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A Practical Look at Monitoring Mastitis Control Programs

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Introduction

Increased involvement in the design and implementation of mastitis control programs is a potential growth area for many dairy veterinarians. As farms have expanded, the detection, diagnosis and administration of treatments for clinical mastitis has become the responsibility of farm workers. On many farms veterinarians are rarely consulted for mastitis unless an affected cow is near death. Several studies have indicated that many dairy veterinarians are only marginally involved in mastitis control programs. Only 24% of dairy farmers (n = 180) enrolled in a milk quality program in Wisconsin indicated that they used their herd veterinarian to plan milk quality programs (Rodrigues et al., 2005) and most dairy veterinarians (n = 42) indicated that they spent <10% of their professional time working to improve milk quality (Rodrigues and Ruegg. 2004). There are ample economic and societal reasons for veterinarians to increase their involvement in mastitis control programs. The occurrence of mastitis reduces milk production, increases the amount of milk discarded and increases premature culling and production costs (Fetrow, 2000). Additionally, both clinical and subclinical mastitis have been demonstrated to reduce reproductive efficiency (Barker et al., 1998, Santos et al., 2004, and Schrick, 2001).

It is well known that mastitis can be controlled by prevention of new infections and elimination of existing infections. The 5-point plan (consisting of post-milking teat disinfection, comprehensive use of intramammary antimicrobial therapy at dry off, appropriate treatment of clinical cases, culling of chronically infected cows, and regular milking machine maintenance) has been demonstrated to successfully control contagious mastitis pathogens. The prevalence of contagious pathogens has decreased as herds have modernized and adopted these practices (Makovec and Ruegg, 2003). Milk quality programs now tend to be focused on prevention of mastitis caused by environmental pathogens and other issues that influence consumer perceptions of milk quality. The purpose of this paper is to describe key performance indicators that dairy practitioners can use to monitor mastitis, milk quality and milking performance.

Developing a Milk Quality Plan

Mastitis is a bacterial disease that occurs in individual animals but mastitis control programs must be implemented at the herd level. Successful mastitis control is dependent on effective detection, accurate diagnosis, evaluation of appropriate treatment options and implementation of preventive practices that address herd specific risk factors associated with exposure to mastitis pathogens. Veterinarians wish to reduce mastitis should regularly review herd records for SCC and clinical mastitis and evaluate key performance indicators (KPI) relative to herd goals. The program should be structured to allow for the evaluation of cow factors, environmental factors and milking machine factors that can contribute to exposure to mastitis pathogens. An effective surveillance system for mastitis includes the following elements: 1) Clear case definitions and effective mechanisms to detect both clinical and subclinical mastitis; 2) Recording systems that allow for timely evaluation of risk factors; and 3) Feedback mechanisms that allow management personnel and veterinarians to manage milk quality.

Defining and Detecting Clinical Mastitis. Clinical mastitis is technically defined as the production of abnormal milk with or without secondary symptoms but the working definition of clinical mastitis varies greatly among farm personnel. On large farms, detection of mastitis is usually dependent on the observational skills of the milking technicians. Veterinarians must actively communicate with milking technicians and farm managers to be sure that the definition of clinical mastitis and intensity of detection are consistent with farm goals. Mastitis case definitions should be simple and easily understood by all farm workers. Mastitis severity scores should be recorded in the permanent cow treatment records for each case (Wenz, et al. 2001). Use of a 3-point scale based on clinical symptoms is practical, intuitive, simply recorded and can be an important way to assess detection intensity (Table 1). When using a 3-point scale, if the proportion of severe cases exceeds about 20% of all cases it is a signal that detection intensity and case definition should be investigated.

Monitoring clinical mastitis. Animal health recording systems should consist of both temporary cow-side records (often used for day to day decision making) and permanent records (such as cow cards or computerized records) that are used to summarize trends over time (Rhoda, 2007a,b). While temporary records (such as treatment notes on white-boards and calendars in milking facilities) are common, recording of mastitis events in permanent treatment records is not frequently done. The ideal system for recording clinical mastitis will allow the practitioner to evaluate important cow factors that define the probability of treatment success and to assess epidemiological trends (Wenz, 2004). To begin involvement in mastitis control programs, veterinarians should ensure that the following questions can be answered: 1) What is the incidence (rate of new cases) of clinical mastitis? 2) What proportion of cases are severe (severity score 3)? 3) What are the most common bacteria that are causing clinical mastitis? 4) What are the current treatment protocols? 5) How many days is milk discarded as a result of treatment? 6) How many cases: a) require changes to the original treatment protocol and b) experience recurrence of the case within the same lactation? 7) What percent of lactating cows are being milked on less than 4 quarters? 8) What percent of cows that experience clinical mastitis are culled in the same lactation or die?

