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Variation in Milk Yield, Contents and Incomes According to Somatic Cell Count in a Large Dairy Goat Population

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Abstract

Between 2009 and 2014, 758,382 monthly test-day records were obtained from 65,056 Murciano-Granadina goats in 132 Spanish dairy flocks. Variables measured were somatic cell count (SCC), milk yield and fat and protein percentages; means were 5.78$\log_{10}$ cells/ml, 2.04 L/day, 5.37% and 3.67%, respectively. Significant effects of year, herd test date, season, parity, month of lactation, litter size and covariables milk yield, fat and protein contents were evidenced on SCC. The regression slopes were negative for milk yield an d positive for fat and protein content, thus pointing out that high SCC in milk were associated with low milk yield and high contents. A second ANOVA was built to evaluate the evolution of test-day variables as SCC level increased within lactation. The percentages estimated in losses of milk yield for SCC levels 1 million cells/ml, 2 million cells/ml, 3 million cells/ml and >7 million cells/ml were 11.4%, 19.5%, 24.2% and 35.7%, respectively. Milk contents gains were also quantified. Milk incomes per goat and day (according to current payment system) revealed important economic losses (from 9.5% to 31.6%) for above-mentioned SCC levels. Results emphasize the importance of SCC as a limiting factor for milk incomes in dairy goats.

Keywords: Goat; Milk yield; Somatic cell count; Losses; Mastitis

Introduction

Subclinical mastitis is a common problem in dairy herds and somatic cell count (SCC) has been widely used in ruminant species as an indirect and inexpensive diagnostic method of udder health status. The importance of subclinical mastitis and SCC as a limiting factor in milk yield is well documented in dairy cattle and sheep [1-3], but very confused in dairy goats, in which non-infectious factors had a major impact on SCC [4,5]. Barrón-Bravo et al. [6] in a study using only information from first lactation for Alpine, Saanen and Nubian goats estimated losses in test day milk yield ranged from 0.5 to 29.1% according to different SCC levels. Similarly, Baudry et al. [7] in French dairy goat flocks found losses in milk yield ranged from 7.9% and 16.9% when a low SCC level was compared with other two high SCC levels. Other authors [8], however, found attenuated losses in milk yield (0.8-2.3%) associated with medium-high intramammary infection prevalences in a given herd, while others [9,10] did not find significant differences in milk yield between infected and uninfected goats. Koop et al. [11] show that milk yield losses caused by subclinical udder infections are limited in goats and that SCC cannot be used to estimate the magnitude of these losses. Thus, the negative correlations between SCC and milk yield might have been confounded with the stage of lactation effect because the inverse-lactation curve between both variables [12]. Therefore, a dilution effect seems to play an important role in the negative association between SCC and milk yield [11,13].

In addition, subclinical mastitis modifies milk composition, but references concerning the relationship between SCC and milk contents are unclear in dairy goats [14]. Thus, several authors reported decreased fat content associated to high levels of SCC [7] while others did not find differences in fat content according to SCC level [15,16] or infection status [17-19] in small ruminants. In other studies, however, higher fat concentration was found in infected glands than in uninfected ones [20] or related to high levels of SCC [6]. Positive [18,20,21]; negative [22,23] or no relationship [9] was also described between protein content and SCC or intramammary infection. The variation of milk contents could be also associated with a dilution or concentration effect in variable milk volumes similarly to SCC, as suggested, for example, Fuertes et al. [21].

Overall, these investigations put into question the relevance of SCC as a valid tool for estimating the magnitude of milk yield and content losses in dairy goats, and at same time, emphasize the need to continue studying in greater depth the relationships between these variables in large goat populations and within stage of lactation in order to avoid the dilution or concentration effect.

The aim of this study was to determine the milk income losses according to somatic cell count levels in a large goat population, particularly within lactation, This information will allow driving optimization with regard to mastitis control programs in dairy goats in connection with testing program report for milk yield and quality.

Material and Methods

Flocks and test-day recording

Between the years 2009 and 2014, a total of 758,382 test-day observations for SCC, milk yield, fat and protein contents were obtained from 65,056 Murciano-Granadina goats in 132 dairy flocks

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enrolled in the Analysis Service of the National Breeding Centre of Granada (Spain).

Murciano-Granadina is the main Spanish dairy goat breed, reared under a semi-intensive system; the current census being 508,000 heads (19.2% of total goat Spanish census). The breeding scheme for milk production based on test-day recording has been implemented since 1992 by the National Association of Murciano-Granadina Breeders (CAPRIGRAN).

