Genetic Parameters and Economic Values of Lactation Somatic Cell Score and Production Traits

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Abstract

Heritabities and genetic and phenotypic correlations for lactation somatic cell score (LSCS) and production traits in first lactation were estimated. Heritability of LSCS was 0.13. Genetic correlations between LSCS, milk, fat and protein yield were positive (0.14 to 0.16). With fat and protein percentage, LSCS showed negative negligible correlations (-0.01 and -0.02, respectively).

Two methods were defined to express LSCS costs. The first method used a non-linear function of the penalty applied in the milk price with respect to LSCS to define the LSCS costs, the second defined the LSCS costs as the sum of frequency of each LSCS class multiplied by its penalty. Economic value of LSCS in the basic situation was -0.783 and -0.540 ptas.score^{-1}.Kg. of milk^{-1}.cow^{-1}.year^{-1} with the first and the second method, respectively. Economic values of production traits were estimated under free market and quota situation, considering the two methods to define LSCS costs.

Results showed that LSCS economic value with the second method was more reasonable and less sensitive to LSCS farm level.

1. Introduction

Mastitis causes important economic losses in dairy herds. The losses are associated with cost of veterinary treatments, losses in production, increased labour and replacement costs. In addition, mastitis infection increases the level of somatic cells leading to reduce income, and as in many countries payment systems for milk include penalties on (too) high levels of somatic cells. Research related to a reduction of mastitis incidence through selection has concentrated on the use of somatic cell count (SCC), at is widely recorded in many countries as part of the milk recording routine in dairy herd improvement programmes. As indicator of both clinical and subclinical mastitis, somatic cell count has several advantages. SCC is easily and cheaply recorded. It is measured on a continuous scale and rather normally distributed once the values have been log-transformed. Estimates of Heritabilities of somatic cells ranged from .05 to .29 with a tendency to increase with parity (Schutz et al. 1990). Several studies (Monardes and Hayes (1985), Schutz et al. (1990), Zhang et al. (1994)) have reported positive genetic correlations between somatic cell score (SCS) and milk yield traits for first lactation data.

Only few studies (Weller et al., 1996) have derived economic values for SCS based on its relationship to price payment systems. However, economic value for SCS is needed to determine the optimal emphasis on SCS trait in selection relative to other traits and to quantify economic benefits from consideration of SCS in breeding programs. Weller et al. (1996) derived economic values for somatic cell score under economic circumstances in Israel. They defined a non-linear function for the milk price differential with respect to the SCS according to the payment scheme of milk for somatic cell concentration.

In Spain, evaluations for SCS are planned to be included in the genetic evaluation procedures soon. However, little it is known about relationships between somatic cell score and other traits like production , type and longevity traits in the Spanish Friesian population cows.

This study aims at, first, exploring genetic relationships between somatic cell score and production traits by estimating variance components, heritabilities and genetic correlations for first lactation somatic cell score (LSCS), 305-days first lactation milk, protein and fat yield and protein and fat content and, second, developing a procedure to derive economic value of somatic cell score based on its relationship to milk price and to derive economic values of production traits.

2. Materials and Methods

2.1. Genetic parameters

Test day somatic cell counts for 166,308 Holstein-Friesian cows calving between 1984 and 1995 were obtained from local Friesian Associations of 4 regions in the North of Spain (Galicia, Cantabria, Basque Country and Navarre). Only records from first parity with at least 1 test-day observation in the first 65 days and at least 5 tests in 305 d. were kept. Additional observations were eliminated if age at calving was missing, or if lactation was shorter than 230d.

Records for production traits (milk, fat and protein yield at 305 d. and fat and protein content) were obtained from the Spanish Friesian Association (CONAFE).

Contemporary groups (herd-year) of at least 5 cows were required. Finally, 44,882 first lactation cows from 782 herds were used to estimate genetic parameters for somatic cell score and production traits.

Somatic cell score (SCS) was defined as :

$$SCS = \log_2\left[\frac{SCC}{100,000}\right] + 3$$

(Schutz and Powell, 1993)

Least squares solutions for calendar month of test, stage of lactation and test-day milk were used as additive correction factors for preadjustment of test day SCS records. LSCS, a lactation measure of SCS was defined as the mean SCS of all adjusted test day records during the 305 first days of lactation (Banos and Shook, 1990 and Zhang et al. 1994).

