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Methods to Detect Abnormal Milk — A Review

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ABSTRACT

Screening and confirmatory methods for detecting abnormal milk, mastitic milk, or milk of high somatic cell count are reviewed. Those procedures reviewed in some detail include the Catalase Test, Brabant Mastitis Reaction, pH and chlorine analysis, Ruakura Rolling Ball Viscometer method, California Mastitis Test (CMT), Wisconsin Mastitis Test (WMT), Optical Somatic Cell Count (OSCC), Direct Microscopic Somatic Cell Count (DMSCC), and Electronic Somatic Cell count (ESCC). Other detection methods are tabulated.

Many methods have been developed to screen dairy herds for subclinical and clinical mastitis. A number of confirmatory tests are also available. Table 1 gives most of the latest abnormal milk detection methods. Giesecki and Van den Heever (*21*) have extensively reviewed the literature on methods used to detect subclinical mastitis. A few of these methods have been further refined relatively recently. Somatic cell counts are used by regulatory agencies as a criterion for ascertaining abnormal milk. If the cell count exceeds a given number, action is taken to alleviate the problem. A discussion of some of the more recently developed tests follows:

TABLE 1. *Abnormal milk detection methods.*

Method	Reference(s)
Albumin/globulin ratio	*60*
Behavior of osmotically active substances	*54*
Blood-serum albumin in whey	*48*
Brabant mastitis test (BMR or BMT)	*39,68,100*
California mastitis test (CMT)	*2,19,25,55,56,64,68,74,78, 98,99*
Casein number	*82,85*
Catalase (or Roundy) mastitis test	*18,64,98,99*
Chloride ion	*30,61*
Chloride-lactose number	*44,45*
Coulter Counter (Electronic somatic cell count-ESCC)	*13,17,23,24,26,29,31,37,42,* 43,52,63,70,71,75,77,86,91, *97,99*
Dimastin test	*8,9,47*
Direct microscopic somatic cell count-DMSCC	*4,17,22,44,52,53,54,64,65, 76,84,91*
Electrical conductivity	*14,49,50*
Electronic counters	*92*
Flow-through cytophotometer	*94*
Fossomatic (fluorescense-optical technique)	*16,29*
Freezing point depression	*81*
Lactose content	*79*
Mastirapid mastitis test	*41,44*
Membrane-filter DNA	*3,5,33*
Milk quality gauge (MQG)	*10*
Modified whiteside test (MWT)	*98,99*
Negretti's test and Disk flotation technique	*18*
NK mastitis test	*34,35,36,40*
Optical somatic cell count (OSCC)	*44,83,89,90,96,100*
pH	*100*
Prescott-Breed cell count (smear method)	*41,73*
Ruakura rolling ball viscometer	*17,57,58*
Rennetability of milk	*79*
"Sofia" mastitis test	*62*
Use of difference in lactose content and refractometer number	*87*
Wisconsin mastitis test (WMT)	*1,10,22,32,46,59,66,69, 80,91,93,98,99*

CATALASE TEST

This test is a laboratory screening test used to detect abnormal milk (*98,99*). The test assays the amount of catalase present and this is an indirect measure of the somatic cell count of raw milk. Somatic cells contain a relatively large amount of catalase. In this test, hydrogen peroxide is converted to water and oxygen by the action of catalase. Fermentation tubes have been used to measure the amount of oxygen liberated during the reaction by displacement of the milk as the gas accumulates. Catalase content of normal milk is low, except at the beginning and end of lactation.

For this test to be of practical value, the results must be related to a reference standard. The standard most frequently used is the Direct Microscopic Somatic Cell Count (DMSCC). Since factors other than somatic cells may also affect the Catalase Test, interpretation of the results can be difficult. Various amounts of free catalase and/or bacterial catalase may occur in milk even though the detectable somatic cell count is low. There is no direct relationship between results of the Catalase and DMSCC tests; however, a general workable relationship has been established. Normal milk will generally generate less than 10% oxygen. Twenty percent or more oxygen suggests the presence of 500,000 or more somatic cells/ml.

BRABANT MASTITIS REACTION TEST (BMR)

Jaartsveld (*38*) determined that the capillary flow rate of a mixture of 0.6 ml of milk and 0.4 ml of Teepol No. 414 (10%) or sodium lauryl sulfate (3%) can be related to the somatic cell content of milk. The test is based on the reaction of a detergent and DNA in cell nuclei with the production of a viscous mass. The viscosity is determined by measuring the flow rate from the capillary tube. The BMR was first designated the California Mastitis Tube

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Test (CMTT) and was later called the Brabant Mastitis Reaction Test (abbreviated BMR or BMT).