In a system based on a test-day alternate recording, milk samples were monthly collected as part of the official national recording system used by CAPRIGRAN [24], according to guidelines of International Committee for Animal Recording (ICAR, http://www.icar.org). All flocks were machine milked. Regarding to health status of the flocks involved in this study, traditional measures for mastitis control (milking machine maintenance, postdipping, dry therapy and culling) were implemented separately in each flock. Most of flocks were vaccinated against contagious agalactia, which is enzootic in Spain. Averaged size of flocks was 298 (minimum: 38 and maximum: 1,115) present goats for flock and year.

Milk samples were preserved with bronopol (3.3 µL/mL) and milk composition (fat and protein contents) and SCC of each milk sample was determined with COMBIFOSS 6000 FC (Foss Electric, Hillerød, Denmark) calibrated against known standards, and subjected to quality controls and inter-comparative trials.

Statistical analyses

Test-day records of SCC were transformed in their logarithmic form Ali and Shook [25] to meet the characteristics of hypothesis testing for statistical analyses. To evaluate the systematic factors influencing the variation of SCC, and particularly to know its relationship with the economic variables, such as milk yield, fat and protein contents, a first linear model as factorial design of fixed effect, was used following the GLM procedure of SAS [26]. This model was: $Y_{ijklmno}=\mu+A_i+HTD_{j(i)}+S_k+P_l+L_m+K_n+b_1M_{ijklmno}+b_2F_{ijklmno}+b_3P_{ijklmno}+e_{ijklmno}$, where, $Y_{ijklmno}$ was the dependent variable $\log_{10}$ SCC; µ was the overall mean; A_i was the fixed effect of year of kidding; $HTD_{j(i)}$ was the fixed effect of herd test date within year of kidding; S_k was the fixed effect of season of kidding; P_l was fixed effect of parity effect; L_m was the fixed effect of lactation month; K_n was the fixed effect of litter size; $M_{ijklmno}$, $F_{ijklmno}$, and $P_{ijklmno}$ were the fixed effect of test day observations for milk yield, fat and protein contents, considered as covariables, b_1 to b_3 were the regression slopes corresponding to covariables; and $e_{ijklmno}$ was the residual effect. There were 6 categories for year of kidding (years 2009 to 2014), 7095 for HTD, 2 for season (Fall+Winter, and Spring+Summer), 9 for parity (parities 1 to 9 or later), 10 for month of lactation (months 1 to 10 or later), and 2 for litter size (single or multiple) levels.

A second linear model was built to evaluate the variations in test-day milk yield, fat and protein contents, particularly within the lactation. The model was: $Y_{ijklmno}=\mu+A_i+HTD_{j(i)}+S_k+P_l+L_m+K_n+C_o+e_{ijklmno}$, where, $Y_{ijklmno}$ was the dependent variable milk yield, fat content and protein content; µ was the overall mean; the fixed effects A_i, $HTD_{j(i)}$, S_k, P_l, L_m, and K_n, were the same effects as previously defined, C_o was the fixed effect SCC level; and $e_{ijklmno}$ was the residual effect. The levels for common effects year of kidding, parity, and litter size were the same in first and second models. Season effect was divided into 4 levels (Winter, Spring, Summer, and Fall); month of lactation was divided into 6 levels (1, 2-3, 4-5, 6-7, 8-9, and >9 months); and SCC (x 10^3 cells/ml) was divided into 20 categories (1-200, 201-400, 401-600, 601-800, 801-1000, 1001-1200, 1201-1400, 1401-1600, 1601-1800, 1801-2000, 2001-2200, 2201-2400, 2401-2600, 2601-2800, 2801-3000, 3001-4000, 4001-5000, 5001-6000, 6001-7000, and >7000). To evaluate yield and content variations within lactation, this second model was repeated 6 times, one for each lactation level, for each variable, to know the evolution of SCC categories within each lactation period (1, 2-3, 4-5, 6-7, 8-9 and >9 months postpartum) with the objective of avoiding the possible distorting effect of stage of lactation considered as a whole. The number of test day observations for each lactation period was 78,467, 203,382, 182,358, 143,326, 92,981, and 57,868, respectively. Initially, the number of levels elected within the month of lactation effect was higher, one per each month of lactation, but finally this number was reduced to 6 in order to simplify the study.

