J. Dairy Sci. 99:1–22
http://dx.doi.org/10.3168/jds.2016-11172

Influence of raw milk quality on processed dairy products: How do raw milk quality test results relate to product quality and yield?

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ABSTRACT

This article provides an overview of the influence of raw milk quality on the quality of processed dairy products and offers a perspective on the merits of investing in quality. Dairy farmers are frequently offered monetary premium incentives to provide high-quality milk to processors. These incentives are most often based on raw milk somatic cell and bacteria count levels well below the regulatory public health–based limits. Justification for these incentive payments can be based on improved processed product quality and manufacturing efficiencies that provide the processor with a return on their investment for high-quality raw milk. In some cases, this return on investment is difficult to measure. Raw milks with high levels of somatic cells and bacteria are associated with increased enzyme activity that can result in product defects. Use of raw milk with somatic cell counts >100,000 cells/mL has been shown to reduce cheese yields, and higher levels, generally >400,000 cells/mL, have been associated with textural and flavor defects in cheese and other products. Although most research indicates that fairly high total bacteria counts (>1,000,000 cfu/mL) in raw milk are needed to cause defects in most processed dairy products, receiving high-quality milk from the farm allows some flexibility for handling raw milk, which can increase efficiencies and reduce the risk of raw milk reaching bacterial levels of concern. Monitoring total bacterial numbers in regard to raw milk quality is imperative, but determining levels of specific types of bacteria present has gained increasing importance. For example, spores of certain spore-forming bacteria present in raw milk at very low levels (e.g., <1/mL) can survive pasteurization and grow in milk and cheese products to levels that result in defects. With the exception of meeting product specifications often required for milk powders, testing for specific spore-forming groups is currently not used in quality incentive programs in the United States but is used in other countries (e.g., the Netherlands).

Key words: somatic cell count, bacteria count, quality, premium incentive payment

INTRODUCTION

Changes in dairy product distribution patterns, product formulations, the export market, and consumer expectations have all resulted in a greater demand for dairy products that meet high quality standards both initially and over a longer shelf-life. To consistently manufacture high-quality dairy products, processors are demanding higher-quality raw milk, which can be defined as (1) compositionally complete (e.g., protein and fat levels within the norm); (2) free from off-flavors and odors; (3) free from detectable drug residues, added water, or other adulterants; (4) having low total bacteria counts; and (5) having low SCC. To ensure that they are using quality raw milk, processors routinely monitor supplies when they are received at the dairy processing plant and at the producer level.

Raw milk quality measurements most often considered in regard to potential effect on processed product quality are the SCC and total bacterial counts (e.g., standard plate count, SPC). At higher levels, somatic cells and bacteria are associated with increased activity of enzymes that damage milk components and potentially result in product defects. The ability of enzymes associated with increased SCC or bacteria counts to influence the quality of processed dairy products depends on several factors including enzyme level, specificity, heat stability, temperature of processing and storage, pH, moisture, and the presence of inhibitors and activators, thus the potential effect will vary with the enzyme, the product, and the conditions. Some enzymes, such as the native milk protease plasmin and select microbial enzymes, are heat stable and continue to act after pasteurization or more severe heat treatments (Fairbairn and Law, 1986; Mottar, 1989; Sørhaug and Stepaniak, 1997; Datta and Deeth, 2001; Considine et al., 2004; Ismail and Nielsen, 2010).

Regulatory limits designed to protect public health under the US Pasteurized Milk Ordinance (**PMO**; FDA 2013) for grade A producer milk are 750,000/mL bulk tank SCC (**BTSCC**) and 100,000 cfu/mL SPC.