Roughley et al. (*80*) modified this method and reported the results in terms of a milk gel index. The correlation coefficient (r) between the BMT and the Breed smear method (*73*) was 0.851 (*7*). Dijkman et al. (*15*) found that the BMT was useful for screening purposes but was of questionable use for grading farm milk, mainly because of poor accuracy and reproducibility in the 500,000 to 1 million somatic cell count range. The test also correlated poorly with the ESCC and DMSCC methods.

pH TEST

The pH of normal milk is 6.6 to 6.7. Mastitic milk may have a pH 6.8 or above (*6*). Methods of testing pH of milk employ the use of Bromthymol Blue (BTB) or Bromcresol Purple (BCP) as indicators in solution or on pH paper. When using BTB, abnormal milk causes a color change from grass green to blue-green; with the BCP, the change is from light to deeper purple. These tests provide only limited information and their results correlate poorly with those of the California Mastitis Test (CMT) and Catalase Test (*6,100*).

CHLORINE TEST

Milk-secreting cells are unable to prevent serum chloride from entering milk during a mastitis infection. Since sodium chloride is osmotically active, a compensating decrease in lactose content of milk occurs. For this reason, the chlorine content or the chlorine/lactose ratio can be used as indicators of abnormality. Chlorine content of an acidified milk mixture, at pH 2.0, can be measured by titrating silver nitrate to a potential of + 250 mv as determined by use of a pure silver electrode and pH meter (*30*). Each ml of the silver nitrate solution corresponds to 0.0100% of chlorine in a 10-ml milk sample. Chlorine content of over 0.14% indicates mastitic milk, and 0.12% is considered normal (*6*). This test, like the pH test, gives only limited information in detecting subclinical mastitis.

RUAKURA ROLLING BALL VISCOMETER

The Raukura rolling ball viscometer (*17,58*) can be used to measure the viscosity of the milk-reagent mixture resulting from use of the California Mastitis Test reagent. The viscosity of the milk-reagent mixture is inversely related to the distance of travel of a stainless steel ball down an inclined tube during a pre-determined time lapse. The correlation coefficient between the inverse of the viscometer reading and the DMSCC is 0.92. In a scale range of 1-10, the viscometer has a sensitivity in predicting somatic cell counts at levels of 150,000 to more than 1 million cells per ml. Duirs and Cox (*17*) have shown that the RBV has a correlation of 0.84 with the DMSCC and the Electronic Somatic Cell Count (ESCC- Coulter Counter) methods. They have concluded that with adequate operator training, to minimize variation in testing techniques, the RBV provides a satisfactory and simple alternative to the DMSCC and ESCC methods when used on "fresh" milk samples.

The RBV has grown in popularity in New Zealand, the country in which it was developed. The RBV technique is not as yet widely used elsewhere, although considerable interest is being shown in its potential (*58*).

CALIFORNIA OR RAPID MASTITIS TEST (CMT OR RMT)

The CMT (*19,25,55,56,74,78*) was derived from the Modified Whiteside Test (MWT) and is an efficient screening test for mastitis and abnormal milk. It is simple to do and can be used in the barn as a cow-side test. The CMT reagent is a neutral detergent (alkyl arylsulfonate) which makes it possible to add a pH indicator (bromcresol purple) to evaluate the alkalinity of milk in addition to estimating cell counts (*27*). The reaction of detergent and DNA in cell nuclei produces a viscous mass. Viscosity, as with the RBV, relates to the total somatic cell concentration.

The CMT test is conducted using a white plastic paddle with four shallow cups in which milk is collected from each of the four quarters. After adding an equal amount of reagent to each cup, the paddle is rotated to mix the milk and reagent thoroughly. The mixture is scored by using seven different symbols: — (no reaction), T (trace reaction), 1,2,3 +, and y. Generally a score of 1 is considered as indicative of presence of 500,000 or more somatic cells per ml, a score of 2 as 1 million or more cells per ml, and a 3 score of over 5 million cells per ml. Symbol + shows that the pH of the milk is 7.0 or over, while the symbol y (yellow) means the mixture is acidic (*20,100*). The + or y symbol is added to the score whenever the reaction is alkaline or acidic.

