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R-PM-2: Milk Quality in the 21st Century

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INTRODUCTION

High quality raw milk is free of undesirable flavors, chemical or antibiotic residues, is low in somatic cells and bacteria, and contains a minimum of 3.5% butterfat, 3.1% protein, and 4.8% lactose. However, from a veterinary perspective SCC (somatic cell count) has become the "gold standard" measure of milk quality. The herd SCC level is dependent on the number and duration of infections present plus rate of new infections. Since mammary gland infection is multi-factorial, the epidemiological principle of "sufficient cause" has bearing on whether or not exposure to mastitis pathogens will cause mammary gland infection. For example, in order for a new mammary gland infection to occur, there not only must be teat exposure to a mastitis pathogen but also a circumstance (i.e., air slips) that results in the pathogen penetrating the teat canal. Even then, the pathogen must be of sufficient dose and virulence to overwhelm the cow's immune system allowing establishment of an infection. The sum of all these factors results in "sufficient cause" for an infection to occur. The whole thrust of mastitis control has been to identify those critical factors necessary for infection to occur and block them by strategic intervention (i.e., teat dipping) so that infection does not occur. By consistent application of control practices, high quality, low SCC, low bacteria count, and antibiotic and chemical free wholesome safe milk can be produced.

STATUS OF GLOBAL MILK QUALITY AND REASON FOR THE MILK QUALITY QUEST

Either through regulatory mandate or market access requirement, the European Union's 400,000 three-month geometric mean SCC limit and the 100,000 cfu/ml (colony forming units) maximum bacteria count are the world's raw milk quality standards. However, the quest for raw milk quality goes beyond the minimum quality and safety standards. Fueled by processor requirements to maximize processing efficiency and product shelf life, consumer demands for consistent product quality, and concern over animal well-being, there will be continued pressure to improve cow comfort, hygiene, and health, including udder health. What SCC is low enough and what is practical? Barbano et al. (1) indicated that raw milk with low SCC (<100,000) and bacteria counts will be needed to assure adequate dairy product stability and shelf life in the US market where grocer consolidation has resulted in longer distribution systems. Further that a limiting factor in expansion of global markets will depend on raw milk quality at the farm. Schepers et al. (61) found that most all uninfected healthy cows had SCC less than 100,000. Although a 200,000 SCC threshold is still used to distinguish between infected and uninfected populations, some feel that a 100,000 threshold may be more appropriate. Our assessment is that a 200,000 or less herd average SCC is a reasonable milk quality goal for all dairies and that it will be the expectation for 21st century milk quality. Microbiological challenges still plague a good share of the world's dairy producers. Because of cooling challenges, the 100,000 cfu/ml world standard for these farmers may be difficult to meet. Boor et al. (9) in a random sampling of 855 New York dairies found a standard plate count average of 11,400 cfu/ml and that 50% of those herds were <10,000. In western countries today where adequate refrigeration is readily available on every dairy, total bacteria counts <10,000 cfu/ml are expected.

BTSCC AS A MEASURE OF MASTITIS, MILK QUALITY, AND HERD MANAGEMENT

The average of all individual cow SCC data is the best measure of herd subclinical mastitis (41). A large number of herds do not participate in DHI milk recording programs leaving the bulk tank SCC parameter as the only means of assessing herd SCC levels. However, a low BTSCC (bulk tank somatic cell count) imperfectly correlates with low level mammary gland inflammation and also with other important milk quality factors such as microbiological quality (plate counts, PI counts, Coliform counts) (8, 62). Food safety and the relative risk of antibiotic residue can be positively correlated to rising BTSCC (57, 58). Poor environmental housing conditions have also been shown to increase the probability of having antibiotic resistant mastitis on the farm (36).

Numerous studies have shown a correlation between established mastitis control practices and SCC (2, 5, 7, 15, 17, 19, 22, 24, 32, 38, 40, 42, 45, 46, 50, 71).. During the past 20 years, environmental factors such as freestall and bedding management have also been recognized as important factors affecting BTSCC (29). Barkema et al. (3, 4) differentiate management practices between "low" BTSCC (<150,000), "mid" BTSCC (150-250,000), and "high" BTSCC (250-400,000). They found that that those management practices known to be important for managing "high" BTSCC (>250,000) herds, such as post-milking teat dipping, dry cow therapy, milking technique, and antibiotic treatment of clinical cases, were also important in differentiating the "mid" and "low" category BTSCC herds. In the "low" (<150,000) category herds, significantly more attention was paid to general hygiene ($p < 0.05$) than the higher BTSCC herds. For example, herds with BTSCC <150,000:

- had cleaner cows and drinking cups were cleaner
- were more likely to remove udder hair
- had cleaner freestalls and cleaned the freestalls more frequently each day
- used more bedding
- checked dry cows daily for evidence of clinical mastitis
- had cleaner calving pens as rated by a standardized hygiene scoring system
- had cleaner milking parlors as rated by a standardized hygiene scoring system
- kept milk from fresh cows out of the bulk tank longer
- were more consistent in the use of post-milking teat dipping and had utilized the practice longer than other herds
- were more consistent in dry cow treating all cows and had been using the practice longer than other herds
- treated clinical cases for a longer duration
- were more apt to provide nutrient supplementation for springing heifers, and dry and lactating cows

Several other studies have also found similar subtle differences in management detail and consistency between low BTSCC herds and higher BTSCC herds (32, 41, 56, 64). The association between best management practices and lower BTSCC have been thoroughly studied (6, 7, 12, 13, 14, 15, 17, 18, 19, 25, 26, 27, 30, 31, 32, 33, 43, 45, 49, 50, 51, 53, 65, 66, 70). These findings are not surprising, but they are vindication for those who have been emphasizing these points for many years.