Received March 17, 2016.
Accepted August 3, 2016.
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Most producers strive to meet more stringent values often linked to quality incentives or "premium" payments offered by cooperatives or other buyers of raw milk. These incentives are typically tier based, with higher-quality raw milk receiving a higher premium payment. Combinations of tier goals generally range from 100,000 to 350,000 cells/mL for SCC and from 5,000 to 20,000 cfu/mL for bacteria counts (Table 1). For example, a higher payment would be given to a producer with raw milk that has a monthly average SCC of <100,000 cells/mL and bacteria count of <5,000 cfu/mL compared with a producer with an SCC of 250,000 cells/mL and bacteria count of 15,000 cfu/mL. In most cases, meeting premium incentive requirements is based on meeting additional test criteria (e.g., free from antibiotics; acceptable freezing points; and in some cases meeting limits of alternative bacterial methods such as the laboratory pasteurization count or preliminary incubation count). Manufacturing grade milk (e.g., grade B milk) that can be used for cheese and other non-grade-A dairy products has less stringent bacterial standards (i.e., 500,000 cfu/mL) but the same SCC standards under the USDA Dairy Programs (USDA, 2011). Grade B milk represents a small percentage (~1%) of the US milk supply (USDA, 2015) and typically is not included in premium incentive programs.

Although the reasoning for offering monetary incentives for higher-quality raw milk may be simply to encourage and reward dairy farmers for their efforts, the likely rational for processors is to pay for high-quality raw milk that allows for more efficient processing and the manufacture of higher-quality products as a return on their investment. Milk-quality premiums are sometimes used as a competitive milk procurement tool to attract high-quality milk to a plant. The influence of raw milk quality based on SCC and bacterial numbers has been studied for many products, but most published work is based on the use of relatively high count raw milks. Additional work considering lower levels of these parameters and products with longer shelf-life expectations is needed. In addition, a growing need exists for more specific microbiological testing, such as for endospore (spore)-forming bacterial groups that might survive processing and cause further defects in some products (e.g., pasteurized milk). This article will provide an overview of raw milk–quality testing parameters and the current knowledge on the influence of the quality of bovine raw milk on processed dairy products, with an emphasis on levels of SCC, total bacteria counts, and spore-formers in raw milk. We will also provide a perspective on the current status of producer milk quality and the role of quality incentive programs. Where applicable, we will attempt to identify areas where further work is needed.

RAW MILK SCC AND DAIRY PRODUCT QUALITY

Somatic cells found in bovine milk are primarily lymphocytes, macrophages, and polymorphonuclear leucocytes, but they may also include a low percentage of epithelial cells (Schukken, 2007). Increases in SCC levels in raw milk are associated with mastitis, an inflammatory reaction of the mammary gland most often due to bacterial infection. Although an SCC of approximately 70,000 cells/mL is considered average for milk from an uninfected, healthy udder quarter, counts of 200,000 to 250,000 cells/mL are often used as benchmark values of infection because mean values vary with age, days in milk, and production levels (Schukken, 2007). The SCC can exceed several million cells per milliliter in milk from an infected quarter, and as the percentage of infected quarters increases, so does the BTSCC. Although BTSCC have been used to estimate the percentage of the herd infected, these values vary based on the infecting agent, stage of infection, and other factors (Auldist and Hubble, 1998; Le Maréchal et al., 2011).

Somatic cell count levels in US grade A raw milk are determined by electronic or direct microscopic methods outlined in *Standard Methods for the Examination of Dairy Products* (**SMEDP**, 17th ed.; Nierman, 2004). Methods used to qualify grade A milk supplies are approved through the National Conference on Interstate Milk Shipments (**NCIMS**) process. Automated flow cytometry systems such as the Bentley Somacount (Bentley Instruments, Chaska, MN), Fossomatic 5000/

Table 1. Examples of SCC and SPC limits[1] used to qualify for tiered[2] milk quality incentive payment programs[3]

Quality test	Tier 1	Tier 2	Tier 3
SPC range	5,000–10,000	10,000–15,000	10,000–20,000
SCC range	100,000–200,000	150,000–250,000	200,000–350,000

[1]Ranges based on information provided from 3 cooperatives that have farms in New York State and the surrounding area.

[2]Tier 1 provides the highest incentive price per hundredweight, and tier 3 the lowest.

[3]To receive incentives, all 3 cooperatives required negative ("not found") drug residue tests. Other criteria required by 1 or more included laboratory pasteurization count limits, preliminary incubation count limits, freezing point limits, sediment value limits, and dairy farm inspection scores.