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Current and future prospects of milk quality from the Finnish dairy industry point of view

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ABSTRACT

The traditional milk quality concept reflects solely the dairy processors demands for raw milk quality. The quality criteria included typically concentration of fat and protein as well as milk hygiene (total plate and somatic cell counts) and possible some other physical traits, which still form the milk payment scheme on most countries. The consumer awareness of e.g., animal health and welfare and tightened customer demands for traceability of food items in the international trade has resulted in renewed milk quality concept. Total Quality Management systems are important tools for dairy industry to achieve customers' and consumers' trust for the good management practise of the whole milk chain and safe dairy products.

KEY WORDS: raw milk, quality criteria, milk composition, dairy industry

INTRODUCTION

Traditionally dairy industry has a demand for raw milk of high physical quality, e.g., low total plate (TPC) and somatic cell counts (SCC) and a high concentration of fat and protein. These traits still form the basis of raw milk payment schemes in most countries as they have an important impact on the self life of liquid milk products as well as product yield and quality (IDF, 2006). However, during the past 20 years dairy industry has adopted new quality traits that are partly integrated in the payment systems (IDF, 2006). The new traits include e.g., drug traces (antibiotics), off-flavours, freezing point depression (FPD) and free fatty acids (FFA). The dairy companies producing hard cheeses also have a demand for low level of clostridia spores (CS) in raw milk and may use penalties or interrupt milk collection if high CS numbers exist repeatedly.

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The above physical quality criteria can be understood as a milk processors demand for high quality raw material. Indeed, high physical raw milk quality is an essential prerequisite for the production of high quality dairy products. However, a more novel approach is to interpret raw milk quality from the customers' viewpoint, i.e. satisfying also the demands given by the retail industry and consumers. This approach has widened the milk quality concept to include e.g., animal health and welfare, production methods and origin of raw milk and even environmental impacts of the whole production chain (i.e. traceability). The traceability concept in turn has led to the development of Total Quality Management systems (TQM). They include instructions for the good management practise in primary milk production and dairy processing, quality criteria and assurance as well as all relevant documents and measurement data of raw milk and processed dairy products. The final aim of the documented and possibly certified TQM covering the whole milk chain is to achieve consumer acceptance and trust for high quality and safe milk products.

The purpose of this paper is to shortly review the current situation and future prospects of the raw milk quality issues from the Finnish dairy industry point of view with particular emphasis on market (retail industry and consumers) demands.

MILK FAT AND PROTEIN CONCENTRATION

Among the milk components fat and especially protein hold the highest economic value, comprising 55-65% of the cow milk dry matter (DM). Milk DM concentration has a fundamental economic impact on the production of cheeses, milk powders and e.g., yoghurt, because the ratio of raw milk needed per kg final product decreases with increasing DM concentration. In liquid dairy milk products only fat concentration has nowadays economic importance due to possibility of manipulation of fat content by separation. However, legislation may be changed in the future allowing also the control of protein concentration in liquid milk products.

In optimal situation the value of fat and protein in milk payment systems corresponds to the real market value of the respective milk components. However, manipulating milk composition by feeding and especially by animal breeding is a slow process, and hence the changes made in the payments systems are quite conservative and slow. The dairies have two basic elements in the payment systems: 1. the proportion paid for DM to total milk volume and 2. the value ratio paid for protein to fat.

In Finland the proportion of DM of the total raw milk payment has been approximately 70 or 90% calculated from the total or dairy payment with or

without subsidies, respectively (Figure 1). If two dairy farms are producing the same amount of milk protein and fat, the farm producing higher milk volume (i.e. has lower content of protein and fat in milk) will get higher total payment because subsidies and quality premium are directed to total milk volume. Virtually this means that water+lactose has a small positive economic value in
milk. On the other hand, the value ratio of protein to fat has changed dramatically from below one to 3.5, being currently about 2.7 (Figure 1). In line with the payment scheme fat concentration of raw milk has decreased about by 0.13 and protein increased by 0.12 g/kg per annum during the latest 15 years (Figure 2). For milk fat concentration the driving force has been animal