MANAGEMENT ATTITUDE A DETERMINING FACTOR

Management attitude and the application quality of management practices are not always easy to determine. Seabrook (63) found in comparing dairies with the exact same facilities, feed, genetic base, and environmental circumstance often resulted in differing productivity. The only difference between these herds was the herd manager, thus, implicating management as the main cause of productivity difference. Although common sense tells us that those farms that visually appear to be neat and tidy are usually at a higher plane of sanitation, this is not entirely accurate. Tidiness does not always coincide with low BTSCC. There are some untidy farms that succeed in consistently producing high quality low BTSCC milk and vice versa. Bennett found, however, that BTSCC level is a dependable predictor not only of milk quality but also of general herd management (8). A survey of Dutch dairy farmers demonstrated that farmers' attitudes toward mastitis explained most of the variation in regard to total BTSCC (33). Not only do farmers need the correct technical tools to lower BTSCC, they need to perceive that they are in control of the situation and can make a positive impact on their current status for any positive change to occur.

The bottom line reflecting differences in management attitude are captured somewhat in the following questions: Are you just milking cows or are you producing quality milk? Are you just dipping teats or are you using a dip cup to completely immerse teats? There is an attitude difference and the resulting behavior is reflected in BTSCC. Whether or not high quality milk is produced depends on whether milk quality management practices are consistently and correctly implemented. The idea that attitude is a determining factor in success is nothing new to any of us. There has been some indirect implication of an attitude affect on milk quality. Surveys of US dairies show that, in general, large herds have lower BTSCC than small herds (48, 52, 58, 69). While care must be taken not to surmise cause and effect relationships from any observational study, these observations hint that there may be a basic attitude difference between management of small and large herds. Grade A milk producers in Wisconsin produced milk with BTSCC 92-132,000 lower than Grade B producers (59). This also suggests that there may be a different milk quality mind-set among Grade A producers than Grade B producers. The relative risk of an antibiotic residue increased with increasing BTSCC (57, 58, 63). There are reports correlating sloppy treatment record keeping with increases in antibiotic residue (58). In addition, these same herds with antibiotic residue violations tend to be herds with higher BTSCC. On the other hand, a survey by Sawant et al. showed that large herds were more at risk for antibiotic residue violations than smaller herds (60). Certainly, there have been many studies that indirectly implicate management attitude as a factor in the production of quality milk. However, there have been few studies that have attempted to directly correlate attitude and behavior with milk quality. Barkema et al. (4) may be one of the first studies that demonstrated a direct and significant BTSCC difference between dairy farmers who were categorized by their management style as "clean and accurate" (BTSCC <150,000) and those categorized as "quick and dirty" (BTSCC 250-400,000). The association between management style and BTSCC was high (p <0.001). Seventy-three percent of the high BTSCC (250-400,000) herds were categorized as "quick and dirty" and 74% of those farms with low BTSCC (<150,000) were categorized as "clean and accurate". The farmers categorized as "clean and accurate" were characterized as younger, more education minded, better record keepers, and more hygienically meticulous. The most striking difference between the "clean and accurate" farmers and the "quick and dirty" farmers was that the former preferred to work precisely while the latter preferred to work quickly. For example, "clean and accurate" farmers:

- were more likely to use records daily
- rarely forgot to take milk samples for culture on the clinical cases
- enjoyed milking more
- were more likely to believe it is important to work hygienically with clean hands, boots, etc.
- less likely to start milking later than planned
- kept farmyard, milking parlor, and bulk tank room cleaner as determined by a standardized hygiene scoring system

Deming (68) suggested that attitude is the key component in the quest for "continuous improvement" for any process. He maintained that every process is one of four states: *Ideal State, Threshold State, Brink of Chaos,* and *State of Chaos* (Figure 1). A process in the *Ideal State* is a process "in control" and is meeting performance expectation 100% of the time. "In control" meaning that the outcome of the process is predictable and, in the case of the *Ideal State*, is meeting performance expectations all the time. The process in the *Threshold State* is also "in control" but does not meet performance expectations 100% of the time. The *Brink of Chaos* process is "out of control" because performance outcome is not always predictable, but since performance standards are lower, performance expectations are still met 100% of the time. A process in a S*tate of Chaos* is "out of control". The performance outcome is always unpredictable and the performance standards are not being met.

It would be rare and probably impossible to find a dairy operation with all of its processes in the *Ideal State*. It is obvious from study of herd records that the best farms will have proportionately more of the production system processes in the *Ideal State* and fewer in the *State of Chaos* than poorly managed farms. The objective of excellent herd management is to move each production system process toward the *Ideal State*. However, there are universal forces acting on every process that over time will cause deterioration, decay, wear and tear, breakdown, and failure. This is called entropy. Morris et al. (44) recognized that the difficulty of maintaining mastitis control measures is almost inevitable. Turnover in employees, taking shortcuts on established protocols, wearing out of equipment and facilities, and running out of critical supplies are all examples of process entropy. Mastitis was ranked as the highest animal health concern of managers of large dairies, along with attracting and training quality employees (13). It is likely not a mere coincidence that these concerns are listed simultaneously among large dairies. Without attention, all processes will eventually migrate to a *State of Chaos*. The only way to overcome this natural phenomenon is to continually repair the effects of process entropy. Routine repair and maintenance of equipment and facilities, as well as motivation and training of employees, are examples of process entropy repair. The more proactive and consistent (i.e., "clean and accurate") the dairy is in maintaining optimum function of each process, the more likely they will succeed in reaching and maintaining the *Ideal State*.