Genetic parameters were estimated using a multiple trait animal model with REML-EM algorithm applying the same design matrix for all traits analysed (Misztal, 1992). The model included herd-year of calving, age at first calving in months, month of first calving, animal and residual effects.

2.2. Economic values

Profit or efficiency equation was used to derive economic values by partial differentiation to production and somatic cell score traits.

Total annual profitability of a dairy herd (T) is described by the following equation:

$$T_{(ptas.herd^{-1}.year^{-1})} = N(R - C) - c_f \qquad (1)$$

where,

N :	Number of present lactating cows (Cow.herd^{-1}).
R and C :	Average revenues and costs during a lactation per cow (ptas.cow^{-1}.year^{-1}), respectively.
c_f :	Fixed costs of farm (ptas.herd^{-1}.year^{-1})

Average revenues per cow per year were written as :

$$R = (p_m - C_{LSCS}).M + (p_f - C_{LSCS}).F + (p_p - C_{LSCS}).P + (p_{cc}.W_{cc})(1/L - \%Mt_c) + (p_{nb}.BW)(\%CP(1 - \%Mt_{cf}))$$

where,

M, F, P :	annual production of milk carrier, fat and protein (Kg.cow^{-1}.year^{-1})
p_m ,p_f , p_p :	basic price per unit of milk carrier, fat and protein (ptas.Kg^{-1})
C_{LSCS} :	costs associated with the lactation somatic cell score (ptas.Kg^{-1})
p_{cc} :	price of culled cow (ptas. Kg of live weight^{-1})
W_{cc} :	life weight of culled cow (Kg.cow^{-1})
L :	length of productive life (years)
$\%Mt_c$:	mortality of cows
p_{nb} :	price of new born calves (ptas.Kg.$^{-1}$)
BW :	birth weight calves (Kg.calf^{-1})
$\%CP$:	fraction of cows calved per year is equal to 365d/calving interval (calving.cow^{-1}.year^{-1})
$\%Mt_{cf}$:	mortality of calves.

Average costs per cow per year were described by :

$$C = c_m.M + c_f.F + c_p.P + C(E_M) + C(E_{Gest}) + C(E_{gth}) + Fc_a + (1/L+\%Mt_h).CH$$

where,

c_m, c_f and c_p : feed cost per unit of milk carrier, fat and protein, respectively (ptas.Kg^{-1}).
$C(E_M)$, $C(E_{Gest})$ and $C(E_{gth})$: annual maintenance, gestation and growth energy costs of a cow (ptas.cow^{-1}.year^{-1}), respectively.
Fc_a : fixed costs per milking cow (include costs of labour, veterinary applications, medicines, artificial insemination, semen and other costs) (ptas.cow^{-1}.year^{-1}).
CH : rearing costs per heifer (ptas.heifer^{-1}).
$\%Mt_h$:mortality of heifers (between the first week of life and the first calving).

Economic values of production traits on herd level were calculated in situation of free market and under a multiple quota system introduced in EU. The multiple quota system restricts the milk production and fat content at the herd level. The milk quota at herd level was defined as milk at the reference fat content. It was determined by :

$$Q = N \cdot \left[milk \cdot \left(1+q_{fc} \cdot (fc-fc_r)\right)\right]$$

Q : *milk quota with fat content at reference level*
N : *Number of average present lactating cows*
q_{fc} : *penalty factor in milk output (=18)*
fc, fc_r: fat content and fat content at reference level.

A deviation of the fat content from the reference content introduced a scaling of the milk quota. Under quota, a change in milk production traits affect the number of cows.

Economic values of production traits in situation without quota were calculated by the following expression:

$$\frac{1}{N} \bullet \frac{\partial T}{\partial x_i} = \frac{\partial R}{\partial x_i} \frac{\partial C}{\partial x_i}$$

Under quota situation, economic values of production traits were expressed by:

$$\frac{1}{N} \bullet \frac{\partial T}{\partial x_i} = \frac{\partial R}{\partial x_i} \frac{\partial C}{\partial x_i} \frac{1}{N} \bullet \frac{\partial N}{\partial x_i} CDOTT_a$$

T_a = R - C :is the average annual profit per cow.