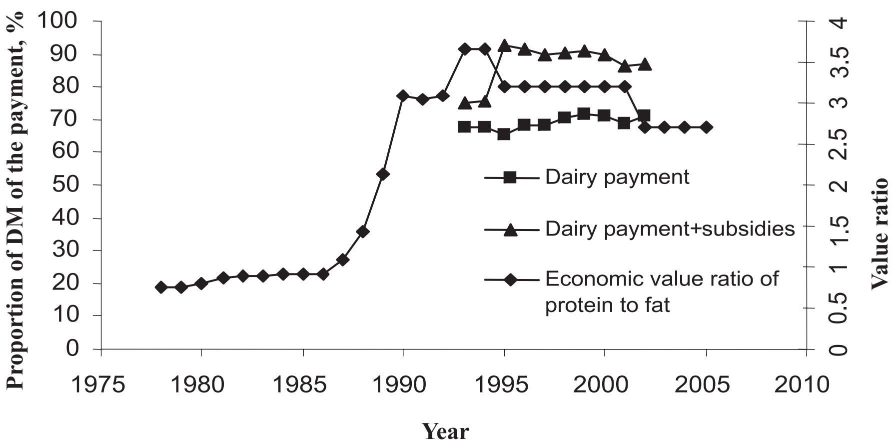

Figure 1. Farm raw milk payment in Finland between 1985 and 2005; the proportion of milk dry matter of the total payment (dairy payment or dairy payment+subsidies) and economic value protein to fat ratio (unpublished, Finnish Dairy Association, 2005)

breeding, the annual genetic trend of dairy cows being -0.18 g/kg (FABA, 2005). Although part of the phenotypic trend may be explained by the small increase in the proportion of Holstein-Friesian breed, the Finnish dairy cow feeding type tends to sustain high fat concentration (Huhtanen, 1998). In contrast, the genetic trend of dairy cows for milk protein concentration is close to zero (FABA, 2005) suggesting that the positive phenotypic trend is due to more intensive feeding or more evidently because farms with a low feeding intensity have finished milk production (Kaustell et al., 1996; Huhtanen and Nousiainen, 2004). Kaustell et al. (1998) reported based on milk recording data that with increasing milk yield the increase in milk protein only partly compensates the lowering milk fat concentration. Consequently raw milk DM concentration tends to decrease along with more intensive feeding and increasing milk yield. However, the changes in protein and fat concentration with increasing milk yield are essentially dependent on the means to improve milk yield. For example, both milk protein and fat concentration tend to increase in response to improved silage digestibility and restriction of in-silo fermentation (Huhtanen, 1998).

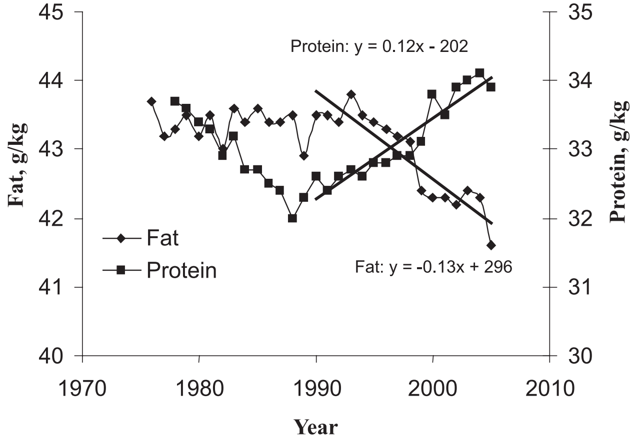

Figure 2. Current trends of fat and protein (6.38×N) in raw milk collected to dairies in Finland between years 1975-2005 (unpublished, Finnish Dairy Association, 2005)

In the future market demand and value for milk fat is evidently decreasing due to following reasons: 1. butter export subsidies outside EU are finished until 2013 resulting in higher milk fat supply on the European market and 2. the average fat content of both cheeses and liquid dairy products is steadily decreasing. These changes may put pressure to change the value ratio of protein to fat in payment schemes. However, this would lead to increased feeding costs on dairy farms to maximize milk volume and protein content and a further lowering milk DM trend. This progress may not be feasible in terms of higher risk for e.g., udder health and lower efficiency of nutrient [nitrogen (N) and phosphorus (P)] utilization. Another possibility is to base the payment schemes totally on DM (i.e. equal value for all milk solids), or even put negative value for milk liquid. It may be concluded that optimization of milk payment schemes for both market demands and sustainable primary milk production is a complex task.