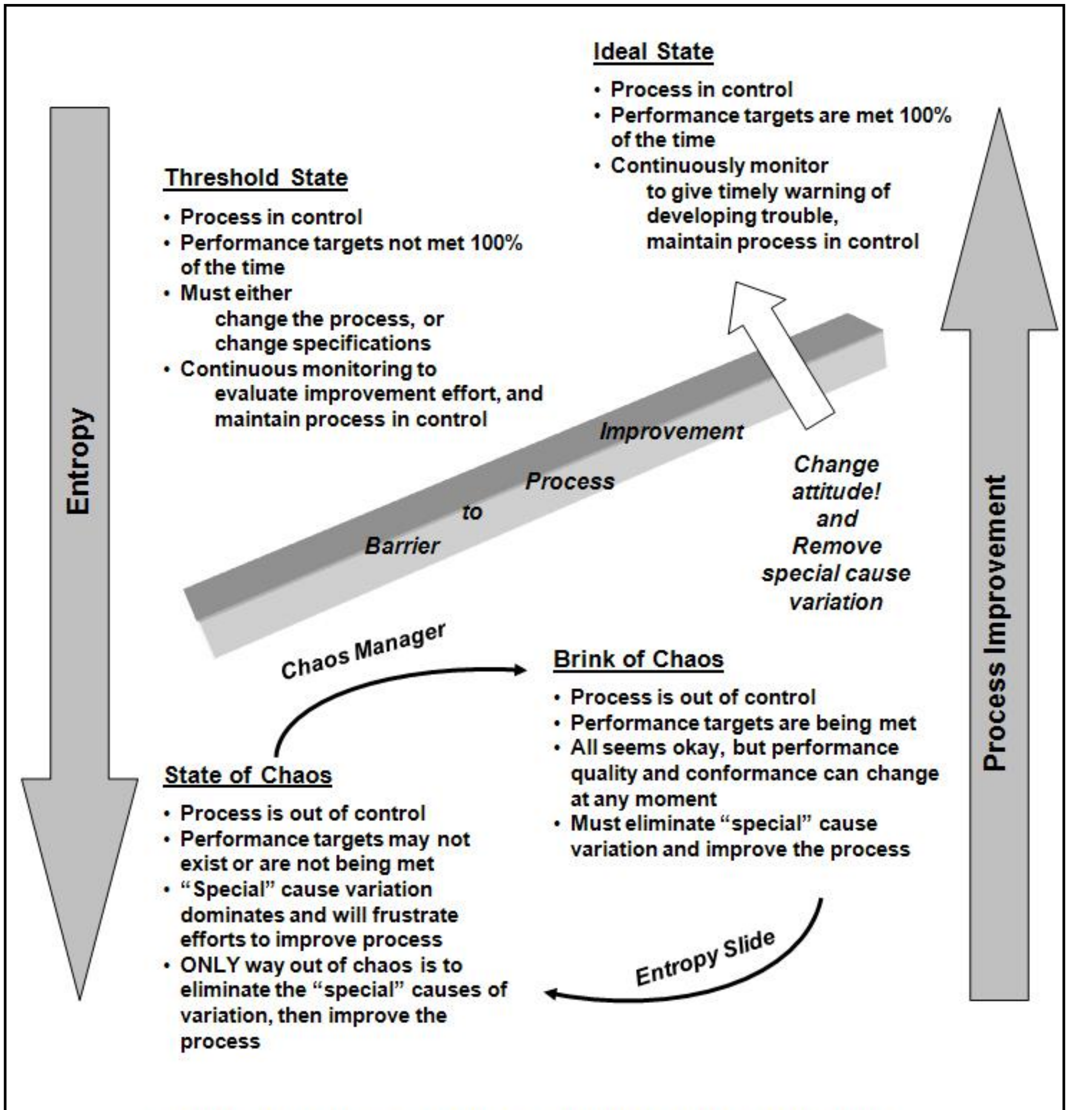

Figure 1. Process status in a dairy production system.
(Adapted from Wheeler and Chambers, 1992)

Frequently, veterinarians, milk plant field staff, and state milk inspectors are called to a farm to respond to a process in a *State of Chaos*. The farm has a situation in which they know they are in trouble. For example, the BTSCC has just exceeded the legal limit and the farm has been issued an ultimatum to lower the BTSCC or face the consequences of losing their market. The producer is asking you to be a chaos manager. The producer's expectation is for you to get the SCC down to legal limits as soon as possible. Using your diagnostic skill, you identify the chronically high SCC cows, and may recommend culling some of those cows and to use a quarter milker on a few other high SCC quarters. The goal was achieved. With your assistance, the farm is now able to sell their milk again. The farmer is happy and feels temporarily out of trouble. However, even though the milk now conforms to the legal standards, in reality the processes that govern milk quality have not changed and are still likely "out of control". Your intervention as a chaos manager has moved the situation from a *State of Chaos* to the *Brink of Chaos*. However, without further intervention to ***change the attitude and the processes***, this herd is doomed to slip back into a "state of chaos" and the cycle of despair continues. A recent multiyear mastitis intervention program in Australia demonstrated that a change in culture to deal with mastitis must take a multidisciplinary approach and many years of effort to effect true change (11).

The greatest barrier to achieving the quality of management depicted by the process in the Ideal State is attitude. The only way to sufficiently overcome process entropy and reach the more desirable "threshold" and "ideal" states is by commitment to the concept of continuous process improvement and a continuous monitoring system that alerts the herd manager to the effects of process entropy. The causes of abnormal variation must be found and eliminated, and then emphasis must be placed on process improvement. This is why it is critically important that the herd manager and the herd consultants have a shared vision of what the goals are and a firm commitment to the long-term process of continuous improvement. Not only must the goal to produce quality milk be clear, the attitude reflected in management behavior must demonstrate consistent application of quality milk management practices.

CONSISTENCY FACTOR

Deming once said, "If I had to reduce my message to management to just a few words, I'd say it all has to do with reducing variation." It seems likely that understanding variation is the key to successful herd management. A sure signal of process improvement is a reduction in variation. Reducing variation in the BTSCC requires accurate and consistent application of milk quality management practices. Figure 2 is a statistical process control (SPC) chart of a large Wisconsin dairy that had kept their BTSCC under 200,000 for 20 years. During the period from January 1st through mid-February, the BTSCC was averaging 140,000 and was "in control". However, the herd manager felt that the herd BTSCC should be 100,000 or less, as had been the case during previous years. During the March 21st meeting with the milking parlor staff, there was a consensus reached:

- that more attention be placed on pre-milking teat end sanitation, and
- that cows with extremely high SCC quarters would be identified with a leg band so that the high SCC quarters could be milked into a quarter bucket

The plan was implemented immediately. Did the program work? Study of Figure 2 clearly indicates a dramatic and significant decline in herd BTSCC. Using routine control chart interpretation, by March 26 the herd manager knew with 98% certainty that the plan was working and could use the chart as positive feedback to the parlor crew to reinforce their dedicated effort. This chart illustrates two points. First, when the milking process was improved, the BTSCC variation was reduced. Secondly, use of statistical process control is effective in monitoring daily BTSCC for the purpose of quality improvement.

