

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 μ g/L (63-122 μ g/L) in the summer season at pasture and 232 μ g/L (103-272 μ g/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 μ g/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 as 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 μ g/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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