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Milk quality – a future approach from a researcher's point of view

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ABSTRACT

The approach to the term "milk quality" varies among consumers, dairies and researchers and is therefore very difficult to define. Three main elements of the term are however dealt with in this paper. An increased understanding of the nutritional value of various milk components is necessary. How breeding and feeding can influence the nutritional quality of the milk or whether the processing properties of the milk are changed needs further investigation. A need for documentation of various quality aspects of milk produced in different regions will appear. Further research on the functional effect of genetic variants of proteins on dairy products is necessary if this factor is going to be an element in the breeding programmes.

KEY WORDS: milk quality, consumer preference, feeding, bioactive components, genetic polymorphism of proteins

INTRODUCTION

The term "milk quality" can have different meaning in different situations. The approach to the term may vary among consumers and also among dairies producing different dairy products. A future approach to milk quality from a researcher's point of view will depend on the respondent, probably influenced by

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the researchers own research interests and particular research field. For a researcher oriented towards technological and applied aspects of the milk quality term, the future approach should to a certain extent be in line with that of the industry and the consumer. A relevant starting point for discussion of the future milk quality is therefore the expressed needs or views of the consumer.

Milk quality may for instance relate to the bacteriological quality of the raw milk or to bacteriological quality and safety after processing. The bacteriological composition of the milk may also have varying importance depending on the type of product produced.

The chemical composition of the milk is a quality factor of relevance for both the consumer and the dairy industry. A high content of protein in the milk for cheese making and high fat content in milk for butter making are examples of rather obvious demands from dairy processing plants. High content of β-carotenes in order to increase the intensity of the yellow colour of butter is another possible quality aspect for milk and cream used for butter production and also for production of cultured cream. For most products, a high content of antioxidants is important for the prevention of unacceptable quality defects caused by fat oxidation.

Various genetic variants of milk proteins may influence the quality of the milk when used, for instance, in cheese making. Although the knowledge of genetic polymorphism of proteins in milk is increasing, there is insufficient knowledge about the effect of genetic variants of milk proteins on the final products. There is therefore a reluctance to use genetic variants as a possible factor in the breeding programme. Further research on the effect of various genetic variants of the milk proteins on the properties of the milk and dairy products is necessary.

Consumers may pay attention to the nutritional quality of milk and dairy products. They may for instance be concerned about the health aspects of the relatively high saturation of milk fat, frowned upon by some nutritionists. Actions to increase the proportion of unsaturated fatty acids in the milk are therefore often considered as a future approach for the milk quality. It is however important to underline that the most critical quality parameter in all products is the flavour. The flavour of milk and milk products should therefore never be underestimated in the future work for enhancing the quality of milk and milk products.

Consumers have shown an obvious interest for an increased diversification in the properties of the available food products. An increased need will appear for documentation of various quality aspects of milk produced under different conditions in different localities and regions. The dairy industry must therefore develop the ability to differentiate the quality of milk and milk products according to place of origin and perhaps also according to season.

THE CONSUMER'S DEMAND TO MILK PRODUCTS

Various observations indicate that the consumers are increasingly interested in a greater diversification and variety of foods on the food market.

In Norway, the Ministry of Agriculture and Food is responsible for the food and agricultural policymaking. The food policy aims to provide consumers with wholesome, high quality food products, and to ensure that the food production process is carried out with environmental, public health and animal welfare concerns in mind. On the initiative of the Ministry of Agriculture and Food, a project called "Consumer panel for food policy" published a report in February 2004 (Forbrukerrådet, 2004) with the title "The food market in the future - choice alternatives, quality and distribution of food in Norway" ("Fremtidens matvaremarked - om utvalg, kvalitet og distribusjon av mat i Norge"). The work was financed by the Norwegian Food Safety Authority and the Consumer Council of Norway was responsible for the project, project management and reporting. Some of the conclusions in the report are of particular interest for the evaluation of future aspects of milk quality and milk products because they may be regarded as generally valid for consumers in many countries.

The panel particularly underlines an increased need for diversity and variation in choice of food items. The consumer prefers to have the option to choose between different goods produced and manufactured in different ways, preferably with the use of different raw materials and ingredients with different origin and characters. They ask for real differences in qualities like taste, flavour and appearance and also products of differing importance for health and the environment. The panel asks for an increased selection of regionally-produced food and underline that they look for an increased availability of food produced locally. One of the political statements from the panel is that if the agriculture in Norway is to survive increased competition from imported food, then the food producers in this country have to change their strategy and move away from what they call "standardizing" and making the food "anonymous". They claim that the products must retain their identity through differentiation based on geographical origin, nature-specific advantages, and variation in production and manufacturing methods and local traditions in food preparation.

A substantial increase in the number of small-scale local producers of food items, for instance the rapid increase in the number of small-scale local producers of dairy products, may be seen as an activity adapting to the kind of views expressed by the panel as referred to above.

If this is accepted as a more general consumer trend, it may influence the way we are looking at milk quality in the future and the way we describe, document and prove variations in quality properties of locally or regionally produced dairy products. According to the panellists from the reported project the consumer will only be satisfied with the differentiation of products if they can observe or be convinced about a real quality differentiation. For the dairy industry this may lead to a particular need to produce local varieties of, for instance, cheeses or butter and to prove that a real quality difference can in fact be observed. Simply using another name or claiming that a product is produced in a particular region may not be sufficient for the consumer in the future. This concept may be rather demanding for an industry that aims to operate with high efficiency and at as low cost as possible. On the other hand such a trend may also open up for some unexplored possibilities.

THE INFLUENCE OF PASTURE ON THE QUALITY OF MILK AND THE PROPERTIES OF DAIRY PRODUCTS

The Norwegian Dairy Company TINE BA, scientists at the Department of Animal and Aquacultural Sciences, Department of Chemistry, Biotechnology and Food Science at the Norwegian University of Life Sciences, and the Norwegian Food Research Institute (Matforsk) have studied in detail the quality aspects of milk produced in one particular region of Norway (Valdres) where approximately 70% of the milk during the summer season is produced at pasture in the mountain area.

It would be interesting to explore the possibilities for production of, for instance, cultured cream, butter and cheese from mountain pasture milk in order to present products of special regional origin made from milk produced during particular weeks during the summer in, for instance, the Valdres-region. The milk and the products must then have some specific and identifiable properties and qualities which differentiate them from similar products from milk either produced elsewhere in the country or during the winter season. Such products may be considered by the consumer as somewhat exotic, original and exclusive and could probably be marketed as a niche product and thereby commanding a higher price than the ordinary products. These kinds of products would also increase the diversity of the food supply in the country.

During the seasons, 2005 and 2006, we have been able to follow four different herds grazing in the same mountain area during the summer season. The four herds had approximately the same variation in calving, somewhat randomly spread during the period October to May. Milk was collected from each herd whilst they were still fed indoors, before they were taken to the mountain pasture. Milk samples from each herd were collected at certain intervals during the mountain pasture period. The analyses of these samples and the evaluation of the results from the 2006-season are not yet completed, but some of the results from the 2005-season give interesting indications of some particular differences between the milk from the indoor feeding period, “winter milk”, and the milk from the mountain pasture season.

Some of our results from the analysis of the milk, cultured cream and butter made from the milk collected in 2005 for the experiment described above, are presented below. Of course the subject has to be studied further during a greater number of summer seasons before scientifically sound conclusions can be presented. However some of the preliminary observations can be listed as follows:

- The fatty acid composition in the milk differed between “winter milk” and milk produced at mountain pasture. The differences were greatest between “winter milk” and the first observations of milk from mountain pasture (June). At the end of the mountain pasture period the composition changed in the direction of “winter milk”, but was still different from the “winter milk” produced in May.
- The relative amount of the saturated fatty acids, myristic acid (C14), and palmitic acid (C16), was reduced from the relative amount observed in the “winter milk” to the relative amount observed in July. In spite of a slight increase in the relative amount of these fatty acids at the end of the mountain pasture period, the relative amount was lower than in the “winter milk”. The proportion of oleic acid (C18:1), linolenic acid (C18:3), vaccenic acid (C18:1) and conjugated linoleic acid (CLA) (C18:2c) was higher in milk from the mountain pasture period than in the “winter milk”. While the relative amount of linoleic acid (C18:2) was lower in the mountain pasture milk than in the “winter milk”.
- An off flavour in the cultured cream produced, possibly related to oxidation, was not influenced by the origin of the milk.
- The evaluation of the flavour and aroma in the butter prepared from the various milk samples gave a slight indication that butter produced from mountain pasture milk obtain a somewhat better score than butter made from “winter milk”.
- Some ketones were formed in the butter samples. The amounts of 2-propanone, 2-butanone and 2-pentanone were highest in butter made from the “winter milk”. The absolute lowest content of these ketones was found in the butter made of milk from mountain pasture in July.
- An interesting increase of terpenes was observed in the butter made from the mountain pasture milk collected in August. We observed a 10-fold increase in the amount of α-pinene, the dominating terpene, in butter made from the August milk compared to butter made from the milk collected in July. Butter made from “winter milk” had only very small or negligible amounts terpenes. The relatively high amount of terpenes in the mountain pasture milk from August may influence the flavour of the products. This observation has to be further investigated and the possible effects of terpenes on the quality of the products have to be clarified.

- The preliminary results from the 2006-season indicate a relatively considerable increase in the amount of α-tocopherol in the mountain pasture milk compared to the “winter milk”. The results show a 30 to 50 % increase in the amount of α-tocopherol in the mountain pasture milk compared to “winter milk”, depending on when the milk was collected and also depending on herd. Highest amounts were observed in the milk collected in August.

Our preliminary observations indicate that milk production on mountain pasture in Valdres during the summer period may give milk with a higher amount of unsaturated fatty acids, reduced amount of ketones, higher amount of terpenes and higher amount of α-tocopherol. We have also obtained some indications that the composition of the milk may influence the quality properties of some dairy products. This has, however, to be investigated further before any solid conclusions can be made. If the milk and the products from the mountain pasture period can be characterized as different from the milk from the indoor feeding period, the dairy industry may have a potential to produce products with seasonal character and properties. In that way the dairy industry may increase the diversity of dairy products on the market, which would be in accordance with the consumer panel’s conclusions as discussed above.

In future considerations on milk quality, it may be of interest to intensify the use of pasture in order to accentuate various quality characteristics of the milk and the milk products. A recognition of need for research and practical experiments, in order to know more about the effect of various feeding regimes on the quality of milk and dairy products is necessary before too many practical decisions are taken. In our preliminary studies in collaboration with TINE R&D, we have therefore published two review articles base on the available international literature for information on the oxidation stability of milk produced on pasture (Borge et al., 2006) and about how changes in the milk composition, due to extensive use of pasture, may influence the properties and qualities of dairy products made from such milk (Wetlesen et al., 2006).

Some conclusions from our review of the literature regarding the effect of pasture on the quality of milk and milk products are presented below. A relatively clear conclusion is that milk produced during pasture grazing has an increased amount of polyunsaturated fatty acids and an elevated amount of conjugated linoleic acid (CLA) (C18:2c) (Schroeder et al., 2003).