Milk collected for later CMT testing should be refrigerated, (but not frozen (*76*) to prevent bacterial growth, and should be tested within 24 to 36 h. Boric acid (1.5%) may be used as a bacteriostatic agent. Since other preservatives, such as potassium dichromate, formalin and mercuric chloride alter the DNA, no CMT reaction occurs when they are used (*100*).

As a subjective procedure, CMT is more difficult to standardize between analysts and laboratories than methods such as the WMT, ESCC and DMSCC. Read et al. (*78*), in an evaluation of five screening tests (CMT, Catlase, Milk Quality Test, MWT, and WMT) and two confirmatory test (ESCC and DMSCC), noted that all screening tests studied showed considerable variability. These researchers suggested that screening tests could be used to indicate whether or not a bulk milk might have an unsatisfactory somatic cell count. A confirmatory test should be made to determine whether the sample in question exceeded the somatic cell standard of 1.5 million somatic cells per ml.

WISCONSIN MASTITIS TEST (WMT)

The WMT uses the CMT reagent diluted 1:1 with distilled water. It is based on an increase in milk-reagent

viscosity. The viscosity is determined by measuring the amount of the mixture remaining in a special test tube after a 15-sec outflow through an orifice in the cap. The measuring gauge, placed next to the test tube, is calibrated to determine the height in mm of the remaining mass or in somatic cell concentration per ml. The WMT score correlates well with the DMSCC method. Workers have found a 0.89 (*78*), and 0.85 (*91*) correlation coefficient between these two methods and a value of 0.88 between the WMT and the ESCC (Coulter Counter) (*91*). The dimensions of the WMT test tubes are 12.5 × 125 mm, with matching caps having an orifice of 1.15 mm. and an orifice in the side of the test tube at 65 mm from the outside bottom (*93,100*). Advantages of this test are as follows: (*a*) WMT permits examination of a large number of samples per unit of time — there is no delay for results and retests may be made rapidly, (*b*) the test uses a readily available, inexpensive, stable and noncorrosive reagent, (*c*) the test can be used to estimate cell content of bulk, bucket or quarter milk samples, and (*d*) the test uses inexpensive and simple equipment.

Disadvantages of this test (*98*) are as follows: (*a*) the WMT does not lend itself to cow-side use as readily as the paddle type tests. (*b*) the test has no permanent reaction that can be examined or re-examined at leisure, as the dried or stained smears for the DMSCC, and (*c*) milk must be refrigerated promptly and preferably tested on the day of collection. The reaction diminishes slowly on storage at 32 to 40 F and milk scores appear lower than they actually are (*32*).

A WMT value of 11 mm or over suggests that the milk has more than 500,000 somatic cells/ml. A WMT value of 20 or over suggests that the milk has greater than 1.5 million somatic cells/ml. In the U.S., this level (*66,67,98*), if confirmed by DMSCC, is considered an actionable level. Ginn (*22*), in a commercial laboratory, confirms the highest 10% of the WMT scores greater than 21 mm. Of 22,553 such tests, 9.95% or 2,243 were "confirmed" between May 1 and December 31, 1971. Only 0.68% had a DMSCC of greater than 1.5 million per ml of milk.

Table 2, adapted from reference (*98*), shows the "significance" of somatic cell counts over a range of counts. Among the tests mentioned, the WMT is the most objective.

TABLE 2. *Significance of somatic cell counts of milk over a range of counts.*[a]

Somatic cell count/ml	Significance
0 - 250,000	No pathogenic bacteria present, no mastitis. Negative reactions by MWT[b] and CMT tests. WMT readings of 5 or less. Less than 20% oxygen for Catalase Test.
250,000 - 500,000	Considered normal milk (no pathogenic bacteria) May show trace (T) reaction by CMT. (A precipitate begins to form, thickening into a gel as concentration of cells increases.) Catalase — less than 20% oxygen MWT — (trace reaction) WMT — (5-13 mm)
500,000 - 1,000,000	Some mastitis or other abnormality is present. CMT — weak positive (*1*) (a distinct precipitate forms, but no gel, and may be reversible, disappearing upon continued movement of the paddle). Catalase — (20-30% oxygen) MWT — trace reaction; about 40% of the tests may still show negative. WMT — (11-19 mm)
1.0 - 1.5 million	Milk is abnormal, either from mastitis or for other reasons. CMT — [weak positive (*1*)] Catalase — (30-40% oxygen for counts to 2 million) MWT — (83% of tests show 1 + reaction) WMT — (17-22 mm)
1.5 - 2.0 million and higher	Milk is abnormal CMT — positive (1 to 2). Mixture thickens immediately, with some suggestion of gel formation. Upon swirling, mixture tends to move toward the center, leaving bottom of outer cup edge exposed. Catalase — (40% and over) over 2 million. MWT — (1 + to 2 +) WMT — (20-25 mm)

[a]Adapted from reference (*98*).
[b]Key: (MWT): Modified Whiteside Test, (WMT): Wisconsin Mastitis Test, (CMT): California Mastitis Test, Catalase Test.

