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# RELATIONSHIP OF SOMATIC CELL COUNTS IN GOAT MILK TO MASTITIS AND PRODUCTIVITY

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## SUMMARY

This paper covers research since the Symposium on Somatic Cell Counts (SCC) at Bella, Italy, in 1994. The different testing procedures and equipment in use for SCC have variable applicability to goat milk, unless correction factors and calibration with goat milk are used. The method for arbitration is the pyronin Y-methyl green stain and the Direct Microscopic Somatic Cell Count (DMSCC). Culturing goat milk samples from commercial herds showed variation in SCC can be 90% due to non-infectious factors, and a correlation with standard plate counts (SPC) of bacteria was only r = 0.44. Among pathogens found in goat udders, *Staphylococcus aureus* caused higher levels of SCC than coagulase negative *staphylococci.*

Prevalence of pathogenic species varies between *S. aureus, S. epidermidis,* and coagulase negative staphylococci. Polymorphonuclear neutrophils predominate in goat milk and at higher levels than in cow milk under non-infectious conditions. Patho-histological sections of goat udders with high SCC showed absence of mastitic conditions in some cases. Healthy goat udders can have high SCC levels normally. Stage of lactation always elevates SCC. In contrast to cow milk tests, a single SCC test in goat milk has little value unless stage of lactation and parity is incorporated. Linear and curvilinear regressions have been calculated for the prediction of SCC vs. stage of lactation. Estrus can also elevate SCC. Goat milk samples before, during and after milking differ significantly in SCC. Hand milking may cause higher SCC than machine milking. More studies on the effects of SCC on productivity of goat milk, cheese and yoghurt yield are needed. Overall, the incidence of subclinical and clinical infections in goat udders is less than in cow udders, and there is less risk of antibiotic contamination. Different threshold levels have been proposed for SCC, but their predictive value of udder infections has been variable.

***Keywords: Goats, somatic cell count, non-pathological factors, mastitis***

## INTRODUCTION

Somatic cell counts (SCC) are widely used monitors of udder health and milk quality in the dairy cattle industry of many countries. Maximum SCC levels in milk are held as standards by health officials to assure quality supply from dairy farmers to consumers of milk and dairy products (Harmon, 1994). The allowable maximum levels of SCC have been lowered from 1.5 million a few years ago to 750,000/ml in USA, to 400,000 in many European countries, and soon also in USA (Slusser, 1999). The maximum level in goat milk has been exempted to remain at 1 million, at least in USA (Hinckley, 1990; Scruton *et al.*, 2000). Reasons were research documenting physiological differences in the process of milk secretion between dairy cows and dairy goats (Haenlein and Hinckley, 1995), further that these differences create a lack of justification for applying cow milk regulatory standards to goat milk, specifically for SCC, that present cow milk standards for SCC are discriminatory against goat milk, and that separate standards must be determined.

Commercial goat milk production for fluid milk sales or processing into yoghurt, cheese and other products is subject to local and federal health regulations, which have been using dairy cow milk standards (Harding, 1995). Research on SCC in cow milk has been extensive and has concluded that except for normal diurnal variation few factors other than infection status have a significant impact on cow milk SCC (Harmon, 1994), but research in goat milk is still needed (Randy *et al.*, 1990; Atherton, 1992), especially for the establishment of goat milk standards (Hinckley, 1990; Cremoux, 1998; Baudry and Mercier, 1998; Toussant, 1998; Kapture, 1985; 1991).

Goat milk production and processing worldwide is about 2 % of total milk production from all recorded animals (FAO, 1998), but it is of major economic importance in some countries, especially the Mediterranean area (18%) with about 2 million tons (Haenlein, 1996). Adding sheep milk, the economic significance of small ruminant milk production is more than 18 million tons worldwide, with more than 30% in Somalia, Greece, Bangladesh, Iraq, Iran, Afghanistan, Syria, Indonesia, Algeria, Sudan of all milk

produced, thus of great value for protein and calcium supplies to people, avoiding malnutrition and undernutrition, and supporting farmers in desert and mountain areas, where cattle and buffaloes can not survive (Haenlein, 1998). During the last 15 years, the total goat population worldwide has increased from 469 to 703 million head (150%) (FAO, 1998) and their milk production from 7 to 11 million tons (147%).