Practitioners who work with small herds, will generally need to review data found in paper based treatment diaries and will need to include data collected over longer time periods (3-4 month periods) in order to discern trends. For larger herds, computerized dairy management record systems can be configured to allow practitioners to rapidly review appropriate data (Rhoda, 2007a,b). For ease of interpretation, data entry should be structured to avoid redundancy, and only one mastitis event should be entered for each discrete case (defined at the cow level) (Wenz, 2004). Researchers generally define separate cases of clinical mastitis based on an interval of 14-21 days between occurrences but this time period is not based on sound research and may be adapted to meet the needs of the farm. Key performance indicators that are defined at the cow-level (occurrence of mastitis in 1 or more quarters of a cow) rather than the individual quarter are easier to record and may better reflect the important economic consequences of mastitis (Table 2). Goals for KPI are derived from populations of herds and may need to be adjusted for individual herd circumstances.

Monitoring Subclinical Mastitis. It is not possible to control any subclinical disease without a clear understanding of prevalence and a mechanism to monitor incidence. Prevalence of mastitis is a function of incidence (development of new subclinical cases) and duration. For

some herds, prevalence of subclinical mastitis may exceed goals even when relatively few new infections are occurring because of chronic infections caused by contagious pathogens. Alternatively, goals may be exceeded because of environmental mastitis problems that are characterized by high incidence of new infections of relatively short duration. The first step in monitoring subclinical mastitis is to ensure that SCC values are routinely obtained from all cows on a regular basis. Generally all cows with SCC values >200,000 cells/ml (linear somatic cell score of approximately 4.0) are considered to have subclinical mastitis.

Assessments of subclinical mastitis should begin with the following questions: 1) What is the prevalence of subclinical mastitis (defined based on SCC)? 2) What is the incidence of subclinical mastitis (defined based on SCC)? 3) What are the most common bacteria recovered from cows with SCC values >200,000 cells/ml? 4) What proportion of subclinical cases are chronic (persist more than 2 months)? 5) What is the prevalence of subclinical mastitis by days in milk and parity? 6) What proportion of cows have subclinical mastitis at the first test and the last test? Data to answer these questions can often be found in summarized reports available from DHIA testing centers or the data can be downloaded and manipulated in customized spreadsheets or dairy management programs. Common KPI for subclinical mastitis are: **85% cows with somatic cell counts ≤200,000 (prevalence)** and less than ***<5% of cows developing new subclinical mastitis infections per month*** **(incidence) (Table 3).**

Somatic cell counts should be reviewed monthly at both the herd level and at the cow level. At herd level, evaluation of monthly SCC patterns can be highly diagnostic for troubleshooting subclinical mastitis problems. For example, herds that exceed targets for prevalence of subclinical mastitis at first test are often herds that are experiencing problems with environmental mastitis pathogens. In these cases, housing conditions, udder hygiene and management of dry and periparturient cows should be investigated. In contrast, when contagious mastitis is a problem, prevalence of subclinical mastitis usually increases as lactation progresses and as cows age because of more opportunities for exposure to infected milk. When contagious mastitis is suspected, transmission of mastitis pathogens during milking should be investigated with special emphasis on detecting inadequate teat dipping or the presence of fomites (such as towels used to clean or dry more than one cow). A large proportion of cows with apparently chronically increased SCC (more than 2 consecutive monthly tests exceeding the threshold) indicates that cows are infected with host adapted pathogens that are usually transmitted in a contagious manner. At the cow-level, practitioners often find it helpful to review a list of individual cows sorted by SCC to identify cows that may require individual interventions. The use of a rapid cowside quarter-level SCC test, can help farmers make important management decisions such as whether or not to segregate, treat, culture, withhold high SCC quarters or cull the cow.