NUTRITIONAL MANIPULATION OF MILK FAT COMPOSITION

Milk fat contains naturally a high proportion of saturated fatty acids (FA, up to over 70 g/100 g) due to *de novo* synthesis of FA in the mammary gland and the efficient ruminal biohydrogenation of unsaturated FA from dietary origin. The consumption of saturated milk FA is often related to hypercholesterolaemia and cardio-vascular diseases in humans. However, the hypercholesterolaemic responses are most evidently associated to intake of C_{12}-C_{16} of milk FA, the other FAs being neutral or possibly having favourable effects (Givens and Shingfield, 2006).

It is well documented that the composition of milk fat can be manipulated by dairy cow feeding in a way that decreases the unfavourable responses in human nutrition (e.g., Bauman et al., 2005; Givens and Shingfield, 2006). Increasing the intake of pasture, good quality grass or clover silage, and supplementing the diets with oats and high fat oil seed cakes instead of barley and low fat protein sources are simple methods in manipulating milk fat composition. Indeed, it can be expected from the previous (Kankare et al., 1992) and recent data (Shingfield et al., 2005) that the difference in saturated to unsaturated FA ratio in milk fat produced between summer and winter milk fat has decreased markedly in Finland due to changes in dairy cow in-door feeding. The average proportion of saturated FA is still quite high as compared to nutritional recommendations and there is a decreasing potential by including more unsaturated FA in dairy cow rations. However, the amount of vegetable fat fed should be controlled to avoid unfavourable oxidative changes in milk fat, decrease in milk protein concentration and digestive disorders in cows. Also the current animal breeding strategy with declining genetic trend for milk fat concentration may decrease the proportion of saturated FA because the importance of mammary *de novo* synthesis of FA of milk fat is lowered.

The intensive recent research has shown that conjugated linoleic acid (CLA) may have several positive responses in human nutrition (Givens and Shingfield, 2006). Milk fat is a major source of CLA for humans and the concentration of CLA in milk fat may be increased with the same dietary manipulations that decrease the proportion of saturated FA. However, the commercial potential of milk CLA concept has not been fulfilled as expected, although some product applications already exist on the world market. There are perhaps some evident reasons for this situation: 1. the positive effects of milk CLA on human health are still somewhat unclear, 2. the concept itself is new and difficult to advertise and 3. the parallel increase of milk trans FA (mostly vaccenic acid). Despite natural milk trans FAs do evidently not encompass the same negative nutritional responses as those originating from technological processing of vegetable fat, dairy companies are still somewhat cautious in the commercialization of CLA. In addition, production and collection of CLA-enriched raw milk may cause extra costs for many dairy companies.

Besides CLA, increasing milk ω-3 FA by feeding may also have market value and demand. The concept is perhaps more well-known among consumers than that of CLA and therefore is easier to commercialize. The dietary means (pasture, red clover silage and supplementation with linseed and fish oil) in increasing milk ω-3 FA are also well-documented (Petit et al., 2002; Dewhurst et al., 2003).

It may be concluded that the market demand for manipulating milk fat composition by feeding may be increased in the future. As a consequence, new dairy product concepts may appear in the market or the positive responses are attached to image of dairy products generally. However, more exact quantitative data of the dietary alternatives in manipulating milk FA composition is still needed. Moreover, dairy industry is waiting for new research data describing the nutritional responses to milk fat *trans* FA.

MILK HYGIENE AND BACTERIOLOGICAL QUALITY

Currently the average raw milk quality expressed as SCC or TPC in Finland fulfils well the demands of dairy industry (Figure 3). However, milk industry is concentrating on a larger units resulting in longer transportation distances of raw milk with a final aim to increase the efficiency of production processes and to reduce the variation in product quality. Hence, the quality criteria may be assessed by a dairy plant depending on specific product demands rather than existing general quality criteria within a dairy company. Consequently, it is evident that the management of quality variation between raw milk lots becomes more important than the average quality level.

The merging primary production has an important impact on the raw milk quality in the dairy plant. As the herd size and the amount of milk produced per dairy farm increases, a milk quality problem on a single dairy farm may more easily compromise the quality of processed milk products. Moreover, the new production technology and management methods (e.g., automated milking systems, feeding technique etc.) may induce new milk quality problems like too high concentration of FFA or atypical FPD (freezing point depression) values. Thus the production processes on each single farm need to be systematically controlled and even automated alert systems may be required to minimize the risk for appearance of non-marketable raw milk lots. For example, alert systems are already available for milk temperature control on a dairy farm.