The objectives of this paper are to discuss studies on SCC in goat milk since the International Symposium on Somatic Cells and Milk of Small Ruminants (Rubino, 1996), and to assess the extend of variation due to non-veterinary factors, the implications for goat and sheep farmers, for health regulation officials, and to aid in establishing a valid goat milk standard, which is applicable every month of the year. This topic has been presented in part also at the Jordan 1st International Conference on Sheep and Goat Diseases and Productivity (Haenlein, 1999).

## 2. Testing procedures

To establish normal SCC values for goat milk, the standards for normal cow milk have been found inappropriate (Maisi, 1990a; Atherton, 1992). There are many cytoplasmic particles normally in goat milk due to the apocrine type of milk secretion, while in the cow udder it is merocrine. These cytoplasmic particles contain no DNA, are in the size-range of somatic cells or leukocytes in goat milk, and are mistakenly counted as somatic cells, when particle counting methods are used. SCC in cow milk is indicative of, although less than equal, the number of leukocytes in milk, which increase in numbers with mastitic conditions. Goat milk, in contrast, contains many non-leukocyte cytoplasmic particles normally, that have nothing to do with mastitic conditions. Only methods, which identify DNA can give reliable estimates of leukocytes and mastitis in goat milk, and only they are to be used for determining SCC in goat milk and for legal standards (Maisi, 1990a, 1990b; Poutrel and Lerondelle, 1983; Lerondelle and Poutrel, 1984; Zeng *et al.*, 1999).

There are several methods and equipment for testing SCC, the quick California Mastitis Test (CMT), electronic machines like the Coulter Counter, the Fossomatic, and then procedures for testing DNA specifically, the pyronin Y-methyl green stain, NAGase, and the Direct Microscopic SCC (DMSCC), besides antitrypsin and ATP (Vihan, 1989; Poutrel and Lerondelle, 1983; Emanuelson *et al.*, 1988; Maisi, 1990a; 1990b; Kapture, 1991; Haenlein, 1995; Contreras *et al.*, 1996; Zeng *et al.*, 1999; Scruton *et al.*, 2000). CMT levels in goat milk can correspond well with levels in cow milk, but NAGase and antitrypsin values have differed (Maisi, 1990a). CMT levels in goat milk identified infected udder halves, while NAGase and antitrypsin differed depending on stage of lactation and type of infection. CMT gave the lowest (18%) overall false prediction of presence or absence of mammary infection, NAGase 31% and antitrypsin 40%.

Normal goat milk (219 samples) (Poutrel and Lerondelle, 1983) had 58% negative CMT scores, but there were 26% CMT-1, 11% CMT-2, and 5% CMT-3, despite being bacteriologically negative. Coulter Counter tests for these normal negative goat milk samples were 1.4 million SCC (standard error 1.6 million) and with the Fossomatic 614,000 (standard error 692,000). The use of the Coulter Counter has been considered inappropriate for goat milk without using a correction factor. For the detection of subclinical and clinical mastitis the three methods gave variable results, and the conclusion was, that prediction of udder infection in goats by SCC is unreliable, unless the pyronin Y-methyl green stain and DMSCC is used for confirmation (Zeng *et al.*, 1999; Scruton *et al.*, 2000).

Unreliability of electronic machine SCC is especially true when there is no goat milk calibration (Zeng *et al.*, 1999). Fossomatic and pyronin green stain tests gave comparable results, when the Fossomatic was calibrated with goat milk. When the Fossomatic used cow milk calibration, the SCC of goat milks were too high by 24%.