OPTICAL SOMATIC CELL COUNT (OSCC)

A semi-automatic cell counting system, developed commercially by Technicon Instruments Corporation (Terrytown, NY) (*89,90*) involved continuous flow analysis. This system, the Technicon Optical Somatic Cell Counter II (OSCC II), has the precision of the DMSCC, a coefficient of variation of 3%, correlation coefficient of 0.96 with the DMSCC, and ability to evaluate 120 samples per hour (*90*).

The OSCC II measures light scattering that occurs as somatic cells pass through a light beam of an electronic microoptical system. Scattered light pulses are transformed into electrical pulses by a photomultiplier tube. The number of somatic cells corresponds to the electrical pulses. All larger entities, especially fat globules, have to be dissolved before counting. Before analyzing, the samples must be pretreated with a formalin fixative at a rate of 0.05 ml per 4 ml of milk sample. Fixation is carried out at room temperature (20-23 C) for 18 h, or 55 C for 45 min (*90,96,100,101*).

Wang and Richardson (*101*) simplified sample preparation for the OSCC II by using a Fisher Auto Diluter Model 250 (Fisher Scientific Company, Pittsburgh, PA). This improvement made the OSCC II test simpler and more time-saving, with no loss in accuracy. These workers established the workability of the OSCC II system in a central milk testing facility involved in the routine testing of Dairy Herd Improvement (DHI) milk samples.

The A/S N. Foss Electric firm (Hillerød, Denmark), has developed the "Fossomatic" (*28*) test, which determines the number of somatic cells in milk by automated and continuously operating fluorescence microscopy. The correlation with the DMSCC is high (*16,29*). The Fossomatic principle involves the formation of a fluorescent complex from a dye bound between DNA

of the cell nucleus and ethidium bromide, which emits a strong fluorescence when excited with light from a xenon lamp within a certain wavelength range. Other particles may also fluoresce, but at a different wavelength and intensity. Thus their influence can be optically filtered out.

After heating to 40 C, the milk samples are inserted into racks which transfer the samples to the stirrer and subsequent pipetting position. A sample of 200 μl is taken and transferred to the turret where it is diluted 1:20 with 1.8 ml of dye solution and 2.0 ml of buffer. After extensive stirring at 60 C, a sample of 20 μl is applied to a rotating disc by a microsyringe, providing a liquid layer of 0.5 mm width and 10 μm thickness. The available sample volume represents a liquid layer approximately 3500 mm long which is exposed to the optical system.

Blue light of a wavelength up to 580 nm is directed toward the rotating disc, exciting the cell complex to emit fluorescent light with a wavelength from 590 nm and up. An optical system transfers the light pulses to a rectangular slit where a photomultiplier tube transforms the light into electronic signal. This signal is fed to a digital display, an oscilloscope and a printer. The result multiplied by 1000 gives the cell content per ml (*28*).

DIRECT MICROSCOPIC SOMATIC CELL COUNT (DMSCC)

Prescott and Breed (*73*), developers of the first microscopic procedure for examination of milk films, identified two procedures: (*a*) the Direct Microscopic Count (DMC) and (*b*) the Direct Microscopic Leucocyte Count (DMLC) to enumerate bacterial cells and leucocytes, respectively. Work completed by many investigators has indicated that the term "somatic cells" is more indicative of those body cells in milk generally associated with inflammation of the cow's udder than the more specific term "leucocyte." Accordingly, the Direct Microscopic Somatic Cell Count (DMSCC) (*99*) discussed below includes body-cell-counting procedures developed by Prescott and Breed (*73*), Levowitz (*99*), and Brazis et al. (*4*).

In the DMSCC, the microscope is first adjusted and calibrated so that the microscopic factor (MF) may be determined (*4,54*). A film containing 0.01 ml of milk is spread over a 1-cm² area on a glass microscope slide and then fixed and stained with a modified methylene blue reagent. The total cell count is determined by averaging the cell number in 10-60 fields, depending upon the number per field, and then multiplying this average by the MF.