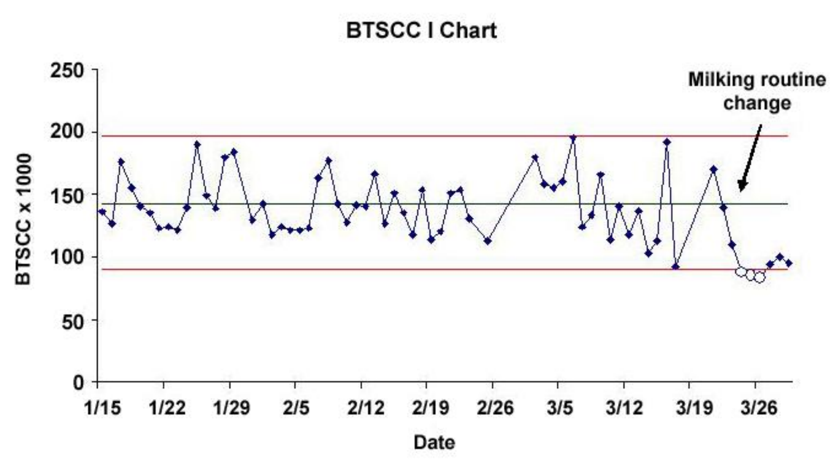

Figure 2. Control chart of a Wisconsin dairy demonstrating the effectiveness of a milking routine change in reducing BTSCC and variation in BTSCC.

QUALITY MILK MOTIVATION

What motivates dairies to produce high quality low BTSCC milk—education, incentives, or penalties? Is education the answer? The theory being that if they know what to do, they will do it. Not always! Knowledge is power only where it is put to use. Much of what is known today about mastitis control has been common knowledge for many years. Frustration with the total lack of interest by dairy farmers in applying the NIRD research led Morris (44) in 1971 to conclude that as long as farmers could get paid the same price for tainted milk as higher quality milk, there would be little incentive to adopt mastitis control practices. Booth (10) also concluded in 1975, "...it appears that any real impact in controlling mastitis will only be created by direct financial incentives. Penalties, which would only directly affect a small proportion of farmers at the worst end of the scale, are unlikely to result in any significant improvement in control of mastitis nationally." Dramatic reductions were realized in the UK when quality incentives were introduced. Recognition that high SCC milk reduced cheese yield stimulated the beginning of quality premium incentives in the Upper Midwest. Quality premium incentives offered by Wisconsin Dairies in 1979 had a marked affect on BTSCC from 1979 to 1988 and clearly demonstrated that monetary incentives did stimulate dairies to produce low BTSCC milk (20). It is estimated that a quality program offered by a cooperative in the Northeast from 1998 to 2005 was able to lower BTSCC by 6% (47). Wisconsin dairies that participated in milk quality teams to reduce BTSCC used pricing premiums as tools to show the success of adaption of new methods to manage milk quality (56). Penalty programs also can work. Canadian milk pricing penalty program has had a significant impact on BTSCC (23, 63). Both quality premiums and penalty programs are examples of extrinsic motivations. Penalty programs have been shown to be a more powerful motivator of change than quality premiums (67). Tangible extrinsic motivators (money, promotions, and awards) will work but may be more short-lived and are incentive dependent. Promotions and awards in the form of positive press and recognition from a processing plant are not of enough value for farmers to change milk quality programs (67). Upon removal of the extrinsic based incentive, process entropy is almost certain to occur. For example, when Upper Midwest milk processors began component pricing, the price adjustments placed somewhat less economic incentive on low BTSCC. Whether it is cause and effect, we cannot be sure; however, it appears that during this period of time, there had been a plateau in BTSCC improvement. Farm profitability along with using milk quality incentives to lower SCC were positively linked to managers who implemented "continued training" on their farms (64). Intrinsic motivation, on the other hand, are intangible feelings of an internal desire to do things right or to be the best at something. Those driven by intrinsic incentives (i.e., the "clean and accurate" producers) will likely continue producing high quality milk regardless of whether quality premiums are offered. This is not surprising. A Dutch study found that improvement in mastitis management is "mainly driven by factors that are internal to the farm and the individual farmer" (67). In the context of quality performance, it should be obvious that the most powerful motivation is intrinsic development of a "milk quality mind-set". A survey of Danish producers identified teamwork and animal welfare as the major products they expected veterinarians to provide to their dairy operation (37). It is within this framework that veterinarians and other herd consultants can develop the tools to improve milk quality.

The question is... how do we develop a "milk quality mind-set"? It is a fair assumption that education will continue to be the foundation of developing a "milk quality mind-set". However, it is doubtful that education and just knowing the "why" and "how" of producing quality milk will be enough. The concept of an epidemic may provide some insight. Malcolm Gladwell (21), in his book "The Tipping Point", points out that those epidemiological principles apply to how ideas and products are spread as much as how disease is spread. All epidemics have a tipping point, which is a point where the disease begins to spread rapidly in epic proportions in a contagious manner. The "tipping point" is that point when the circumstance is "right" for the epidemic to occur. Gladwell says three factors are needed to start an idea epidemic:

- **The Law of the Few.** It only takes a few very dedicated, enthusiastic, and persistent people to make a difference.
- **The** "**Stickiness**" **Factor.** It is not what you say but how you say it. The key to making a message contagious is to make it memorable (i.e., "Winston tastes good like a cigarette should").
- **The Power of Context.** The time/circumstance is right for a mindset to change—not gradually but in a dramatic moment and in geometric progression. Educationally, we might call this "the teaching moment".