SCC in goat milk could vary due to handling, shipment time, storing and different laboratories, but using the pyronin green stain method no differences were found after 3 days shipment in an icebox, storing in a refrigerator for 3 days, or between different laboratories (Zeng *et al.*, 1999; Clarke *et al.*, 1996). Instantaneous milk quality testing using electrical conductivity has much interest, but no significant correlations between SCC and electrical conductivity in Alpine and Nubian milk has been found (Park, 1991). Culturing milk for pathogen identification monthly in 380 Alpine goats (Wilson *et al.*, 1995) showed more than 90% of the differences in SCC were not due to intramammary infections. Positive culture results, increased days in milk, decreased milk yield, higher lactation number, and winter months (equal to late lactation) as variables explained 23% of the total variation in SCC. Linear logarithmic scores for SCC of all culture positive samples were 4.9 (373,000) during the 1st month of lactation and 6.0 (800,000) during the 9th month; all negative samples 4.6 (303,000) during the 1st month and 5.7 (650,000) during the 9th month.

Testing goat milk for standard plate counts (SPC) of bacteria besides SCC (Zeng and Escobar, 1995), showed high quality averaging 95,000 colony forming units (cfu)/ml ($\log_{10}$ 3.98, range 2.00 -

5.6), well below the regulatory limits of 100,000. SCC were correlated with SPC only at r = 0.44. In other studies, SCC were not significantly correlated to total bacterial cell count in goat milk (r = - 0.036), coliform counts (r = - 0.167), or staphylococcus counts (r = 0.168), and thus could not explain high SCC (Park *et al.*, 1986).

**3. Relationship to mastitis**

In Greek goats throughout lactation, *Streptococci* infections were rare, in contrast to dairy cows (Kalogridou-Vassiliadou, 1991). Mastitis-related pathogens were present in normal goat milk, 59% *Staphylococci* (*S. aureus* 17%, S.epidermidis 14%, *S.capitis* 13%, *S.hyicus* 11%), 30% *Bacilli*, 4% Coliform, 3% *Micrococci*, 2% *Streptococci*, 1% *Corynebacteria*, 1% *Pseudomonas*. In French goats, 2% of udder halves were infected by S. aureus, 23% by coagulase negative *Staphylococci*, but 75% were not infected (Lerondelle *et al.* 1992). Infection by *S. aureus* caused high somatic cell levels at 7.9 million, while coagulase negative *Staphylococci* had 1.0 million and non-infected udder halves 520,000 cells/ml by the Fossomatic test. There were no differences between infected and non-infected udder halves in somatic cell counts, but this differs with other studies (Dulin *et al.*, 1983; Lerondelle and Poutrel, 1984).

In Spanish Murciano-Granadina goats (Contreras *et al.*,1996), the prevalent pathogens were 70% coagulase negative *Staphylococci*, 1% coagulase positive *Staphylococci*, 12% *Corynebacteria*, 9% *Mycoplasma*, 8% *Enterobacteria, Pasteurella, Streptococci*, and yeast. Similar results were reported for goats in Taiwan (Sung *et al.*, 1999) and India (Vihan, 1989). SCC were related to CMT scores at r = 0.65, and to lactose contents at r = - 0.53. In US goats (Contreras *et al.*, 1999), most pathogens were *Staphylococci* (96%), and *S. epidermidis* was predominant (67%). Somatic cell counts were higher in milk from udder halves with subclinical infection of *S. epidermidis* (1.8 million) than in milk with other *Staphylococci* infections (1.6 million). Caprine arthritis encephalitis (CAE) virus has been related to mastitis but SCC have been variable (Hinckley, 1990; Lerondelle *et al.*, 1992; Nord and Adnoy, 1997).

Somatic cells in goat milk, aside of the cytoplasmic particles, are composed of different types of leukocytes (Dulin *et al.*, 1982), with a distribution in one study of 87% neutrophils, 9.9% macrophages, 2.8% lymphocytes, averaging 1.3 million SCC (Droke *et al.*, 1993). Neutrophil range was 40 – 79% in uninfected udder halves, macrophages 15 - 38%. Relative changes in leukocyte types have been correlated with SCC and prediction equations calculated (Rota *et al.*, 1993a,b). High percentages of polymorphonuclear neutrophils were found in goat milk with low SCC (<500,000), but they increased with stage of lactation and age, while lymphocytes and macrophages decreased.