Milk and milk products with an increased content of polyunsaturated fatty acids may be less stable to oxidation. The oxidation stability of milk is determined by the interaction between components able to undergo oxidation and various components acting as pro-oxidants or anti-oxidants. A future approach would therefore be to investigate how the level of antioxidants in the milk is influenced by the pasture or the feeding regime in general. Studies by Havemose et al. (2004) have shown that the content of fresh green plants in the fodder increase the amount of antioxidants in milk, in accordance with our own results obtained from use of mountain pasture in Valdres. From our review we can conclude that most reports underline a positive rather than a negative effect of pasture on the oxidative stability of the milk, and a positive influence on the flavour properties of the milk as well.

Milk from pasture has in several studies led to dairy products which have often been regarded as better or as having different properties compared to products made from milk based on indoor feeding (Bartsch et al., 1976; Buchin et al., 1998; Bugaud et al., 2001; Jaros et al., 2001; Coulon et al., 2004; Hauswirth et al., 2004; Lieber et al., 2005). Walker et al. (2004) concluded in their review article with the following: "*...our understanding of the effects of cow nutrition on the concentration and composition of fat and protein in milk derived from pasture-based production systems is poor as comparatively little research has been conducted in this area"*. In another review article Chilliard and Ferley (2004) concluded: *"...that it is important to better understand the effects of using grass-based diets, new combinations of feedstuffs in concentrates, and oil seed technology and processing. Few direct comparisons have been made so far, and there is a need to evaluate more deeply how the different feeding strategies could change the milk fat quality"*.

There is a particular interest among researchers for further studies on the effect of pasture on the milk quality and on the quality of the dairy products. We therefore believe that part of the future approach to milk quality will take this into account and lead to better understanding of how feeding may differentiate and influence the milk quality and the quality of the dairy products. Such understanding, and greater commercial use of these differences, will be in line with the demands from the majority of consumers.

VARIATION IN NUTRITIONAL QUALITIES OF MILK AND MILK PRODUCTS

The typical consumer of today is highly aware of the nutrients and health-properties of food, and health consciousness related to food intake is high among a large share of the population. Modifiable risk factors seem to be of greater significance for health than previously anticipated (Yusuf et al., 2004). Prevention of disease may in the future be just as important as treatment of diseases. The market for healthy food and functional food is increasing. Based on this knowledge, agricultural food production needs to meet the demand for healthy products. Milk and milk products may also be modified in a more healthy direction by feeding of the cow, breeding and intelligent use of modern dairy science and technology.

Composition of the milk fat

In one of our projects we have studied the literature with the aim of establishing an updated knowledge about the possibility to increase the nutritional quality of milk through feeding. One of the main reasons for making this update was to develop a further study aimed at increasing the nutritional quality of milk and dairy products. Part of that study has started but it is too early to present the design of the experiments or any of the results. It is, however, possible to point out known facts concerning the nutritional quality of milk and suggest some improvements which should be the aim of future research.

High intake of saturated fat raises blood cholesterol levels and diets rich in saturated fat have traditionally been regarded as contributing factor to heart disease, weight gain and obesity (Insel et al., 2004). High cholesterol levels are considered a main risk factor for coronary heart disease, in particular LDL cholesterol (Hegstedt et al., 1993). Between 50 and 70% of the fatty acids in normal milk are saturated. It has been found that the saturated fatty acids lauric acid (C12), myristic acid (C14) and palmitic acid (C16) cause an increase in the blood serum LDL cholesterol level (Kris-Etherton and Yu, 1997), and high level of serum LDL-cholesterol increase the risk for coronary heart disease (Stamler et al., 1986). The Norwegian authorities recommend a reduction or limitation of the intake of saturated fatty acids in order to reduce the incidence of coronary heart disease. It is therefore desirable to reduce the content of these fatty acids in milk fat, especially palmitic acid (C16).

Among the various fatty acids present in milk are also the unsaturated fatty acids. Oleic acid (C18:1) is the single fatty acid with the highest concentration in milk, varying between 17 and 29% according to feed administration, breed and season (Jensen, 1995; Chilliard and Ferley, 2004). Milk and milk product contributes substantially to the dietary intake of oleic acid (C18:1). Oleic acid (C18:1) is regarded as positive for health, as a diet containing high amounts of monounsaturated fatty acid will lower plasma cholesterol, LDL-cholesterol and triacylglycerol (Kris-Etherton et al., 1999). A future approach could therefore be to improve the nutritional quality of milk by increasing the content of oleic acid (C18:1) through changes in the feeding regime. It is the cow's intake of oleic acid (C18:1) and its extent of biohydrogenation in the rumen and/or the intestinal supply of stearic acid (C18) and its extent of desaturation to oleic acid (C18:1) in the udder that mainly influence the milk fat content of oleic acid (C18:1). Thus, it is possible to obtain milk fat with a high proportion of oleic acid (C18:1) on diets with high content of oleic acid (C18:1) and/or diets with high content of polyunsaturated acids which are desaturated to stearic acid (C18) in the rumen. A realistic goal is about 30 to 25% oleic acid (C18:1) in the milk fat at pasture and on indoor feeding with grass silage, respectively, assumed supplementing with an appropriate fat source (Fearon et al., 2004; Ryhänen et al., 2005).

The predominant polyunsaturated fatty acids in milk are linoleic acid (ω-6) and α-linolenic acid (ω-3). It has been argued that the Mesolithic man had a ratio of 1-4:1 between the ω-6 and the ω-3 fatty acids in his diet, against the most European diets today that have a ratio of 10-14:1 (Bartsch et al., 1999). Eskimos, and some populations in Japan, have a high intake of ω-3 fatty acids and a low rate of coronary heart diseases and some cancer. Conceivably, a lower incidence of cardiovascular diseases and cancer could be related to the ratio of ω-6 to ω-3 fatty acids in the diet. In milk the ratio between ω-6 and ω-3 fatty acids is low and favourable compared to most other non-marine foods. Milk fat from cows given a normal indoor diet consisting of conserved grass, green plants and concentrate have an ω-6: ω-3 ratio about 4:1, but cows on pasture during the summer season may give a milk with the ratio reduced to 2:1 (Stene et al., 2002; Chilliard and Ferley, 2004; Ledoux et al., 2005). In Norwegian milk today the ratio between ω-6 and ω-3 fatty acids is 3:1. The future approach should be to increase the absolute content of both of these fatty acids but at the same time reduce the ratio between them to 2:1 or lower by means of adjustment of the feeding regime. Based on our literature evaluation in 2005, we see that a future approach for milk quality based on the possible influence by feeding could be to develop a feeding regime of the cow which can give us milk in which we have:

- Reduced the amount of medium and long chain saturated fatty acids
- Increased the content of oleic acid (C18:1) to the range of 25-30% of the milk fat
- Increased the content of polyunsaturated fatty acids
- Increased the content of ω-6 and ω-3 fatty acids and to reduce the ratio ω-6: ω-3 to 2:1.

Iodine in milk

Milk is the most important source for iodine. Iodine is an essential component of the thyroid hormones. These hormones control the regulation of body metabolic rate, temperature regulation, reproduction and growth. The dairy industry may play an important role in securing stable iodine supply. The content of iodine in the milk depend to a great extend of the feed. A study conducted by Dahl et al. (2003) shows that Norwegian milk contained on average 88 μg/L (63-122 μg/L) in the summer season at pasture and 232 μg/L (103-272 μg/L) in the winter season. The main reason for this difference is the fact that the feed industry adds iodine to cattle feed and that the intake of concentrate is much higher in the winter season than in the summer season. Cows on pasture should therefore be given some concentrate with relative high level of iodine in order to give milk with an more even iodine content throughout the year. With the recommended iodine intake of 150 μg/day for adults, a daily intake of 0.4 litres of milk meets the requirement with 25% during the summer and more than 60% during the winter season. Through a good designed feeding regime it is therefore possible that milk could become the most important source of iodine in the diet. It should therefore be one of the milk quality goals for the future to increase the stability of the iodine content in milk throughout the year by reaching the level of approximately 250 µg/L, both in summer and winter milk.

Some specific bioactive components

Another future approach for the development or evaluation of the quality of milk may be based upon the availability of bioactive components in milk and how these components can be utilized with regard to their health aspects. The extent to which the content of various bioactive components in the milk can be influenced by breeding and or feeding should also be investigated. Since the bioactivity of milk provides the dairy industry with an exciting future, it is necessary to have greater knowledge of how we can develop the advantages that milk contains a whole range of bioactive compounds of which only a few have so far been isolated and produced on a commercial scale. Will it be possible in the future to tailor the quality of milk according to the need for commercial production of one or more of the available bioactive components? According to Jiménez-Flores (2006) a recent National Academy of Science Report in USA on "Frontiers in Agriculture Research" identifies research on bioactive food components as a key focus area for future research to enhance human health through nutrition.

Milk has been proven to be a rich source of chemically defined components that can be isolated and utilized as ingredients in functional foods and nutraceuticals as health-promoting ingredients. The dairy industry has an important role to develop and supply consumers with products containing milk-derived bioactive components showing activity in, for instance, boosting the immune system, killing pathogenic micro-organisms or reducing blood pressure (Korhonen, 2006).

One of the most active fields of research in dairy science and technology concerns bioactive components in milk and milk-derived sources for such components. A number of components and sources are under investigation by leading research teams all over the world. One focus area is on bioactivity of the whey proteins β-lactoglobulin and α-lactalbumin and of caseins and the peptides from these proteins (Chatterton et al., 2006; Expósito and Recio, 2006; Gauthier et al., 2006; Korhonen and Pihlanto, 2006; López-Fandiño et al., 2006; Pihlanto, 2006a). Inhibition of angiotensin-converting enzyme, anti-microbial activity, anti-carcinogenic activity, hypocholesterolaemic effect, antioxidative effect, immunomodulatory effect and metabolic and physiological effects are among the effects studied. Biologically active peptides or functional peptides are defined as food derived peptides that in addition to their nutritional value exert a physiological effect in the body (Pihlanto, 2006b).

The multifunctional possibilities of the caseinomacropeptide (CMP), the hydrophilic part of the κ-casein, have recently been reviewed by Thomä-Worringer et al. (2006b) with focus for instance on patients suffering from hepatic diseases, in cases of phenylketonuria, increased zinc absorption and administering of sialic acid for improvement of brain functions as for instance improving learning ability, and on anti-toxic, anti-viral and anti-bacterial properties of both intact CMP and peptides derived from this component. Thomä-Worringer et al. (2006a) have also investigated the physicochemical properties of CMP related to the formation of air/water and oil/water interface and conclude that CMP showed good stabilizing properties at such interfaces. Synergistic effects were found for mixtures of CMP and whey proteins making the CMP a good candidate as a food structuring agent.

The anti-microbial and anti-viral activities as well at the immunomodulatory and antioxidant activity of the iron-binding glycoprotein lactoferrin in milk have been reviewed recently by Pan et al. (2006) and Wakabayashi et al. (2006).

Also the oligosaccharides from milk have been found to have bioactive properties. Human milk contains 5-10 g/L of lactose-derived oligosaccharides, which are therefore the third largest component of human milk. The levels of oligosaccharides in milk of domestic mammalian animals are much lower but nevertheless have been explored as a source of bioactive components (Kunz and Rudloff, 2006; Mehra and Kelly, 2006). Although clinical studies are still missing the potential for milk oligosaccharides to modulate the gut flora, to affect various gastrointestinal activities and to influence inflammatory processes have been investigated. The oligosaccharides may also influence the development of the brain and the central nervous system functions in infants because of the presence of sialic acid in the molecules.

