	1.2

^{TS} or ^P indicates that the univariate relationship was significant at $P < 0.15$ and the variable was included in the multivariate model for Parlor (P) or tie-stall (TS).

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Farms included in the study that had milking parlors (n = 56), milked about 363 cows (42-1250), had an average bulk tank SCC of 248,000 cells/ml and employed about 5 milking technicians per week. The cows produced about 12.5kg per milking (more than half milked 3x/day) with a peak milk flow of 3.5 kgs/minute and the milking units were attached for about 5.8 minutes. Farms included in the study that milked cows in tie-stall barns (n = 19), milked about 63 cows (35-118), had an average bulk tank SCC of 230,000 cells/ml and employed about 2 milking technicians per week. The cows on these farms produced about 16.5 kg per milking (all but 2 milked 2x/day) with a peak flow of 3.6 kgs/minute and the milking units were attached for about 7.0 minutes.

The final models for the association between milking practices and bacterial counts are shown in Table 2. For herds using parlors, defecation during milking and larger herd size were significantly associated with the occurrence of coliform bacteria in milk. For smaller herds that were milked in tie stall barns, the failure to use a complete milking routine (a routine that includes forestripping, premilking drying of teats and post-milking teat dipping) significantly increased coliform counts, as did the employment of additional milking technicians. For herds using parlors, there were no significant relationships between milking practices and the number of Staph aureus found in milk. For smaller herds, there was a significant association between bulk tank SCC and the number of Staph aureus colonies found in milk, indicating that the most important factor for these herds is likely the prevalence of subclinical infections. The use of manual mode for >10% of milking units (the failure to effectively use the automatic take-off units) was significantly associated with overall bacterial counts of herds that used parlors while for smaller herds, the failure to use a complete milking routine most important factor influencing this count.

Table 2. Final models for parlor and tie-stall barns demonstrating the relationship between milking practices and bacterial counts (log₁₀ transformed, for example: 10¹ = 10cfu/ml, 10² = 100 cfu/ml)

	Coliform log ₁₀		Staph aureus log ₁₀		SPC log ₁₀	
	Parlor	Tie-stall	Parlor	Tie-Stall	Parlor	Tie-stall
Defecation observed in Parlor						
Yes	1.9 ^a					
No	1.2 ^b					
Herds size: for every 100 cows	+1.0					
Use a complete milking routine						
Yes		0.9 ^a				2.7 ^a
No		2.0 ^b				3.3 ^b
Technician/month: per 100 cows		+1.1				+15.0
Bulk Tank SCC						
≤250,000 cells/ml				0.9 ^a		
>250,000 cells/ml				2.0 ^b		
Use of manual mode of milking per 100 units per hour						
No use of manual					2.7 ^a	
1 -10 % of units					2.5 ^a	
> 10 % of units					3.1 ^b	
Teat cleanliness score (for each 1% increase in dirty teats)						+1.0

Conclusion

Increased bacterial counts generally suggest problems with milking equipment or cooling but consultants should be aware that milking practices can influence these counts. Several aspects of milking management (usage of manual detachers, defecation in the milking parlor, teat cleanliness, failure to use a complete milking routine) may be associated with bacterial counts and investigations of microbial quality should not overlook such issues.

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