Evaluating the suitability of milk for cheese making by on-line sensing

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Abstract

In modern dairy farms, cows are milked at different stages of lactation, while a relatively large number of their glands is infected with a variety of bacteria. Thus, bulk milk quality depends on the mixture of the milked quarters. Even though many dairy animals with subclinical chronic infections are not noted because there are no recognizable symptoms and the milk appearance is normal, subclinical mastitis affects milk quality.

In small ruminant's dairy systems, the quality and suitability of milk for cheese making is analyzed by laboratory milk testing. In this research, sheep at mid lactation (90-130 days in milk) and at the end of the lactation (~70 days before next parturition) were studied. Of those, 36 glands were infected with *Staphylococcus epidermidis* and *Staphylococcus chromogenes* and 43 glands were uninfected. Milk yield of uninfected glands was higher than in uninfected ones (2.83 vs. 1.75 L d^{-1}) while somatic cell counts was lower (154×10^3 vs. $2,150\times10^3$; $P<0.001$). Percent fat was lower and protein was higher in the milk from the infected glands in comparison to uninfected ones, while percent casein of total protein was significantly higher in milk from the uninfected glands (78.3±0.5 and 67.3±0.6; $P<0.001$). Lactose concentration was lower in the infected glands than in the uninfected ones (41.1±0.2 g L^{-1} vs. 48.1±0.3 g L^{-1}; $P < 0.001$). Cheese-making parameters were measured by the Optigraph. Clotting time was significantly longer and curd firmness was significantly lower in milk from the infected glands in comparison to uninfected glands.

Signals obtained by the on-line milk testing device (AfiLab® S.A.E. Afikim, Israel) for cows significantly correlated with measures of milk quality on the animal udder level obtained by the Optigraph i.e., clotting time and curd firmness. Thus, this achievement will allow small ruminant's milk producers to qualify on-line their milk for its potential for cheese production.

Keywords: small ruminants, subclinical mastitis, milk recording, cheese-making.

1. Introduction

Mammalian species produce milk for their offspring, therefore the quantity and composition depend on the newborn needs and change over time during the lactation. However, the variations in milk quantity and composition are not only among species but also within-species owing to diverse genotypes, management, stage of the lactation and their interactions. Additionally, glands infected with microorganisms, mainly bacteria, have negative effects on milk yield and quality. These effects are primarily localized in the infected glands due to induction of milk-born negative regulatory signals that lead to changes in the secretory pathways of lactose, lipids, proteins and other components (Silanikove *et al*., 2006; 2010).

In modern dairy farms, animals are milked at different stages of lactation, with a relatively large number of glands infected with a variety of bacteria. Thus bulk milk quality is the mixture of all the milked quarters. In traditional farming, surplus milk is used for dairy products with an effort to match between milk quality and optimal products yield. Therefore, milk from infected animals is carefully monitored and diverted from entering the bulk milk tank.

Many of the animals with subclinical chronic infection are not detected because there are no recognizable symptoms and the milk appearance is normal. Routine milk testing such as CMT on the animal side or more advanced techniques like the sophisticated cell counters allow the identification of subclinically infected animals close to the occurrence of the infection. However, these methods are laborious and/or require special equipment to perform and in many cases identify the infected animals long after the

infections occurred. On-line computerized milking systems are designed in part to overcome these obstacles and to apply genuine real-time data acquisition on individual animals, including milk yield and conductivity.

Recently, new information collected on-line in the milking parlour facilitated achieving a good correlation between milk quality and its suitability for cheese making. This achievement is of major interest to the small ruminant industry because most of that milk is used for cheese production.

2. Materials and Methods

2.1. Animals

Assaf dairy sheep in mid-lactation (ML) and at the end of lactation (EL), ~70 days before next parturition entered the study. Prior to the study, sheep were tested for bacterial infection and SCC. Of the ML sheep, 47 glands were free of bacteria (ML-F) and 56 glands were subclinically infected (ML-I) with CNS, mainly *Staphylococcus epidermidis* and *Staphylococcus chromogenes*. In the EL, only the milk of 30 glands free of bacteria was collected for the study. The sheep were kept in 4 m^2 closed sheds with extra 4 m^2 of open yard for each animal. Food was offered in mangers located in free-stall barns.

