AS1131 (Revised)

Mastitis Control Programs

Milk Quality Evaluation Tools for Dairy Farmers

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Several different methods are used to assess milk quality. Some methods such as somatic cell count (SCC) and standard plate count (SPC) are mandated. Other methods, while not mandated, are used to monitor milk quality and help diagnose potential on-farm problems/deficiencies associated with abnormally high counts and poor quality milk.

Regulatory tests establish that the milk being shipped by producers meets the legal minimum quality standards established by the Food and Drug Administration (FDA) and adopted by state departments of health. These regulations are in the Pasteurized Milk Ordinance (PMO). Tests are conducted for SCCs, bacterial numbers, and the presence of antibiotics and added water.

Producers can use these and a variety of informational tools to monitor the mastitis in their herds and the quality of milk being shipped to processors (Table 1).

Table 1. Mastitis and milk quality tests.

Test	Abbrev.	Measurement	Tests Conducted By
Somatic Cell Count	SCC	White blood cells in milk	Regulatory, Co-op/Plant, DHI, Vets, Independent/University
Individual Cow Somatic Cell Counting Program	Cow-SCC	SCC in individual cows at monthly intervals	DHI, Independent
Bulk Tank Somatic Cell Count	BTSCC	SCC of bulk tank milk	Regulatory, Co-op/Plant, Vets, Independent/University
Direct Microscopic Somatic Cell Count	DMSCC	Standard method for determining SCC of a milk sample	Regulatory, Co-op/Plant, Independent/University
Wisconsin Mastitis Test	WMT	Indirect measure of SCC in a milk sample (antiquated)	Co-op/Plant, Vets, Independent/University
California Mastitis Test	CMT	Cow-side test for SCC in milk	Vets, Producers
Standard Plate Count	SPC	Total number of bacteria in a milk sample	Regulatory, Co-op/Plant, Independent/University
Preliminary Incubation	PI	Number of psychotrophic (cold-loving) bacteria in a milk sample	Co-op/Plant, Independent/University
Bulk Tank Milk Cultures	BTMC	Estimates total number and type of bacteria in a milk sample	Vets, Co-op/Plant, Independent/University
Cow/Quarter Cultures	—	Infection status of cows/quarters and pathogen type	Vets, Independent/University, Co-op/Plant

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Somatic cell count (SCC) is used throughout the world as an indicator of milk quality. Milk from uninfected mammary glands contains less than 100,000 cells/milliliter (ml). The SCC will increase in a quarter as a result of an infection. An SCC of greater than 200,000 cells/ml suggests that an inflammatory response has been elicited, or that a mammary quarter is infected or is recovering from an infection, and is a clear indication that milk has reduced manufacturing properties.

The bulk tank SCC (BTSCC) can be used to gauge the udder infection status of an entire dairy herd and also gives a good indication of the loss in milk production due to mastitis. As the BTSCC increases, the percentage of mammary quarters infected increases and the percentage of production loss increases.

Most herd milk contains between 200,000 and 500,000 cells per/ml of milk. These herds are losing at least 8 percent in potential milk production. Thus, methods of mastitis control that reduce SCC not only will improve milk yield, composition and quality but also will decrease economic losses due to mastitis.

The bacterial count is another primary measure of milk quality. Bacteria are present in milk as a result of milking infected mammary quarters, contamination from the environment during milking, dirty milking equipment and growth during milk storage. The majority of bacteria in milk are the result of contamination from the environment and dirty equipment. The contribution from infected mammary quarters generally is small by comparison. Milking wet, dirty udders, together with poorly cleaned and sanitized inflations, milking claws, hoses, pipelines and bulk tanks. are primary sources of high bacterial counts. The overuse of inflations leads to the rubber cracking and ideal areas for bacteria to grow. This is a frequent cause of high bacterial counts.

Table 2 lists the types of information derived from the analysis of one or more tests on a milk sample to determine SCC or bacterial content. No one test simultaneously determines both. Analysis of bulk tank milk samples yields information on the herd, while analysis of milk samples from individual cows/quarters yields specific information about that cow/quarter. Whole-herd information also can be obtained by testing individual milk samples from all cows in the herd.