In their recent book "Made to Stick" (28), Chip and Dan Heath outline six principles of what makes a message "sticky" and why some ideas survive and thrive as well as why some will die. Sticky messages will present a simple idea, make people pay attention, understand and remember, agree and believe, and care enough to take action. This book is worthwhile reading for those who are trying to find a "sticky" message to motivate dairies to improve milk quality. Jansen et al. (34, 35) in a Dutch study brought to light the need to tailor the message about milk quality to the target audience. When farmers are motivated to improve milk quality, for example, when they are nearing the 400,000 SCC limit or have too many clinical mastitis cases, traditional education tools (meetings, workshops, fact sheets, etc.) seem to work. Unfortunately, dairy farmers are not a homogonous group in the way they respond to new information and have varying degrees of risk aversion. Any successful effort will not be a one-size-fits-all solution. Whether it be a single item management change, or a multifaceted effort to improve udder heath, it is important to find a means to make your message "sticky" as well as choose the correct delivery system to maximize the effectiveness of the message.

21ST CENTURY MILK QUALITY MONITORING OPTIONS

There is a steady trend toward larger more technologically sophisticated dairies. Approximately 50% of the US milk supply now comes from herds with >500 cows and 65% from herds with >200 cows. There has also been a steady consolidation among grocers and milk processors with escalating demands for higher quality safe dairy products. Herd managers feeling greater pressure to improve production efficiencies as well as maintain animal health and well-being need more timely performance feedback for management decisions. Yet there are fewer dairy educators, consultants, veterinarians, milk plant field staff, or dairy suppliers to cover greater geographical areas to meet the service and information needs of modern dairies. "Do more with less" is an all too familiar edict from company headquarters to field staff. The resource in shortest supply for each of us is time.

While DHI and on-farm herd record evaluation is a very important part of the consulting effort, observations made during farm visits, and daily feedback from bulk tank SCC and component analysis can provide essential balance and valuable insight for herd problem solving. There is a plethora of underutilized bulk tank data as well as on-farm scoring schemes that could facilitate more comprehensive and objective observation at the farm, ranging from cow comfort and hygiene to milking routine and teat end evaluation. However, because current on-farm scoring data collection is too cumbersome and time consuming, systematic data collection of on-farm observations is rarely done, and when done, usually not completed in sufficient quantities or representative enough of the populations of interest to be statistically defensible (54). Yet most will agree that properly collected data at routine farm visits could offer more precise reflection of management effectiveness and animal well-being. The need for a more streamlined data collection and analysis system has been recognized for some time.

Understanding variation, the value of frequent feedback and identifying "real" change

Dairy farm managers and their consultants have in the past restricted their analysis to limited comparisons of performance means without full consideration of variation. For example, comparing last month's average of some herd performance variable with this month's average. Such an analysis may not only be misleading but is usually out of context with the daily management activity. Consequently, consultants and/or employees may be blamed or rewarded for random variation in performance and not on the basis of "real" change. This leads to management decision errors and frustration for everyone—the consultants, the managers, and their employees (16). The need for fact-based management decisions is apparent. Applying statistical methods to analyze data already available on the farm has the potential of improving process and personnel performance monitoring, thus, providing more effective management tools for dairy farm managers and their consultants. Moreover, it can assure more frequent performance feedback to those directly responsible for the process (i.e., milkers, feeders, breeders) as compared with the retrospective monitoring garnered from once per month record analysis that is often out of time order context with daily management (55). Understanding variation is necessary to improving process performance. Statistical process control is an analytical approach utilizing the theory of variation as a means of explaining with statistical certainty when process performance is improving, staying the same, or getting worse. Each of the tools described in this paper uses statistical process control methods to analyze bulk tank and on-farm scoring data.

Automated assessment of milk quality process capability

There are many processes involved in producing quality milk (i.e., bedding management, pre-milking cow prep, pre- and post-milking teat dipping, equipment clean-up), the sum total performance of which can be measured by variables like bulk tank and individual cow SCC, and the number of clinical cases. Systematic study of these data can give insight into the quality and consistency achieved in the farm performance of those processes, thus, determining the milk quality outcome. Statistical process control software like ChartRunner™, which has many excellent features, can be used to generate control charts to monitor many of these variables. However, manual data entry is still required. MilkLab™, a commercially available service from Agrimetrica (Figure 3), will automatically generate BTSCC and milk component (fat, protein, and MUN) control charts providing email alerts (to any designated users) when statistically significant data distribution shifts occur. This feature alerts herd managers and dairy consultants to any statistically significant process changes even though they may be subtle, thus, giving 24/7 surveillance and early warning of emerging process changes. MilkLab™ will also automatically collect and plot Bactoscan™, PLC, PI, LPC, and Coliform counts if samples are collected and submitted to a participating milk testing lab. Where milk weights and pen counts are provided, control charts for milk production and milk per cow can be plotted. Dry matter intakes can, at present, be uploaded to the system manually.

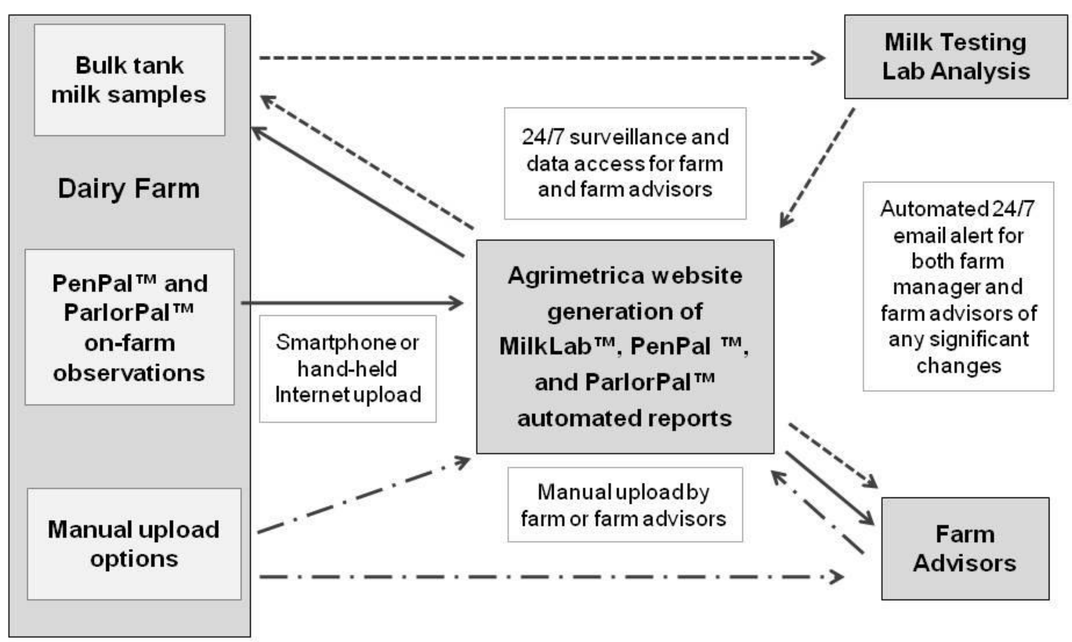

Figure 3. Data flow diagram of the Internet-based www.Agrimetrica.com automated monitoring system.

