Milk Quality Influences Cheese Yields

Milk somatic cell counts can affect cheese manufacturing.

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Over the past ten years the relationship between milk somatic cell counts and milk quality has been investigated. Recent research has found that as milk somatic cell counts increase, the level of proteolytic enzyme activity in milk increases. The most important proteolytic enzyme associated with an increasing milk somatic cell count is plasmin. Plasmin breaks down casein during milk handling and storage. When milk casein is enzymatically damaged, it may be lost in the whey during cheese making and result in lower cheese yields.

Other factors besides mastitis may influence native milk protease activity. Many cheese manufacturers have offered milk quality payment premiums so that farmers would have an additional economic incentive to reduce somatic cell counts. Decreasing milk somatic cell counts benefits both the cheese maker and the farmer. The farmer will obtain higher milk production from cows that are free of mastitis, and the cheese maker will obtain higher cheese yields.

Current research indicates that there is a sharp drop in cheese yield once a milk somatic cell count reaches approximately 100,000 cells per mL, and then a more gradual decrease as somatic cell counts increase to 1,000,000 per mL. High milk somatic cell counts may also influence starter culture activity and moisture content of the cheese.

Mozzarella cheese yield and quality are two very economically important factors for the cheese industry. Some yield losses and quality defects can result from poor raw milk quality, while other losses and defects relate to poor or incomplete execution of good cheese manufacturing practices.

During the past five years there has been increasing interest in the influence of milk quality on cheese yields. This has been particularly true for milk somatic cell counts. Research reports have indicated that increasing milk somatic cell counts will cause a decrease in cheese yields. However, there has been very little published research that has quantitatively characterized the relationship between somatic cell counts and cheese yields under practical cheese making conditions.

The popularity of somatic cell counts in milk premium payment programs has resulted from advances in electronic testing technology. These allow rapid and economical quantitative determinations of milk somatic cell counts. This gives the cheese maker an objective and repeatable test on which a milk quality premium can be based, even though the exact quantitative relationship between milk somatic cell counts and milk value have not been fully characterized.

Characterizing the impact of somatic cell counts on milk value is difficult because increasing somatic cell counts can influence both cheese yield and cheese quality. Cheese yield improvements are quantitative and recognizable, and can be related directly to revenue loss.

Poor milk quality can result in poor cheese quality. Changes in dairy product quality due to poor milk quality are much more difficult to assign a specific economic value for an assessment of revenue loss. If a high somatic cell count in milk causes texture or other quality defects and a customer is dissatisfied with the product how does the management of a mozzarella cheese plant quantify and account for the economic loss?

High Somatic Cell Count Damage. All milk contains some level of somatic cells which are mostly epithelial cells or other types of somatics which do not cause significant milk quality problems. When there is a bacterial infection, tissue damage, or an inflammation of the mammary tissue, the number of somatic cells in the milk increase dramatically.

It is difficult to determine how much of a change will occur in cheese yields.

In normal milk, more than 80 percent of somatic cells are epithelial cells or other somatic cells normally found in milk. As we compare normal milk with >100,000 somatic cells per mL to milk from cows with subclinical mastitis (500,000 cells per mL), the number of lymphocytes increase about 3.9 fold, the neutrophils increase 26 fold, and the epithelial cells increase about 2.8 fold. Neutrophils make up nearly 50 percent of somatic cells present in milk from cows with subclinical mastitis. In milk from cows with clinical mastitis (>1,000,000 cells per mL), the neutrophils make up an increasing proportion of the somatic cells present.

The exact nature of this change will be highly variable from cow to cow, but the general trend of changing ratios of somatic cell types illustrated in Table 1 would be typical of...
the changes in types of somatic cells which occur during the course of an infection.

Why is the proportion of somatic cell types different in normal milk than in milk from cows with mastitis? The specific function of a neutrophil, which is a type of white blood cell, is to destroy invading bacterial cells, foreign proteins, and tissue debris in an area of tissue inflammation and infection. Therefore, during mastitis, which is an infection and inflammation of the mammary tissue, it is reasonable to expect an increase in the proportion of white blood cells called neutrophils.