SCC Limit

The current upper legal limit for SCCs of 750,000 cells/ml has been in place since 1993. Under the PMO, milk from each dairy farm must be tested for SCCs at least four times every six months. Most plants test every tank from every farm. If a farm has two samples out of four that exceed the 750,000 limit, it receives a notice. If a farm has three samples out of five that exceed the limit, it gets degraded and no longer can sell Grade A milk. Before 1993, the legal limit was 1 million cells. Before 1986, it was 1.5 million.

Many in the industry have thought that the SCC limit in the U.S. should be reduced to 400,000 to bring the U.S. regulations more in line with those from other countries, especially those that serve the growing global dairy product market. Recently, the U.S. has exported the equivalent of up to 12 percent of its milk production.

The issue came to a head during the May 2011 biannual National Conference on Interstate Milk Shipments (NCIMS), in part, because of stepped-up enforcement of the European Union's long-standing regulation that dairy products imported from the U.S. be from sources with SCCs below 400,000. This was deemed to apply to each individual farm, not just the average of a group of farms.

Table 2. Information derived from mastitis and milk quality tests.

Test	Importance of Information	Disadvantages
BTSCC	1. Indicator of herd mastitis prevalence	1. No indication of which cows/quarters are infected 2. No indication of pathogens involved 3. Poor monitor of environmental mastitis
SPC	1. A monitor of milking equipment sanitation, milking time hygiene and efficiency of milk cooling	1. No indication of bacterial types 2. No indication of specific source of contamination
LPC **PI**	1. A monitor of pasteurization, ensure quality of the final product 2. Indication of bacterial contamination from environmental sources 3. Low values necessary for quality bonus payments	1. Only indication of cold-loving bacterial types 2. No indication of causative agents 3. No indication of the specific environmental source
Individual Cow SCC	1. Monitor of subclinical mastitis in a cow 2. Can be used to assess subclinical mastitis in a herd 3. Informed management decisions (culling) 4. Assess monetary losses associated with subclinical mastitis	1. No indication of causative agents 2. Poor monitor of environmental mastitis 3. Poor indicator of clinical mastitis
CMT	1. Inexpensive, rapid and subjective evaluation of quarter SCC at cow-side	1. Interpretation is difficult 2. Relative numbers of pathogens are poorly related to infection prevalence 3. The source of organisms other than contagious pathogens is not indicated
BTMC	1. Estimates SPC 2. Detects presence of specific pathogen types 3. Indicates primary bacterial contaminants 4. Can be used to evaluate milking time hygiene	1. Interpretation is difficult 2. Relative numbers of pathogens are poorly related to infection prevalence 3. The source of organisms other than contagious pathogens is not indicated
Cow/Quarter Cultures	1. Only method that determines infection status of a cow/quarter 2. Identifies specific causative agents in clinical and subclinical mastitis	1. Costly 2. Requires special training to collect and analyze samples

The NCIMS meets every other year to discuss points in the PMO, which serves as the basis of inspections and quality control for dairy farms and dairy plants that handle Grade A milk. Action taken by the NCIMS is advisory to the FDA, which is responsible for inspections and milk safety.

Proposals to lower the SCC limit to 400,000 have been submitted by the National Mastitis Council several times. The proposals primarily have been rejected on the basis that SCCs/mastitis constituted an animal health issue, not a human health or milk safety issue. The USDA's Dairy Industry Advisory Committee recommended that a farm-level, Grade A SCC limit of 400,000 be implemented during a 48-month period or less.

In the end, the proposal to lower the SCC legal limit for Grade A milk to 400,000 by 2014 was narrowly defeated. Undoubtedly, attempts will be made to change the SCC limit in the 2012 Farm Bill or through some other legislation. Nonetheless, keeping all bulk tank milk SCCs at less than 400,000/ml is a worthy goal for all dairy farms to improve cow health, increase milk production and achieve milk quality payment incentives.

