Economic Selection for Female Fertility: Fertility Traits and Their Relationship with Production

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Abstract

Relationship between production, profit and fertility was studied. Phenotypically, less fertile cows produce more milk; however they stay less number of lactations in herd and produce less kg of milk per lifetime, reducing its profitability. Production and fertility are genetically negatively correlated, as well. INS is less correlated to production than days open and days to first service. If INS is included in an index combining fertility and production profit would increase by 229 €/cow, meanwhile it would be 56 € / cow lower if days open is the fertility trait. INS should be registered and used in the genetic evaluations since it is free of management decision and it would maximize profitability at balancing economically production and fertility.

1. Introduction

Female fertility has become one of the most important functional trait in later years because of its economic importance (González-Recio *et al.,* 2004), as well as its effect on animal welfare and farmer's quality of life. Fertility has recently been included in the total merit indices from several countries (INTERBULL, 2005), and genetic evaluations across countries for fertility, via MACE (Schaeffer, 1994), will be available in the near future (Jorjani, 2005). However, the emphasis placed on milk production is over 50 % in the total merit indices in most leader countries (Miglior, 2004). Antagonism of production and reproduction (Jong, 2005; Veerkamp *et al.,* 2001) makes improvement of fertility rather difficult. Optimum balance between production and fertility must be pursued to maximize profitability.

Further drawbacks of fertility are threshold traits, censored records and data recording system. Methods that take censoring into account could improve genetic evaluations and parameter estimation (González-Recio *et al.,* 2005; Chang *et al.,* 2005). Calving dates are regularly registered in the milk recording schemes, but insemination events are not. The milk recording schemes give a partial overview of reproductive situation, but cannot consider management decisions such as prolonging lactation voluntarily or improper heat detection. The reproductive recording schemes incorporate information from insemination events (e. g. date, technician, service sire, type of insemination, pregnancy check, or heat detection). Therefore, INS might be the trait which thoroughly describes the reproductive ability of cows.

This paper will show an overview of previous researches concerning selection for female fertility, such as its economic importance, methods for analyzing INS and DO, as well as some guidelines to combine productive and reproductive selection.

2. Material and methods

2.1. Data

Data were provided by two regional associations (Basque and Navarra) from the Spanish Holstein Association (CONAFE). Milk yield and reproductive data from 1994 through 2004 were used in the analyses. Days to first service after claving (DFS), days open (DO) and INS were calculated from reproductive scheme. Fertility records were considered as censored if no subsequent calving was reported or if the successful insemination was unknown. The last known insemination and its date were considered as the censoring points for INS and DO, respectively. In addition, if no pregnancy was achieved after the fourth insemination, those records were included in a fifth category that represented more than 4 inseminations. The edited data set contained 71,217 lactation records from 41,515 cows, and the pedigree file contained 85,974 animals.

2.2. Fertility costs

Fertility costs were calculated for each INS level by adding up costs from doses of semen, hormonal treatments, culling due to fertility and opportunity cost due to delayed incomes from milk and calf in next lactation. Every cost term was calculated as in González-Recio *et al.* (2004), and was expressed in euros.

Records were obtained from 12,486 cows calving in 2001 to calculate FCOST for up to seven INS. The FCOST was calculated relating to INS level (up to seven INS).

2.3. Profit equation

Adjusted equation of FCOST was included in a bio-economic model to calculate profit and derive economic values.

Profit (PROF) per cow per year can be described by the following equation: $\text{PROF} = \text{R-C}$ where, R is average revenues during a year per cow, and C is average costs during a year per cow (see details in González-Recio *et al.,* 2004).

2.4. Bivariate models

A Bayesian bivariate model for linear-linear or linear-threshold analyses, with allowance for censored records for fertility traits (Chang *et al.,* 2005; González-Recio *et al.,* submitted), was fitted as follows:

$$\begin{bmatrix} \mathbf{y}_1 = \begin{pmatrix} \mathbf{y}_{o1} \\ \mathbf{y}_{c1} \end{pmatrix} \\ \mathbf{y}_2 = \begin{pmatrix} \mathbf{y}_{o2} \\ \mathbf{y}_{c2} \end{pmatrix} \end{bmatrix} = \mathbf{x}\boldsymbol{\beta} + \mathbf{z}_h\mathbf{h} + \mathbf{z}_p\mathbf{p} + \mathbf{z}_a\mathbf{a} + \mathbf{e},$$

where $\mathbf{y}_1$ and $\mathbf{y}_2$ are vectors of observed ($\mathbf{y}_{o1}$, $\mathbf{y}_{o2}$) and augmented censored ($\mathbf{y}_{c1}$, $\mathbf{y}_{c2}$) records for trait 1 and 2, respectively, (augmented unobserved liability in case of INS). The production traits were total yield per lactation (kg) for milk (**MY**), fat and protein. Fertility traits were DFS, DO and INS. The systematic effects ($\boldsymbol{\beta}$) in the model were as follows: DFS as a covariate (only in the model for INS), lactation-age at calving (16 levels); month of calving (12 levels), and year-season of calving (29 levels). The random effects were: **h** = herd (569 levels); **p** = permanent environmental effect of the cow (41,515 levels), **a** = additive genetic effect of animal (85,974 levels), and **e** = random residual assumed independently distributed.