2.2. Milk sampling

Foremilk milk (5 mL) was sampled for testing after cleaning and disinfecting the glands during the morning milking. Bacteriological analysis was performed according to accepted microbiological procedures described by the US National Mastitis Council (Oliver *et al*., 2004). On the test days, an additional sample (100-300 mL of the whole milk) was taken from each gland for analysis as follows: SCC by the Fossomatic 360 and gross milk composition, i.e., protein, fat and lactose with the Milkoscan FT6000 (Foss Electric, Hillerod, Denmark) at the Israel Cattle Breeders Association Laboratory (Caesarea, Israel). Casein content was determined according to standard methods (Marshall, 1992). Curd firmness (CF) and clotting time (RCT) were determined by the Optigraph (Ysebaert, Frepillon, France) as described by Leitner *et al*. (2006).

2.3. Statistical analysis

All statistical analyses were carried out with JMP software (SAS Institute, 2000).

3. Results

End-lactation sheep were on the average 204 days in milk (DIM) while the ML-F and ML-I were on the average 99 and 119 DIM, respectively (Table 1). Daily milk yields were ~2.3 L day^{-1} in ML-F, significantly higher than ML-I (1.57 L d^{-1}), whereas both were significantly higher from the EL, which produced 0.99 L d^{-1}. SCC was significantly higher ($P<0.001$) for ML-I than ML-F and EL, with no significance between the latter (7211, 129, 403 × 10^3 cells mL^{-1}, respectively). Fat was higher in the EL than ML-F and ML-I but significantly ($P<0.05$) only from the ML-I. No significant differences were found among the groups in percent protein and casein. However, percent casein of total protein was significantly lower ($P<0.001$) in ML-I. Lactose was significantly lower ($P<0.001$) in ML-I than ML-F; the lowest lactose concentration was recorded in EL. RCT was significantly longer ($P<0.001$) in both ML-I and EL than in ML-F. CF at 40 min after enzyme addition (CF-40) was significantly lower ($P<0.001$) in ML-I and EL than in ML-F in comparison to ML-F (8.22, 14.54 and 18.27, respectively).

The correlation between protein, casein and Protein + fat and CF was not significant. The correlation between casein or % casein of total protein and CF was positively significant, whereas the correlation between lactose and CF was negative, and highest (r = 0.591). SCC and log SCC also correlated negatively, but with lower r.

Table 1. Mean and SE of days in milk, milk yield, milk composition: fat, protein, casein, % casein, lactose and RCT and CF according to groups of sheep designated: Mid–lactation, bacteria free (ML-F), Mid–lactation-infected (ML-I) and End-lactation, bacteria free (EL).

	ML-F	ML-I	EL	R^2	P *[F]*
No. of quarters	41	56	39		
DIM	99±9.2 [b]	119±8.5 [b]	204±4.9 [a]	0.452	*P*<0.001
Milk (L d^{-1}) [1]	2.28±0.16 [a]	1.57±0.18 [b]	0.99±0.18 [c]	0.333	*P*<0.001
SCC (×10^3)	129±48 [b]	7211±1197 [a]	403±94 [b]	0.299	*P*<0.001
Fat (g L^{-1})	72.7±0.32 [ab]	68.7±0.32 [b]	76.1±0.34 [a]	0.062	*P*<0.001
Protein (g L^{-1})	47.74±0.17	50.1±0.17	51.8±0.18	0059	NS
Casein (g L^{-1})	35.8±0.11	34.1±0.11	36.3±0.16	0.051	NS
% Casein[2]	76.39±1.43 [a]	67.94±1.44 [b]	74.57±0.5 [a]	0.294	*P*<0.001
Lactose (g L^{-1})	47.9±0.12 [a]	40.5±0.1 [c]	43.8±0.13 [b]	0.205	*P*<0.001
RCT (sec)	547±22 [c]	1820±205 [a]	802±37 [b]	0.255	*P*<0.001
CF-40 (V)	18.27±1.10 [a]	8.22±0.98 [c]	14.54±1.27 [b]	0.301	*P*<0.001

[1]Sheep milk
[2]% Casein = Casein/protein × 100
[a-b]Parameter within row with no common superscript differ significantly (*P*< 0.05)

Table 2. Correlations and P[r] of protein, casein, protein + fat, percent casein, lactose, SCC and log SCC with CF of milk from all the sheep in the study.