Another area considered as bioactive components from milk is some components from the milk lipids. The polar lipids in the milk fat such as the phospholipids and sphingolipids, mainly positioned in the milk fat globule membrane, are regarded as bioactive components in milk with anti-cancer, bacteriostatic and cholesterol-lowering properties as some of the main functions (Rombaut and Dewettinck, 2006). Recent studies reviewed by Marten et al. (2006) looked into the bioactivity of medium-chain triglycerides from the milk fat. Studies confirm that medium-chain triglycerides have the potential to reduce body weight and particularly body fat.

PROTEIN POLYMORPHISM AND GENETIC VARIANTS OF MILK PROTEINS

Work with milk quality may in the future take into the account that there are a number of genetic variants of various milk proteins. Some exhibit different functional properties which may influence the processing properties of the milk.

Whether or not this knowledge should be used in the systematic breeding of cattle or not is still under discussion. The consequences of breeding according to genetic variant of different milk proteins must be evaluated thoroughly before such breeding programmes are put into practice.

Genetic polymorphism of proteins in cows' milk

Genetic polymorphism is defined as the existence of two or more alleles of a gene, where the frequency of the rare allele is higher than what will be expected from recurrent mutations, considered as higher than 1%. All the major milk proteins like α_{s1}-, α_{s2}-, β-, and κ-caseins, β-lactoglobulin and α-lactalbumin have shown genetic polymorphism. The genetic polymorphism of κ-casein and β-lactoglobulin has been studied most thoroughly. Milk containing the so-called BB-phenotype of β-lactoglobulin have been shown to contain more casein and a higher casein number than the AA-phenotype. The BB-milk is therefore expected to be more suitable for cheese production than the AA-milk (McLean et al., 1984; van den Berg et al., 1992; Ikonen et al., 1997; Ostersen et al., 1997). The BB-phenotype of κ-casein has been associated with superior cheese making properties of the milk and with increased cheese yield (Schaar, 1984; Schaar et al., 1985, Walsh et al., 1995, 1998a,b).

Devold et al. (2000) published analyses of 59 Norwegian Red Cattle from the herd at the Norwegian University of Life Sciences and found that the most dominant polymorphs were α_{s1}-casein BB (83%), β-casein A1A1, A1A2 and A2A2 (21, 52 and 24%, respectively), κ-casein AA, AB and AE (65, 14 and 18%, respectively). α_{s1}-casein CC, β-casein A1B and A2B and κ-casein BB occurred at very low frequencies. For α_{s2}-casein and α-lactalbumin, only one genetic variant was observed for each protein: α_{s2}-casein AA and α-lactalbumin BB. An unpublished study carried out by the same group of researchers, analysing milk from 800 animals of Norwegian Red, gave results that agreed well with the published results. The published study (Devold et al., 2000) also showed that the different genotypes of α_{s1}-casein significantly affected the composition of the protein fraction in the milk and also that the different genotypes of α_{s1}-casein and κ-casein affected the mean size of native and heated casein micelles. Walsh et al. (1998b) have shown that the BB-phenotype of κ-casein gives a higher κ-casein content, resulting in smaller micelles and that smaller micelles are associated with shorter rennet coagulation time and higher curd firmness.

Genetic polymorphism of proteins in goats' milk

It is well established that the casein composition of goats' milk is also influenced by genetic polymorphism and the α_{s1}-casein is the most extensively studied. So far, more than 18 alleles have been identified, and are distributed amongst seven different classes of protein variants which again are grouped in the so-called “strong”, “medium”, “weak” and “null” (Martin et al., 2002; Devold, 2004) indicating the level of synthesis of the α_{s1}-casein. The “null” variants, the 01 and 02 alleles, are associated with lack of synthesis of this protein (Leroux et al., 1990). Vegarud et al. (1999) found 7 polymorphic forms of α_{s1}-casein in Norwegian goats’ milk.

Vegarud et al. (1999) analysed samples from individual goats from herds from three different regions in Norway: North, West and South-East, and found that >70% of the milk samples were of the “null” variant of α_{s1}-casein, indicating that this casein was lacking in the milk. The milk samples without α_{s1}-casein had significantly reduced renneting properties compared to the samples containing α_{s1}-casein. Similar results were obtained by Devold (2004) by examination of milk from 254 goats from 9 different herds. These results differ considerably from the results obtained from other European caprine breeds. The investigation also concluded that the different groups of α_{s1}-casein significantly affected milk composition, for example crude protein, casein, pH and calcium-ion activity. The authors stress that the potential for improving milk coagulation properties by selecting for “strong” α_{s1}-casein variant may be significant. On the other hand a considerable number of milk samples in the study were unable to form a strong rennet gel, regardless of group of α_{s1}-casein. Further investigations are therefore necessary in order to understand the reasons for the weak rennet coagulation of goats’ milk before a decision concerning breeding regime is taken.

The lack of proper renneting properties of goats’ milk has been known for long time and have caused practical problems in goat’ milk cheese-making and in the production of goats’ milk casein for the production of whey for brown whey cheese production. Some results from the investigation of the gel formation properties of goats’ milk were published in 1984 (Abrahamsen and Nilsen, 1984). The rennet gel formation of goats’ milk was then compared with that of cows’ milk. The curve measured by means of an Instron-equipment showed that the goats’ milk had a considerably weaker gel. Further investigations of the renneting properties of milk samples from goats from the Northern region of Norway (163 samples) and from the heard of goats at the Norwegian University of Life Sciences (150 samples) showed that a relatively high number of samples from the Northern region did not form a gel when measured by the so-called Formagraph-method (Ådnøy et al., 1992, 1996). Of the samples from the Northern region 25% did not reached a firmness of the gel giving the normal 20 mm gap in the Formagraph diagram. For the samples from Ås the corresponding number was 4%, indicating great geographical differences in the goats’ milks ability to form an acceptable rennet gel. It is however interesting to observe that the investigations on genetic variants of α_{s1}-casein reported above showed a lower share of milk samples with the “null” allele for α_{s1}-casein in the milk from the Northern region than from the

Western- and Eastern region. This may, as expressed by Devold (2004), indicate that environmental and feeding regimes or other factors influencing the milk composition may also play a certain role in the renneting properties of the goats' milk.

The acid gel formed in fermented Norwegian goats' milk is also much less firm than the acid gel of fermented cows' milk (Abrahamsen and Holmen, 1981; Abrahamsen, 1987; Abrahamsen et al., 1995). Yoghurt produced from goats' milk achieved a far less firmness of the acid gel and a substantially less viscosity of the stirred gel than achieved for cows' milk yoghurt. Goats' milk yoghurt made from goats' whole milk, in which the total solids was increased by 2.5% with goats' skimmed milk powder, showed almost the same firmness of the acid gel as goats' milk yoghurt without addition of powder. The only way to achieve a gel firmness comparable to the gel firmness obtained by whole cows' milk added 2.5% total solids by use of cows' skimmed milk powder, was use of ultrafiltrated goats' milk with an increase of total solids of approximately 3.5%. The present quality of Norwegian goats' milk indicates that the milk cannot be processed in the same way as cows' milk if yoghurt with firmness and viscosity comparable to the properties obtained in cows' milk yoghurt is expected by the consumers. For the development of such products we either have to change the quality of the goats' milk, preferably by increasing the amount of α_{s1}-casein in the milk, or we have to apply a far more expensive method to increase the total solids in the milk used, for instance, for yoghurt production.

The future approach for development of the goats' milk quality must take into consideration the fact that the majority of Norwegian goats produce milk lacking α_{s1}-casein and their milk has therefore inferior renneting properties leading to severe difficulties in cheese-making. It has been argued that the lack of α_{s1}-casein may give the Norwegian goats' milk an advantage from a nutritional point of view because of a possible easier digestion of this milk. However, Almaas et al. (2006) investigated *in vitro* digestion of bovine and caprine milk by human gastric and duodenal enzymes and concluded that no significant differences were observed between the digestion of goats' milk with a high level of α_{s1}-casein, and milk from typical Norwegian goats lacking this protein.

CONCLUSIONS

A future approach to the term milk quality may reflect varying understanding of the term. An important question will however always be whether changes in the milk composition, in one way or another, may influence the functional properties of the milk with regard to how the milk behaves during dairy processing, and whether the sensory properties of the resulting dairy products will change.

Some points may be listed as possible conclusions from the evaluation given:

- Consumers ask for an increased selection of regionally-produced food and emphasise the need for an increased availability of food produced locally or regionally. They claim that the food products must retain their identity through differentiation based on geographical origin, nature specific advantages, variations in production and manufacturing methods and local traditions in food preparation.
- If the milk and the products from the mountain pasture period can be characterized as different from the milk from the indoor feeding period, the dairy industry may have the potential to produce products with local character and properties.
- Milk from pasture has in several studies led to dairy products regarded as better than or different from products made from milk based on indoor feeding. A future approach of milk quality development should take into account future studies of the influence of pasture on the quality of milk and milk products.
- One future approach for milk quality could be to develop a feeding regime for the production of cows' milk which will have:
  - a reduced amount of medium and long chain fatty acids
  - increased content of oleic acid (C18:1) to the range of 25-30% of the milk fat
  - increased content of polyunsaturated fatty acids
  - increased content of ω-6 and ω-3 fatty acids and ratio between them reduced to 2:1
  - increase and stabilize the iodine content throughout the year at the level of 250 μg/L.
- Milk has been proven to be a rich source of a variety of bioactive components. A future approach for milk quality will be to develop milk with increased amount of certain bioactive components.
- The influence of breeding on the expression of different genetic variants of the milk proteins should be investigated and be a part of the work in the future approach of milk quality.

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Milk quality – a future approach. From the dairy industry´s point of view

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ABSTRACT

Historically, milk quality has been defined as product related quality. Lately, more focus has been given to production related quality and consumer demands. The quality of Norwegian milk is very high, and the Norwegian dairy breed, has achieved great recognition abroad. The Norwegian Food and Nutrition Policy goals state that food should be nutritionally adequate and safe, healthy and produced in a sustainable way. We will influence the nutritional quality through feeding and breeding, and study taste and qualities of milk and products made from this milk. We will also focus on naturally bioactive components, and milk products according to place of origin and season.

KEY WORDS: milk quality, challenges, consumer request, objectives for the future

INTRODUCTION

TINE BA is the country's leading supplier of food products and Norway's leading value generator. TINE BA is the sales and marketing organization for Norway's dairy cooperative and is responsible for product development, quality assurance, production and distribution planning, marketing and the export of TINE products.

The quality of the milk delivered by farms is vital as far as the end result is concerned. This is why TINE provides an extensive advisory service to its owners. Having our own advisory service which works to increase the profitability of TINE's producers is important. The KSL Quality System for Agriculture documents how the production takes place and provides farmers with a management system for improving production operations. KSL is a tool that is linked to payments for raw

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milk in order to improve the work done on quality throughout the entire value chain.

TINE Raw Materials is a separate division in TINE that is, from both an accounts and administrative point of view, separate from the rest of TINE. TINE Raw Materials' job is to purchase the milk from TINE's producers and sell it on to the dairy companies through the system of market regulation for milk, including TINE's industrial enterprises. The Norwegian Agricultural Authority (SLF) decides who can participate in the system of market regulation for milk.

2006 is the 125th anniversary of the dairy cooperative in Norway, and TINE is represented throughout the country with its 17.850 owners, around 5.350 employees, 52 dairy plants, and 6 plants for the production of other products than dairy products. The producers deliver approx. 1.450 billion litres of cow´s milk and about 20 million litres of goat´s milk every year. The group's turnover in 2005 was NOK 14.7 billion.