Costs associated with the level of lactation somatic cell score results from the penalty applied in the milk price according to the payment scheme for somatic cell count level in Spain. The actual payment system gives discontinuous penalty in the price of milk for five classes of somatic cell count level. Table1 gives frequencies and amount of penalty of each LSCS class.

Table 1. Frequency distribution of lactation somatic cell score and penalty applied for each class of SCC.

SCC	LSCS class	Frequency	Penalty (ptas. Kg^{-1})
400,000	< 5	63.4	0
400,000 - 600,000	5 - 5.585	17.8	2
600,000 - 800,000	5.585 - 6	7.7	3
800,000 - 1000,000	6 - 6.322	2.9	4
1000,000	> 6.322	8.2	5

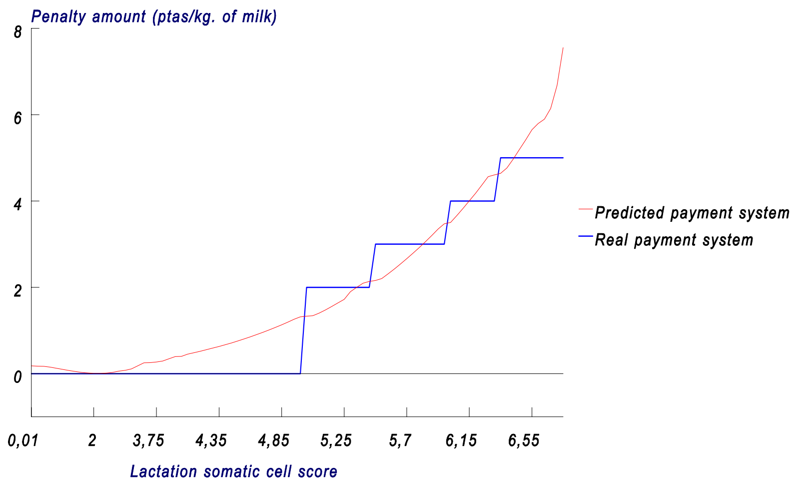
Two methods were defined to express LSCS costs from the discontinued penalty system of the milk, following the level of somatic cell concentration.

The first way (Method1) is similar to Weller et al. (1996), according to the payment scheme for SCC, the penalty applied in the milk price was defined as a non-linear function with respect to LSCS. Using a regression procedure of SAS (SAS, 1995), the following expression of C_{LSCS} in function of the lactation somatic cell score was obtained:

$$C_{LSCS} = 0.1 - 0.166 \cdot LSCS - 0.020 \cdot LSCS^{2} + 0.080 \cdot [2^{LSCS}]$$

The R-square of the model is equal to 0.83. Figure 1 illustrates the actual and predicted, by the non-linear function, penalty applied for the milk price in function of the lactation somatic cell score level.

PeFig 1: Pe Fig. 1. Penalty on milk price as a function of LSCS level



The economic value with Method1 is given by the following expression:

$$a_{LSCS} = -[-0.166-0.04 \cdot LSCS+0.08 \cdot (2^{LSCS}) \cdot L(2)]$$

Method2 follows a methodology used by Meijering (1986), Bekman and Van Arendonk (1993) and Dekkers (1994) to derive economic values of dystocia. Costs of somatic cell score were defined as the sum of the frequency of each LSCS class multiplied by its penalty (Table 1). LSCS economic value was defined by determining the effect of an increase in the LSCS herd level on the proportion of cows producing milk in each LSCS class.

Let P_i be the penalty associated with a LSCS in class i , p_i the frequency of LSCS class i and t_i the threshold that separates LSCS class i from class i + 1 .

Let μ and σ be the average and standard deviation of LSCS.

Costs associated with mean and distribution of LSCS (C_{LSCS}) were calculated from:

$$C_{LSCS} = \left[\Phi\frac{(t_1-\mu)}{\sigma}\right]\cdot P_1 + \left[\Phi\frac{(t_2-\mu}{\sigma} - \Phi\frac{(t_1-\mu)}{\sigma}\right]\cdot P_2 + \left[\Phi\frac{(t_3-\mu)}{\sigma} - \Phi\frac{(t_2-\mu)}{\sigma}\right]\cdot P_3 + \left[\Phi\frac{(t_4-\mu)}{\sigma} - \Phi\frac{(t_3-\mu)}{\sigma}\right]\cdot P_4 + \left[1-\Phi\frac{(t_4-\mu)}{\sigma}\right]\cdot P_5$$

where,

φ (t) : is the cumulative standard normal distribution function.