Histological and pathological tests on fresh udder half tissues of goats with low (950,000), medium (1.5 million) and high (3.3 million) SCC revealed no changes in the mammary glands or other mastitic evidence (Zeng and Escobar, 1995), indicating that healthy dairy goats with healthy udders may produce milk with > 1 million SCC, particularly in late stage of lactation.

**4. Non-pathological factors**

**4.1. Days in lactation**

Dairy goat reproduction in many countries is seasonal (Haenlein and Hinckley, 1995), which is different from dairy cattle management. Goat farm tank milk composition differs towards late lactation. A rise in SCC in late lactation is a physiological fact independent of any infection in the udder (Emanuelson *et al.*, 1988). In Spanish Verata goats free from mastitis it was found that DMSCC were at the beginning of lactation 920,000, during the middle 580,000, and at the end 1.8 million (Rota *et al.*, 1993b). Similar and often much wider differences have been reported by others (Dulin *et al.*, 1983; Maisi, 1990a; Kalogridou-Vassiliadou *et al.*, 1992; Droke *et al.*, 1993; Rota *et al.*, 1993a; Wilson *et al.*, 1995; Zeng and Escobar, 1995; 1996; Galina *et al.*, 1996; Zeng *et al.*, 1997), concluding that single SCC of goat milk have little value, unless stage of lactation and parity are incorporated (Rota *et al.*, 1993b).

Regression equations according to the incomplete gamma function of Wood ($Y[n] = A[n^b \times e^{cn}]$) were calculated for stage of lactation against SCC (Rota *et al.*, 1993b), where Y(n) is SCC on the nth test day, A is a scaling factor at the start of lactation, b and c are coefficients of shape as parameters of the curve, e is the base of natural logarithm, and – b/c is the day of minimum SCC. These should be useful for health officials.

Data from a large population (n = 2,276 – 3,978) of U.S. dairy goats on official monthly record keeping program (DHIA) also showed the seasonal nature of SCC (Haenlein and Hinckley, 1995). Similar data from dairy goat record keeping programs in France have shown seasonal variations in SCC from 1 to 2 million (Cremoux, 1998). A linear regression for US dairy goats (Haenlein and Hinckley, 1995; Haenlein, unpublished data, 1999) can estimate SCC depending on days in milk: $Y (SCC \times 10^3) = 283.5 + 3.026X$ (days in milk); standard error of Y = 129.5; standard error of X = 0.485; $r^2 = 0.64$.

### 4.2. Estrus

Experimental studies with injections of estrogens into dairy cows have shown that SCC will increase during estrus independent of changes in milk yield (Haenlein and Krauss, 1974). This has also been observed by goat farmers and veterinarians (Wilson *et al.*, 1995), but has not been studied much in goats (Rubino, 1996). Aleandri *et al.* (1994) reported increased SCC by 300,000 in Saanen and Alpine mastitis-free goats, and by 233,000, when bucks were introduced and estrus began. Estrus in goats can coincide with late lactation and explain in part SCC increases unrelated to mammary infections.

### 4.3. Before, during and after milking

Goat milk samples taken before, during and after milking by stripping showed significant differences (Haenlein, unpublished data 1999) This is indicative of the many factors impacting SCC in milk other than pathogenic factors.

### 4.4 Handmilking

In a comparative study of goats milked by hand or machine (portable buckets or a pipeline system) the overall mean SCC was $\log_{10}$ = 5.97 (930,000) with levels for hand milking = 6.01, buckets = 5.97 and pipeline = 5.94, which were not different statistically (Zeng and Escobar, 1996). However, standard plate counts of bacteria (cfu/ml) differed significantly, lowest for bucket milking ($\log_{10}$ = 2.44), intermediate for pipeline (2.97) and highest for hand milking (3.62), and were correlated with SCC insignificantly at r = 0.14 (n = 313).