A neutrophil moves quickly to areas of tissue damage and infection. It has a very potent arsenal of weapons to fight infection. These weapons include extremely active proteases, lipases, phospholipases, and specific chemicals that are inhibitory to bacteria. All of these enzymes and bacterial inhibitors are carried into milk with the neutrophils.

Because of the mammary tissue damage resulting from mastitis, there is a leakage of blood plasma into the milk. Blood plasma contains many enzymes such as proteases and lipases which can accelerate the breakdown of milk protein and fat.

Currently it is thought that the most important enzyme (for cheese yield and quality) which enters milk from the blood plasma is a proteolytic enzyme called plasmin. Plasmin will breakdown milk casein. Recent research information indicates that plasmin cannot be inactivated by normal milk pasteurization and may even survive some ultra high temperature (UHT) processing conditions.

Research shows that increasing milk somatic cell counts will cause a decrease in cheese yield.

The primary mastitis-induced changes in milk which will influence dairy product quality and cheese yield, are the result of changes in the amount or activity of proteolytic and lipolytic enzymes in milk. These enzymes digest and breakdown protein and fat causing yield losses, and possibly resulting in the development of undesirable flavor and texture.

Thus the most important point to recognize is that the cause of cheese quality and yield problems (related to mastitis) is increased proteolytic and lipolytic enzyme activity in the milk. The yield potential and the quality of milk will continue to decrease with time. The rate of milk component breakdown will increase with increasing milk temperatures.

Commingling of high somatic cell count milk with low somatic cell count milk may result in some damage to milk casein and fat in the low somatic cell count milk. The amount will depend on how long and at what temperature the milk is stored.

Changes in Milk Quality. Our research and research conducted in other laboratories indicate that when a somatic cell count increases, the proteolytic enzyme activity in milk increases. Based on this observation we have assumed that when a somatic cell count decreases after mastitis has been eliminated, the level of proteolytic enzyme activity in milk increases. Based on this observation we have assumed that when a somatic cell count decreases after mastitis has been eliminated, the level of proteolytic activity in milk returns to pre-infection levels.

The proteolytic activity of milk was studied before, during, and after mastitis. An inoculum of Streptococcus agalactiae was infused into one quarter of each of six cows to elicit an experimental infection. Uninfected quarters in each cow were used as controls. Bacteriological cultures and milk somatic cell counts were used to monitor the infection status. Sodium dodecyl sulfate polyacrylamide gel electrophoresis was used to measure milk proteolytic activity.

Somatic cell counts and total milk proteolytic activity increased significantly in infected quarters. No changes were observed in somatic cell counts or milk proteolytic activity from the uninfected quarters during or after the infections. After eliminating the infections through antibiotics, somatic cell counts in milk from the infected quarters decreased to levels not statistically different from the pre-infection period.

Total proteolytic activity of milk from the previously infected quarters decreased after the infections were eliminated, but still remained significantly higher than pre-infection levels. The increased level of proteolytic activity in treatment quarters, post-infection, when compared to pre-infection proteolytic activity, may have been due to continued leakage of blood plasma into the milk, resulting in higher plasmin

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Table 1. Change in Types of Somatic Cells Present in Milks With Increasing Somatic Cell Counts.

<table>
<thead>
<tr>
<th>Milk Type</th>
<th>Somatic Cell Type</th>
<th>Normal (&lt;100,000 cells per ml) % of Total</th>
<th>Subclinical Mastitis (500,000) % of Total</th>
<th>Clinical Mastitis (1,000,000) % of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td></td>
<td>Lymphocytes</td>
<td>6.1</td>
<td>4.8</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>Neutrophils</td>
<td>9.1</td>
<td>47.6</td>
<td>71.6</td>
</tr>
<tr>
<td></td>
<td>Epithelial</td>
<td>84.8</td>
<td>47.6</td>
<td>25.8</td>
</tr>
</tbody>
</table>

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Some detrimental effects of mastitis on milk quality may continue after the infection has been eliminated and milk somatic cell counts have returned to low levels. Severe and repeated infections in the same cow over several lactations may cause an elevation of background milk proteolytic activity for that cow. This aspect of milk proteolytic activity and the impact of mastitis needs to be studied in more detail.