The DMSCC is usually considered the reference standard for other methods for detecting abnormal milk. As a confirmatory test, it is relatively rapid, permitting a microscopic determination of somatic cells in 10 to 15 min. Milk films can be prepared quickly, stained, examined later and kept for re-examination. Tentative identification of bacterial flora may be made during examination of the milk film, although bacteria responsible for mastitis are not usually observed in fresh, unincubated milk.

The DMSCC has several disadvantages (*99*) which limit its usefulness. Measuring the small quantity (0.01 ml) of milk is difficult. Foam may cause inaccurate measurement by both glass pipettes or metal syringes (syringe may also add metal filings). Correct preparation of stain or proper staining of slides are necessary. If the stain is not prepared properly, the film will erode during the rinsing stage. If the film is not properly dried, the film will crack. Enough time must be allowed for correct staining. The small amount of milk examined in this test tends to limit its precision because of uneven spreading of milk over the 1-cm² area of slide; high or low counts may result. Failure to count the required number of fields, when a specified number of individual fields are recommended for the field counting procedure, also reduces precision. Use of a double tally assists in enumeration of fields counted as well as the number of somatic cells in each field. Distinguishing among nucleated and non-nucleated body cells, dirt and/or other artifacts can be quite difficult. Too little or too much light, along with inexperience with the method, can cause problems in the recognition of nucleated body cells generally. Error may occur in the arithmetical calculation of counts. Fatigue, a common problem to laboratory technicians reading many slides consecutively, reduces precision. Initial cost of equipment is relatively high in comparison to that of the CMT, MWT, and Catalase tests, but is less than that for OSCC and ESCC instruments.

A comparison (*78*) of the abnormal milk confirmatory procedures showed the Electronic Somatic Cell (ESCC) to be more precise, with approximately one-fourth the replicate log standard deviation of the DMSCC (0.012 vs. 0.047). Thompson et al. (*91*) showed that the coefficients of variation computed at the DMSCC count near one million were 15.6% (DMSCC), 6.3% (WMT) and 4.2% (ESCC).

The DMSCC, used as a confirmatory method, in conjunction with WMT as a screening test, proved to be quite successful in a dairy quality control laboratory (*22*). Modifications of the reticle-strip counting method of the DMSCC (*4*) were made at this laboratory, thereby reducing the total time of making films and reading to an average of 9.6 min per milk sample (*22*). The modified method was accurate and was easily understood by the technicians.

Like other abnormal milk detection methods (WMT, Catalase, and ESCC), milk samples for DMSCC should not be frozen before analysis. Freezing significantly reduces test scores (*76*). Holding samples in a refrigerator at 4 C for up to 4 days has no significant effect on the DMSCC results (*72*). Some workers feel that rapid testing of milk samples, a necessary requirement for other detection methods (MQG, WMT, CMT, ESCC), should be broadened to include all tests, including DMSCC, as a general rule (*72,99*) for greatest precision and accuracy.

ELECTRONIC SOMATIC CELL COUNT (ESCC)

Except for the DMSCC and the OSCC, tests described thus far do not provide particularly accurate results;

most are subjective, and all of them take considerable time. The DMSCC is somewhat more accurate than other methods, but it is a fatiguing test and is not suitable for dairy herd improvement testing (*100*).

Application of an Electronic Somatic Cell Counter (ESCC), namely the Coulter Counter (Coulter Electronics, Inc., Hialeah, FL) for estimating somatic cells in milk has been studied. There are many models of Coulter Counters available, each with specific operating and sample preparation requirements. Researchers have found success with the Coulter Counter Models Z_B, Z_{BI}, Z_F, FN or equivalent.

The Coulter Counter is based upon the "Coulter Principle" (*11*). As particles or cells pass through an aperture and displace an equal volume of electrolyte, the resistance in the path of current changes. This results in corresponding current and voltage changes. The quantity (magnitude) of this change is directly proportional to the volumetric size of the particle or cell. The number of changes within a specific length of time is proportional to the number of particles or cells within the suspension.