In a study at the University of Delaware (Haenlein, unpublished data 1999) with 11 Alpine goats in late lactation for 6 test days no conclusive difference in SCC for hand vs. bucket machine milking could be established, although some individual goats (5/11) had higher levels during hand milking (range 177,000 – 1,398,000) than when the same goats were milked by machine (range 78,000 – 1,637,000).

### 4.4. Age

It has been shown that average SCC in goat milk are significantly affected by parity (Maisi, 1990a; Wilson *et al.*, 1995; Contreras *et al.*, 1999). Polymorphonuclear neutrophils increased from 52% in the 1st lactation to 69% in the 4th lactation, while macrophages decreased from 20% to 14%, lymphocytes from 12% to 5%, and degenerated cells from 16% to 13% (Rota *et al.*, 1993a). Average SCC in milk from 100 Verata goats free from clinical mastitis increased from 1st (1.3 million) to 4th lactation (2.0 million) in Spanish Verata goats (Rota *et al.*, 1993b), and from 942,000 in 1st to 1.6 million in 2nd, and 2.2 million in 3rd and greater lactations in 138 US dairy goats (Contreras *et al.*, 1999).

## 5. Stress

Among other factors affecting SCC, alimentary stress such as acidosis and the consequences of high grain feeding have been found to increase SCC in goat milk and must be taken into consideration before using SCC as diagnostic test of mammary infections (Lerondelle *et al.*, 1992). Vaccination also increased SCC.

## 6. Relationship to productivity

A few studies have found decreases in goat milk production due to increased SCC, but data were confounded with advancing stage of lactation or cases of mastitic infection (Zeng and Escobar, 1995; Zeng *et al.*, 1997). Cheese production yield of the soft chevre type was not correlated with SCC in goat milk, although yield ranged from 7.2 kg milk/kg cheese for goat milk with > 1 million SCC vs. 7.7 kg for milk with < 250,000 (r = -0.25) (Galina *et al.*, 1996). CMT scores were correlated to cheese yield at r = - 0.32.

Productivity losses in dairy cow herds due to mastitis have been reported to exceed $ 2 billion/year in the USA (Harmon, 1994) and are related to SCC to 0% at 200,000, 6% at 500,000, 18% at 1 million and 29% at 1.5 million in bulk tank samples from analyses of large data sets of monthly dairy herd record keeping (DHIA). Similar analyses for dairy goats on DHIA have so far not shown conclusive trends of productivity losses (Haenlein and Hinckley, 1995), possibly due to the confounding with stage of lactation and the dominance of seasonal breeding of goats.

## 7. Comparison to sheep and cow milk

Prevalence of subclinical infections in goat udders were found to be less than expected in cow udders under similar hygienic conditions (Poutrel and Lerondelle, 1983; Fox *et al.*, 1992). However, goat milk from infected udder halves had a much higher level of SCC than expected, suggesting that the goat udder response to infection as measured by SCC is greater than that of the cow. Composition of SCC in milk differs between goats and cows (Contreras *et al.*, 1997). For animals free of intramammary infection,

neutrophils constitute 45 – 74% of the somatic cells in goat milk but only 5 – 20% in cow milk, which means that neutrophil migration into goat milk is faster than in cow milk and may contribute to higher SCC. The yearly incidence of clinical mastitis over a 10 year period averaged 0.5% in 138 goats (Contreras *et al.*, 1997), suggesting that the high number of neutrophils in goat milk is protection against clinical mastitis. In comparison, in a herd of 100 dairy cows the incidence of clinical mastitis would be 82 cases/year, and the risk from antibiotic contamination because of treatment for mastitis would be much greater in a cow herd than in a goat herd .

In contrast to dairy cows, it has been found that in dairy goats new infection rates after kidding due to coagulase negative *staphylococci* were low, regardless of drying-off antibiotic treatment or not (Fox *et al.*, 1992). This suggested that only selective dry-off treatment of udder halves should be practiced, if infected glands can be correctly identified. Since somatic cell counting as a diagnostic tool is not accurate, bacteriological culturing instead is proposed.