Milk incomes per goat and day were finally calculated according to regional prevailing price system, the basic price being 9.65€ × (fat +protein contents) per 100 liters of milk. On this floor price penalties of 1.80€ per 100 liters were applied for SCC between 1200 x 10^3 and 2000 x 10^3 cells/ml and penalties of 4.20€ per 100 liters for SCC >2000 x 10^3 cells/ml, respectively.

This research was carried out in accordance with EU Directive 2010/63/EU for animal experiments.

Results

The statistics of test day variables studied in Murciano-Granadina goats are shown in Table 1. Coefficients of variation was highest for milk yield and lowest for log SCC, and fat content evidenced a higher variability than protein content, as expected. Averaged duration of lactation in the present study was 224 ± 96.3 days.

Variables	Mean	SD	Minimum	Maximum	CV,%
$\log_{10}$ SCC	5.780	0.547	3.301	7.575	9.46
Milk yield, L/d	2.042	0.959	0.210	9.940	47.00
Fat, %	5.375	1.269	2.010	9.990	23.61
Protein, %	3.676	0.547	2.010	6.990	14.89

Table 1: Descriptive statistics for test day milk variables studied in Murciano-Granadina goat between 2009 and 2014.

Table 2 shows the test of significance and variance explained by factors affecting SCC variation. Herd test date was the more important effect as it explained 15.53% of total variance. Parity and lactation stage were also very important factors influencing SCC variation. Milk yield, fat and protein contents studied as covariables were statistically significant (P<0.001); regression estimates were negative for milk yield (-0.121) and positive for contents (0.006 for fat content and 0.135 for protein content), as showed in Table 3. Therefore, as SCC increased, milk yield decreased and fat and protein increased; the gain being more pronounced for protein content that for fat content.

The analysis of variance for milk yield and contents is shown in Table 4. All studied effects contributed significantly to variation of the variables. In accordance with the variance explained by different effects, herd test date (22.22% to 42.26%) was the most important factor followed by month of lactation (4.61% to 16.13%), SCC level (1.61% to 4.41%), parity number (0.11% to 4.38%), season (0.18% to

2.38%), litter size (0.00 % to 3.96%), and year of kidding (0.03% to 1.18%).

Source of variation	df	F	Variance explained (%)
Cov. Milk yield	1	26615.60***	-
Cov. Fat content	1	96.19***	-
Cov. Protein content	1	8745.05***	-
Year of kidding	5	201.37***	0.28
Herd test date (year of kidding)	8072	24.87***	15.53
Season of kidding	1	1349.81***	1.67
Parity number	8	7196.65***	6.77
Month of lactation	9	882.84***	5.75
Litter size	1	1631.36***	1.61
Residual	750282	-	68.40
***P<0.001.			

Table 2: Test of significance of fixed effects of test-day $\log_{10}$ SCC and percentage of variance explained in the model.

The evolution of milk yield within different lactation categories (Figure 1) evidenced very significant milk yield losses as SCC level increased. Indeed, averaged losses for SCC levels 1000 x 10^3 cells/ml, 2000 x 10^3 cells/ml, 3000 x 10^3 cells/ml and >7000 x 10^3 cells/ml were 11.4%, 19.5%, 24.2% and 35.7%, respectively.

Covariable	Parameter in the model	Estimate	F
Milk yield	b_1	-0.121	163.14***
Fat content	b_2	0.006	9.81***
Protein content	b_3	0.135	93.51***
***P<0.001.			

Table 3: Estimate of regression of milk yield, fat and protein contents on $\log_{10}$ SCC.

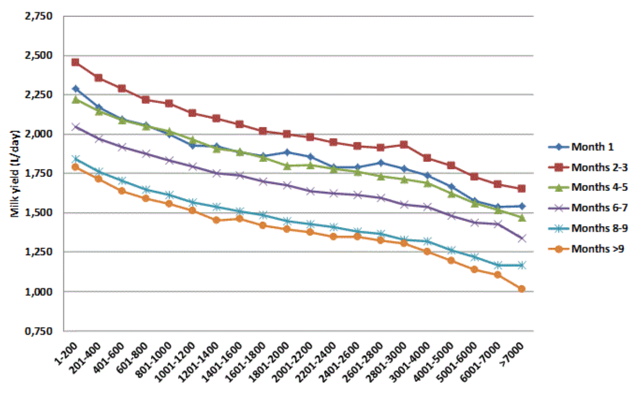

Figure 1: Evolution of test-day milk yield as SCC level (x10^3 cells/ml) increases within 6 lactation categories in Murciano-Granadina goats (SEM: 0.016).