$\frac{t_i \mu}{\sigma}$: distance between LSCS mean (μ) and fixed threshold t_i in units of standard normal LSCS scale.
P_1, P_2, P_3, P_4 *and* P_5 are penalties of each class of LSCS (ptas.Kg^{-1}).

The incidence of classes is given by

$$\Phi\left(\frac{t_i \mu}{\sigma}\right)\Phi\left(\frac{t_{i1} \mu}{\sigma}\right),$$

which is equal to the area between thresholds t_i and t_{i-1} under the standard normal distribution function.

The economic value of LSCS with Method2 is equal to :

$$a_{LSCS} = -1/\sigma \cdot \begin{bmatrix} (P_2 - P_1)\cdot\Phi\left(\frac{t_1-\mu)}{\sigma}\right) + (P_3 - P_2)\cdot\Phi\left(\frac{t_2-\mu)}{\sigma}\right) + \\ (P_4 - P_3)\cdot\Phi\left(\frac{t_3-\mu)}{\sigma}\right) + (P_5 - P_4)\cdot\Phi\left(\frac{t_4-\mu)}{\sigma}\right) \end{bmatrix}$$

where:

φ(t) :the standard normal density function.

Parameters in the basic situation:

Prices and production level parameters used in the basic situation were given by the analysis of economic data of 239 dairy farms in the Basque country between 1993 and 1995. Average milk production cows was 7350 Kg. with 3.8 % fat, 3.0 % protein and 4.34 of LSCS.

3. Results and Discussion

3.1. Genetic parameters

Heritabilities, genetic and phenotypic correlations for LSCS and production traits are in Table 2.

Heritability of LSCS is 0.13, this value is in the range of previous estimates (Schutz et al. (1990), Boettcher et al. (1992), Lund et al. (1994) and Rogers et al. (1995)).

Genetic correlations between LSCS, milk, fat and protein yield were positive (0.14 to 0.16). LSCS showed negative negligible correlations with fat and protein percentage, -0.01 and -0.02, respectively. In the literature, genetic correlations between LSCS and yield traits tend to be positive for first lactations but declined for later lactations. With milk composition traits, correlations are small, negative for fat percent and positive for protein percent (Monardes & Hayes, 1985, Banos & Shook, 1990 and Schutz et al. 1990). Although small, the positive genetic correlations with yield traits suggest some genetic antagonism between desired increased milk yield and reduced somatic cell count level.

Phenotypic correlation between LSCS and production traits were low and negative, except with protein content, which a had a low positive correlation. Estimates are in agreement with results of Schutz et al. (1990) and Boettcher et al. (1992). It seems that cows with mastitis, and therefore high LSCS, were likely to have depressed yields.

In general, results suggested that mastitis as indicated by SCC was more common in progeny of sires that transmitted higher milk, fat and protein yield.

3.2. Economic values

Table 3 gives the economic values of milk production traits and LSCS at basic situation for free market and under multiple quota system, considering Method1 and Method2 to evaluate SCS costs.

Economic value of LSCS in the basic situation was -0.783 and -0.540 ptas.score^{-1}.Kg of milk^{-1}. cow^{-1}.year^{-1} with Method1 and Method2, respectively.

Economic values of LSCS calculated by Method1 depend on the mean level of LSCS. At LSCS farm level less than 2.20, the economic value is slightly positive (Fig. 2). This means that the defined non-linear equation does not describe correctly the payment system. With Method1, LSCS costs is underestimated when LSCS farm level had lower values and overestimated when it had higher values, because the amount of penalty considerate is only relative to the farm LSCS mean class.

With Method2, economic values of LSCS are negative for all LSCS levels (Fig. 2).

Changes in the profit are obtained only when a genetic increase in LSCS gives rise to an increased penalty. This is right when the increase in the LSCS jumps over the boundary of a penalty levels class. If the genetic increase in LSCS is limited within the boundaries of a penalty level class, the marginal increase does not lead to a change in profit and expected economic value of LSCS should be zero. Neither of the two methods contemplate this situation. However, Method2 gives LSCS economic value less sensitive to LSCS farm level (Fig. 2).

