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Short communication

Estimate of milk and curd yield loss of sheep and goats with intrammamary infection and its relation to somatic cell count

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Abstract

Equations for predicting milk and curd loss due to intramammary infection in sheep and goat herds were derived. The empirical equations were derived from previously published studies conducted by this team with Assaf sheep and crossbreeds of goats in Israel. From these equations, it appears that infection of 25, 50 and 75% of the udders in a given herd was associated with loss of 4.1–12.2.5% milk in sheep and 0.8–2.3% in goats; whereas curd loss was 5.2–15.5% in sheep and 3.3–9.8.9% in goats. Based on percent of udder infection and projected SCC, the following categories are suggested for classification of sheep and goat milk: i. High-quality milk <800,000 SCC/mL, associated with infection of ~25%; ii. Medium quality milk <1,500,000 SCC/mL, associated with infection rate between 25 and 50%; iii. Low-quality milk >1,500,000 SCC/mL, associated with infection rate above 50%; iv. Milk containing >3,500,000 SCC/mL should not be accepted for human consumption.

Keywords: Sheep; Goat; Udder infection; Milk yield; Curd yield

1. Introduction

The major income from dairy animals is derived from their milk; therefore, factors that reduce milk quantity and quality can cause high economic losses to the farmers. In the case of dairy goats and especially sheep, most, if not all of the milk is processed into fermented products and cheese; therefore, any reduction in the content of the dry matter, mainly casein, will have a detrimental influence on the industrial value of the milk. In recent years there is an effort in industrialized countries to implement payment schemes for goats and sheep milk based on somatic cell count (SCC) and protein content, similar to those practiced for bovine milk (Gonzalo et al., 1994). Consequently, factors influencing milk quality that were ignored hitherto are now proving to be more crucial to the farmers than ever before. Goat and sheep farming encompass a greater variety of breeds and more different management systems than the farming of dairy cows. To date, variations between countries in the acceptable levels of SCC in healthy udders exist (Maisi et al., 1987; Fthenakis et al., 1991; Fthenakis, 1994; Gonzalez-Rodriguez et al., 1995). Moreover, the effect of the number of somatic cells in the milk on the final product (quality and yield) is unclear.

In Israel, clinically infected glands of goats and sheep are not always treated, and even if treated, it saves the animal but leads in most cases to irreversible loss of

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gland function and degeneration of the infected gland. Consequently, either the animal is culled or the infected gland is not milked for the rest of the animal's productive life. Thus, although clinical mastitis causes direct economic loss to the farmers, in most cases it does not affect the quality of the bulk milk. In contrast, subclinically infected udders are subtle and therefore are milked into the bulk milk tank.

In dairy cows, subclinical mastitis, ranging from 20–50% (Wilson et al., 1997; Janosi and Baltay, 2004; Pitkala et al., 2004) is largely ignored because the increase in SCC in infected gland is modest (about 300–500 $\times$ 10^3 cells/mL) and the mixing with the milk from uninfected quarters is sufficient in most cases to appreciably lower the effect of SCC on the cow level, and hence, the herd bulk milk (Djabri et al., 2002).

Previous studies of dairy sheep and goats (Gonzalez-Rodriguez et al., 1995; Mavrogenis et al., 1999; White and Hinckley, 1999; Leitner et al., 2004a,c; Luengo et al., 2004) demonstrated that intramammary infection (IMI) in its subclinical form is the single most important factor affecting milk quality and quantity, although other factors such as stage of lactation, lactation number, time of day, lentivirus infection and management (Menzies and Ramanoon, 2001) could be of relevance. The major types of bacteria involved in dairy cow subclinical mastitis are the same as in sheep and goats, which are various coagulase-negative staphylococci (CNS), that are found on the skin of the udder and its surroundings (Haenlein, 2002; Bergonier and Berthelot, 2003; Bergonier et al., 2003; Leitner et al., 2000, 2003, 2004a,b,c). However, because sheep and goats have only two mammary glands mixing of milk with high SCC coming from infected glands with low SCC from a healthy gland is insufficient to reduce the SCC on the animal level and obviously not in the bulk milk tank. These changes in SCC were found to be associated with loss of curd yield and deterioration in its quality (Leitner et al., 2004a,b).