Source of variation	df	Milk yield		Fat content		Protein content	
		F	%VE	F	%VE	F	%VE
Year of kidding	5	140.78***	1.06	25.07***	0.03	253.67***	1.18
Herd test date (year of kidding)	8072	44.70***	22.22	71.14***	42.26	47.52***	25.46
Season of kidding	3	265.77***	0.18	227.83***	1.82	634.03***	2.38
Parity number	8	5860.76***	4.38	11.23***	0.19	101.16***	0.11
Month of lactation	5	2429.80***	8.90	2637.49***	4.61	6530.64***	16.13
Litter size	1	4645.89***	3.96	371.93***	0.02	182.28***	0.00
SCC level	19	2359.53***	4.41	520.45***	1.61	1896.46***	3.35
Residual	750268	-	54.90	-	49.46	-	51.39
***P<0.001.							

Table 4: Test of significance and percentage of variance explained (VE) in the model for test-day milk yield, fat and protein contents affected by systematic factors of variation.

In contrast to what happened with milk yield, the evolution of fat and protein contents was always positive as SCC increased (Figures 2 and 3), and fat content (2.22%, 4.20%, 5.21%, and 10.28%) and protein content (1.68%, 3.57%, 5.34%, and 12.68%) experienced important percentage increases for the same above-mentioned SCC levels.

Depending on the results of the present research, the evolution of final milk income according the current price system, including prevailing penalties, was negative as SCC increased (Figure 4). The economic losses expressed in percentage were 9.55%, 17.88%, 23.86%, and 31.59%, respectively, for above-mentioned SCC levels.

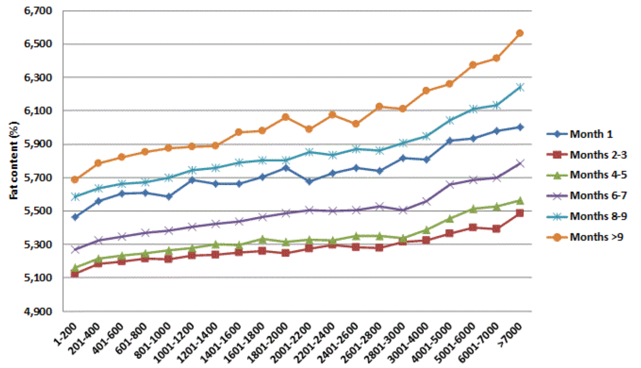

Figure 2: Evolution of test-day fat content as SCC level (x10^3 cells/ml) increases within 6 lactation categories in Murciano-Granadina goats (SEM: 0.024).

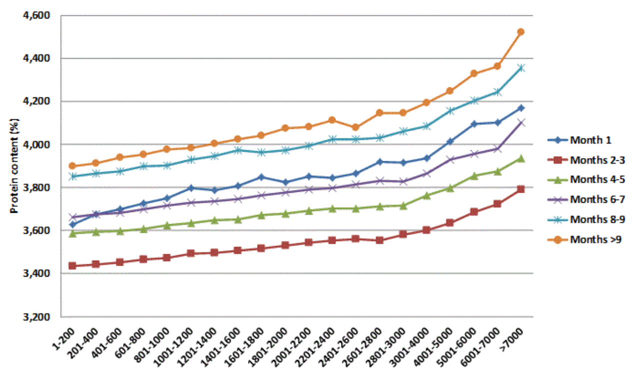

Figure 3: Evolution of test-day protein content as SCC level (x 10^3 cells/ml) increases within 6 lactation categories in Murciano-Granadina goats (SEM: 0.010).

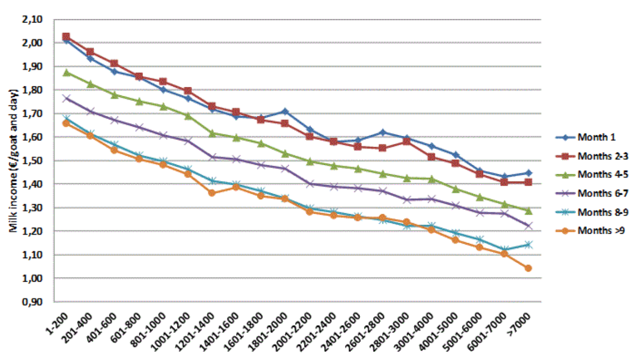

Figure 4: Evolution of milk income (euros per goat and day) as SCC level (x10^3 cells/ml) increases within 6 lactation categories in Murciano-Granadina goats (SEM: 0.015).