This presentation will focus on the challenges in the light of the dairy industry and TINE BA in particular. We will briefly mention the consumer and authority demands, present the milk quality status in Norway of today, and shed light on some of the goals of our research projects related to cow´s milk quality.

MILK QUALITY FROM THE DAIRY INDUSTRY´S POINT OF VIEW

Challenges facing the dairy industry in Norway

Increasing globalization and reduced protective duties will cause more international trading also with food items. Norway has a high price level, which implies that our country represents an interesting market. A WTO agreement could pressure the price level and subsequently cause an increase in the import of goods. An increase in trade between the EU and Norway would cause the same.

What will then become the most important competitive conditions for the Norwegian dairy farming? Increasing commerce will probably intensify the consumer focus and a demand for more multiplicity. If we are to be competitive we will have to offer extra values like for instance different quality aspects. We will to a considerable extent have to develop further added value and uniqueness preferred by the consumer for the specific products.

The market for milk as beverage is expected to be particularly exposed for an increase in competition from abroad. This competition concerns UHT (Ultra High Temperature) milk, ESL (Extended Shelf Life) milk and fresh milk produced in our nearest neighbouring countries. The distribution of UHT milk is less cost demanding. We will probably experience an increased competition between fresh milk and different types of UHT products. Chances are that we will have to maintain and further develop the area of fresh milk. The main challenge will then be to obtain a high quality that will oust any possible import of UHT and fresh milk.

In the long run an increasing commerce may possibly necessitate multilateral legislation. Such legislation may facilitate the cross-border trade. When a tariff barrier is being gradually phased out, it is expected that a harmonization of legislation and regulations for labelling and labelled articles will become even more important. The situation today is that we already have a comprehensive common legislation within the EU/EEA.

A possible WTO agreement will first and foremost focus on accessibility to the markets, reduction or conclusion of competitive advantages as for instance export subsidy and less specific (volume) support to dairy farmers. More use of measures independent of production is expected. This may imply measures linked to the degree of quality assurance on the farm, milk quality, a demand for fresher milk, organic products, a focus on safe food and health, season and regional products etc.

Milk volume, price and market shares

It is possible to imagine different scenaries for the development of milk volume, price and market shares, depending on how the Norwegian dairy industry will manage to compete in the future market:

1. The Norwegian dairy industry will not be able to compete on all product areas as today. We will have to reduce the milk volume and keep only the most profitable products. The quality must be high and our products will need some competitive advantages against imported goods. This will probably not be lower prices, but other added values the consumers are willing to pay for.
2. We maintain the milk volume on the stabilized level for the last years, that is approx. 1.500 mill. litres cow's milk. This implies a continuation of the positive trend obtained by the increase in sales of refined "special products", an increase that will compensate for the reduction in sales and market shares of "volume products". We will have to continue the development of the important R&D area as well as marketing, and we will have to introduce at least the same number of new products as today. The pressure on prices is expected to increase with an increase in imports and we will still need to focus on cost-effective production in all parts of the food chain. This, however, must not be at the expense of the quality of the products. This particular scenario presumes that the Norwegian agribusiness has found a way to compete by offering products with distinctive features, features that the consumers value. It is quite possible that the consumers will want to buy Norwegian food, because this will provide more safety regarding: ethical and

environmental issues in connection with the production of food, traceability and an agriculture which attends to animal health and food safety in a better way than our competitors. Both consumers and the authorities want to sustain an agriculture and production of food in Norway.

3. The Norwegian dairy industry will be able to compete with the imports well enough to be able to increase the milk volume. This also implies that we have niches abroad for some profitable export products. The scenario has much in common with the second scenario, but in this third scenario one emphasizes the successful adjustments made regarding structure, cost-effective production, quality and profitable innovations in all sections. It also includes profitable export products.

Quality in TINE BA´s point of view

Historically, milk quality has been defined as product related quality and quality measures have mainly been fat and protein content, sensory quality, number of bacteria and somatic cells. The latest years, more focus has been given to production related qualities like the product yield, functional and manufacturing properties and freshness.

Perception is also a part of the quality term. As consumers, we all demand safe, healthy and fresh food, but we are also aware of taste and price. The products must also be functional in a cooking perspective. There is an increased consumer focus on animal health and welfare and the possibility of tracing products back to the producer. The area of origin of different products is also of interest and may be used to provide the products with interesting background information (storytelling).

Milk quality status in Norway today

According to the "historically quality parameters" the quality of Norwegian milk is in the absolute front. TINE BA has several R&D projects going on to sustain and even increase the quality of the milk on the farm level.

The development of the supplier's milk quality is positive (Table 1). This applies to the smell/taste, the total bacteria count and somatic cells. Since 1995 the use of antibiotics in the dairy farming has been reduced more than 50%. If we compare the microbiological quality of the milk on the farm, Norwegian milk proves to be the best in the Nordic countries. The same applies to the cell-count. High quality is important as a basis for high quality products. A low cell-count will in addition contribute to improved qualities of the milk used for cheesemaking and improved cheese profit.

Table 1. Quality development in Norwegian supplier's milk, 2001 to 2005

Criteria	Year				
	2001	2002	2003	2004	2005
Cow					
bacteria, % of Elite milk[1]	96.04	96.43	97.52	97.67	97.70
organoleptic, % samples cl. 1[2]	97.47	97.68	98.07	98.96[3]	99.06[3]
Elite milk, % of volume	89.68	90.49	91.15	92.50	92.64
somatic cell, % of Elite milk[4]	93.20	94.08	93.89	94.11	93.95
protein, %	3.21	3.26	3.26	3.29	3.32
fat, %	4.04	4.00	4.01	4.03	4.07
Goat					
bacteria, % of Elite milk[1]	90.58	8.53	91.42	91.63	93.29
organoleptic, % samples cl. 1[2]	89.74	91.05	93.08	95.88	96.04
Elite milk, % of volume	77.07	79.10	80.97	82.66	83.89
somatic cell, % of Elite milk[4]	81.13	84.90	83.81	85.56	86.03
protein, %	2.71	2.96	2.94	2.96	2.99
fat, %	3.55	3.53	3.58	3.66	3.76

[1] the criteria for Elite milk concerning bacteria is below 20.000 cfu mL^{-1}

[2] the criteria for Elite milk and cl. 1 milk concerning organoleptic analysis is now equal and below 1.3 mmole FFA l^{-1}

[3] a shift in the analytical method took place in 2004. The organoleptic test was replaced by the analysis of free fatty acids

[4] the criteria for Elite milk concerning somatic cell is below 230.000 for cow milk and 1.500.000 cells mL^{-1} for goat milk

We also see a positive trend when it comes to the milk's content of fat and protein. Norway has traditionally had a lower chemical content in the supplier's milk than many other countries. This is mostly due to the farming system in Norway with a high share of forage and more extensive farming. Chemical content may also be influenced by systematic breeding, and breeding with the intention of obtaining a high content of protein has for long been one of several important breeding objectives for the breeding organization, GENO. The genetic potential for the protein percentage is however higher than the actual protein percentage because of our feeding arrangements.

The detection of antibiotics in Nordic milk is not a basis for comparison, because different methodologies are used in the different countries. For the same reason organoleptic quality is not suited as a basis for comparison. Free fatty acids have now replaced traditional organoleptic evaluation in Norway. Different methodology is also used in the detection of bacterial spores in the supplier's milk. Approximately 82 and 95% of the samples showed low content of respectively anaerobic spores (*Clostridium*) and aerobic spores (*Bacillus cereus*) in 2005.

The zoonose status in Norway as in Sweden and Finland is good. The question of chemical contaminants is more difficult to answer. The documentation could have been better, nevertheless, we assume the situation to be good. The level of radioactivity varies from one year to another based on the local climatic conditions. The focus has been on cesium (^{137}Cs) since the Tsjernobyl accident in 1986.

Norwegian milk's competitive edge

NRF, Norwegian Red is a high producing dairy breed. GENO is a co-operative owned and managed by Norwegian dairy farmers. GENO´s main aim is to breed the NRF in the most optimal way according to dairy farmers requests. The organization is responsible for both developing and managing breeding schemes, as well as reproductive techniques. The whole food chain is focused, from the NRF breed with special emphasis on production, health and fertility through feeding strategies of milk producing cows with the objective to produce high quality milk with special emphasis on protein and fat quality, and finally the dairy production. The following characteristics of Norwegian milk and NRF dairy breed (Table 2) can be given.

Table 2. Characteristics of Norwegian milk and NRF dairy breed

Statement	
Norwegian cows are healthy	We have very healthy and fertile cows. Our animal health situation is the best in the world. This is partly due to breeding and partly due to combating of infectious diseases. Minimal use of antibiotics combined with natural conditions.
Breeding for health and fertility	We are in a class of our own when it comes to breeding on health and fertility through a unique registration and use of data including an animal health record. Health traits and fertility have been included in the net merit index since the 1970s.
Combating and prevention of infectious diseases	For more than 100 years we have systematically worked for the prevention and combating of serious infectious diseases (e.g., BSE, foot-and-mouth disease, paratuberculosis) and less serious contagious diseases (e.g., ringworm and BVD).
Complete cow's inspection	Norway has a well developed ”Kukontroll” (cow's inspection) with extensive information on each individual. The information regarding health, veterinary treatment and fertility is unique in Norway. About 95% of the Norwegian dairy farmers are affiliated with the “Kukontroll”.
Good hygiene on supplier's milk	Norwegian milk has for a number of years had very low bacterial content as a result of hygiene focus, well-established cleaning procedures and efficient cold storage units. Norwegian supplier's milk is also characterized by a very low ”cell-count”. This shows that the milk delievered to the dairies is milk from healthy cows. There has been a strong reduction in the medication of Norwegian cows for the past 10 years (reduced by over 50%).

continued on the next page

Table 2. Continued

Statement	
Distinctive features of a brief and intense growing season	Norway has a brief, but intense growing season with plenty of daylight. The country's climate and topography are well suited for grass production and feed grain production. Dairy farming is the most important contributor to value creation and also contributes to sustaining the cultural landscape. The growth and fodder especially influences the composition of the fatty acids in the milk. The fat is, however, important for the colour, taste and health-related conditions. The Norwegian feeding regime gives a relatively high content of polyunsaturated fatty acids.
Complete food chain	We have control of a complete food chain. This is an advantage where traceability, food safety and innovation is concerned.
Low pollution	National and local pollution is low.
Low-scale farming	Our structure reduces the danger of infection. Despite a development in this field also in Norway, we will always maintain farming on a low-scale basis, which distinguishes us from most other milk producing nations.
We also have some challenges we have to be aware of:	
The Norwegian strategy for feeding	Norway is, geographically, a long country with dairy farming widely spread all over the country. In a climatic perspective we are close to the limits for what is possible regarding the growing of grain and forage crops. Norwegian dairy farming is very important to the cultural landscape. Our climate protects us from many fungus infections and vermins and the use of pesticides is very restricted compared to many other countries. We use a great deal of coarse fodder in dairy farming. During the winter season the feeding is unbalanced with extensive use of silage. Norway has far more occurrences of ketosis than our neighbouring countries.
Quality challenge	The milk quality must be completely controlled all the way to the consumer. Natural conditions causes long transportation distances for milk and dairy products.
Chemical contaminants in the milk	Low chemical content in the milk.
Radioactivity	Radioactivity is a risk factor we supervise due to our geographical localization.