Standard Plate Count

The primary bacterial count used is the standard plate count (SPC), sometimes referred to as the plate loop count or raw count. The SPC determines the total number of bacteria in a milk sample that can grow and form countable colony forming units on a standard methods agar plate when 1 ml of milk is incubated aerobically at 90 F for 48 hours. Ideally, raw milk should contain less than 5,000 bacteria/ml. If sanitation in the cows, the milking procedures and the milking equipment is good and cooling is adequate, an SPC of 10,000/ml or less is achievable by most farms. The maximum legal limit for the SPC is 100,000/ml for Grade A milk and 500,000/ml for Grade B or manufacturing milk.

Eliminating all sources of bacterial contamination of milk is impossible; however milk from clean, healthy cows that has been collected properly generally has an SPC of less than 1,000 colony-forming units (cfu)/ml.

Consistent application of proper milking practices, udder hygiene, and good mastitis prevention and control practices should allow dairy producers to produce milk with an SPC of less than 5,000 cfu/ml. High bacterial counts (greater than 10,000 cfu/ml) suggest that bacteria are entering milk from a variety of possible sources.

The most frequent cause of high SPCs is poor cleaning of milking systems. Milk residues on equipment surfaces provide nutrients for growth and multiplication of bacteria that contaminate milk of subsequent milkings. Cows with mastitis (streptococcal and coliforms), soiled cows, unclean milking practices, failure to cool milk rapidly, failure of the water heater, and extremely wet and humid weather also can contribute to high SPCs in raw milk. Some limitations of the SPC method are: 1) no indication of the bacterial types present, 2) no indication of the specific source of high counts and 3) the SPC does not give a complete count of all bacteria because some bacteria only grow at lower temperatures.

Preliminary Incubation Count

Another measure of milk quality is the preliminary incubation count (PI count or PIC). Results of this test are interpreted as a general reflection of milk production practices on the farm and are used as a tool to identify inadequate on-farm sanitation practices and holding temperature of milk in the bulk tank.

To determine the PIC, a sample of milk is incubated for 18 hours at 55 F, followed by the SPC procedure. The PI count is based on the theory that the normal microbial flora of the cow will not grow substantially when incubated at this combination of time and temperature.

Other microorganisms in milk due to poor sanitation, cooling and milking practices can grow to significant levels at these times and temperatures. These microorganisms are called psychrotrophs, or cold-loving bacteria. Psychotrophic bacteria will continue to grow at temperatures below 45 F. These organisms and the enzymes they produce are associated with off-flavors, milk spoiling and short shelf life. This has led some people to believe that the PIC is the best measure of raw milk-keeping quality and sanitation practices on farms.

No legal limit has been set for the PIC. A PIC below 50,000 is acceptable, but a goal of 25,000 or less should be achievable. Many can have a PIC of 10,000 or less, just like the SPC, if sanitation, cooling and milk procedures are done properly and monitored.

Another approach for determining the quality of the milk and good practices on the farm is the PIC in relation to the SPC. If the PIC is greater than three times the SPC, the farm has a potential problem. For example, if a milk sample has an SPC of 10,000 and a PIC of 11,000, then no substantial increase occurred and the PIC would not imply poor cooling, milking or cleaning practices. If the PIC had been 30,000 or greater, this would imply that procedures on the farm should be checked.

Failure to cool milk rapidly, marginal cooling, prolonged storage times, milking cows with wet teats, and/or extremely wet and humid weather conditions also may result in high PI counts. Another example would be if the sample has an SPC of 100,000 and a PIC of 115,000. Although the PIC count is greater than 100,000, the sample provides no additional information because no substantial growth occurred. In this case, an SPC of 100,000 would be indicative of a bacterial problem by organisms that grow poorly at 55 F within 18 hours.

Co-op/plant quality premium tests include the determination of SCC and bacterial numbers, generally by both the SPC and preliminary incubation (PI) methods. Minimum standards to receive bonus payments for high-quality milk will vary among milk procurement agencies, but in general, bonus payments start at 300,000 somatic cells/ml and 10,000 bacteria/ml by both the SPC and PI methods. Milk also generally has other requirements to meet, such as the absence of antibiotics.