Discussion

Milk yield (2.04 L/day) and fat (5.37%) and protein (3.67%) contents are within the range of estimates recorded for the same breed [27] or American Nubian breed [6], but milk yield was smaller and the contents were higher than results found in Alpine and Saanen goats belonging to American Dairy Goat Association (U.S.A.) [6]. Logarithmic and geometric means for SCC (5.78$\log_{10}$ cells/ml and 602 x 10^3 cells/ml) were similar to SCC mean values reported in other studies [14] and breeds [4].

Results of both ANOVAs demonstrate the importance of herd-test-date factor as it is associated with the actual circumstances of the flock on the day of testing. Ptak and Schaeffer [28], in dairy cows, and El-Saied et al. [29], in dairy sheep, noted that adjustment for herd test date reduced the residual variance considerably, indicating the importance of taking into account effects specific to the day of test within each herd. Nevertheless, the main purpose of both ANOVAs was to study the significance of SCC and productive variables; the other factors of variation have been analyzed previously [4,6,19].

The important percentage losses estimated from test day milk yield for Murciano-Granadina goats, as SCC level increased, were similar than those reported by Baudry et al. [7] in 254 dairy goats flocks in France (7.9 to 16.9%) when milk yield of 3 SCC levels (< 750 x 10^3 cells/ml; between 750 x 10^3 and 1750 x 10^3 cells/ml; and >1750 x 10^3 cells/ml) were compared. It is important to note that a great SCC variability was found within the group of pathogens traditionally considered as major, responsible for mastitis in small ruminants [3]. In this sense, very high SCC (up to 7000 x 10^3 or higher) are not uncommon in the case of infections by *Pasteurella* spp., Str. *agalactiae*, or Staph. *aureus* [14].

Unlike the milk yield, fat and protein contents decreased as SCC level increased. According Raynal-Ljutovac et al. [14] it should be noted that a decrease of fat content during intramammary infection could seem logical considering the reduced synthetic and secretory capacity of the mammary gland. Nevertheless, no studies have rigorously evidenced this fact in goats. Therefore, fat content increase can be attributed to a concentration effect associated with the marked and progressive reduction in milk yield in infected goats as inflammatory response increased, compared with those uninfected ones. Indeed, a recent study in dairy goats [6] showed that high fat contents were accompanied by lower milk production capacity as SCC levels increased, according our results.

In the case of protein content, besides this concentration effect in milk volumes gradually decreasing because of growing inflammatory response, higher concentrations of blood protein in milk (IgG, whey protein and albumin) associated to mammary infection or SCC, seems well established in small ruminants [18,21,30,31]. Both effects, protein concentration in decreased milk yield and higher soluble protein concentration in milk, could explain the higher variation and regression slope found for protein content that for fat content (Table 3) as SCC increased. However, this higher protein percentage is not associated with a higher curd yield in cheese making, since only the casein concentration, and not soluble protein, is directly correlated to the cheese yield [31]. This is of interest because, in current price system of milk, bonuses are applied for total protein, not for casein content, causing an overestimation of milk final price. Globally, evolution of losses in milk incomes according the prevailing price system is showed in Figure 4.

These results showed the suitability of SCC as a valid tool for estimating the magnitude of yield and economic losses in dairy goats. These results emphasize the need for the establishment of prevention and control programs of subclinical mastitis based on SCC in dairy goats, as well as the appropriateness of test day recording scheme for this purpose.

Conclusions

As a whole the findings of the present study highlight the economic losses that can be attributed to intramammary infections evaluated by SCC in dairy goats. Thus, increased SCC was associated with reduced milk yield and increased fat and protein contents in comparison with goats harboring low SCC; the slope of regression between SCC and contents being lower for fat content. Evaluation of these yield and quality variations is of fundamental economic importance within the systems of quality payment for goat milk applied by processing companies. In conclusion, important milk income losses per goat and day (from 9.6% to 31.6%) were evidenced as SCC level increased above 1000 x 10^3 cells/ml. These results emphasize the validity of SCC test day recording as an important basis for subclinical mastitis control programs in dairy goat flocks.

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