Parameter	R	*P*[r]
Protein (g L^{-1})	-0.074	NS
Casein (g L^{-1})	0.352	0.002
% Casein [1]	0.222	0.01
Protein + fat	01.41	NS
Lactose	0.591	<0.0001
SCC (×10^3)	-0.510	<0.0001
SCC (log)	-0.232	<0.0001

[1]% Casein = Casein/protein × 100

4. Discussion

No correlation was found between fat, protein and casein concentrations and CF, while a positive correlation was found between lactose and CF and a negative correlation between % casein and SCC and CF, consistent with previous findings (Leitner *et al*., 2007; 2008). The study highlighted the effectiveness of measuring lactose content in predicting milk quality, since the correlation between lactose and CF was higher than between % casein and SCC and CF.

Subclinical infection of glands with CNS at mid-lactation simultaneously affected milk yield and milk quality measures, clotting time and curd firmness. Milk yield was least and insignificantly affected, since in sheep it was found that glands infected with CNS compensate their milk yield by the uninfected gland. Consequently, loss of milk yield on the whole animal level is attenuated in sheep (Leitner *et al*., 2004, 2008). Nevertheless, it should also be noted that deterioration in milk quality is almost certainly associated with loss of curd yield. Moreover, when milk is used for curdling and cheese production, the negative effect of CNS infection, when only one gland is infected, on losses due to reduced curd yield is greater than the contribution of milk yield loss (Leitner *et al*., 2008).

End of lactation negatively affected milk yield and milk quality. The inflammatory response at the end of lactation may be interpreted as a pre-adaptive response to the forthcoming involution stage, because the acute inflammatory response associated with this adaptation will aid in clearing existing bacterial infection; thus, preventing the transfer of infection from current lactation to the next.

Changes in lactose as an indication of infection and deterioration in milk quality are well-known during clinical (Werner-Misof *et al*., 2007) and subclinical mastitis (Leitner *et al*., 2004, 2007). The reduction of lactose concentration in subclinically infected animals in which the tight junction integrity is maintained, indicates that the reduction is related to reduced secretion of lactose by the mammary gland cells. Indeed, it is the milk-borne regulatory element (i.e., β-CN f(1–28)), which blocks apically located K^+-channel and affects the secretion of lactose into the milk (Silanikove *et al*., 2000; 2009). Interestingly,

reduction of lactose to around 4% signifies milk that will not coagulate and thus is of no value for cheese production (Fig. 1), which is also associated with casein degradation and liberation of casein-degradation products that reach a level that would completely impede curdling.

The result of this research provides small dairies that process their own milk to cheese with a new technology that will enable them to separate the milk that will not coagulate. This milk can still meet the criteria for being used for drinking; thus, allowing the farmers to exploit the milk produced more economically. The effectiveness of lactose, % casein and SCC in predicting milk quality for cheese production is lost on the dairy tank level because of its dilution with good quality milk. Nevertheless, the effect of subclinical mastitis on milk quality remained significant (Leitner *et al.*, 2007). Thus, future developments of new techniques for on-line measures of milk quality, particularly the level of lactose, will allow the producers to meet the top dairy price-quality standards by separating milk according to its best properties, cheese production and drinking, thus maximizing their profit from milk selling.