Authority regulations

The Ministry of Agriculture and Food is responsible for food and agricultural policymaking in Norway. The food policy aims to provide consumers with wholesome, high quality food products, and to ensure that the food production process is carried out with environmental, public health and animal welfare concerns in mind.

The Norwegian Food Safety Authority are responsible for establishing regulations that ensure that no one will become ill by eating food in Norway. All producers or whole sellers of food are responsible to act in accordance with these regulations. Due to the EEA Agreement the Norwegian food legislation is to a large extent harmonized with the EU legislation. TINE BA has developed an advanced food safety system to be able to supply the market with safe food.

Human nutrition science has taken a major step forward from focus on the prevention of nutrient deficiencies to an emphasis on maintenance of good health and reduced risk of chronic diseases. Research has demonstrated that what and how much we eat affects growth, development and aging, and that dietary intake is linked to risks for development of diseases like cardiovascular disease, obesity, osteoporosis, cancer and diabetes. The cost of nutrition related diseases clearly points to the need of effective strategies to lower the cost of health care through the prevention of disease.

In the light of the results from research Norwegian health authorities make recommendations for dietary intake of different nutrients, and one of the most focused recommendation is reduced intake of fat, especially saturated fat. Milk fat has a relatively high content of saturated fat, and this has led to a negative consumer perception and a public health concern. The Norwegian health authorities and the consumers expect the food producers to be on the market with health promoting products, and to fulfil these expectations TINE BA emphasise research on and development of such products.

Consumer requests

“Traditional foods” are considered as one of the most important trends within the science of food. There is a growing interest abroad for the ”Scandinavian kitchen”. Our food traditions are regarded as exotic by foreigners because of our characteristic nature and culture.

”Food is fashion” was the catchy slogan through the mid/end 90’s. The situation is however changed. The focus now is on tradition, retro, romance, nostalgia and safety. The Scandinavian consumers are among the most traditional and conservative when it comes to food and acceptance of new ingredients, new dishes and cooking methods.

These predictions are made by the Scandinavian trend institute, the Danish PEJ group (2006). The main focus now is on 4 so-called “trend universes”; 1. essential cooking, 2. the food doctor, 3. gourmet express, and 4. the local kitchen. According to the PEJ group these trends will make strong manifests in the near future.

In accordance with the trend report ”Norsk Spisefakta” by Synovate MMI (2006), it may seem as we have had enough of foreign food, and that we prefer

Norwegian food to a greater extent. Moreover, even more youths seem to take an interest in Norwegian food and Norwegian food traditions. The youth of today emphasizes the origin of the food, fresh raw materials - implying short distances, traceability and that the food itself has a story to tell.

However, there are several hurdles facing the small scale producers and the food industry. According to Jordana (2000) traditional foods are restricted by the current conditions in the market but they have good perspectives for growing in the future if some challenges are overcome. These challenges are: 1. communication (a traditional product is exotic in other markets and therefore has to be promoted); 2. legal protection of collective brands (insufficiently guaranteed in the different markets); 3. quality assurance (must be a priority objective, as in all the branded products); and 4. innovation.

In addition to the usual consumer drivers such as taste, convenience and presentation, food purchasing behaviour is also being driven by health-orientated factors. People are increasingly managing health through diet and many consumers report that specific health concerns influence their diet. Consumer awareness of diet-related diseases and the demand for health promoting products are challenges to the dairy industry. To meet these demands from both consumers and health authorities TINE BA has developed products low in fat and sugar, and products with added value. Examples of such products are low fat milk enriched with vitamin D and milk fermented with probiotic bacteria. More products with added value will be developed during the next years.

To develop products with improved nutritional value TINE BA also intend to change milk fat quality by lowering the content of saturated fat and increasing the content of unsaturated fat. Research projects conducted in cooperation with the Norwegian University of Life Sciences will reveal whether these changes are possible to achieve by feeding and breeding. Enhancing the health effects of naturally bioactive components by feeding or breeding and/or addition of bioactive components to dairy products is an important area for the future.

Additionally, consumer awareness is also to a greater extent focused on animal health and welfare which is reflected in an increasing interest for organic products. This has resulted in The Norwegian Government's aim that organic food production should be 15% of the total food production within 2015. It is a challenge to TINE BA to produce more organic milk.

MILK QUALITY - A FUTURE APPROACH

Quality objectives for the future

Increased prosperity and less physical activity have resulted in excessive obesity in the population. Obesity indicates that diet and lifestyle are inferior, but it even disposes for serious diseases like cardiovascular failures, diabetes and cancer.

The quality of food as a competetive preference is an important factor for the future. At the same time health promoting products, organic products, and functional food are in progress. Strictly relevant for the dairy industry are goals aiming to improve the milk quality in the light of the recent research into nutrition, to meet the demands from the authorities, and finally, to live up to consumer requests.

The need to improve milk quality

Milk represent one of the most important output from agriculture to the consumer. To stay competitive in a future market with the potential of increased import pressure and less loyal Norwegian consumers, TINE BA must maintain and improve competitiveness with respect to both product quality and productivity. The quality aspect of bovine milk are still questioned with respect to some health effects. Important for TINE and the Norwegian agriculture would be to find new methods to reduce certain fatty acids in the milk (e.g., saturated fatty acids). So fare neither animal breeders nor feeding specialists have the conclusions for assessing these parameters.

However, the fatty acid composition of milk seems to display genetic variability of the most common fatty acids in milk. There appears to be a potential for improving health benefits and reducing health risks by animal breeding as well as by modified feeding strategies.

We have several projects influencing milk quality both in TINE R&D and in TINE advisory service for producers. Briefly presented are the goals of our main research projects related to milk quality as follows.

Low fat-and low calorie products

In collaboration with Campus Ås we have projects on developing low fat- and low calorie products with good sensoric properties. These include technology aspects, consumer demands and sensory aspects.

Functional food

It seems possible to change the fatty acid composition by feeding and breeding, and in the future we believe we will be able to influence other parameters like genetic variants of proteins, bioactive peptides, immunoglobulins and important minor components in the milk and make "Natural Functional Food". We also have focus on addition of different bioactive components to our dairy products to make Functional Foods.

Breeding

In collaboration with Campus Ås (University of Life Sciences, Cigene, Matforsk - Norwegian Food Research Institute) Gilde BA and GENO, TINE BA takes part in a research project: "Functional genomics for optimized milk and meat quality".

The objective of the project is to improve the nutritive and sensory quality of milk and meat products and increase the competitiveness of the Norwegian agricultural sector, by combining modern biospectroscopy and functional genomics with the unique cattle recording systems in Norway.

The bovine genome sequence will be published in 2006. Norway has one of the world's best databases on the genetic history, productivity and health of individual cows and bulls. Together, these resources offer dramatically new tools for understanding and improving important aspects of animal health, production economy, nutritive and sensory quality of milk and meat products and consumer acceptability.

TINE uses an advanced and extensive quality control system for milk based on FT-IR spectroscopy, generating millions of informative, multi-channel measurements of milk per year. This project will try to extract much more information from these milk measurements by calibrating them for a number of new phenotypes (i.e. fatty acid profile). A variety of phenotypes will hopefully be obtained from these analyses.

New statistical tools will be used to determine the genetic component in FT-IR-based milk quality traits and to detect loci affecting the respective trait of interest. Interesting genes (mutations) will be pursued by new techniques within transcriptomics, proteomics and biospectroscopy at Campus Ås in an interdisciplinary effort.

Feeding and farming systems

There is strong evidence in the recent literature that it could be advantageous to reduce the content of saturated fatty acids in bovine milk such as lauric- (C12:0), myristic- (C14:0) or palmitic acid (C16:0), and instead increase mono-and poly-unsaturated fatty acids (oleic acid 18:1 *cis-9*, α-linoleic acid 18:3-n3), as well as the dominating conjugated linoleic acid (CLA), rumenic acid (18:2 *cis-9 trans-11*). The three saturated fatty acids increase the level of LDL-cholesterol in serum (Kris-Etherton and Yu, 1997). High levels of serum LDL-cholesterol is a strong risk factor for cardiovascular disease (Stamler et al., 1986).

It is possible to improve the nutritional quality of the milk by means of feeding, in particular the pasture, but also by feeding indoors (Chillard et al., 2000; Walker et al., 2004). The feed also influences the sensorial and technological characteristics, so that it may be possible to create products the consumers will recognize by their distinctive features (Wetlesen et al., 2006). Characteristics related to emotions regarding the dairy farming are also part of the quality concept. Seeing cows at grass during the summer is for many people a positive experience, and they consider this milk "natural" to a greater extent than usual. This is best expressed by mountain dairy farming.

Several studies made by the University of Life Sciences, where TINE BA has participated, show that by increasing the intake of polyunsaturated fatty acids and by reducing the share of grain feed it is possible to alter the composition of fatty acids in the milk. The milk from cows given a low share of grain feed will contain more CLA and vaccenic acid, linoleic acid, α-linoleic and oleic acid, and less of the saturated fatty acids (12:0, 14:0 and 16:0).

In collaboration with Campus Ås (University of Life Sciences, Matforsk - Norwegian Food Research Institute, Bioforsk-Norwegian Institute for Agricultural and Environmental Research) we will concentrate on reducing the contents of medium- and long chained saturated fatty acids and on increasing the contents of mono- and polyunsaturated fatty acids (specially ω-3) in the milk fat. In addition we will try to achieve a more stable content of iodine and selen. We will also study the taste and product quality of the milk and products made from this milk and focus on the place of origin and season.

CONCLUSIONS

Increasing globalization and reduced protective duties will cause more international trading. If we are to be competitive in the future we will have to offer extra values like for instance different quality aspects. We will to a considerable extent have to develop further added value and uniqueness preferred by the consumer for the specific products. This will probably include increased focus on place of origin and season. There also appears to be a potential for improving important health benefits and reducing health risks by animal breeding as well as by modified feeding strategies.

The fact that quality of Norwegian milk and NRF dairy breed is high must not be a hindrance for the work with improved product quality in TINE BA.

To fulfil consumer and public demands and requests TINE BA faces some challenges. We need insight into what the consumer expects from TINE BA and continuous information about and how to fulfil these requests. To succeed we need the right competence within the organization and in cooperation with external research institutes, to obtain knowledge about how to develop safe, healthy products with good taste. We also need knowledge about how to communicate the product advantages to the consumer.

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The issue 'Raw milk quality' from the point of view of a major dairy industry

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ABSTRACT

The mission of Arla Foods is to provide modern consumers with milk-based products that create inspiration, confidence and well-being. Consequently, Arla Foods continuously needs to obtain and implement all necessary knowledge of relevance for controlling the quality of our products.

The ongoing dramatic changes in the international market place, caused by global changes in lifestyles and requirements of consumers, require high standards of quality assurance regarding diversity, quality and safety of products and the environmental, ethic and animal welfare aspects of the food production. Consequently, the need for inclusion of the whole food production chain to develop strategies for production of foods with high quality has never been more urgent.

Even though raw milk quality has always been a cornerstone for Arla Foods, the above-mentioned requirements of the modern consumer request a constant expansion of our raw milk quality concept of a major dairy industry towards issues of importance for the consumers. Thus, raw milk quality cannot contain only quality characteristics that just meet statutory quality requirements and quality characteristics of importance for the settling price of the dairy farmers.