Measuring and monitoring bacteriological quality of bulk milk. Processors are increasingly paying premiums based on bacteriological qualities of raw milk. Many processors measure bacteriological quality of milk on every tanker load of milk and provide online access to daily milk quality reports. 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) via mastitis organisms from within the udder (Reinemann et al., 1999). Raw milk from healthy udders normally contains < 1,000 total bacteria per ml; and therefore do not significantly contribute to total numbers of microorganisms in bulk milk, or to a potential increase in bacterial numbers during refrigerated storage (Murphy and Boor, 2000). It

is unusual for mastitis to contribute to increased total bacteriological counts in raw milk but occasionally cows with mastitis can shed large numbers of microorganisms. Investigations of bacteriological quality of raw milk begin with the following questions: 1) How many tests of bacteriological quality have been performed and do the counts demonstrate a trend or a "spike?" 2) What is the average, minimum and maximum standard plate count? 3) What other diagnostic tests of milk quality have been performed and how do they compare? 4) If available, what are the values for: a) laboratory pasteurized count (LPC); b) preliminary incubated count (PIC); and c) coliform count (CC)?

The SPC is an overall measure of milk quality but a single SPC value is not very useful diagnostically. Consistently increased values for SPC are an indication of a milk quality problem and the best diagnostic strategy is to perform strategic sampling of milk at various points throughout the milking process. Comparison among the values of diagnostic counts (SPC, LPC, Coliform count, and SCC) can give valuable clues as to the likely source of the problem (Reinemann, 1999). The LPC is basically a SPC performed on milk that has been heated to 145F (62.8C) and held for 30 minutes (low temperature-long time pasteurization). The objective of performing the LPC is to identify organisms that survive pasteurization (thermoduric bacteria). Typical mastitis causing organisms do not survive pasteurization. Thermoduric bacteria may include Micrococcus, Microbacterium, Lactobacillus, Bacillus, Clostridium and occasional Streptococci. Increased LPC are often associated with the development of biofilms on unclean equipment. The LPC should be less than 100 to 200 cfu/ml and a LPC below 10 cfu/ml indicates excellent equipment hygiene (Reinemann et al., 1999). ***Goals for high performing herds are set by processors and are not uniform across the industry but SPC of <5,000 cfu/ml and LPC of < 200 cfu/ml are reasonable goals for high performing herd (Table 4).***

Microbiological Analysis of Bulk Tank Milk. Microbiologic examination of bulk tank milk is a standard element of mastitis control programs and is the first step in the development of a milk quality plan. Bulk tank cultures (BTC) are often used to screen for mastitis pathogens in herds (or groups) of lactating dairy cows. The sampling interval, sample collection, microbiological methods and report format have not been standardized and it is difficult to compare results of BTC among laboratories. To ensure that diagnostic test results will be useful, veterinarians should submit bulk tank milk samples to a single, specialized laboratory that uses methodologies that include plating dilutions of milk and use of selective medias for isolating and counting bacterial colonies. Protocols for bulk tank culturing can be found at the NMC website http://www.nmconline.org . In most instances, milk quality laboratories should include screening for mycoplasma spp. in their normal diagnostic protocols.

The interpretation of BTC results can be confusing because isolates can arise from subclinical mastitis infections, inclusion of milk obtained from cows with clinical mastitis in the bulk tank and from environmental contamination during milking. The best use of results of BTC is to identify herds that have cows subclinically infected with contagious mastitis pathogens (such as *Staphylococcus aureus, Mycoplasma bovis or Streptococcus agalactiae)*. In almost all instances, the occurrence of these pathogens in bulk tank milk is highly predictive of the presence of infected cows within the dairy herd (Wilson and Gonzalez, 1997). However, the failure to isolate pathogens from bulk milk DOES NOT indicate that infected cows are not present in the herd, as the test is not very sensitive and it is not unusual to identify infected cows in spite of an apparently negative bulk tank culture. Likewise, the number of organisms isolated does not

correspond to the prevalence of infected cows in the herd and comparisons of colony counts before and after implementation of a control strategy should not be used to assess response to interventions.

Interpretation of BTC results must be performed by considering characteristics of the individual organisms that are recovered from the milk. Typical KPI for evaluating BTC reports are available (Table 5) but the scientific validity of the recommendations have not been well documented. Pathogens found in bulk milk samples can originate from infected udders, teat skin or contamination during milking. Non-agalactiae *streptococci* are usually present in the environment of the cow. While shedding of bacteria from subclinical infections can contribute to excessive numbers of environmental *streps*, poor premilking hygiene should always be investigated when excessive numbers of these organisms are found, especially when the BTC results also indicate excessive numbers of coliform bacteria. The natural duration of intramammary infections caused by coliform organisms is short, therefore excessive numbers of coliforms suggests poor premilking hygiene or environmental contamination. As is typical for all diagnostic tests, confidence in the results increases when the test results are repeatable. When an unusual result of a BTC is found, the first step should be to repeat the test to verify the diagnosis. The submission of bulk tank milk samples that have been independently collected for 4 consecutive days and submitted together is recommended by many laboratories to increase the sensitivity (Farnsworth, 1993). In most laboratories the samples will be commingled and processed as one sample to reduce costs.