Other factors in addition to mastitis may influence native milk proteolytic activity and casein damage. These factors are very poorly documented and further research is needed to identify the best indicators of milk quality for payment programs.

Milk somatic cell counts are a very effective tool for the farmer for mastitis control. It appears that a simple testing method which would measure milk proteolytic activity or undamaged milk casein may be a better index of milk quality and potential cheese yield for the cheese maker than milk somatic cell counts.

How Somatic Cell Counts Influence Cheese Yields. Cheese yield is dependent on two factors: cheese yield potential of milk and manufacturing conditions. The physical condition of milk casein and fat (the amount of proteolytic and lipolytic damage) will influence the efficiency of their recovery as cheese.

The modified Van Slyke and Price cheese yield formula (shown below) is one method used to predict mozzarella cheese yield from a chemical analysis of milk composition. As milk casein and fat decrease, cheese yields will decrease.

\[ PY = \frac{(0.85F + (C - 0.1)) \times 1.13}{1 - W} \]

\( PY = \) Percent Yield
\( F = \) Percent Fat in the Milk
\( C = \) Percent Casein in the Milk
\( W = \) Percent Moisture in the Cheese/100

There is conclusive evidence that an increase in a milk somatic cell count is accompanied by an increase in proteolytic activity in milk. It has always been said that a high somatic cell count milk had low casein. For many years it has been assumed that a cow makes less casein and more whey proteins during an infection. However, several investigators have determined that this is not the case in the normal range of somatic cell counts from 100,000 to 1,000,000.

The milk casein is actually being broken down by proteolytic enzymes. When this occurs large casein molecules are broken into smaller casein fragments which are lost into the cheese whey and do not contribute to the cheese yield. Therefore, in the cheese yield formula shown above enzymatic damage to casein would have the same impact on a cheese yield as decreasing the casein content of the milk.

It is very difficult to determine exactly how much of a change in a milk somatic cell count will change a cheese yield. Currently there is no formula or calculation which can be used to tell a cheese maker how much a cheese yield will decrease if the somatic cell count increases in 100,000 cells per ml increments.

A study is being conducted at Cornell University to determine a quantitative relationship between increasing milk somatic cell counts and Cheddar cheese yields. Results from the work on Cheddar cheese would be applicable to mozzarella. The range of somatic cell counts being studied is from 30,000 to 1,300,000 cells per ml. Each batch of cheese is made from 100 lbs of milk.

Batches of milk are collected at the Cornell dairy farm and cheese is made from one half of the batch at approximately 24 hours after milking. Another batch of cheese is made from the other half of the batch of milk after 120 hours of 4°C storage.

Preliminary results from 44 batches of cheddar cheese indicate that the major impacts of increasing milk somatic cell counts are on yield, moisture, and starter culture activity. Cheese yield decreases with an increasing somatic cell count but not in a linear fashion. When the milk somatic cell count reaches approximately 100,000 cells per ml, there is a sudden decrease (about 1%) in cheese yield.

As the milk somatic cell count increases from 100,000 to 1,300,000, the rate of decrease in the cheese yield is much slower and may be an additional one to two percent depending on the milk handling conditions (time and temperature). Milk handling and cheese making conditions used in this study represent the best case milk handling conditions. Observed changes are probably conservative.

Average psychrotrophic bacteria counts of one-day-old raw milk in this study were less than 15,000 per ml and less than 250,000 per ml for five-day-old raw milk. Bacteria counts were maintained at low levels by good sanitation, rapid milk cooling, and storage at 4°C.