As subclinical mastitis is not visually detected and sometimes hard to evaluate, there were few attempts to evaluate its incidence in herds through indirect markers, such as the bulk tank somatic cell count (BTSCC). Lukas et al. (2005) suggested that monitoring BTSCC in dairy cows could be used to estimate subclinical mastitis prevalence during the monitored test days. Similarly, in dairy goats and ewes, a relationship between the annual geometric mean of BTSCC and the estimated prevalence of IMI was demonstrated (Bergonier et al., 2003; Berthelot et al., 2006).

The aim of this presentation is to evaluate the losses of milk and consequently cheese at the herd level in relation to IMI in herds of Assaf sheep and Saanen and Shami $\times$ Anglo-Nubian goats, the major dairy breeds and crossbreeds of small ruminants in Israel. In order to do so we re-analyzed previously published data (Leitner et al., 2004b,c,d). An outcome from this analysis would provide farmers with a tool to assess the economic losses associated with prevalence of IMI in their herd, and dairies with a scheme to grade sheep and goat milk according to BTSCC.

2. Methods

The results of studies that included an overall follow-up of health measures on a herd level (Leitner et al., 2003, 2004d) and individual level of animals within a herd, using the udder-half model (Leitner et al., 2004b) (Table 1) were analyzed. The data on the herd level provided a large set, albeit one major drawback being that it was not possible to separate the recording of milk between animals with infection in one or two glands. In these studies, milk yield was recorded by the owners at the animal level; therefore, the analysis of the data was based on animals with two uninfected glands compared to animals with both glands infected. The udder-half model, where each animal had one udder half chronically infected with bacteria in a subclinical form of mastitis and the contra lateral gland free of bacteria provided more insight for the understanding and mea-

Table 1
Milk and curd loss due to subclinical IMI for sheep and goat

Specie	No. of animals	SCC ($\times$1000)		Milk (infected halves)			Milk loss (%)		Curd loss (%)	Study reference
		−	+	0	1	2	1	2		
Sheep	823	141	2089	2.88	2.80	1.81	2.8	37.2	–	Leitner et al., 2003 (1)
	745	374	3272	2.05	1.78	1.44	13.2	29.8	–	Leitner et al., 2004d (2)
	26	270	2358	–	–	–	–	52.6[a]	4.37[a]	Leitner et al., 2004b (3)
Goat	682	485	2203	2.68	2.68	2.45	0	9.7	–	Leitner et al., 2004d (2)
	25	417	1750	–	–	–	–	31.9[a]	9.97[a]	Leitner et al., 2004c (4)

0, not infected; 1, infected in one gland; 2, infected in 2 glands.
[a] Results obtained by the udder-half model.

surement of the direct effect of subclinical infection on milk yield and quality. Using herd level and the udder half model resulted in large differences in milk loss in the same specie. These differences were explained by the compensation of the uninfected half, which produced more milk when the contra lateral gland was infected, resulting in grater calculated loss in the infected half (Leitner et al., 2004c). In contrast, when milk loss was compared for uninfected and infected animals in both glands, the actual milk loss to the farmer was obtained (Leitner et al., 2003, 2004d). In order to empirically calculate the milk loss on the herd level, it was estimated that of the total infected udder halves, 1/3 are coming from animals with 2 infected glands and 2/3 are from animals with only one infected gland.

Curd loss was calculated as the difference between curd obtained from milk from healthy glands and curd from milk of infected glands using the results obtained in the udder-half model, therefore, the loss is the sole difference due to infection. Measuring curd yield was done by taking similar volume of milk from both uninfected and infected glands. The data collected throughout these experiments is summarized in Table 1.

