# Genetic analysis of true profit for Spanish dairy cattle

**M.A. Pérez[1], D. Hernández[2], R. Alenda[1], M.J. Carabaño[2] and N. Charfeddine[3]**

[1] *ETSIA, Universidad Politécnica, Ciudad Universitaria, 28040 Madrid, Spain*
[2] *INIA, Apartado de correos 8111, 28080 Madrid, Spain*
[3] *CONAFE, Apartado de correos 31, 28340 Valdemoro, Madrid, Spain*

## Abstract

In this study, 7738 cows with production, type, and productive life traits from 239 herds with information on milk, meat, food, housing, and labour costs were used. A lifetime net profit value was calculated for each cow. An average cow had the first calf at 28.6 months of age, 6149 kg of milk in the first lactation, a productive life of 1236 days, 3.28 lactations and a net profit of 410 euros per year of productive life. Heritability of true profit was equal to 0.091. Genetic correlations with production and longevity traits were moderately high, ranged between 0.76 to 0.83. Genetic correlations with type traits were low, around zero, ranged between -0.33 and 0.21. A high genetic correlation was achieved with milk per day of productive life (0.92). Net merit index was the best predictor of the breeding value of true profit, with only 32% as coefficient of determination. Protein yield alone explained a 30% of the true profit. The best prediction of the true profit was achieved with the net merit index, plus rear leg side view, udder cleft and body depth, with 40% of total variation.

## 1. Introduction

The ultimate true breeding objective in dairy cattle is lifetime profitability per unit of time, which is related with True Herd Life (THL). This net profit trait is a function of revenues, mainly from milk (around 90%) and meat production, and costs (rearing, feeding, health, reproduction and housing).

Early studies of the net profit as a trait were done at farm level (Andrus and McGilliard, 1975; Balaine *et al.*, 1981; Tigges *et al.*, 1984). In those studies, milk yield was already the most important trait related with profit. Visscher and Goddard (1995b) found moderate heritability of the net profit in Australian dairy cow population and high correlations with stayabilities and yield traits.

Selection for profitability in Spain can be done by indexes that combine production and type breeding values. The ICO index was established by consensus based on selection response and used for ranking bulls and cows nation wide. Recently, Charfeddine (1998) developed a net merit index derived by direct methods that included economic and production data. Predictions of longevity in those indexes are indirectly predicted by type traits. Traits related with lifetime net profit could be used in developing new indexes that predict profitability at early stage of the life of an animal.

The first aim of this study was to present heritability of true profit and genetic correlations with production, longevity and type traits. A second aim was to predict the breeding value of the true profit based on early stage of life breeding values of production and type traits.

## 2. Material and methods

### 2.1. Data

Data were from 239 herds in the Basque Country region of Spain. Individual milk production data obtained from 1990 to May 1999 within the official milk recording system included 58,784 lactations from 21,640 cows. Several edits were performed in order to obtain adequate data sets for the statistical analyses. In a first step, data from animals first calving before April 1996 were selected to allow for at least four years of productive life. Age at first calving was required to be between 18 and 40 months. Interval between successive calving needed to be between 300 and 550 days in order to avoid animals lacking intermediate lactations. All animals were required to have milk, fat and protein information. After these edits, data from 9708 cows were retained and used for the estimation of breeding values. These EBV's were used in the stepwise regression analysis. An additional requirement imposed on the minimum number of data in the comparison groups for the variance components estimation yielded a data set including data from 7738 cows for this analysis.

## 2.2. True profit and indices ICO and MEG

True profit (TP) per year was obtained from the difference between returns (R) and costs (C) per year

$$TP = R - C$$

with

$$R = \{TMP x mp + NL[(1-CM) x cp]\}(365/PL) + sv$$

$$C = [FCH + cp + OCH](365/PL) + FCC + OCC$$

where, TMP is total milk production, mp is milk price including bonus and penalties; NL is number of lactations, CM is calf mortality, cp is calf price, PL is productive life measured as days between first calving and last test-day recorded, sv is the salvage value of the culled cow, FCH is the food cost for rearing a heifer, OCH is other costs associated to rearing a heifer, such as veterinary, medicines, labour, housing, etc., FCC is food cost for cows per year, OCC is other variable costs for cows per year. TMP, NL and PL were obtained for each cow from the milk recording data; mp, CM, sv, cp and other than food costs for cows and heifers were obtained as average values of economic data from the 239 herds participating in the study in year 1995 (Charfeddine, 1998). Individual food costs per cow were estimated from food requirements at different physiological stages and production levels (Charfeddine, 1998)

Combined index ICO, which is the official selection index provided in the national evaluations in Spain is obtained as,

$$ICO = 8\left(10\frac{KF}{SD_{kf}} + 51\frac{KP}{SD_{kp}} + 5\frac{PP}{SDpp} + 4\frac{FL}{SD_{fl}} + 15\frac{MS}{SD_{ms}} + 15\frac{FC}{SD_{fc}}\right)$$

where, KF and KP are kilograms of fat and protein, respectively, PP is protein percentage, FL is feet and legs, MS is mammary system, FC is final class, and, SD is the standard deviation of predicted breeding values.