Informational tests include the regulatory and co-op/plant quality premium tests. In addition, many veterinary diagnostic and other laboratories do bulk milk tank cultures (BTMC). This test estimates the total number of bacteria in the bulk tank milk and provides information on the specific types of bacteria present. It is a good place to start when troubleshooting a herd mastitis problem. The SPC and PI tests do not reveal the specific types of bacteria present.

Other Tests

- The **laboratory pasteurization count (LPC)**, also known as the thermoduric count, is an estimate of the number of bacteria that can survive laboratory pasteurization at 62.8 C (143 F) for 30 minutes. This process destroys most of the mastitis-causing pathogens, selecting for those bacteria that can survive pasteurization temperatures (thermoduric bacteria). Some milk processors perform this test to ensure the quality of the final product.

  Bacteria not killed by pasteurization are enumerated using the SPC method. LPCs are generally much lower than SPCs. An LPC of greater than 200 cfu/ml is considered high. A high LPC most often is seen with persistent cleaning problems; faulty milking machine or worn out parts such as leaky pumps, old pipe line gaskets, inflations and other rubber parts; and milkstone deposits. Significant contamination from soiled cows also can contribute to high LPCs.

- The **coliform count** is a test that estimates the number of bacteria that originate from manure or a contaminated environment. Milk samples are plated on violet red bile agar or MacConkey's agar and incubated for 48 hours at 32 C (90 F), after which typical

coliform colonies are counted. Coliform counts reflect hygiene and sanitation practices followed on the farm.

Coliforms enter the milk supply as a consequence of milking dirty cows or dropping the milking claw into manure during milking. Coliform counts greater than 100 cfu/ml are considered high and suggest poor milking practices, dirty equipment, contaminated water, dirty milking facilities, and/or cows with subclinical or clinical coliform mastitis.

Testing Milk From Individual Cows

The primary purpose for testing milk from individual cows/quarters is to evaluate mastitis. None of the tests applied to milk from individual cows is used by regulatory agencies or co-op/plant quality premium programs. Individual cow tests are simply informational and the next logical step for troubleshooting herd mastitis problems.

The most widely used program for determining the SCC of milk from individual cows is the Dairy Herd Improvement (DHI) SCC program. Some independent mastitis-testing laboratories offer a similar service, and some milk procurement agencies will test milk samples from individual cows for SCC. The DHI SCC program determines somatic cells in composite milk at monthly intervals.

These data can be used to determine which cows are likely to be infected, but they cannot be used to determine which of the four mammary quarters are infected or the type of pathogen causing the infection. The California Mastitis Test (CMT) is the most widely used cow-side test for estimating the SCC of individual quarters.

Somatic cell counts measure inflammation and are an indirect measure of the presence or absence of infection. The true infection status of a cow/quarter can be determined only by microbiological analysis (culturing) of aseptically taken milk samples.

Milk samples to be tested can be composite samples (an equal volume of milk from each quarter is drawn into the same tube) or individual quarter samples. This type of testing determines the presence or absence of pathogens and the type of pathogen. Results from multiple samples taken through time are more reliable indicators of infection status than results from a single sample.

When culturing a single milk sample, four types of results are possible:

1. The sample yields the correct result
2. A pathogen is isolated, but the quarter is truly not infected — *a false positive*
3. Nothing grows (no isolation), but the quarter is truly infected — *a false negative*
4. The sample is contaminated, three or more pathogen types grow and the results are impossible to interpret — *contaminated sample*

The number of samples yielding incorrect results will vary between 10 and 20 percent of milk samples when routinely sampling cows. However, the percent of incorrect samples can be as high as 30 to 50 percent if the samples are only from clinical quarters.

Conducting Milk Quality Tests

Bulk Tank Milk Tests

Regulatory tests are conducted in laboratories operated by state departments of health or equivalent agencies or in laboratories approved by these agencies. The PMO indicates that milk from all herds will be tested at least four times in any six-month period. Somatic cell counts are determined almost exclusively by electronic counting methods using a series of milk samples with varying cell concentrations.

