Farm-Level Factors that Influence the Cheese Making Capacity Of Milk.

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People ask, "Why is cheese expensive?" One reason is that only about 50% of the milk solids is recovered in cheese. Table 1 shows the percentage of each of the principal milk components that are recovered in a typical rennet coagulated cheese such as Cheddar. Cheese makers are always looking for ways to increase yield and improve quality, but the pathway to enhanced yield and quality begins at the farm. Some farm related factors that influence cheese yielding capacity of milk are breed and other genetic effects, stage of lactation, season, mastitis, and temperature history. We will discuss each of these in turn but, to provide context, we begin with a brief description of the role of each of the principal components of milk in cheese making.

Roles of principal milk components in cheese making

Crude protein in Canadian milk is 3 – 4% distributed as 77% casein, 17% serum proteins and 6.0% non-protein nitrogen. Canadian raw milk is now priced based on true protein. On this basis, typical milk protein is mostly in the range of 2.8 – 3.7 distributed as 81.9% casein and 18.1% serum proteins (see Table 2). For our purposes in this paper, we'll work with crude protein.

Caseins. In rennet coagulated cheese and cheese made by acid coagulation of warm milk (e,g., cottage cheese), the caseins form a gel which traps fat globules, water-, and water-soluble components such as serum proteins, lactose, and minerals. As indicated in Table 1, a typical value for recovery of crude protein in cheese is about 79%, of which most is casein, and a small amount is serum protein and non-protein nitrogen.

Serum versus whey proteins. Whey proteins include serum proteins like β-lactoglobulin and α-lactalbumin, which are not sensitive to coagulation by renneting or acidification but also include fragments of caseins produced by rennet or bacterial enzymes. Whey proteins play a more functional role in heat-acid precipitated varieties such as ricotta and Paneer; heating to temperatures greater than 85°C followed by acidification causes whey proteins to form mixed curds of caseins and whey proteins.

Milk fat is present as particles called milk fat globules of 1 – 15 microns in diameter. The principal roles of fat in cheese are to soften the texture and contribute flavour. As listed in Table 1, milk fat recovery from rennet coagulated cheese is about 93%.

Breed and genetic variance of proteins

Differences in fat, protein, and yield of milk account for most breed effects on cheese yield (see Table 3). However, several genetic protein variants are associated with improved cheese making properties and cheese yielding capacity. The most important is the k-casein BB variant, which may increase cheese yielding capacity by as much as 5% (Kroeker et al., 1985; Bittante *et al*., 2012). Notice that Jersey milk has the highest frequency of k-casein BB.

Stage of lactation

Late lactation milk has mixed effects on cheese yield. Yield is increased by higher levels of protein and fat and by greater retention of moisture. On the other hand, late lactation milk coagulates poorly leading to increased fat and protein losses in the whey (Sapru *et al.,*1997). Late lactation milk also has more plasmin, an enzyme that breaks down proteins, which are then lost in the whey.

Season

Milk fat and protein are generally minimum in late summer and maximum in late fall. Cheese yield follows similar trends as illustrated in Fig 1.

Mastitis

Cheese yield from mastitic milk is reduced mainly by: (1) Altered milk composition, especially reduced casein; (2) Proteolysis of caseins by plasmin; and (3) Poor curd quality for both rennet and acid coagulated cheeses, leading to losses of curd particles in the whey. The threshold levels associated with yield loss vary from 100,000 cells/ml (Barbano 1991 and 2000) to 300,000 cells/ml (Jadhav *et al.,* 2018). Politis et al. (1988a & 1988b) observed 5% cheese yield reduction at SCC of 500,000 and 9% at SCC of 1,000,000/ml. The average bulk tank SCC in Ontario is about 240,000/ml (Sneltjes *et al.,* 2020), so it may not be possible for most farms to consistently achieve a level less than 200,000 cells/ml.

Psychrotrophic bacteria

Psychrotrophic bacteria (PB) dominate commercial milk microflora. That's because PB grow well at cold temperatures while producing heat stable lipases (enzymes that break down fat) and proteases (enzymes that break down proteins). The bacteria do not survive pasteurization, but many of their lipases and proteases do. The enzymes are usually produced on poorly cleaned product contact surfaces. During cheese making the enzymes continue to work causing loss of fat and protein fragments into the whey. The enzymes may also produce rancid and bitter flavours during ripening.

Temperature History

Many of the parameters affecting quality and yield are influenced by temperature history, for examples: (1) growth of spoilage and pathogenic bacteria; (2) bacterial lipases and proteases: and (3) lipoprotein lipase and plasmin that occur naturally in milk. Most of the spoilage bacteria are psychrotrophic and grow well down to about 4°C, but very slowly at 2°C or less. This means it's important to cool the milk quickly to less than 2°C, preferably before the milk is pumped into the bulk tank. This will slow down bacterial growth and activity of both bacterial and native enzymes. It's also important to minimize agitation to avoid activation of lipoprotein lipase.

Having emphasized the importance of the cold chain to milk quality, please note that many cheese varieties can be safely made at the farm or at local coops from uncooled and unpasteurized milk. Many international standards for cheese of *Protected Designation of Origin* require cheese to be made of evening milk, not cooled to less than 15°C, mixed with milk from the following morning. The uncooled milk preferentially supports the growth of lactic acid bacteria which suppress the growth of spoilage and pathogenic bacteria. This is one way to further diversify Canadian cheese varieties.