Consequently, Arla Foods has recently implemented a quality assurance programme called Arlagården, which includes quality requirements compatible to those that also satisfy consumer demand for "soft" values, i.e. the consumers can be assured that Arla Foods is consistently concerned with the proper exploitation of resources, the environment, animal welfare, ethics etc. throughout the entire production process.

Nevertheless, Arla Foods will continuously need to obtain new knowledge to expand the raw milk quality term as our fulfilment of the company mission is continuously challenged by new demands from our costumers including the modern consumer. This calls for strategic multi-disciplinary research of importance for raw milk quality, which can further improve quality assurance programmes for raw milk production in the years to come. This includes research, which additionally can 1. develop sustainable management systems, 2. make nutrigenomics in relation to animal health functional in management decision systems, 3. combine raw milk composition and human health, 4. improve milking systems, handling and storage of raw milk, 5. improve hygienic design at the modern milk farm, 6. develop simulation models of importance for developing effective hazard analysis critical control points (HACCP) concepts, and finally, 7. develop robust and sensitive in-

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and at-line methods including microbial rapid methods applicable at all stages of the milk chain. These areas of research are briefly described in relation to the urgent needs of a major dairy company of tomorrow.

KEY WORDS: raw milk quality, consumer, traceability, sustainability, animal welfare, nutrigenomics

INTRODUCTION

There are dramatic changes in the international market place, caused by global changes in lifestyles and requirements of consumers. These changes require high standards of quality assurance regarding diversity, quality and safety of products and the environmental, ethic and animal welfare aspects of the food production. Consequently, the need for inclusion of the whole food production chain to develop strategies for production of foods with high quality has never been more urgent.

Especially, the quality of raw material of bovine origin has during the past years become an increasing issue for the consumers. This is due to the recent deplorable incidents in the dairy sector like bovine spongiform encephalopathy (BSE), verotoxigenic *E. coli* (VTEC), chronic wasting in cattle, and recall of antibiotic-containing consumption milk. Moreover, outbreaks of various diseases in Europe like foot-and-mouth disease have induced public concern about the way that husbandry animals are kept and transported. From a European policy point of view, the European Food Safety Authority, EFSA has launched Regulation (EC) No 178/2002 (http://eur-lex.europa.eu/LexUriServ/site/en/oj/2002/l_031/l_03120020201en00010024.pdf), and the recent EC Action Plan on the Protection and Welfare of Animals 2006-2010 (http://ec.europa.eu/food/ animal/welfare/actionplan/actionplan_en.htm), which both emphasizes the need to monitor farms for food safety, public health, animal health and welfare. These state that major dairy industries no longer can rely on only the classic technology e.g., milk cell count, bacterial counts, antibiotic residues, freeze point decrease, protein and fat content and sensory quality measures in the development of tomorrow's quality concepts.

In Scandinavia, quality management programmes for bovine farm animals have been developed (Knudsen, 1997). In 2003 Arla Foods implemented a quality assurance programme called Arlagården, which includes quality requirements compatible to those that also satisfy consumer demand for "soft" values in the milk production (http://www.arlafoods.com/C1256E9400315C5D/ O/CF0E82D208D8F774C12570F1004A0D67).

The programme comprises a clear description of the requirements, which the diary farmers are to satisfy, if they wish to deliver milk to Arla Foods. The programme state clearly which requirements originate from acts - for example the Danish Animal Feed Act or the Danish Act on the Protection of Animals, and which recommendations or requirements originate from the agricultural sector or from Arla Foods only. In this connection it is important to notice that the requirements in Swedish and Danish legislation are stricter than in most other countries. The programme specifies what type of documentation the diary farmer must be able to present. Moreover, Arla Foods can enforce sanctions if serious deficiencies are found on the farms. The sanctions can be fines, reduced milk prices or temporary milk collection stop until the deficiency has been rectified.

As mentioned above, the programme is based on the fact that the consumers of today wish to gain a much broader insight into the term food quality. Thus safety and complementary traceability as well as considerations regarding animal welfare and environment are now considered to be important parameters of quality on equal terms with milk composition, and are constantly developed in dialogue with all interested parties in the milk production chain (Figure 1). In Box 1 a brief description of these four quality parameters is given, as they are considered at present in the programme.

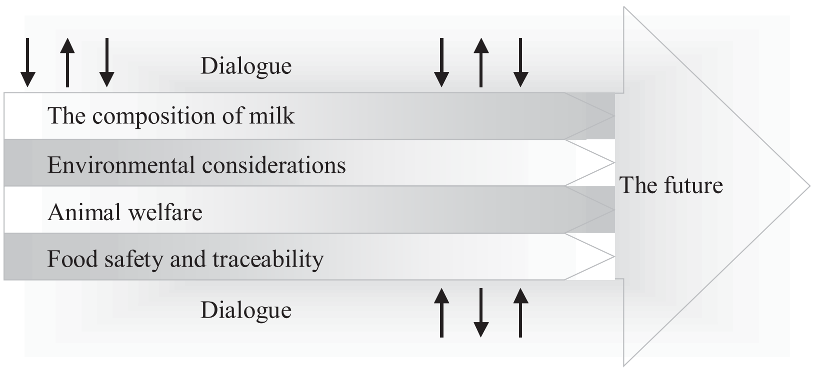

Figure 1. Presentation of the continuous development in milk quality parameters in a dialogue with interested parties

Naturally, Arla Foods also focuses very much on the taste, smell and raw material quality of milk. Therefore, the quality programme requires that cows are not given feed which may have a negative effect on milk taste, smell and quality.

Beside the above-mentioned “soft” quality characteristics, major dairy companies are constantly challenged on their production of new and diversified products, which contain stories, sensory diversity, nutritional benefits etc. Nevertheless, most major dairy companies have not yet explored the potential, which exists in differentiating raw milk with the exception of conventional and organic raw milk production. This is so despite the fact that it should be possible to introduce potential quality control tools into the primary production, and to make differentiated raw milk production with regard to taste, nutritional value and sustainability, etc.

Box 1

Traceability

More than ever before, customers as well as consumers demand that products can be traced back to the producer in case of quality defects. Through the programme, traceability will become more visible in all respects:

- The origin of the feed appears from the invoices and delivery notes of the suppliers
- The requirements that milk producers must keep a pharmaceutical record state the medicine used
- Milk samples are taken continuously at each dairy farm
- By means of recordings it is possible to trace the diary farms on which the milk has been weighed in the tanker which has transported the milk, and the dairy to which the tanker has delivered the milk.

Safety

The milk production on farms, which supply milk to Arla Foods, must in every way take place under satisfactory conditions. Therefore, the quality programme is based on the precautionary principle. Safety requirements are given a high priority, and the key words are risk assessment and risk management.

In addition to the requirements of the legislation, the Arla Farm programme requires that:

- Cows must be fed high-quality concentrate from approved farm supply companies
- Roughage has not been cultivated on fields to which sludge has been applied
- A water analysis must be performed annually
- To avoid infectious diseases, live animals cannot be imported to the dairy farm
- On purchase of new milk bulk tanks, tank alarms are to be installed which sound an alarm at divergences and register the milk temperature and the cleaning process continuously
- The milking equipment must be cleaned after each milking, and the milk bulk tank must be washed after emptying
- The collecting area for the tanker must be kept clean and separated from the passage of the cows into and out of the cowshed
- To avoid infection, forty eight hours must pass between visits to foreign herds and subsequent contact with Danish or Swedish herds
- The milk are continuously tested for the content of somatic cells, bacteria, antibiotics and for visible changes.

Animal welfare and environment

Animals must be well kept, and the production methods must be respectful of nature o n the farms, which supply milk to Arla Foods. Subsequently, Arla Foods' animal welfare and environment requirements for milk producers are higher than the requirements of both the Swedish and Danish legislation, even though the legislative requirements of both Denmark and Sweden are high compared with other countries. Moreover, Arla Foods recommends that the dairy farmers join prophylactic animal health programmes. In order to use of nutrients. Furthermore, it is recommended that pesticides and insecticides are not used preventively but only when the acceptable thresholds of weed, disease and fungus damages have been exceeded.

http://www.arlafoods.dk/appl/HJ/HJ201AFD/HJ201CFG.NSF/AllGraphics/HBLL6KVH52/$FILE/BrochureArlagaarden_UK.pdf

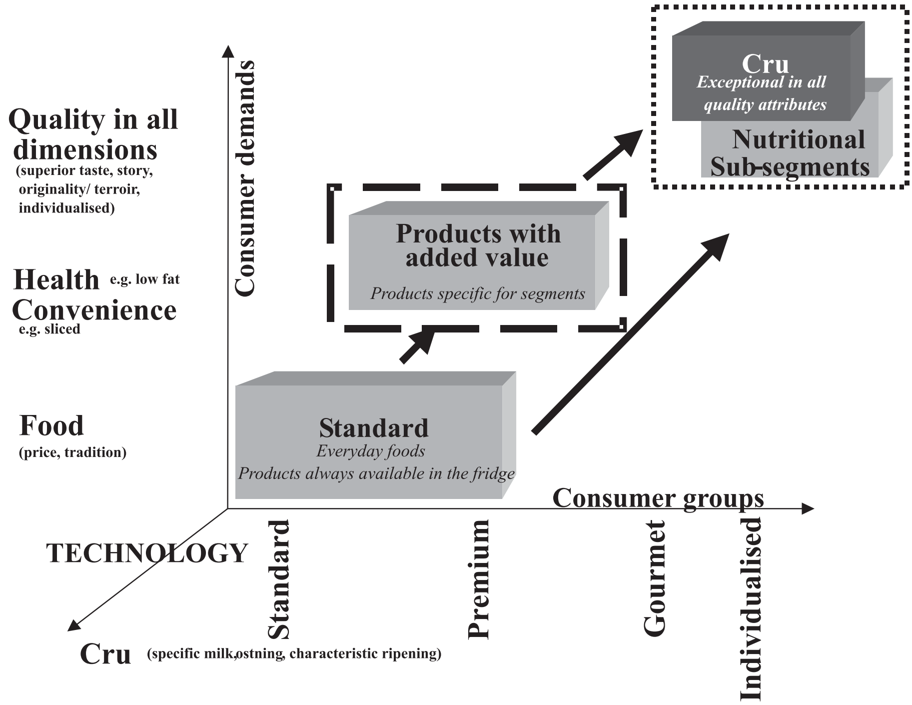

Figure 2. The milk and dairy product market of tomorrow

Innovation at the dairy market is and will progressively be mainly customer-driven. Figure 2 gives a graphical representation of the possibilities in such a market. The standard segment will still dominate and represent the biggest milk tonnage and products that the consumers will always want to have in their fridge. However, the earning capacity of the dairy industry and hereby also the potential for a higher financial return to the milk producers, is in the segments represented by 'value-added products', 'cru products' and 'individualized nutritional products', which all need inclusion of values from the whole milk production chain.

Consequently, major dairy companies that include values from the whole food production chain and combine this with specific or new technological initiatives will without doubt be in a profitable situation. Niche production is a superior platform for subsequent expansion into the mainstream segments of local markets (Gupta and Govindarajan, 2000). However, before this becomes operational, scientific tools need to be developed to an operational level where they can contribute with new information and technologies to be included in tomorrow's quality assurance programmes supporting production of dairy products of high and diversified qualities.