The heritability estimates were calculated as:

$$\mathbf{h}^2 = \frac{\boldsymbol{\sigma}_a^2}{\boldsymbol{\sigma}_a^2 + \boldsymbol{\sigma}_e^2 + \boldsymbol{\sigma}_p^2}$$

Posterior distributions of the parameters were estimated using a Gibbs/Metropolis combination (Sorensen and Gianola, 2002). The analyses were based on a single chain of 100,000 iterations, with the first 10,000 samples discarded.

Censored Traits. Days open was analyzed using a linear censored model, such that unobserved responses were augmented using a truncated normal process (González-Recio *et al.,* In press). If trait *i* was INS (an ordinal categorical trait), a threshold model was implemented on the scale of a latent unobserved variable (λ) (Gianola, 1982, Gianola and Foulley, 1983), fixing residual variance equal to 1. Situations in which INS was censored at the last insemination were accommodated as described by González-Recio *et al.* (2005).

2.5. Incorporating fertility into the selection index

Index development was based on the selection index theory reviewed by Hazel *et al.* (1994). Actual milk, fat and protein yield were included in the aggregate genotype, as were two fertility traits indicating beginning of ovarian activity and pregnancy rate (DFS and

INS, respectively). The economic values obtained in earlier studies were used (González-Recio *et al.,* 2004). Three indices were proposed: actual milk, fat and protein yield were always considered, along with various combinations of fertility traits (specifically INS, DO, INS+DFS).

3. Results and discussion

The data set contained 30 % and 36% right censored records for DO and INS, respectively. Production traits and DFS had no censored records, because only complete lactations with a first insemination event were included.

3.1. Profit, productive and fertility traits by INS level

The least squares means for profit, productive and fertility traits by INS level are shown in Table 1. Cows that needed more INS to get pregnant had higher milk production (both actual and 305-adjusted), and longer DIM, but also longer DO and DP. These cows stayed shorter in herds and had lower lifetime production. Lifetime production and number of lactations decreased as more INS were required.

3.2. Genetic parameters

Heritability estimates for productive and fertility traits are shown in Table 2. Positive genetic correlations were estimated among all fertility traits suggesting accordance with increased INS, DO and DFS for less fertile cows. The estimates ranged from 0.41 between INS and DFS to 0.87 between DO and DFS (Table 2). Days open and INS had a genetic correlation estimate of 0.71. Other researches (Veerkamp *et al.,* 2001; Kadarmideen *et al.,* 2003; Chang *et al.,* 2005) reported similar genetic correlations. Cows with higher yield tend to have poorer reproductive performance. The genetic correlations shown in Table 2 suggest that DO is more adversely correlated to production traits (0.63-0.76), whereas INS seemed to be less affected for high yields (0.16 - 0.23). Longer DO may not be an economic burden if an adequate production level can be maintained, because management decisions to delay first insemination in high yielding cows might mislead actual relationship between DO and milk production. Hence INS is a preferable trait to select female fertility because it is less influenced by management decisions and reflects female fertility in a more direct way.

3.3. Expected genetic gain

The strong genetic correlations between fertility and productions, joint with low heritabilities for female fertility suggest that it is unlikely to improve fertility by combined selection for production and profitability. Nonetheless, the inclusion of fertility in the total merit indices could low down genetic degradation of female fertility.

Table 3 shows the expected economic progress regarding the fertility traits chosen to select fertility joint to production traits. Slight deterioration of reproductive performance is achieved with all of the proposal indices, although maximization of profitability would be obtained. This results suggest that higher incomes from improvement of production could compensate the increase in cost due to poor fertility.

The highest genetic progress for profit (+$272) was obtained when INS was the only fertility trait in the selection index, whereas including DO as the only fertility trait led to the lowest progress in profit. An index balancing DO and INS would assign a positive coefficient to longer DO due to its high genetic correlation with yield, which may be hard to interpret. Improvement of fertility could be achieved by emphasizing weights for fertility in the selection indices, nonetheless profitability would be reduced.