On-farm data collection and same day web report generation

Veterinarians, nutritionists, milk plant field staff, and other dairy consultants as part of each herd visit conduct a "walk through", generally observing evidence of animal health and well-being, as well as herd management effectiveness. Observations of cow hygiene, comfort, body condition, locomotion, and numerous other scores, as well as evaluation of milking equipment, milking routines, and teat condition would be common. However, time pressures, and antiquated data collection and analysis methods discourage most farm consultants from extensive collection of this data. Most are then stuck using their best "guestimates" of the circumstances at each farm visit with no reliable means of comparing current observations with previous herd visits. PenPal™ and ParlorPal™ are recent software innovations that not only facilitate fast and efficient electronic collection of farm observation data but also provide nearly instant Internet-based analysis and report generation (see Figure 1). This approach eliminates tedious data entry and report generation, making possible thorough discussion of herd issues at each farm visit for every client. However, it must be emphasized that data collection must be disciplined to assure that a representative sample in sufficient quantities is collected to be statistically defensible. A good rule of thumb would be to score all animals in herds less than 100 cows, and in larger herds, score a minimum representative sample of 80 cows or 20% of the herd, whichever is largest (39, 54).

Dairy monitoring tools with web-based software platforms like MilkLab™, PenPal™, and ParlorPal™ offer many advantages for dairy consultants. MilkLab brings added value to underutilized bulk tank test data providing with statistical certainty indication of shifts in processes affecting milk quality or components. This information is accessible to all whom the herd manager has given access and the automated email alert system provides timely warning when significant changes have occurred at the farm. The use of smart phones and handheld computers for collection of on-farm data not only increases the speed and efficiency of data collection but also eliminates redundant data entry altogether, removes tedious report generation, and provides professional reporting during the farm visit. Coupling these tools with use of current DHI and on-farm herd records should greatly enhance the dairy consultant's ability to bring added value to their client's herd health, productivity, and profitability.

CONCLUSIONS

Consistent production of quality milk is dependent on quality attitude and quality application of mastitis control practices. The greatest impact will probably result from development of a "milk quality mind-set" through a balanced program of frequent and routine quality monitoring feedback, education, and encouragement of quality premium payments under the simultaneous pressure of regulation and consumer demands. Whatever the mechanism, we need to create a "milk quality mind-set" epidemic. The time is right and the need is clear.

REFERENCES

1. Barbano DM, Y Ma, MV Santos. 2006. Influence of raw milk quality on fluid milk shelf life. J Dairy Sci 2006 89:E15-19E.
2. Barkema HW, MJ Green, AJ Bradley, RN Zadoks. 2009. Invited review: The role of contagious disease in udder health. J Dairy Sci 92:4717-4729.
3. Barkema HW, YH Schukken, TJGM Lam, ML Beiboer, G Benedictus, A Brand. 1998. Management practices associated with low, medium, and high somatic cell counts in bulk milk. J Dairy Sci 81:1917-1927.
4. Barkema HW, JD Van Der Ploeg, YH Schukken, TJGM Lam, G Benedictus, A Brand. 1999. Management style and its association with bulk milk somatic cell count and clinical mastitis. J Dairy Sci 82:1655-1663.
5. Barnouin J, S Bord, S Bazin, M Chassagne. 2005. Dairy management practices associated with incidence rate of clinical mastitis in low somatic cell score herds in France. J Dairy Sci 88:3700-3709.
6. Barnouin J, M Chassagne, S Bazin, D Boichard. 2004. Management practices from questionnaire surveys in herds with very low somatic cell score through a national mastitis program in France. J Dairy Sci 87:3989-3999.
7. Bartlett PC, GY Miller, SE Lance, LH Heider. 1992. Environmental and managerial determinant of somatic cell counts and clinical incidence in Ohio dairy herds. Prev Vet Med 14:195-207.
8. Bennett RH. 1987. Milk quality and mastitis: The management connection. Proc, Natl Mastitis Council Ann Mtg, Feb 20-23, 1987, Orlando, FL. p 133-150.
9. Boor KJ, DP Brown, SC Murphy, SM Kozlowski, DK Bandler. 1998. Microbiological and chemical quality of raw milk in New York State. J Dairy Sci 81:1743-1748.
10. Booth J. 1988. Incentives help reduce mastitis. Proc, Natl Mastitis Council Ann Mtg, Feb 8-10, 1988, Reno, NV. p 3-10.