Increasing milk somatic cell counts caused cheese moisture to increase and starter culture activity to decrease. Over the range from less than 100,000 to 1,300,000 somatic cells per ml, the moisture content of the cheese may increase by 1.6 percent and the make time (time from addition of starter to a milking pH of 5.30) may be increased by 15 minutes. The changes in moisture and starter culture activity could adversely influence cheese quality.

High milk somatic cell counts will cause low cheese yields. In addition, high somatic cell counts may cause problems with cheese moisture control and starter culture activity during cheese manufacture. Increasing milk somatic cell counts are correlated with increasing proteolytic enzyme activity in milk. The source of the proteolytic enzymes are from the cow. The bovine proteolytic enzyme plasmin is a major cause of casein proteolysis related to mastitis.

Many cheese manufacturers have offered milk quality payment premiums so that farmers would have incentives to reduce somatic cell counts.
shelf life of foods that contain oil or fats.

**Anti-Caking Agent** - FMC Corporation featured Avicel microcrystalline cellulose, an anti-caking agent designed for production of certain types of grated high moisture cheeses, such as Cheddar and Mozzarella. It blends easily with the shredded cheese particles and can be easily distributed on the surface of the cheese so as not to distract from product appearance. Adverse temperature, humidity and particle size conditions can be overcome when it is applied to grated or shredded high moisture cheeses.

**Sealer & Coder - North American Packaging Systems (NAPS)** was at the show featuring the TS-3 Industrial Tape Sealer with Imprinter from Thurne Corporation. The pressure-sensitive tape securely seals bag top for positive closure. Heated steel type transfers clean, sharp, dry imprints onto closure tape. Paper tabs on ends of tape permit easy opening. NAPS also demonstrated the Mini Coder Coding Machine which can print up to 120 packs per minute. Features including baselock individual letters or logos and a self-contained cartridge using quick drying ink.

**Fabricators - Beaver Metals, Inc.** featured their stainless steel and aluminum fabricators. The company supplies belt conveyors, process food cookers, portable cheese tables, salt and gum dispensers, holding tanks, produce washers and more.

**Sampling System - Nelson-Jameson Inc.** highlighted the Tru-Test Sampling System. Features include stainless steel construction, disposable syringes, sterile wipes and more. The Tru-Test system provides sufficient sample volume for accurate analysis. Continuous process contamination monitoring makes the identification of contamination sources quicker and easier.

**Separators - Separators, Inc.** remanufactures a wide range of separators to meet the various needs of dairy processors. Representatives were available to discuss the company's products and services. Each unit is rebuilt with all parts replaced and bowl is rebalanced. The company specializes in remanufacturing parts, services and controls for separators.

**Packaging System - T.W. Kutter** highlighted the TIROMAT, an automatic roll-fed thermoform, fill and seal machine. This flexible system is generally custom manufactured to solve specific objectives, such as providing extended shelf life for highly perishable products. It improves visual appeal of a package while providing product protection. The compact system combines two rolls of material — a forming web and a lidstock web — into a series of tightly sealed individual packages. Quick, uncomplicated tooling and film changeover allow the production of an almost unlimited variety of package sizes and shapes with a minimum of downtime.

**Tanks & Brining Systems - N.L. Johnson, Inc.** was at the show featuring their sanitary corrosion resistant tanks and serpentine brining systems. Brining systems feature a serpentine canal, continuous flow systems and individual stackable brine tanks. Johnson also supplies vats, carts, tank covers, drain tables, curing shelves, storage tanks, mixing tanks, chutes and funnels.

**Cheesemaking Machinery - Stoelting** was at the show featuring a line of cheesemaking equipment for Hackman Mkt Oy. Hackman manufactures equipment for the production of hard and semi-hard cheeses and many types of soft cheese. The line included: vats in a number of types and sizes, mould presses and brining equipment.

**References**


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This paper was presented by Dr. David M. Barbana at the 24th Annual Marshall Invitational Italian Cheese Seminar. Madison, Wisconsin.