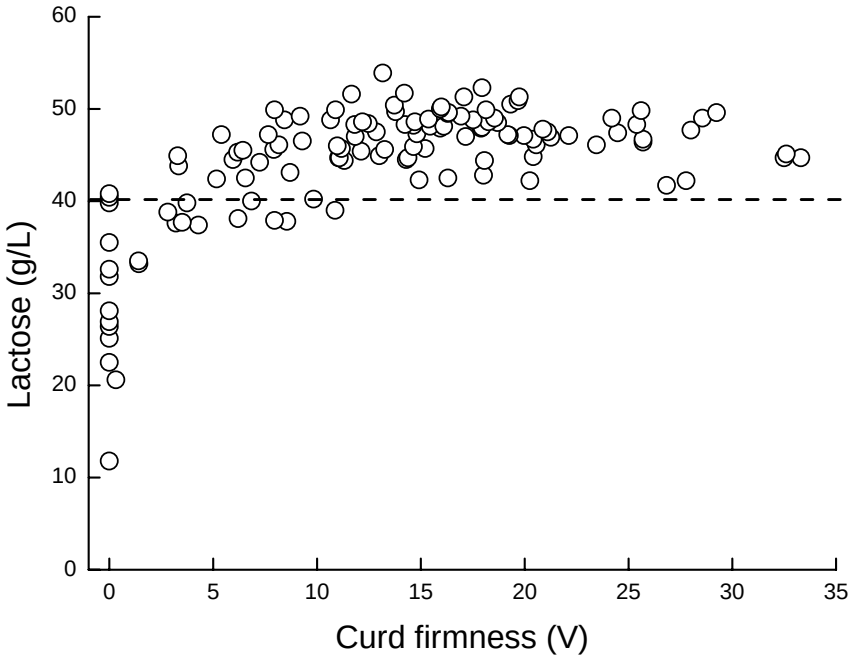

Figure 1. Lactose concentration in milk and its relation to curd firmness as measured by the Optigraph.

5. References

Leitner, G., Chaffer, M., Shamay, A., Shapiro, F., Merin, U., Ezra, E., Saran, A., Silanikove, N. 2004. Changes in milk composition as affected by subclinical mastitis in sheep. J. Dairy Sci., 87:46-52.

Leitner, G., Krifucks, O., Merin, U., Lavi, Y., Silanikove, N. 2006. Interactions between bacteria type, proteolysis of casein and physico-chemical properties of bovine milk. Int. Dairy J., 16:648-654.

Leitner, G., Merin, U. Lavi, Y., Egber, A., Silanikove, N. 2007. Aetiology of intramammary infection and its effect on milk composition in goat flocks. J. Dairy Res., 74:186-193.

Leitner, G., Silanikove, N., Merin, U. 2008. Estimate of milk and curd yield loss of sheep and goats with intrammamary infection and its relation to somatic cell count. Small Rumin. Res., 74:221-225.

Marshall, R. T. (Ed.) 1992. Standard Methods for the Examination of Dairy Products (16th ed.), American Public Health Association, Washington DC, USA.

Oliver S.P., Gonzalez R.N., Hogan J.S., Jayarao B.M., Owens W.E. 2004. Microbiological Procedures for the Diagnosis of Bovine Udder Infection and Determination of Milk Quality, in: The 4th ed., National Mastitis Council, Verona, WI, USA.

SAS Institute, 2000. JMP Statistics and Graphics Guide, Version 5. SAS Institute Inc., Cary, NC, USA.

Silanikove, N., Shamay, A., Sinder, D., Moran, A. 2000. Stress down regulates milk yield in cows by plasmin induced b-casein product that blocks K^+ channels on the apical membranes. Life Sci. 67:2201-2212.

Silanikove, N., Merin, U., Leitner, G. 2006. Physiological role of indigenous milk enzymes: An overview of an evolving picture. Int. Dairy J., 16:535-545.

Silanikove, N., Shapiro, F., Shinder, D. 2009. Acute heat stress brings down milk secretion in dairy cows by up-regulating the activity of the milk-borne negative feedback regulatory system. BMC Physiol., 9:13.

Silanikove, N., Leitner, G., Merin, U., Prosser, C.G. 2010. Recent advances in exploiting goat's milk: quality, safety and production aspects. Small Rumin. Res., 89:110-124.

Werner-Misof, C.M., Pfaffl, W., Bruckmaier, R.M. 2007. Dose-dependent immune response in milk cells and mammary tissue after intramammary administration of lipopolysaccharide in dairy cows. Veterinarni Medicina, 52:231–244.