11. Brightling PB, RD Dyson, AF Hope, J Penry. 2009. A national program for mastitis control in Australia: Countdown Downunder. Irish Vet J, Vol 62:Suppl 52-58.
12. Calu MPL, JJ Windig, RF Veerkam. 2005. Associations among descriptors of herd management and phenotypic and genetic levels of health and fertility. J Dairy Sci 88:2178-2189.
13. Caraviello DZ, KA Weigel, PM Fricke, MC Wiltbank, MJ Florent, NB Cook, KV Nordlund, NR Zwald, CL Rawson. 2006. Survey of management practices on reproductive performance of dairy cattle on large US commercial farms. J Dairy Sci 89:4723-4735.
14. Chassagne M, J Barnouin, M Le Guenic. 2005. Expert assessment study of milking and hygiene practices characterizing very low somatic cell score herds in France. J Dairy Sci 88:1909-1916.
15. Crist WL, LE Heider, PM Sears, HL Barr, JJ Kowalski, GH Schmidt. 1982. Effectiveness of education efforts in implementing mastitis control procedures in commercial dairy herds. J Dairy Sci 65:828-834.
16. Deming WE. 1986. Out of the crisis. The MIT Press, London, UK.
17. Elmoslemany AM, GP Keefe, IR Dohoo, BM Jayarao. 2009. Risk factors for bacteriological quality of bulk tank milk in Prince Edward Island dairy herds. Part 1: Overall risk factors. J Dairy Sci 92:2634-2643.
18. Elmoslemany AM, GP Keefe, IR Dohoo, JJ Wichtel, H Stryhn, RT Dingwell. 2010. The association between bulk tank milk analysis for raw milk quality and on-farm management practices. Prev Vet Med, Vol 95, Issue 1-2, 1 June 2010. pp 32-40.
19. Erskine RJ, RJ Eberhart, LJ Hutchinson, SB Spencer. 1987. Herd management and prevalence of mastitis in dairy herds with high and low somatic cell counts. JAVMA 190:1411-1416.
20. Evenson TC. 1988. Quality and protein incentive programs for Wisconsin Dairies Cooperative. Proc, Natl Mastitis Council Ann Mtg, Feb 8-10, 1988, Reno, NV.
21. Gladwell M. 2000. The tipping point. 1st Ed, Little, Brown and Co, Boston-New York-London.
22. Goodger WJ, T Farber, J Pelletier, P Johnson, G deSnayer, J Galland. 1993. The association of milking management practices with bulk tank somatic cell counts. Prev Vet Med 15:235-251.
23. Godkin A. 1999. Monitoring and controlling mastitis: Progress in Ontario. Proc, Natl Mastitis Council Ann Mtg, Feb 14-17, 1999, Arlington, VA. p 1-9.
24. Green MJ, KA Leach, JE Breen, LE Green, AJ Bradley. 2007. National intervention study of mastitis control in dairy herds in England and Wales. Vet Rec 160, 287-293.
25. Green MJ, AJ Bradley, GF Medley, WJ Browne. 2007. Cow, farm, and management factors during the dry period that determine the rate of clinical mastitis after calving. J Dairy Sci 90:3764-3776.
26. Green MJ, AJ Bradley, GF Medley, WJ Browne. 2008. Cow, farm, and herd management factors in the dry period associated with raised somatic cell counts in early lactation. J Dairy Sci 91:1403-1415.
27. Haskell MJ, FM Langford, MC Jack, L Sherwood, AB Lawrence, KMD Rutherford. 2009. The effect of organic status and management practices on somatic cell counts on UK dairy farms. J Dairy Sci 92:3775-3780.
28. Heath C & D Heath. 2007. Made to stick: Why some ideas survive and others die. Random House, NY, NY.
29. Hogan JS, KH Hoblet, KL Smith, DA Todhunter, PS Schoenberger, WE Hueston, DE Pritchard, GL Bowman, LE Heider, BL Brockette, HR Conrad. 1988. Bacterial and somatic cell counts in bulk tank milk from nine well managed herds. J Food Prot 51:930-934.
30. Hovinen M, MD Rasmussen, S Pyörälä. 2009. Udder health of cows changing from tie stalls or free stalls with conventional milking to free stalls with either conventional or automatic milking. J Dairy Sci 92:3696-3703.
31. Hultgren J, C Svensson. 2009. Lifetime risk and cost of clinical mastitis in dairy cows in relation to heifer rearing conditions in Southwest Sweden. J Dairy Sci 92:3274-3280.
32. Hutton CT, LK Fox, DD Hancock. 1990. Mastitis control practices: Differences between herds with high and low SCC. J Dairy Sci 73:1135-1143.
33. Jansen J, BHP van den Borne, RJ Renes, G van Schaik, TJGM Lam, C Leeuwis. 2009. Explaining mastitis incidence in Dutch dairy farming: The influence of farmers' attitudes and behavior. Prev Vet Med 92:210-223.
34. Jansen J, RJ Renes, TJGM Lam. 2010. Evaluation of two communication strategies to improve udder health. J Dairy Sci 93:604-612.
35. Jansen J, CDM Steuten, RJ Renes, N Aarts, TJGM Lam. 2010. Debunking the myth of the hard-to-reach farmer: Effective communication on udder health. J Dairy Sci 93(3):1296-306.