The current dairy statistics tends to demonstrate that milk quality may be compromised on a larger dairy farms generally, and especially on farms using new production technology (Figure 3). However, this field statistics should be interpreted with caution, because herd size and type of technology may be confounded. Despite similar trends for automatic milking have been noticed in other countries (e.g., Rasmussen et al., 2002), more research data is needed of the milk quality on a larger dairy farms using modern production technology.

It is well documented that for acceptable organoleptic and bacteriological raw milk quality good silage quality is a basic requisite. Raw milk clostridia spores (CS) deteriorating fermentation of hard cheeses originate largely from bad quality

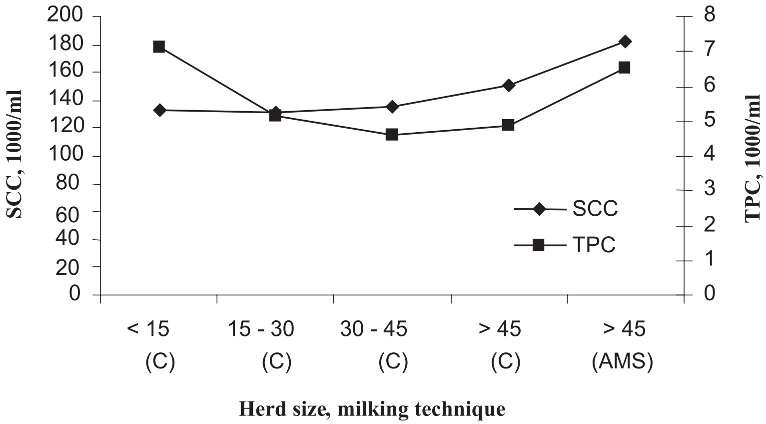

Figure 3. The effect of herd size and milking technique (C = conventional, AMS = automatic) on the somatic cell (SCC) and total plate (TPC) counts on dairy farms with increasing herd size or on dairy farms with automatic milking technique (AMS) (Finnish Association for Milk Hygiene, 2005)

silage. Good milking practise and stall hygiene may help to control this problem, but if silage is of very bad quality, high CS numbers in raw milk may be unavoidable (Vissers et al., 2006). Rasmussen et al. (2002) reported an increase in the number of milk anaerobe spores on farms moving from traditional to automatic milking. A combination of bad quality silage, low stall hygiene and AMS may be difficult to handle, because udder hygiene during milking is not manually controlled and the equipment may transmit spores from dirty cows to clean cows. However, published research data from this point is lacking. A low CS count is an important factor for many dairies, due to a general trend for making cheese without antibacterial additives (nitrate). Although CS and other bacteriological problems in raw milk may be relieved with modern dairy processing technology [bactofugation, micro-filtration, and ESL (extended self life) treatment], it causes additional processing costs for dairies. Thus a good silage quality continues to be a vital element to dairy farms and industry for high quality and profitable raw milk production.

ANIMAL HEALTH AND WELFARE

The free world trade of feeds, animals, sperm and embryos most evidently increases the risk for spreading of infectious animal diseases. The freedom of dangerous OIE A-list diseases (OIE, 2005) and other infectious diseases is an unavoidable prerequisite for the international trade of milk products. This also tends to be more often a customer and legislative demand in the several market areas. Prevention of infectious diseases involves responsibility in production management from all actors of the milk chain including dairy farmers.

In the future preventive health management of production diseases will be a normal routine on most dairy farms. The preventive health management scheme includes that the health status and production conditions of dairy herds is regularly audited by veterinarians and if needed, documented improvement instructions will be given. It may be expected that this system becomes a market demand within a relatively short time period. Ethically acceptable and sustainable milk production also involves that species-specific needs of dairy cattle in the stall design and herd management (e.g., normal movements and social contacts within a group of animals) and feeding (e.g., rumen function) are taken in account. Most probably animal welfare issues may further increase in importance as a consumer demand in the food market in the future. Thus more research data is needed in order to understand how animal welfare may be measured to facilitate the further development of animal welfare standards. Currently the average culling age of dairy cows in the Nordic countries is relatively low (less than five years). According to Nousiainen (2006) slightly more than half of the culling decisions are obligatory (not voluntary) in Finland. The low culling age and a high proportion of obligatory animal disposals may suggest that problems in animal longevity and welfare really exist. This also increases the feeding cost per litre milk and decreases the efficiency of nutrient utilization. Consequently, the existing breeding criteria should be critically discussed, and possibly a partial shift from selection for production traits to selection for better longevity and disease (e.g., udder health and fertility) resistance is needed.