Managing the Milking Process. A consistent method of pre-milking sanitation and uniform attachment of properly functioning milking machines are both fundamental processes that help ensure production of high quality milk. While most dairy veterinarians are not comfortable assuming primary responsibility for milking parlor design or maintenance of milking equipment, knowledge of basic milking equipment function is essential. Appropriate testing of milking equipment requires specialized equipment and should follow procedures that have been defined by the NMC (NMC, 2007). Some dairy veterinarians may wish to invest in equipment such as air flow meters, digital vacuum recorders and specialized milk flow meters while others may be more comfortable interpreting reports produced by milking equipment service professionals. An appropriately designed mechanical milking system will provide stable partial vacuum and effective compression at the teat end to rapidly remove milk without causing congestion. There are a number of measurements that can be performed to investigate airflow, pulsation characteristics and vacuum level. When initiating an investigation of milking machine function, key performance indicators include average claw vacuum and maximum claw vacuum fluctuation (Table 6). Practitioners should ensure that all pulsators are properly functioning and calibrated to provide sufficient duration of the massage phase of the pulsation cycle. Tests of milking equipment should be performed during milking time as part of scheduled maintenance program, when changes are made to the milking system and whenever farm conditions indicate the need to improve milking performance or mastitis control.

Consistent use of good milking practices is essential to control mastitis. As part of the milk quality plan, production medicine practitioners should routinely observe the milking process and be prepared to evaluate compliance with KPI for milking performance (Table 6). Several components of the milking process merit special attention.

a. *Premilking teat disinfection*. Methods of premilking teat preparation have been extensively studied (Galton, et al., 1984, Galton et al., 1986, Ruegg and Dohoo, 1997). There is no question that the most effective method to disinfect teats is to predip using an effective disinfectant. Pre-dipping using iodine has been demonstrated to reduce standard plate counts and coliform counts in raw milk by 5 and 6 fold, respectively as compared to other methods of premilking udder preparation (Galton, et al., 1986). Effective predipping also contributes to improvements in food safety. Predipping has been shown to reduce the risk of isolation of *Listeria monocytogenes* from milk filters obtained from New York dairy herds by almost 4 fold (Hassan et al., 2001). For effective reduction in bacterial numbers, the disinfectant must be in contact with teat skin for sufficient time to adequately kill bacteria. Teat dips must be properly formulated, stored in clean containers, completely applied to debris free teats, and allowed sufficient time (usually at least 30 seconds) for action before removal.
b. *Examination of foremilk*. The examination of milk before attaching milking units is useful to ensure that abnormal milk is diverted from the human food chain and to identify cases of clinical mastitis at an early stage when the only symptom may be mildly abnormal milk. Forestripping is adequately performed when 2-3 streams of milk are expressed and is an effective means to stimulate milk letdown. When both predipping and forestripping are practiced, there is no data that indicates that the order that the steps are performed will affect milk quality (Rodrigues et al, 2005). Milking technicians should be encouraged to wear disposable nitrile or latex gloves to reduce the potential spread of mastitis pathogens by contaminated hands.
c. *Drying of Teats*. Effective drying of teats is probably the most important step to ensure hygienic teat preparation. Drying of teats has been demonstrated to reduce bacterial counts of teat ends from 35,000 – 40,000 cfu/ml for teats that were cleaned but not dried to 11,000-14,000 cfu for teats that were dried using a variety of paper towels (Galton et al., 1986). A single dry cloth or paper towel should be used to dry teats of each cows. The use of a single towel to dry udders on more than 1 cow has associated with a greater monthly rate of clinical mastitis (7.8% for herds that used 1 towel/cow versus 12.3% for herds that used towels on >1 cow; (Rodrigues et al., 2005).
d. *Attaching the milking unit.* One objective of the milking routine is to attach the milking unit to well-stimulated cows that have achieved milk letdown, thus maximizing milk flow (Figure 10A). The time period between stimulation of the cow and unit attachment is often referred to as the "prep-lag" time. A number of studies have been performed to determine the optimal prep-lag time (Maroney et al., 2004, Rasmussen et al., 1992). It is well recognized that the need for stimulation varies depending on yield, stage of lactation, milking interval and breed (Bruckmaier, 2005). Historically, a prep-lag time of 45-90 seconds has been recommended, but negative consequences (reduced milk yield) have not been reported until lag times have exceeded 3 minutes (Dzidic et al., 2004, Maroney et al., 2004, Rasmussen et al., 1992). The failure to achieve adequate milk letdown will often result in bi-modal milk flow and the application of the milking unit without stimulation or immediately after stimulation should be discouraged. It appears that prep-lag times longer than 90 seconds will not be uniformly detrimental but premature attachment of the milking unit should be avoided (Dzidic et al., 2004, Maroney et al., 2004).