Summary

The absolute and relative amounts of fat and protein are the most important factors determining cheese yielding capacity of milk. Fat, protein, and cheese yield capacity on a per kg basis are highest in the late fall and winter, and lowest in the summer. Late lactation milk has higher ratios of protein to fat, relatively more whey protein and less casein, and more plasmin activity. Protein phenotypes remain of long-term interest to make small incremental increases in cheese making capacity. To minimize bacterial and enzymatic spoilage, cool milk quickly to <2ºC, minimize temperature fluctuation, avoid agitation, and fastidiously clean milking equipment.

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Table 1. Distribution of milk components during cheese making assuming milk fat is standardized to 3.3 % fat, cheese moisture is 40% moisture, and cheese fat is 31% fat. Expected yield is about 10% of milk weight. Adapted from Hill (1995).

	Fat	Protein	Carbohydrate	Ash	Total Solids
Milk	3.3	3.2	5.0	0.73	12.4
Cheese	31.0	25.0	1.7	2.2	60.0
Whey	0.22	0.61	5.30	0.58	7.0
% Transfer	93.0	78.8	3.0	30.0	49

Table 2. True versus crude protein

	Crude protein		**True Protein**	
	% of Milk	% of Crude protein	% of Milk	% of Protein
Casein	2.54	77.00	2.54	81.94
Serum proteins	0.56	17.00	0.56	18.06
Non-protein nitrogen	0.20	6.00		
Total	3.30	100.0	3.10	100

Table 3. The effects of breed on the content and yield of milk fat and protein (Lawrence, 1991).

Breed	**Milk Content (%)**			**Milk Yield (kg/lactation)**	
	Fat	**Protein**	**P/F**	**Fat**	**Protein**
Jersey	5.13	3.8	0.74	230	175
Guernsey	4.87	3.62	0.74	235	176
Ayrshire	3.99	3.34	0.84	210	176
Brown Swiss	4.16	3.53	0.84	243	210
Holstein	3.40	3.32	0.98	264	225

Notes: This data is based on an interregional study in the U.S. P/F is the ratio of crude protein to fat. The average fat and crude protein values for Canadian raw milk are currently about 3.9 and 3.3%, respectively.

Table 4. Frequency of the occurrence of κ-CN BB in several dairy breeds (Wendorff and Paulus, 2011).

Breed	**% Frequency of κ-CN BB**
Jersey	86
Brown Swiss	67
Guernsey	27
Holstein	18
Milking shorthorn	11
Ayrshire	7

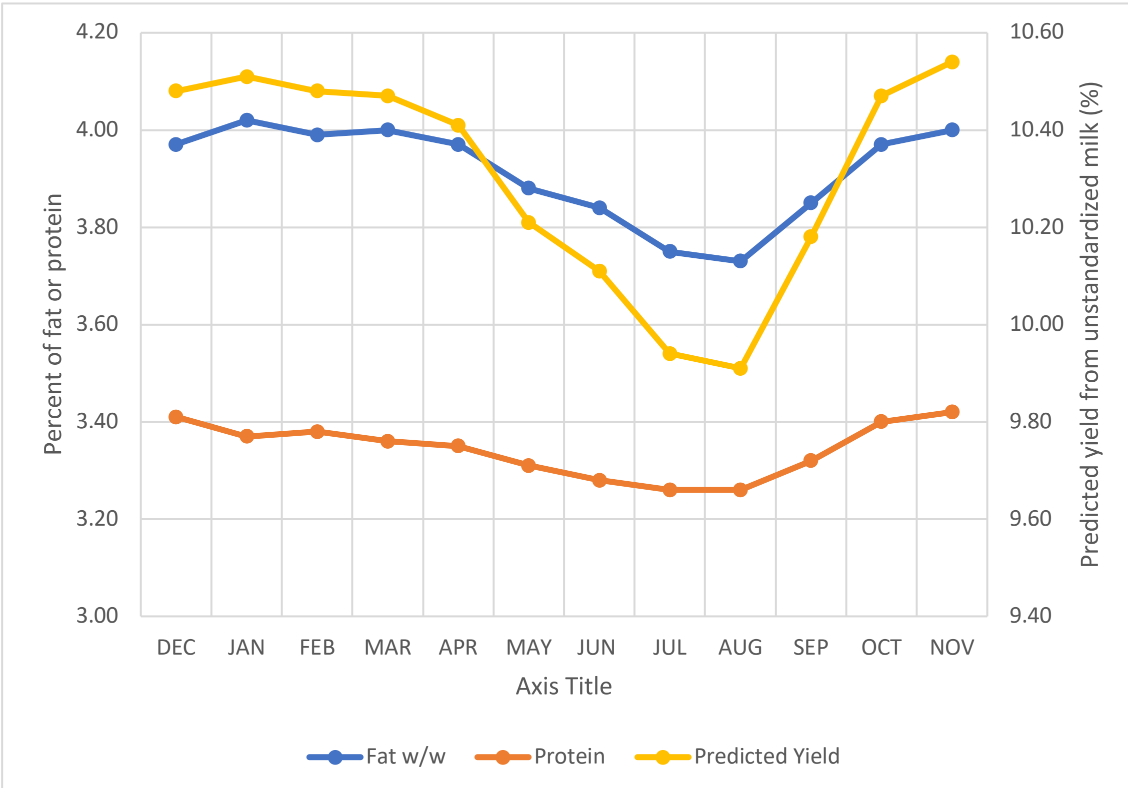

Figure 1. Seasonal variability of Ontario milk composition and cheese yield (Sneltjes *et al.*, 2020). Cheese yields assuming unstandardized milk were predicted for Cheddar cheese of 35% moisture using the Cheddar cheese yield equation of Van Slyke and Price (1949). Adapted from Sneltjes *et al.* (2020).