36. Kirk JH, B McCowan, ER Atwill, KS Glenn, GE Higginbotham, CA Collar, A Castillo, BA Reed, NG Peterson, JS Cullor. 2005. Association of minimum inhibitory concentration cluster patterns with dairy management practices for environmental bacteria isolated from bulk tank milk. J Dairy Sci 88:3710-3720.
37. Kristensen E, C Enevoldsen. 2008. A mixed methods inquiry: How dairy farmers perceive the value(s) of their involvement in an intensive dairy herd health management program. Acta Vet Scand, 50:50.
38. LeBlanc SJ, KD Lissemore, DF Kelton, TF Duffield, KE Leslie. 2006. Major advances in disease prevention in dairy cattle. J Dairy Sci 89:1267-1279.
39. LaMire SD, DJ Reinemann, GA Mein, MD Rassmussen. 1998. Statistical considerations for milking time test. Paper #983128, written for presentation at 1998 ASAE Ann International Mtg, July 12-15, 1998, Orlando, FL.
40. Leslie KE, DF Kelton, VL Edge, LC Wagter, KJ Day, MA Godkin. 2000. Milking management in Ontario dairy herds and relationship to milk quality. Proc, Natl Mastitis Council Ann Mtg, Feb 13-16, 2000, Atlanta, GA. p 111-122.
41. Lievaart JJ, WDJ Kremer, HW Barkema. 2007. Comparison of bulk milk, yield-corrected, and average somatic cell counts as parameters to summarize the subclinical mastitis situation in a dairy herd. J Dairy Sci 90:4145-4148.
42. MacMillin KL, GF Duirs, DM Duganzich. 1983. Associations between dry cow therapy, clinical mastitis and somatic cell count score with milk and fat production in ten New Zealand dairy herds. J Dairy Sci 66:259-265.
43. McLaren CJ, KD Lissemore. 2005. The association of herd milk production and management with a return-over-feed index in Ontario dairy herds. J Dairy Sci 88:419-425.
44. Morris RS, DC Blood, NB Williamson, CM Cannon, RM Cannon. 1978. A health program for commercial dairy herds. 4. Changes in mastitis prevalence. Aust Vet J 54:247-251.
45. Moxley JE, BE Kennedy, BR Downey, JST Bowman. 1978. Survey of milking hygiene practices and their relationships to somatic cell counts and milk production. J Dairy Sci 61:1637-1644.
46. Neave FK, FH Dodd, RG Kingwell, DR Westgarth. 1969. Control of mastitis in the dairy herd by hygiene. J Dairy Sci 52:696-707.
47. Nightingale C, K Dhuyvetter, R Mitchell, Y Schukken. 2008. Influence of variable milk quality premiums on observed milk quality. J Dairy Sci 91:1236-1244.
48. Norman HD, RH Miller, TA Cooper. 2009. Somatic cell counts of milk from Dairy Herd Improvement herds during 2009. AIPL Res Rep SCC11 (2-10).
49. Nyman AK, U Emanuelson, AH Gustafsson, K Persson Waller. 2009. Management practices associated with udder health of first-parity dairy cows in early lactation. Prev Vet Med, Vol 88, Issue 2, Feb 1, 2009. pp 138-149.
50. O'Brien B, DP Berry, P Kelly, WJ Meaney, EJ O'Callaghan. 2009. A study of the somatic cell count (SCC) of Irish milk from herd management and environmental perspectives. Teagasc, Moorepark Dairy Prod Res Centre, Fermoy, Co Cork, Proj #5399.
51. Olderiekerink RGM, HW Barkema, DF Kelton, DT Scholl. 2008. Incidence rate of clinical mastitis on Canadian dairy farms. J Dairy Sci 91:1366-1377.
52. Ott SL, MA Smith. 2000. Bulk tank somatic cell counts of milk in 21 states. 1998. Proc, Natl Mastitis Council Ann Mtg, Feb 25-28, 1998, St. Louis, MO.
53. Pantoja JCF, DJ Reinemann, PL Ruegg. 2009. Associations among milk quality indicators in raw bulk milk. J Dairy Sci 92:4978-4987.
54. Reinemann DJ, MD Ramussen, S LeMire, F Neijenhuis, GA Mein, JE Hillerton, WF Morgan, L Timms, N Cook, R Farnsworth, JR Baines, T Hemling. 2001. Evaluation of bovine teat condition in commercial dairy herds: Getting the numbers right. Proc 2nd International Symposium on Mastitis and Milk Quality, Sep 13-15, 2001, Vancouver, BC, Canada.
55. Reneau JK, JM Lukas. 2006. Using statistical process control to improve herd performance. Vet Clinics of North America: Food Animal Ed. WB Saunders, Philadelphia, PA.
56. Rodrigues ACO, PL Ruegg. 2005. Actions and outcomes of Wisconsin dairy farms completing milk quality teams. J Dairy Sci 88:2672-2680.
57. Ruegg PL. 2005. Relationship between bulk tank milk somatic cell count and antibiotic residues. Proc, Natl Mastitis Council Ann Mtg, Jan 16-19, 2005, Orlando, FL.

58. Ruegg PL, TJ Tabone. 2000. The relationship between antibiotic residue violations and somatic cell counts in Wisconsin dairy herds. J Dairy Sci 83:2805-2809.
59. Ruud LE, KE Bøe, O Østerås. 2010. Associations of soft flooring materials in free stalls with milk yield, clinical mastitis, next term teat lesions, and removal of dairy cows. J Dairy Sci, Vol 93, Issue 4. pp 1578-1586.
60. Sawant A, LM Sordillo, BM Jayarao. 2005. A survey on antibiotic usage in dairy herds in Pennsylvania. J Dairy Sci 88:2991-2999.
61. Schepers AJ, TJGM Lam, YH Schukken, JBM Wilmink, WJA Hanekamp. 1997. Estimation of variance components for somatic cell counts to determine thresholds for uninfected quarters. J Dairy Sci 80:1833-1840.
62. Schukken YH, KE Leslie, AJ Weersink, SW Martin. 1992. Ontario bulk milk somatic cell count reduction program. 1. Impact on somatic cell count and milk quality. J Dairy Sci 75:3352-3358.
63. Seabrook MF. 1984. The psychological interaction between the stockman and his animals and its influence on performance of pigs and dairy cows. Vet Rec 115:84-87.
64. Stup RE, J Hyde, LA Holden. 2006. Relationships between selected human resource management practices and dairy farm performance. J Dairy Sci 89:1116-1120.
65. Svensson C, AK Nyman, K Persson Waller, U Emanuelson. 2006. Effects of housing, management, and health of dairy heifers on first-lactation udder health in Southwest Sweden. J Dairy Sci 89:1990-1999.
66. Valde JP, O Østera, E Simensen. 2005. Description of herd level criteria for good and poor udder health in Norwegian dairy cows. J Dairy Sci 88:86-92.
67. Valeeva NI, TJGM Lam, H Hogeveen. 2007. Motivation of dairy farmers to improve mastitis management. J Dairy Sci 90:4466-4477.
68. Wheeler DJ, DS Chambers. 1992. Understanding statistical process control. 2nd Ed, SPC Press, Knoxville, TN. p 12-20.
69. Wells SJ, SL Ott. 1998. What is the current milk quality in the US? Proc, Natl Mastitis Council Ann Mtg, Feb 25-28, 1998, St. Louis, MO. p 10-19.
70. Wenz JR, SM Jensen, JE Lombard, BA Wagner, RP Dinsmore. 2007. Herd management practices and their association with bulk tank somatic cell count on United States dairy operations. J Dairy Sci 90:3652-3659.
71. Wilson DJ, PM Sears. 1995. Mastitis control management practices and their relationship to bulk tank SCC. Proc, Natl Mastitis Council Ann Mtg, Feb 20-22, 1995, Fort Worth, TX. p 33-37.