e. *Managing cows post-milking*. Post-milking teat antisepsis was initially developed to reduce the transmission of contagious mastitis pathogens and is based on killing bacteria that are present in milk that is present on teat skin after milking has been completed. Post-milking teat dipping is one of the most highly adopted practices in the dairy industry and it is the final hygienic defense against infection after milking is completed. While teat dipping is universally recognized as a useful practice, effective implementation of teat dipping is often variable. To maintain excellent hygienic standards and minimize mastitis, continued education of milking technicians about the principles of mastitis control is often necessary. Evaluation of the effectiveness of post-milking teat dipping is best performed when milking technicians are not aware of the evaluation. When colored teat dips are used, one effective method of evaluation is to surreptitiously score teats of cows in the return lanes after milking. If possible teats from at least 20-30 cows should be examined and the goal is to observe complete coverage (75%) of at least 95% of observed teats. Digital photographs of well covered and inadequately covered teats are an excellent training tool that can be used to demonstrate proper teat dipping.

Conclusion

The delivery of milk quality programs by veterinarians is an important overall component of a dairy production medicine program. Preventing mastitis and improving milk quality is vitally important role that contributes to improved animal wellbeing, enhanced farm profitability and better assurances that food is being produced in a safe and sustainable way. Dairy veterinarians should seek out involvement in continuing education programs that focus on research based methods and advancements in mastitis control. Milk quality programs must continue to advance with changes in pathogens, changes in milking equipment and cow housing systems and as societal expectations evolve.

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Table 1. Distribution of severity scores for clinical mastitis from selected studies.

Severity Score	Clinical Symptom	Study 1[1]	Study 2[2]	Study 3[3]	Study 4[4]	Coliform cases only[5]
		N = 686	N = 169	N = 212	N = 233	N = 144
1 (mild)	Abnormal milk only	75%	57%	52%	65%	48%
2 (moderate)	Ab.milk & swollen udder	20%	20%	41%	27%	31%
3 (severe)	Ab.milk, swollen udder & sick cow	5%	23%	7%	8%	22%

[1]Nash et al., 2002; [2]Oliveira, 2009; [3]Rodrigues et al., 2009; [4]Pinzon & Ruegg, 2010; [5]Wenz et al., 2001 (equivalent scoring system used)

Table 2. Calculation of suggested key performance indicators for clinical mastitis. For ease of interpretation, a case is defined as the occurrence of mastitis in 1 or more quarters of a cow.

Indicator	Calculation[a]	Suggested Goal
Incidence Rate	Sum of first cases occurring in the appropriate time period[a] divided by average number of lactating cows in the same time period[b]	< 25 new cases per 100 cows per year (about 2-3 cases per 100 cows per month)
Proportion of cases scored 3 (severe)	Number of severity score 3 cases occurring divided by the total number of cases occurring	5-20% of total cases
Proportion of cases that die	Number of cows experiencing mastitis cases that resulted in death divided by the total number of cows experiencing mastitis	2%
Proportion of cases requiring treatment changes	Number of cases where the initial protocol is changed or supplemented because of non-response divided by the total number of detected cases[c]	<20%
Proportion of cases that are recurrent (second or greater treatment)	Number of cows with second or greater case of mastitis occurring >14 days post treatment divided by the total number of cases of mastitis	<30%
Proportion of cows with > 1 quarter affected	Number of cases with 2+ quarters affected divided by the total number of cases	<20%
Number of days milk discarded (per case)	Sum of the number of discard days for the time period divided by the total number of cases	4-6 days (unless many cows are receiving extended therapy because of a high prevalence of Staph aureus)
Percent of herd milking with <4 quarters	Number of cows milking with < 4 quarters[d] divided by the number of lactating cows	<5%

[a]numerators and denominators should include the statement "in the appropriate time period." The appropriate time period will vary depending on herd size.;[b] a more correct denominator would exclude cows that had previously experienced a clinical case within that lactation; [c]cases which are detected but do not receive initial antimicrobial treatments should be included in this calculation; [d]herds that use quarter milkers to discard milk from selected quarters should include those cows in the numerator

Table 3. Calculation of suggested key performance indicators for subclinical mastitis.