Cell numbers in the standards are determined by the direct microscopic method, and the cell count is referred to as the direct microscopic somatic cell count (DMSCC). The DMSCC method is considered the standard method with which all other cell counting methods are compared. Even with calibrated machines, any single number generated will have an approximately 15 percent error rate. A 15 percent error rate means that a cell count of 100,000 cells/ml really could be anywhere between 85,000 and 115,000 cells/ml.

The standard plate count method accurately determines the total number of bacteria present in a milk sample, but it does not determine the type of bacteria present. To run the SPC, a precise volume of milk is added to a given quantity of media and the plate is incubated for 24 hours. The number of colonies is counted accurately and expressed as bacteria/ml of milk. Other names often used to describe the SPC are “loop count” and “bacteria count.”

Co-op/plant quality premium tests generally are conducted in laboratories operated by the co-op or plant. Some tests may be carried out in independent laboratories, and some co-ops/plants may utilize the test data derived by regulatory agencies.

Most co-op/plant quality premium programs determine SCCs by electronic means and generally use a Fossomatic or equivalent machine. The Fossomatic counts the number of DNA particles or somatic cell nuclei. Proper calibration of the machines is essential. No single “standard milk sample” is available to standardize all machines. Most laboratories frequently test the accuracy of their machines by comparing the cell count generated with the value derived by the DMSCC method.

Most co-ops/plants determine the number of bacteria in milk using the SPC and PI methods.

The value of the PI count is that it gives a better indication of the shelf life of fluid milk. To determine the PI count, the raw milk sample previously used to determine the SPC is incubated at 55 F for 18 hours and then the bacterial count is determined using the SPC method.

Veterinarians and others frequently are interested in not only the number of bacteria present in bulk tank milk but also the various types of bacteria. A test that is growing in use is bulk tank milk culturing (BTMC). In contrast to the SPC and PI methods, BTMC is not standardized or quantitative, and exact methods vary among laboratories.

A common practice is to spread approximately .01 ml of milk evenly over the entire surface of an esculin blood agar plate. Some laboratories use media that is selective for the growth of staphylococci, streptococci, coliforms or mycoplasma in addition to the esculin blood agar. The total growth on the esculin blood agar approximates, but is not identical to, the SPC. The test primarily is used to determine the presence of contagious pathogens in the dairy. The primary contagious pathogens are *Staphylococcus aureus, Streptococcus agalactiae* and *Mycoplasma* spp.

Individual Cow Tests

Individual cow SCCs most frequently are determined in DHI laboratories, but independent laboratories do offer this service. Cells are counted electronically, generally using a Fossomatic machine. The DHI SCC program generally reports the values as the linear score, but some report the value as thousands of cells (for example, 100,000 = 100). The scale for the linear score is from 0 to 9, which means a linear score of 4 is equal to 200,000 cells/ml and a linear score of 6 is equal to 800,000 cells/ml.

The linear score is preferred because it can be related directly to production losses. Each increase of 1 in the linear score corresponds to a doubling of SCC and a milk loss of 400 pounds (lbs)/lactation (1.5 lbs/day) on second-lactation or older animals and 200 lbs/lactation (.75 lbs/day) on first-lactation animals.

High SCC quarters can be determined at cow-side using the California Mastitis Test (CMT). The CMT test is an estimate of the SCC. Veterinarians usually conduct bacterial analysis of milk samples from individual cows and quarters in their own laboratories or they use the services of independent or university laboratories. The primary purpose of culturing milk from individual cows is to determine the infection status of the cow or quarter and the specific pathogens infecting the herd.

Milk samples for culture must be taken with great care. Teats must be clean and dry and the teat end thoroughly scrubbed with alcohol pads prior to collection. Either composite milk from all four quarters or individual quarter samples can be tested. The most accurate method is to culture individual quarter samples. Composite milk samples often are used in an attempt to reduce the cost of testing. However, composite milk samples have limited microbiological value, and they do not reveal which quarters are infected.