3. Evaluation of losses

The evaluation of milk loss due to infected gland (L) used the mean values of studies 1 and 2 (see Table 1 for details). Thus, for sheep:

$$L = \left[\frac{(37.2 + 29.8)}{2}\right] \times \frac{1}{3} + \left[\frac{(2.8 + 13.2)}{2}\right] \times \frac{2}{3} = 16.3\%$$

Similarly, for goats, L was:

$$L = 9.7 \times \frac{1}{3} = 3\%$$

Curd loss (C) was calculated based on the results obtained in the udder-half model, for sheep: $C = 4.37$ and for goats: $C = 9.97$ (studies 3 and 4, respectively, as summarized in Table 1).

4. Empirical relation

From the data collected, two empirical relations could be developed to calculate herd milk yield loss and curd loss, which combine milk loss and reduction in curd yield due to the percent of subclinical IMI in a given herd of sheep or goats. Curd loss was based on volume of milk needed to produce 1 kg of cheese of 70% moisture.

$$\text{Percent herd milk yield loss (HML)} = \%\ \text{of infected halves} \times L$$

Table 2
Calculated herd milk loss and curd loss in sheep and goat due to infection level

Infection level	Projected SCC (×1000)	Milk loss (%)	Curd loss (%)
Sheep			
25	800,000	4.1	5.2
50	1,400,000	8.2	10.4
75	2,000,000	12.2	15.5
Goats			
25	840,000	0.8	3.3
50	1,200,000	1.5	6.5
75	1,600,000	2.3	9.8

$$\text{Percent herd curd loss (HCL)} = \%\ \text{of infected halves} \times C + \text{HML}$$

An outcome from this analysis would provide farmers with a tool to assess the economic losses associated with prevalence of IMI in their herd, and dairies with a scheme to grade sheep and goat milk according to BTSCC.

The mean results of the studies presented in Table 1 were used for assessing the prevalence of IMI in the herd according to its bulk tank milk SCC. From the data in the publications cited in Table 1, SCC for sheep milk coming from uninfected glands was calculated as 250,000 cells/mL and for the infected ones 2,500,000 cells/mL. Similarly, for goats, SCC of uninfected glands was calculated as 450,000 cells/mL and for infected ones 2,000,000 cells/mL.

In Table 2, estimates of milk and curd losses are presented as a function of IMI in a given flock of sheep or goats, along with the projected SCC due to IMI, leaving out all other parameters such as, pregnancy, days in milk, end of lactation, etc. Applying these equations suggest that infection of 25, 50 and 75% of the udder halves in herds was associated with milk loss of 4.1–12.2% in sheep and 0.8–2.3% in goats; whereas estimated curd loss was 5.2–15.5% in sheep and 3.3–9.8% in goats (Table 2). For the same level of infections BTSCC were calculates as ∼800,000 cells/mL for sheep and goats with 25% udder halves infected and SCC increases to 2,000,000 in sheep and 1,600,000 in goats in a herd with 75% infection. The rather low milk loss predicted for a goat herd with 75% infection is based on our results, but it might as well be that a generous compensation was taken into account by this formula, and in reality, the number of does infected in both halves could be larger, inflicting a greater milk loss than was cautiously given in this example.

The physiological basis for the inter-species differences in milk losses in response to IMI were previously

discussed (Leitner et al., 2004b,c). Briefly, both the content of casein and the activity of plasmin, the major proteolytic enzyme in milk, are greater in sheep than in goats. Consequently, during IMI there is greater liberation of casein degradation products in sheep. Since casein degradation products contain active peptides that down-regulate milk secretion (Silanikove et al., 2000, 2006; Shamay et al., 2002, 2003), they induce greater reduction in the milk yield. In addition, in goats, larger volume of milk is needed to produce 1 kg cheese and the results in the studies showed that higher curd loss occurred in goat milk; therefore, this could explain the high curd loss due to IMI although milk loss was lower than that of sheep.