The present paper touches on some of those items, which need to be further developed before the dairy industry together with the scientific community and the dairy farmers can implement strategies and tools, which will make it possibly to continuously deliver dairy products demanded by the consumers of tomorrow.

WHAT IS RAW MILK QUALITY?

Quality is a philosophical made-up word introduced by Cicero - derived from the Latin word *qualis*, which means "how" or "of which character". This implies that quality can be translated to "how like" or characteristics (Barfield, 1988). However, this also implies that the term 'quality' is without meaning, if not defined. This is the reason why quality often can be interpreted differently, even though people declare to talk about the same issue. This difference in the interpretation is most often also evident in the discussion of raw milk quality. Thus if the milk producer has to define quality, he/she defines quality as good performance of his/her herd resulting in high yield and high fat and/or protein content maybe in combination with low cell number etc. which are the attributes the dairy pays him/her for. In the dairy industry the main quality attributes are optimal hygiene, superior oxidative stability, and good cheese making properties, as these attributes ensure production of valuable dairy products. Finally, the consumer considers safety, good taste, reasonable price, and healthiness to be among the main quality attributes.

The quality attributes demanded by customers/consumers are found to be the main driver of innovation of today (Anonymous, 2003), which is why the food industry including the dairy industry has approached product development from the view of '*Table to Farm*' during the past years.

The demands from customers/consumers will increase continuously as a consequence of changes in socio-economic factors, further education, more ready and exposed information, etc. The milk quality concept is therefore a dynamic entity that will constantly include new quality attributes in addition to those already demanded by the modern consumer (Table 1). Consequently, there is a continuous need for readiness of action by the actors in the milk chain delivering products to costumers/consumers. Moreover, the scientific community has to support with the

Table 1. Milk quality attributes

Quality attributes	
Safety	Traceability
Health	Animal welfare
Flavour	Animal feed
Appearance	Ethics
Convenience	Sustainability
Differentiation	etc.
Price	

necessary knowledge and tools, if the supply of milk and dairy products in Europe also is going to be financially feasible in the future.

DOES THE SCIENTIFIC COMMUNITY FIT THE AIM OF SUPPORTING A MODERN RAW MILK PRODUCTION?

It is interesting that the scientific community of importance for the agro/food industry in many industrialized countries is organized in separately applied disciplines animal/plant science, and food science and technology, etc. They hereby still representing a '*Farm to Table'* approach, which historically was developed to support societies scarce on foods or economies purely driven by bulk production.

At the political level a '*Table to Farm*' concept has been acknowledged as the approach of tomorrow's food production in Europe for more than a decade. Consequently, the funding bodies within EU have during the past decade continuously launched research programmes within the agro/food area, which include the '*Table to Farm*' approach based on a customer/consumer-driven food production, having in mind the necessary change in the scientific community of importance for the agro/food industry. Nevertheless, the expected change in the scientific community of importance for the agro/food industry has only slowly started to take place during this period. Accordingly, the scientific community meant to support modern raw milk production is still far from fully developed to fulfil the demands needed to establish the basis that ensures that milk production in Europe is also financially profitable in the customer-driven sales environment of tomorrow. If the scientific community supporting a financially profitable milk production in the industrialized part of the world has to be fully operational, a rapid change from the '*Farm to Table*' to the '*Table to Farm*' approach needs to take place within a not too distant future. This calls for much more dialogue between scientific disciplines combining the traditional actors with consumer science, sociology, material science, human nutrition, system biologists, etc. It also requires a pronounced degree of multidisciplinarity in problem-solving and establishment of networks or platforms containing all the disciplines with focus on development of tools and solutions for a financially profitable milk production ruled by the demands of costumers/consumers.

NECESSARY SCIENTIFIC INITIATIVES FOR THE MODERN RAW MILK PRODUCTION

In the following are outlined some of the most urgent areas, which have to contribute with new and improved knowledge and tools in support of a modern and flexible raw milk production. However, also other areas not directed towards the quality of the raw milk and not mentioned in the following, need to contribute significantly to keep the milk production of tomorrow successful. This includes improved efficiency in the production, e.g., improved disease resistance, optimal fertility and reproduction, etc., together with especially educational initiatives so that increased competences and implementation of the obtained knowledge and technologies can ensure an optimal management at farm level.

Optimal control of safety in the whole chain

During the past twenty-five years, development of rapid methods has been a main topic in relation to improvement of and responds rapidly to safety issues of importance for food production. This has been necessary to develop appropriate safety control systems. Unfortunately the success has been limited. However, recent developments of biotechnological and nanotechnological tools together with progress within material science begins to bring about sophisticated Polymerase Chain Reaction (PCR) methods, cantilever systems, various micro-array systems, new biosensors, etc. This substantiates an intensified research in new solid on-line/at-line methods, which can measure critical points throughout the milk production chain (e.g., feed, cow, raw milk, milk tank, throughout the processing chain, during storage and distribution with regard to pathogens, indicator organisms of contamination, antibiotics, toxins, chemical contaminants, allergens). Subsequently, this will support the development of hazard analysis critical control points (HACCP)-based quality management systems, where risk identification and prevention will play a paramount role.

Development of the above mentioned HACCP-based quality management systems as well as shelf-life prediction systems also calls for development of sophisticated modelling of growth and decline of pathogens, spoilers and contaminants in the milk and dairy products. These become the basis for the data needed for quantitative risk evaluations, which are the prerequisite for development of solid decision-making systems.

Traceability

Traceability is becoming one of the main quality attributes. Traceability is an extension of the safety attribute mentioned above. However, it also includes information regarding e.g., breed and identity of the animal, geographical origin, diet fed, animal welfare, processing technologies, etc. In addition to safety quality management systems, systems supporting traceability also demand further development and new initiatives within information technology. This is necessary to make it possible to obtain and store information throughout the milk production chain, which subsequently can be obtained by the consumer. At present Radio

Frequency Identification (RFID) transponders seem to be a possibility. However, cheaper initiatives combining such technology with sensor technology, which automatically adds information throughout the production chain, e.g., time-temperature information, would be preferable in the future.

Objective measurement of animal welfare

Animal welfare is and will continuously be an issue of interest to the media and consumers and hereby also to the politicians in a society where the consumers are distanced from the practical animal production. Policy development in the area of animal husbandry continuously suggests that from the perspective of optimizing animal welfare, new management systems should be developed to provide opportunities for livestock animals to be raised in environments where they can engage 'natural behaviour' (Frewer et al., 2005). There is no doubt that animal welfare in the future will be a natural part of quality management programmes, which ultimately will result in HACCP-based quality-based management programmes including good farming practice. Such programmes in Europe have to fulfil the requirements set by e.g., the EU (Noordhuizen and Metz, 2005).

If dairy farmers have to be able to fulfil these challenges in the near future, objective measurements of animal welfare need to be developed and implemented at farm level.

During the past few decades the milk production from the individual cow has been multiplied. To ensure optimal welfare of all the animals in modern milk production, this demands a thorough understanding of especially the energy supply to the cow throughout the lactation period. At present this knowledge is far from appropriate. Accordingly, several of the animals are in energy/physiological unbalance, which reduces the overall welfare. This situation will unquestionably place the milk farmers and the dairies in the blaze of publicity, if this problem is not sought solved as rapidly as possible.

Considering that the bovine genome will be available within the next couple of years and that the omic-sciences and bioinformatics of today have entered a functional stage (Womack, 2005), it seems evident to take a nutrigenomic approach (Dawson, 2006) in solving problems regarding physiological unbalance of the modern milking cow. Such an approach will give biological markers, which subsequently can be used to control feeding. Moreover, in combination with the ongoing development within sensor technology, such an approach will also be able to ensure development of dynamic feed management systems and support implementation of HACCP-quality management systems including welfare at farm level. Finally, the information coming from such an effort will also have a generic value that likewise can be used in the optimization and control of health and welfare issues at farm level, as stressors independently of origin influence the physiological status of the animal directly. Consequently, an approach using nutrigenomics will in general contribute to the potential future establishment of documentation systems for '*the whole cow*'. This will become a cornerstone for farmers and the dairy industry to convince the public of the ethics in modern milk production where effectiveness and industrialization dominate.

Sustainability

Sustainability in livestock farming necessitates both sociological and ecological aspects to be included when considering animal production development. The increasing public awareness of the impact of farming highlights the need for an improved understanding of such effects as well as the need for farmers to document and communicate the side effects of livestock farming to interested parties.

Sustainable milk production is already gaining importance in Europe, lead by organic milk production, where EU already has introduced regulations to standardize organic production throughout the member countries. Whether organic farming systems are more "environmental-friendly' than conventional management is not really the issue. The public has already made this decision, which is also gradually reflected in the products they demand. Consequently, development and documentation of sustainability becomes a main issue in the sale of milk and dairy products. The soil nutrient cycling, methane production and the energy consumption will be key indicators for developing more sustainable ruminant practices. However, also factors such as use of chemicals and antibiotics together with conservation of water will be important. Such a documentation of sustainability in milk production requests appropriate assessment tools. Different types of assessment tools are being developed with the purpose of determining the environmental impact of various livestock production systems at farm level (Halberg et al., 2005). However, the assessment tools need to be developed explicitly for milk production. Product-oriented and life cycle-based environmental assessments technology (LCA) seems to be the most obvious methodologies because of the need to evaluate global emissions and impacts from the whole production chain in relation to types and amounts of products consumed. Likewise, such methodologies are also compatible with ongoing efforts regarding sustainability in the down-stream part of the production of milk and dairy products, e.g., the "Der Grüne Punkt" system (www:/gruener-punkt.de) concerning recycling of packaging material, which has shown marketing potential in Germany.

On a long view, sustainability will without a doubt be an integrated quality attribute, which also includes safety and animal health and welfare issues and hereby becomes a natural part of quality management systems at farm level.

Milk composition and integrity

There is no doubt that increased and documented diversification of milk and dairy products is becoming a main issue in the years to come. Until now this diversification in modern milk production has almost been limited to milk coming from either conventional production systems or organic production systems. However, several of the main dairies have announced that they are going to market specific milk types in the near future.

Initially, these new milk types will focus on milk with diversified health properties, which as a minimum conform to dietary guidelines set forth by governmental agencies, and on the long view benefit human health in general. This is the first step in the renaissance of establishing milk as the preferred quencher of thirst, after nearly two decades, where the dairy industry has suffered from a bad health image due to a postulated 'wrong' fatty acid composition of the milk. However, recent scientific data show that this seems to be a wrong conclusion (Jacobsen et al., 2005; Huth et al., 2006). Some of the new biotechnological initiatives need to come into action to confirm the healthy aspects of milk, if milk has to regain its healthy reputation, and again become one of the preferred healthy thirst quenchers in many industrialised countries.

There is no doubt that the progress, which has taken place within genomics and other omic-sciences, together with the availability of both the human, and soon the bovine genome, will support a new access to milk derived nutritional research. Such an approach will use knowledge of the genes involved in lactation, the functions of milk-related genes, and the biology and physiology of milk consumption including comparative biology. This approach needs to be implemented to establish the basis for documentation of the healthiness of the different milk types produced according to the knowledge obtained in such an approach. Likewise, this approach has the potential to prepare the way for development of diversified milk and dairy products, which fulfil the needs for the individual, whether this is prevention of life style diseases or directly towards e.g., coronary heart disease, type 2 diabetes mellitus, inflammatory bowel disease, etc.