SCC in sheep milk varied between 600,000 and 800,000 in two French populations, depending on stage of lactation (Cremoux, 1998). In Cyprus (1,066 Chios ewes), the incidence of clinical mastitis was 1% (Mavrogenis *et al.*, 1995). The major pathogens were coagulase positive and negative *staphylococci*, lead by *Staphylococcus aureus*. Mean SCC for non-infected sheep milk samples were 1.6 million, while all mastitis positive samples were in excess of 2 million/ml. When SCC increased by 500,000/ml, individual sheep milk productivity 18 g/day (r = -0.33).

In Greek dairy sheep, milk yield decreased 55% during experimental subclinical mastitis with *S. epidermidis* (Saratsis *et al.*, 1999). In 22 Spanish dairy sheep flocks the prevalence of subclinical mastitis based on CMT scores was greater for hand milking (42%) than for machine milking (26%) (Las Heras et el., 1999). In Greek sheep (Fthenakis, 1996), milk samples in the evening had 40% higher SCC than those in the morning. Also increased SCC with advanced lactation were reported. It was concluded that 1 million could be the upper limit for SCC in milk from healthy ewes and that non-pathological factors affect SCC. In Spanish Churra ewes, Fossomatic SCC averaged 3.3 million for hand milked and 1.2 million for machine milked ewes (Fuente, *et al.*, 1997). Morning milk samples averaged 1.9 million and evening samples 2.9 million, partly due to lower milk yield at the p.m. milking.

**8. Legal standards**

For goat milk samples, which were negative on CMT the average SCC by Coulter Counter was 786,000 (standard deviation 552,000) and by Fossomatic 320,000 (standard deviation 273,000). It has been suggested that average somatic cell counts of 1 million by Coulter Counter or Fossomatic could be satisfactory legal threshholds (Poutrel and Lerondelle, 1983), although this would only detect 80% of infections, and Coulter Counter values would be twice as high as Fossomatic. Correlations of r = 0.74 between Coulter Counter and Fossomatic, of r = 0.65 between CMT and Coulter Counter, and of r = 0.71 between CMT and Fossomatic have been reported (Poutrel and Lerondelle, 1983; Kalogridou-Vassiliadou *et al.*, 1992).

For diagnostic relationships between SCC, CMT and subclinical mastitis an optimal CMT score was 0+1 combined (Contreras *et al.*, 1996) for detecting uninfected glands (73%). This agrees also with French studies (Perrin *et al.*, 1997).

It is necessary to distinguish between physiological and pathological factors affecting SCC in goat milk (Poutrel and Lerondelle, 1983). Without including stage of lactation and probably parity, it will not be possible to define standards for SCC by any method correctly. A mathematical determination of normal lactation curves for SCC in goat milk (Rota *et al.*, 1993b), should help towards formulating acceptable standards. Using between 2,276 and 3,978 monthly SCC tests from individual US goats and starting a linear regression on day 90 in lactation, when the initial rise had returned to low levels, it was calculated that for every day advancing in lactation (X) the SCC (x1,000) increased by 3.026 units in average (Y = 283.5 + 3.026X) (Haenlein, unpublished data 1999). This translates into a series of threshold values, which can be proposed for use in formulating standards: 556, 647, 737, 828, 919, 1010, 1100, 1206 SCC(x1,000) for 90, 120, 150, 180, 210, 2540, 270, 305 days in milk (X), respectively. For the establishment of goat milk standards it has been shown that calibration of testing instruments and procedures with goat milk, rather than the usual cow milk is essential for correct results (Zeng, 1996). SCC in goat milk tested by the Fossomatic machine were 27% lower (550,000) when the machine was calibrated with goat milk standards than when cow milk standards were used for calibration (700,000). At the same time, fat and protein % were undereported by 0.04 and 0.27%, respectively.

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