ENVIRONMENTAL IMPACTS OF MILK PRODUCTION

Based on the several LCA (Life Cycle Analysis) -studies, euthrophication is the most important environmental consequence from milk production caused by nutrient leaching and run-off from cropping systems. In a long run nutrient surplus per land area is the most important driver of leaching, i.e. nutrient balance describes roughly the leaching potential. Both surpluses for N and P per land area tend to increase as the milk yield per land area increases (Figure 4). The current trend towards more intensive milk production whether expressed per cow or land area evidently increases the risk for environmental problems (Virtanen and Nousiainen, 2004). The increase in animal density associated to increasing herd size as well as feeding more concentrates and protein supplements are evident reasons for the lower N and P utilization efficiency at a farm level.

Organic milk production contains specific regulations for e.g., crop production and feeding management to control the environmental responses. However, the quantitative regulations for efficiency of nutrient utilization are lacking. In Finland the market share of organic milk products is relatively small (below 1%), but it may increase in the future.

In conventional milk production the environmental measures until today are mainly driven by legislation without any particular market demand. Most of the Finnish dairy farms have been involved in the Agri-Environmental Programme of European Union since 1995. The EU program does not contain quantitative regulations for the nutrient balances and therefore the system may be inefficient. However, the Nordic countries beside the Baltic Sea are facing the eutrophication problem, with increasing public demands for improving the efficiency of nutrient (especially P) use in the animal agriculture. This may lead to quantitative regulations for nutrient surpluses per land area, as is already the case in the Netherlands. Milk urea concentration describes the efficiency of N utilization relatively well, and especially the output of easily leachable urinary N per unit produced milk (Nousiainen et al., 2004). Consequently, in the future dairies could use milk urea concentration as a quantitative criterion of N utilization efficiency.

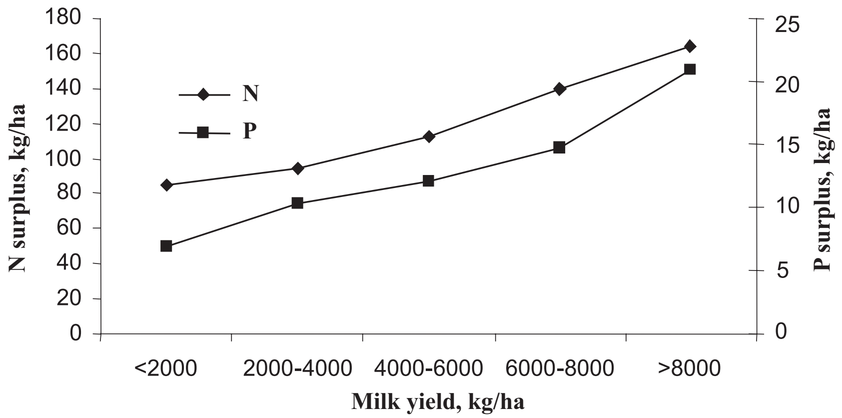

Figure 4. The effect of milk production intensity on the phosphorus (P) and nitrogen (N) balance (kg/ha) on Finnish dairy farms (data from Virtanen and Nousiainen, 2004)

TOTAL QUALITY MANAGEMENT

The increasing consumer awareness of animal welfare and infectious diseases, increasing demand for traceability of food items and environmental problems on areas with intensive milk production has resulted in developing Total Quality Management (TQM) systems also in the dairy sector.

Customer demands in the international trade are tightened. Dairy product traceability, raw milk contaminants (pesticides, heavy metals and microbial toxins) and hygiene, health treatment of animals and feeds used for dairy cattle are of specific interest. Customers want even audit dairy farms and plants to ensure total product quality. This causes great challenges for the whole milk chain and increases the requirement for instructions of good management practise (GMP) both in primary production and milk processing. Documented TQM covering the whole milk chain including quality agreement between dairy farms and companies, universal GMP instructions, training of milk producers in quality management and dairy farm audits continues to be vital tools for the Finnish dairy industry to achieve consumer acceptance and trust for high quality and safe milk products.

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