Milk flavour is another quality attribute, which is an obvious choice when different milk types are going to be diversified, as the consumer immediately recognizes this. To be able to differentiate raw milk with regard to flavour calls for a much better understanding of the influence of especially feeding on the composition of flavour active components in the raw milk. This again calls for a new and further understanding of the interaction of the feed with the microflora in the ruminant and eventually how wanted flavour components are protected in the rumen. Moreover, the interaction of breed effect on feed conversion in relation to flavour formation and development in the raw milk needs to be investigated much more into detail, and again the nutrigenomic approach mentioned above might be a possible tool to obtain such information.

During the past decade the dairy technology has slowly moved into the farm to increase the effectiveness and the handling of the continuously larger herds at the individual farms without additional expensive manpower. This introduction of cooling tanks, automated milking systems (AMS), pumping equipment, cooling systems and extended piping systems requests a completely new understanding on how these systems should be installed, tuned and operated without affecting the quality of the raw milk. These new installations expose the milk to extensive physical stress at a rather high temperature, and this in combination with the subsequent cooling is known to be critical for especially the integrity of the milk fat globule. Moreover, introduction of such systems also increases the possibility for bio-film formation in new segments of the milk chain, and hereby it challenges the hygienic quality of the raw milk. However, at present this knowledge is scarce, and the introduction of these new initiatives at farm level has unfortunately already shown to give rise to milk quality problems (Abeni et al., 2005). Thus an intensive effort within this area is necessary to ensure the quality of the raw milk both with regard to milk flavour, technological quality of the milk and hygienic quality. Moreover, this effort needs to be supplemented with development of education modules, which can be supplied to the farmers, and hereby teach them to work these mini dairies at the farm.

Independently of the demands of the costumers/consumers, the raw milk production has to be financially effective. Consequently, the technological quality of the raw milk is of outmost importance, as the major part of the milk is used in the production of dairy products and ingredients. In most countries the dairies of today demand unitary milk, which not necessarily fulfil the optimal technological quality of all dairy products and ingredients. Accordingly, improving the manufacturing and processing of milk and dairy products using the potential tools in the primary production is another possibility in future milk production. Both genetics and feed are known to influence the technological quality of milk with the genotype being decisive for both protein composition/content and lipid content (Coulon, 2004). Feeding being decisive for lipid and vitamin/mineral composition together with the anti-oxidative status of the milk and to a lesser extent protein content (Jenkins and McGuire, 2006). However, at present the knowledge within this area is far from satisfactory, which is why an extensive effort is needed in the future. Likewise, the control of the nutritional value and of the technological quality of raw milk will without a doubt also benefit from introduction of a nutrigenomic approach in the elucidation of this challenge.

NEW TECHNOLOGICAL TOOLS IN MODERN RAW MILK PRODUCTION

Recent and ongoing advances in biomedical technology will assist in advancing our understanding of disease prevention and health promotion, as well as medical diagnostics and therapeutics (Ross et al., 2004). Likewise, these advances will also soon open the barn door and accelerate our understanding of identical aspects in relation to the milking cow considering the ongoing progress within livestock genomics (Womack, 2005).

These new, emerging technologies such as microarray technology and nanotechnology have the potential to advance nutrition and health science in many aspects of relevance for modern milk production, as mentioned above. This implies both a better understanding of the aspects of importance for ensuring the establishment of the conditions for the "whole cow" and hereby the necessary public acceptance of an effective and industrialised milk production, and the support of milk and dairy products as a natural part of a healthy diet.

Moreover, nanotechnology is meant to be a major driver in the 1. development of biosensors, 2. support of sustainable agriculture, 3. pathogen and contaminant detection, 4. improved animal health, e.g., through development of smart treatment delivery systems, and 5. material science and engineering, e.g., development of material with antibacterial activity and which is easy to clean (Kuzma and VerHage, 2006). These are all areas that can benefit from a modern raw milk production, as mentioned above.

The simultaneous development within information technology makes it already now possible to integrate all data obtained throughout the milk chain. Consequently, data obtained through existing devices in the milk chain in combination with new data coming from the future devices for data collection based on the above mentioned new emerging technologies would be a unique possibility to develop solid decision support systems at all levels in the future.

One of the big challenges in the implementation of these new technologies as rapidly as possible into the area of raw milk production is to establish networks and programmes that support interdisciplinary interactions between the traditional players within milk production, animal scientists and food scientists and human nutritionists, medical scientists and molecular biologists using the new technologies as connecting links. An excellent example of such an arrangement in relation to the biological complex is "*The Milk Genomics Consortium*" that emanates from University of California, Davis, and aims to develop a new approach to nutritional research (human and other species) that uses knowledge of the genes involved in lactation, the functions of milk-related genes, and the biology and physiology of milk consumption (German et al., 2006). However, many more initiatives are necessary, if modern raw milk production has to benefit from these new technologies. Both national and international governmental programmes with support from dairy associations and the dairy industry need to support the establishment and activities of such interdisciplinary networks, if the milk production has to fulfil the demands of the consumers and the public in the near future.

CONCLUSIONS

The ever-increasing requirements of consumers and the public concern regarding sustainable food production in its widest sense have never challenged modern milk production more than today. Consequently, the main dairy industries need to include all aspects in the milk production chain to support a continuous profitable raw milk production. However, at present the scientific basis for developing a sustainable, flexible and diversified milk production that fulfils the requirements of the consumers and the public is not sufficiently strong.

As it is evident from above, optimal control of raw milk quality and development of solid decision support systems become extremely complex in a situation where both the consumers and the public interests have to be taken into consideration in a modern, profitable milk production. This requests that scientific advances including new and emerging technologies progress in the interaction between the more traditionally applied sciences of importance for an efficient milk production, e.g., animal science and food science and technology, and other areas, e.g., molecular biology, human nutrition, medical science, material science, advanced data handling and modelling, under the influence of consumer science and sociology in new networks and platforms.

The main scientific tasks in relation to modern milk production are to obtain an quantitative understanding of biological responses of importance for animal welfare and milk composition that substantiates the development of solid decision support systems and documentation and quantitative understanding of the nutritional value of milk in relation to communication and declaration of milk and dairy products.

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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

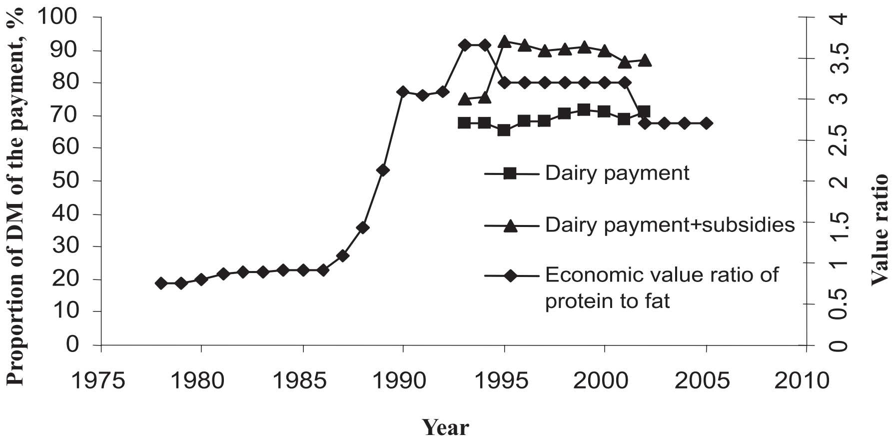

Figure 1. Farm raw milk payment in Finland between 1985 and 2005; the proportion of milk dry matter of the total payment (dairy payment or dairy payment+subsidies) and economic value protein to fat ratio (unpublished, Finnish Dairy Association, 2005)

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).

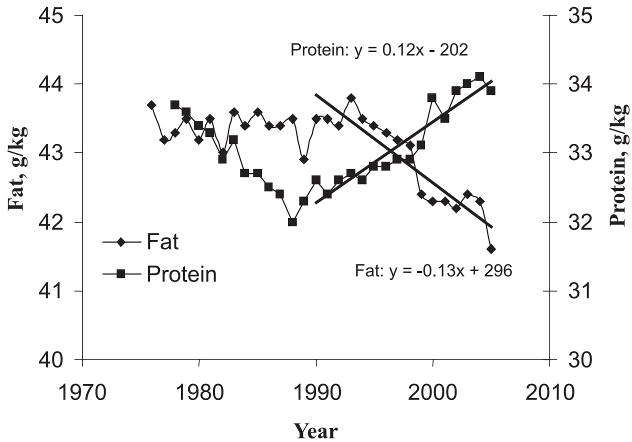

Figure 2. Current trends of fat and protein (6.38×N) in raw milk collected to dairies in Finland between years 1975-2005 (unpublished, Finnish Dairy Association, 2005)

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

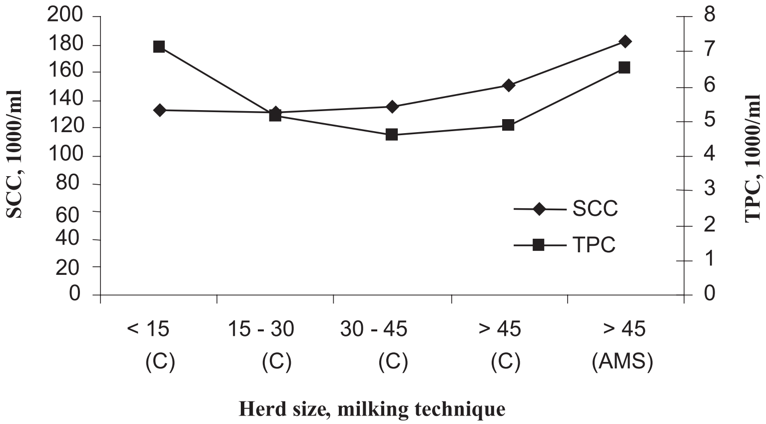

Figure 3. The effect of herd size and milking technique (C = conventional, AMS = automatic) on the somatic cell (SCC) and total plate (TPC) counts on dairy farms with increasing herd size or on dairy farms with automatic milking technique (AMS) (Finnish Association for Milk Hygiene, 2005)

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.

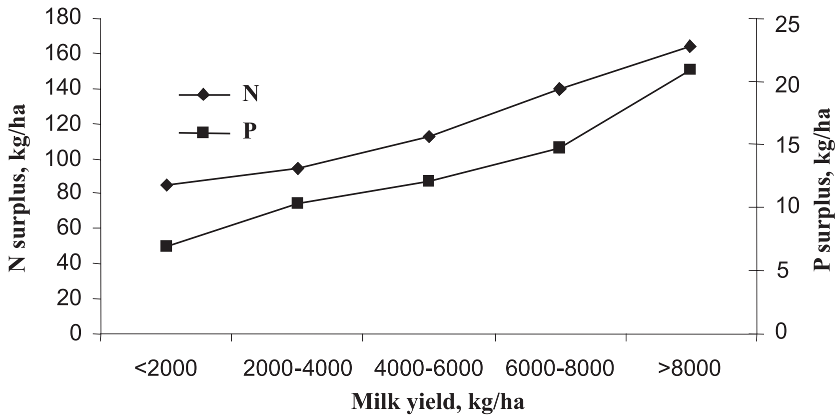

Figure 4. The effect of milk production intensity on the phosphorus (P) and nitrogen (N) balance (kg/ha) on Finnish dairy farms (data from Virtanen and Nousiainen, 2004)

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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