4. Conclusions and applications

Dairy industry attempts to obtain non-problematic cows that are able to maintain a reasonable productive level during longer time in herd, increasing profitability.

Genetic antagonism exists between fertility and production, thus optimal balance between production and fertility should be pursued.

Longer lactation period could be achieved extending voluntary waiting period for high yielding cows, enlarging DO voluntarily, which may mislead actual relationship between production and fertility. Reproductive recording schemes are necessary to register insemination events in Holstein populations, which make possible to include INS in the total merit indices, selecting for female fertility in a direct manner, slowing down the rate of degradation for female fertility, and maximizing incomes from milk sales.

Nonetheless, dairy producer's welfare could be primordial in some circumstances, thus genetic improvement of fertility could rise in importance to obtain non-problematic cows. In such a case, it would be necessary to increase emphasis of fertility traits in the total merit indices.

5. References

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Table 1. Least Squares Means according to INS level for 305-d adjusted (KGM305) and actual (non-adjusted) milk yield (KGM), fat and protein (PROT) per actual lactation, days in milk (DIM), days open (DO), days of dry period (DP), number of lactations in herd (LH) and cumulated lifetime milk production in kg (LP). N is number of records. Data period was from 1998 to 2001.

INS	N	KGM305	KGM	DIM	DO	DP	FCOST[1]	PROF[1]	LH[2]	LP[2]
1	22,133	8324[e]	8978[f]	305[f]	83[g]	59[d]	34	636	2.5[ab]	16,477[cd]
2	12,346	8666[d]	9827[e]	340[e]	124[f]	66[cd]	61	644	3.1[a]	23,341[a]
3	6207	8842[c]	10,600[d]	373[d]	163[e]	72[c]	117	563	2.8[ab]	22,439[ab]
4	3154	8945[c]	11,240[c]	399[c]	198[d]	81[b]	178	470	2.3[bc]	18,714[bc]
5	1399	9151[b]	11,904[b]	420[b]	225[c]	87[ab]	240	416	2.1[bc]	17,296[cd]
6	561	9125[b]	12,151[b]	432[b]	244[b]	94[a]	302	300	1.7[c]	13,882[de]
7	213	9298[a]	12,675[a]	451[a]	271[a]	102[a]	365	238	1.6[c]	12,664[e]

[a,b,c,d,e,f,g] INS means within each trait with different superscript differ ($P < 0.05$)
[1] Estimates for an average cow in 2001.
[2] LH and LP were calculated by average INS level per lifetime, while remaining traits were calculated by INS per lactation.

(Adapted from González-Recio *et al.,* 2004)

Table 2. Heritability[1] (diagonal) and genetic correlations (above diagonal) estimates and their posterior standard deviation (in brackets) between production (total yield per lactation for protein, fat and milk (MY)), and fertility (days to first service (DFS), days open (DO), and number of insemination to conception (INS)).

	Protein	Fat	MY	DFS	DO	INS
Protein	0.19 (0.01)	0.82 (0.03)	0.89 (0.04)	0.58 (0.04)	0.76 (0.04)	0.22 (0.05)
Fat		0.18 (0.01)	0.71 (0.04)	0.53 (0.05)	0.75 (0.06)	0.21 (0.06)
MY			0.19 (0.01)	0.59 (0.04)	0.74 (0.04)	0.16 (0.05)
DFS				0.05 (0.01)	0.87 (0.03)	0.41 (0.07)
DO					0.05 (0.01)	0.71 (0.05)
INS						0.04 (0.01)

[1] $\text{heritability} = \dfrac{\boldsymbol{\sigma}_a^2}{\boldsymbol{\sigma}_a^2 + \boldsymbol{\sigma}_e^2 + \boldsymbol{\sigma}_p^2}$

Table 3. Index weights and genetic gain in euros and on breeding goal traits (total yield for milk (MY), fat and protein (PROT), days to first service (DFS), and number of inseminations per service period (INS)) for each selection index.

Index	Index weights (%)	Expected Genetic Gain[1]					
		MY	Fat	Pr	DFS (d)	INS	€
I_1	39·MY+12·FAT+42·PROT-7·INS	+982	+34	+32	+4.11	+0.03	+229
I_2	38·MY+11·FAT+38·PROT-10·DFS-3·INS	+864	+30	+28	+3.18	+0.02	+202
I_3	34·MY+14·FAT+35·PROT-16·DO	+734	+26	+24	+2.57	+0.01	+173

[1]Genetic gain calculated assuming selection intensity of one and the same generation interval for every trait.