Using the Information to Manage Mastitis and Milk Quality

The production of high-quality milk begins with the understanding that mastitis must be controlled and sanitary conditions must exist throughout the cow's environment. Bulk tank milk tests for SCC, SPC and PI provide producers with valuable information about the current status of mastitis and sanitation in their herds. Co-op/plant incentive programs have greatly increased producers' awareness of these quality tests.

Realistic goals are BTSCCs of less than 200,000 cells/ml and SPC and PI counts of less than 5,000 bacteria/ml. Many dairymen consistently produce milk with SCCs less than 100,000 cells/ml and less than 5,000 bacteria/ml.

A question frequently asked is whether SCCs can get too low. The SCC goals suggested are in the range of counts associated with uninfected quarters and are not physiologically abnormal.

Somatic cell counts are reduced by controlling mastitis and, more specifically, subclinical mastitis.

The BTSCC is a function of the percentage of quarters infected in the dairy herd. The contagious mastitis pathogens, such as *S. aureus, S. agalactiae* and *Mycoplasma* spp., are frequently causes of subclinical mastitis, a high percentage of infected quarters and BTSCCs of 500,000 cells/ml or greater. On occasion, high-SCC herds are found to have a significant problem with the environmental streptococci.

The BTSCC is the first clue to the amount of subclinical mastitis in the herd, and the DHI SCC program can be used to identify the high-SCC cows in the herd. A general rule is that cows with linear scores of 4 or greater are very likely to be infected, and the goal should be to have 90 percent of the cows with linear scores of 3 or lower.

Many producers try to make comparisons between DHI SCC herd means and BTSCCs derived from co-ops/plants. Direct comparisons are generally not valid. Somatic cell counts are very dynamic in individual cows for a given infection status, and the infection status of the herd is variable from day to day.

Bulk tank milk SCCs represent the milk from cows actually milked into the bulk tank, while DHISCC herd means may include cows whose milk was discarded. Samples may have been taken on different days, derived from a different number of milkings and analyzed in different laboratories, and cells may have been counted by different methods.

The specific bacterial cause of high SCCs is important information for the purposes of implementing a control procedure. Contagious pathogens are reduced by teat dipping with efficacious products, using dry-cow therapy, using single-service towels for udder preparation and properly maintaining milking machines. Environmental mastitis is reduced by minimizing exposure to the pathogens in the environment (inorganic bedding materials); milking clean, dry teats and udders; and minimizing liner slips during milking.

Bulk tank milk cultures are a quick way to determine if the contagious pathogens are in the herd. The presence of contagious pathogens in bulk tank milk almost always indicates infected mammary quarters in the herd. However, the absence of contagious pathogens does not prove that no cows are infected. Environmental pathogens present in bulk tank milk have multiple origins and are more likely a reflection of milking time hygiene than infected cows.

Total bacterial numbers from the BTMC should approximate the SPC, provided quantitative technique was used to determine the BTMC. Interpretations based on a single bulk tank sample can be very misleading. Multiple samples through time are highly recommended to obtain the maximum value of the BTMC.

The relative numbers of the various pathogens determined by using BTMC can be useful when trying to determine the possible cause of high SPC or PI counts. High SPC or PI counts are most often the result of dirty equipment, poor milking time hygiene or improper cooling of milk. On occasion, high SPC or PI counts may be the result of intramammary infections in the dairy herd. A high prevalence of quarters infected with *S. agalactiae* or the environmental streptococci can result in a high SPC. Spikes in PI count can, on occasion, be attributed to severe coliform infections that get milked into the bulk tank

Numbers of coliform bacteria can reach several million per milliliter in the infected quarter, and often the cow shows no signs of clinical mastitis until the following milking. The milk from such cows represents a high number of coliform bacteria entering the bulk tank, and coliform bacteria are a prime contributor to PI count.

For more information, see other NDSU Extension Service publications in the Mastitis Control Programs series:

- "Proper Milking Techniques," AS1126
- "Troubleshooting a Mastitis-problem Herd," AS1128
- "Bovine Mastitis and Milking Management," AS1129

For more information on this and other topics, see www.ag.ndsu.edu

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