During development of the method using the Coulter Electronic Counter, the major problems encountered were interference of fat globules and ascertaining the lower threshold setting. The fat globules, in larger numbers and in overlapping distribution, caused counting errors (*71*). Phipps (*70*) observed that incomplete fat dispersal following chemical treatment could produce higher counts in the region of low cell concentrations. However, elimination of fat globules as interfering compounds was achieved by a centrifugation technique (*71*) or by dispersal by chemical treatment (*95*). The chemical method requires that the milk be treated beforehand with formalin, which renders the cells resistant to a fat-dissolving reagent mixture. Phipps (*70*) reported that a minimum time for formalin treatment was 24 h and maximum time was about 4 days at room temperature. Most laboratories found this treatment too time consuming and thus have opted to use the compound, Somafix (Coulter Electronics, Inc., Hialeah, FL) (*52*). Three drops of this formalin-based reagent will rapidly "fix" a 10-ml raw milk sample when the mixture is incubated at 60 C for 6.5 min (1.5-min warm-up time + 5-min reaction time). When DMSCC was correlated with a chemical method and with a centrifugal method of preparing samples for Coulter Counter testing, Pearson et al. (*68*) obtained correlation coefficients of 0.966 and 0.930, respectively.

Studies on the instrument setting referred to as the "lower counting threshold" were of major importance in correlating the ESCC to the DMSCC. Tolle et al. (*94*) suggested an optimum threshold of 4.5-5.0 μm in the calculation of the lower threshold setting. Dijkman et al. (*15*) found a value of 5 μm (65.5 μm^3 - average somatic cell particle size) to agree well when the ESCC counts were compared to the DMSCC. Macaulay et al. (*52*) found that the 4.43 μm value was useful in giving an ESCC to DMSCC correlation coefficient of 0.973. A procedure published in the 14th edition of the *Standard Methods for the Examination of Dairy Products* (*97*), calls for a value of 4.4 μm (44.6 μm^3). Kinsman (*42,43*) also found that this value was useful in accurate Coulter Counter standardization.

The Coulter Counter method has many advantages (*97*). Analysis time per milk sample is minimal. After fixing, samples can be stored. The ESCC device yields cell-size distribution as well as count data.

The Coulter Counter method has few disadvantages (*97*). Instrument cost is high, but may be offset by rapid amortization. Good laboratory cleanliness techniques are required for the instrument and the glassware. Instrument calibration and standardization are needed.

Coulter Counters are semi-automatic because they require further preparation steps beyond cell fixation. Coulter Electronics has recently developed an automatic unit named the "Milk Cell Counter" (*12*). This unit requires that the samples be "fixed" before entry into the system. It tests a maximum of 210 milk samples per h, loaded up to 50 at a time in a sample rack. Essentially the same procedure (*37,97*) is used as with the semi-automatic models. The somatic cell count is printed on a teleprinter and can also be interfaced with a computer. Modified versions of the original units are being used in England and Scotland to do routine cell counts. A unit is currently undergoing tests at the Dairy Quality Control Institute (St. Paul, MN).

Table 3, adapted from Northern (*64*), is a comparison of six common abnormal milk detection methods. The

TABLE 3. *Comparison of abnormal milk screening tests.*[a]

Test parameter	Relationship between tests in terms of test parameter[b]
Accuracy	ESCC[c] = DMSCC > WMT > CMT > CATALASE > WHITESIDE
Simplicity	CMT > WHITESIDE > WMT > CATALASE > DMSCC > ESCC
Equipment cost	ESCC + DMSCC > CATALASE > WMT > ESCC > DMSCC > CMT > WHITESIDE
Repeatability	ESCC > DMSCC > WMT > CATALASE > CMT > WHITESIDE
Objectivity	ESCC > DMSCC > WMT > CATALASE > CMT = WHITESIDE
Total labor required	CATALASE > DMSCC > ESCC > WHITESIDE > WMT > CMT
Specialized training	ESCC > DMSCC > CATALASE > WMT > WHITESIDE > CMT
Time to run test	DMSCC > CATALASE > ESCC > WMT > WHITESIDE = CMT

[a]Adapted from Northern (*64*).
[b]Assume fifty samples are tested.
[c]Key: DMSCC - Direct microscopic somatic cell count, ESCC - Electronic somatic cell count (Coulter Counter), WMT - Wisconsin mastitis test, CMT - California mastitis test, CATALASE - Catalase test, WHITESIDE - Whiteside test.

ESCC, though more costly than the other methods presented, is preferred in terms of repeatability of the test results and objectivity of the test method. Fossomatic and other methods not compared in this table would likewise be more objective and repeatable than screening-type procedures shown.

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