According to Method1, the economic value of LSCS follows a non-linear function with respect to the farm LSCS level. In this case, the question arises as to which criteria should be used to rank candidates for selection. Several alternatives have been considered in the literature (Goddard, 1983). Weller et al. (1996) concluded that for a non-linear profit functions there is not uniformly best selection solution. Groen et al. (1994) and Dekkers et al. (1995) suggest that if changes in the population mean due to selection are small and the economic value is frequently updated, the use of a constant economic value, setting the trait value at the current population mean could work reasonably well. However, in our case in spite of the fact that genetic mean change is expected to be small (moderate heritability), a simplification to constant economic value at current population it is not appropriate. Because LSCS economic values, estimated with Method1, are sensitive to LSCS farm level. And small genetic changes affect LSCS economic value.

Results showed that LSCS economic value with Method2 is more correct and less sensitive for all LSCS farm level.

Under free market situation, economic values of milk production traits is slightly higher with Method1, because LSCS costs is lower . Also, under a multiple quota system, economic values of milk production traits is also slightly higher with Method1, except fat economic value. Economic values of milk, milk carrier, fat and protein under quota system are reduced by $(1/Q).T_a$, $((1-q_{fcr}.f_{cr})/Q).T_a$, $((1+q_{fcr}(1-f_{cr}))/Q).T_a$ and $((1-q_{fcr}.f_{cr})/Q).T_a$, respectively. In the case of the fat this reduction is more important than in the case of other traits. Then, all situation that gives rise more profitability per cow (T_a), decreased fat economic value. For milk, milk carrier and protein the higher milk unit price with Method1 compensate the increase of the amount of reduction.

Economic values of production traits are sensitive to the LSCS farm level with Method1 Those economic values are sensitive to frequencies of LSCS classes with Method2.

As a consequence of the milk/fat quota, economic values decreased largely for milk, milk carrier and fat and slightly for protein.

4. Conclusions

Somatic cell scores were moderately heritable, and limited genetic progress could be made toward decreasing SCS.

An intensive selection for milk yield traits will produce an increase in SCS, due to the positive genetic correlations between LSCS, milk, fat and protein yield.

Economic value of LSCS when LSCS costs were defined as the sum of the frequency of each LSCS class multiplied by its penalty is more reasonable. It is less sensitive to LSCS farm level and could be computed at constant economic value by setting LSCS value and LSCS classes frequencies of the current population distribution.

LSCS economic value in this study is based only on the penalty of the milk price. Therefore, it does not give a correct evaluation of the mastitis economic value.

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Table 2. Heritabilities (on the diagonal), genetic correlations (above diagonal) and phenotypic correlations (below diagonal) of production traits and LSCS in first lactation.

	(1)	(2)	(3)	(4)	(5)	(6)
(1) Milk, Kg	**.31**	.79	.93	-.30	-.42	.15
(2) Fat, Kg	.80	**.26**	.86	.34	-.03	.14
(3) Protein, Kg	.93	.80	**.28**	-.08	.06	.16
(4) Fat, %	-.18	.43	-.07	**.35**	.61	-.01
(5) Protein, %	-.23	-.04	.14	.30	**.31**	-.02
(6) LSCS	-.06	-.04	-.02	-.02	.09	**.13**

Table 3. Economic values of milk production traits and LSCS, considering Method1 and Method2 to calculate costs associated with the level of LSCS, under free market conditions and with a multiple restriction on milk production and fat percentage (quota).

Traits	Free market situation		Quota situation	
	Method1	Method2	Method1	Method2
Milk[1]	27.93	27.40	17.96	17.90
Milk carrier[1]	4.56	4.07	1.29	0.97
Fat[1]	261.44	260.95	82.21	90.53
Protein[1]	471.17	470.68	467.9	467.57
LSCS[2]	-0.783	-0.540	-0.783	-0.540

[1] *: ptas .Kg^{-1}.cow^{-1}.year^{-1}* [2] *: ptas.score $^{-1}$ .Kg of milk^{-1}.cow^{-1}.year^{-1}*
(1 pta . 0.007 $ US)

Fig. 2. Economic values of LSCS in dependence on LSCS farm level according to Method1 and Method2