Indicator	Calculation	Suggested Goal
Prevalence	Number of cows with SCC >linear score 4[a] divided by the number of cows with somatic cell counts	<15% of the herd
Incidence	Number of cows with SCC > linear score 4[a] for the first time in the time period of interest[b] divided by the number of cows with SCC below the threshold in the previous time period	<5% if incidence is determined based on the first SCC above threshold in the lactation; up to 8% if calculated based on month to month changes in SCC[b]
Prevalence at 1st DHIA Test	Number of cows with SCC >linear score 4[a] at the 1st DHIA test divided by the number of cows with first test DHIA somatic cell counts	<5% of 1st lactation <10% of lactation 2+
Prevalence at last DHIA Test before dry off	Number of cows with SCC ≥linear score 4[a] at the last DHIA test before dry off of the lactation divided by the number of cows with last test DHIA somatic cell counts	<30% of cows with last test days before dry off

[a]for the purpose of herd monitoring, linear somatic cell score of 4 is used interchangeably with somatic cell count of >200,000 cells/ml; [b]The appropriate time period will vary depending the intended use of this index. Many DHIA centers & computer management programs will calculate this index based on changes between 2 months. Others may calculate it based on the SCC values available in the current lactation.

Table 4. Key performance indicators and sources of typical bacteria used to troubleshoot problems with bacteriological quality of raw bulk milk.

Indicator	Type of Bacteria Detected	Common Sources	Suggested Goal
Standard Plate Count	Quantifies most viable, aerobic bacteria found in milk	Contamination during milking; problems with milk cooling; cleaning failures	<10,000 cfu/ml
Laboratory pasteurized count	Thermoduric bacteria (such as bacillus, clostridia etc.)	Biofilm development on milking equipment as a result of cleaning failures; occasional problems with contamination	<200 cfu/ml
Preliminary incubated count	Psychrotrophs (such as pseudomonas and others)	Contamination during milking; cooling problems	<10,000 cfu/ml
Coliform count	Coliform bacteria (such as E.coli and Klebsiella)	Contamination during milking rarely mastitis	<100 cfu/ml)

Table 5. Key performance indicator (KPI), sources and suggested interpretation of bulk tank milk culture results.[a]

Bacteria	Goal (cfu/ml)	Typical Sources in Milk	Interpretation
Streptococcus agalactiae	0	Mastitis infections	Isolation of any colonies indicates likely presence of infected cows
Staphylococcus aureus	0	Mastitis infections, teat skin	For both pathogens, isolation from bulk tank milk indicates the likely presence of infected cows; repeated isolation in BTM usually found in herds with greater prevalence
Mycoplasma spp.	0	Mastitis infections	
Coagulase-negative Staphylococci (CNS)	<250-500	Teat skin contaminant	Investigate pre-milking teat disinfection
Environmental streptococci	<500	Contamination from dirty udders or milking equipment; occasionally caused by mastitis infections	When env.strep and coliforms both exceed goals it is a strong indication that the source was poor milking hygiene.
Coliforms	<100		
Others	0	Pseudomonas spp.	Presence of significant numbers often indicates contamination of milk with water
	0	Bacillus spp.	Presence of significant numbers often indicates poor milk sample handling

[a]adapted from Farnsworth, 1993 and Jayarao et al., 2004

Table 6. Selected key performance indicators (KPI) for milking systems and milking performance

Source	Indicator	Suggested Goal
Milking Machine	Average claw vacuum	35-42 kPa
	Maximum claw vacuum fluctuation	< 10 kPa
	Average milk flow	2.3 – 4.1 kgs/min
	Use of manual mode of milking (when automatic detachers are used)	<5% of milkings
	"D" phase of the pulsation cycle	At least 150-200 ms
Milking Process	Premilking teat dip contact time	30 seconds before dry off[a]
	Prep-lag time (time from stimulation to milking unit attachment)	60 to 120 seconds
	Milking unit attachment time	3 to 8 minutes (depending on milk production)
	% of teats with at least 75% coverage with post-milking teat dip	>90%

[a]some product characteristics may allow for more rapid bacterial kill, label instructions for products with published research data should be followed;