Taking into consideration the numerical values calculated in Table 2, it is possible to propose some guidelines to small ruminants' milk and cheese producers. The major obstacle to the activation of a detailed differential payment scheme in the sheep and goat dairy industries has been lack of knowledge regarding the factors that affect the SCC, especially due to breed, DIM, lactation, management, etc. (Ryan et al., 1993; Haenlein and Hinckley, 1995; Wilson et al., 1995). However, the findings of our group, as well as other (Contreras et al., 1997; Gonzalo et al., 2002; Haenlein, 2002) showed that CNS are the major pathogen in IMIs and their effect on IMI was far greater than other effects (Leitner et al., 2004a,b,c,d). Thus, the BTSCC of a given flock should directly reflect the rate of subclinical IMI in that flock. In the light of these findings, a payment scheme that takes into consideration the scientific data and the actual hygienic situation among the Israeli flocks is suggested for grading sheep and goat milk in Israel; which could be also valuable for other locations. Milk with <400,000 SCC/mL reflects a whole-flock infection rate of zero or close to zero, but this situation is ideal and hardly exists in practice. Thus: i. High-quality milk <800,000 SCC/mL, associated with infection of ~25%; ii. Medium quality milk < 1,500,000 SCC/mL, associated with infection rate between 25 and 50%; iii. Low-quality milk > 1,500,000 SCC/mL, associated with infection rate above 50%; and iv. Milk containing >3,500,000 SCC/mL should not be accepted for human consumption.

The latter category calls for some elaboration since in many countries no limits are set to the high range of SCC in small ruminants:

A. In a survey that covers milk hygiene in sheep flocks in Israel during 2006, it was found that of 65 farms, 15 had $<10^6$ SCC, 19 had 1×10^6–1.5×10^6, 15 had 1.5×10^6–2.0×10^6, 14 had 2×10^6–3.0×10^6 and only 2 farms had milk with SCC exceeding 3×10^6, which according to the proposed scheme should have been rejected.
B. Considering the attitude of modern dairy standards, similar to what is given by the Pasteurized Milk Ordinance in the United States is of relevance. It is there cited that: "Lactating animals which show evidence of the secretion of abnormal milk in one (1) or more quarters, based upon bacteriological, chemical or physical examination, shall be milked last or with separate equipment and the milk shall be discarded" (PMO, 2001). Moreover, it continues: "Bovine mastitis is an inflammatory and, generally, highly communicable disease of the bovine udder. Usually, the inciting organism is a streptococcus of bovine origin (type B), but a staphylococcus or other infectious agent often causes the disease. Occasionally lactating animal's udders become infected with hemolytic streptococci of human origin, which may result in milk borne epidemics of scarlet fever or septic sore throat. The toxins of staphylococci and possibly other organisms in milk may cause severe gastroenteritis. Some of these toxins are not destroyed by pasteurization" (PMO, 2001).
C. Research from our laboratory has shown recently that milk is a live bioreactor that constantly generates free radicals (Silanikove et al., 2005). Under inflammatory response such as that associated with 3,500,000 SCC/mL, dangerous nitrosative species may be formed as a direct reaction to potent radicals such as nitric dioxide, or as secondary response to lipid peroxidation. Nitrosative species such as nitrotyrosine and di-tyrosine may pose a threat to the public health.
D. According to our experience, milk with such a high SCC sometime will not form a coagulum, even if a double concentration of coagulating enzyme is used.

Thus, we think that it is timely to consider milk of small ruminants as a food product (similar to bovine milk) and as such, it is imperative not to introduce milk coming from severely infected glands into the bulk milk tank. The proposed milk qualification scheme may be used as a reference guide for that purpose.

5. Conclusions

Subclinical IMI by CNS is the major single factor affecting flock IMI and profitability in small ruminants. Knowledge of the etiology of the infection in the flock could potentially serve as a tool to reduce economic

losses to the farmer by improving flock management and possibly leading to treatment of the infected glands. This information is also valid and valuable for qualifying the milk for cheese production, as well as for establishing acceptable payment schemes.

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