The net merit index, MEG, was obtained in a previous study (Charfeddine, 1998) from the calculation of economic values for the average economic conditions of the 239 herds used in this study. MEG is defined as,

$$MEG = 5.85\ I_{PROD} + 14.17 I_{LONG}$$

where, $I_{PROD}$ and $I_{LONG}$ are sub-indices for production and longevity. Relative weights are 67:33 for production and longevity, respectively. $I_{PROD}$ and $I_{LONG}$ are obtained as follows,

$$I_{PROD} = 0.2KM + 2.59KF + 35.2KP$$

with, KM, KF and KP being kilograms of milk, fat and protein, respectively. Relative weights for these traits are 10:9.7:80.3.

$$I_{LONG} = 67.6FC + 26.06FL + 728.5I_{UC}$$

with, FC being final class, FL feet and legs and $I_{UC}$ an udder composite index. Relative weights are 31:24.4:44.6 for FC, FL and $I_{UC}$,, respectively. $I_{UC}$ is obtained as,

$$I_{UC} = 0.06UT + 0.1FUA + 0.02RUH + 0.15UD + 0.08UC + 0.05FTP$$

with UT being udder texture, FUA fore udder attachment, RUH rear udder height, UD udder depth, UC udder cleft, FTP fore teat placement.

Relative weights are 12:19:3.5:33.5:21:11 for UT, FUA, RUH, UD, UC and FTP, respectively.

2.3. Estimation of genetic parameters

Heritabilities and genetic correlations between true profit and production, type and longevity traits were calculated by REML using the VCE software of Groeneveld and García Cortés (1998). Multiple trait analyses including TP and three more traits simultaneously (for computational reasons) were performed. Traits involved in these analyses were TP, five production traits in first lactation (kg milk, fat and protein, protein and fat percentage), ten type traits (final class, feet and legs, stature, body depth, foot angle, leg side view, fore udder attachment, rear udder height, udder cleft and udder depth), three longevity traits (length of productive life, total days in milk and kg milk per day of productive life.

The model used in the variance components estimation was defined in the same way for all traits as

$$\mathbf{y = HYS + M + AFC + u + e}$$

where, y is the phenotypic observation for each trait, HYS is herd-year-season of first calving, M is month of first calving, AFC is age at first calving, u is the animal additive genetic value and e is the error term.

Type traits were adjusted by the mixed model equations solutions for effects of herd-round-classifier, stage of lactation and lactation-age at classification previous to the REML analyses.

2.4. Stepwise regression

Two stepwise regression analyses were performed in order to identify the traits that provide a better prediction of true profit. In the first analysis, the dependent variables were the production and type traits breeding values (BV), which are the traits currently available in the national evaluation system in Spain. In the second analysis, the combined index ICO and the net merit index MEG, were also included. BV for the production and type traits were obtained using PEST software (Groeneveld *et al.*, 1993) using data from 9708 cows. Only BV of bulls with at least 10 daughters (127 bulls) were subsequently used in the regression analyses.

## 3. Results and Discussion

Phenotypic means and standard deviations of true profit, longevity, production and type traits are in Table 1. Average true profit is 410.64 euro per cow and year. In type traits, average scores were highest for Stature and lowest for Fore udder attachment.

3.1. Genetic parameters

Table 2 shows heritabilities of true profit, productive life, production and type traits. Heritability of true profit is moderately low (0.091), higher than heritabilities of productive life traits and lower than the production and type ones. Visscher and Goddard (1995b) obtained a higher value (0.13) in the Australian Holstein population. The estimate of heritability for productive life (0.034) is lower than the value reported by Charfeddine *et al.* (1997), in the same population. Heritability estimates for production and type traits were in agreement with values presented by Charfeddine *et al.* (1997).

Table 1. **Mean and standard deviation of profit, longevity, production and type traits**

| | Mean | S. D. |
|---|---|---|
| Number of Cows | 9708 | |
| True profit (Euro.cow$^{-1}$.year$^{-1}$) | 410.6 | 233.59 |
| Age 1$^{st}$ calving. (months) | 28.62 | 3.60 |
| Number of lactations | 3.28 | 1.52 |
| Productive life (PL) (days) | 1236 | 592.60 |
| Total days in milk (days) | 1039 | 471.50 |
| Milk per day of PL (kg.d$^{-1}$) | 10.42 | 3.53 |
| Milk[i] (kg) | 6148.7 | 1427.4 |
| Fat[i] (kg) | 238.90 | 62.16 |
| Protein[i] (kg) | 187.30 | 46.58 |
| Fat%[i] | 3.78 | 0.87 |
| Protein%[i] | 2.95 | 0.57 |
| Final Class[ii] | 76.70 | 3.63 |
| Feet and Legs[iii] | 8.35 | 2.32 |
| Stature[iv] | 6.11 | 1.50 |
| Body depth[iv] | 5.57 | 1.38 |
| Foot angle[iv] | 5.22 | 1.45 |
| Leg side view[iv] | 5.72 | 1.22 |
| Fore udder attachment[iv] | 4.95 | 1.18 |
| Rear udder height[iv] | 5.32 | 1.15 |
| Udder cleft[iv] | 5.77 | 1.36 |
| Udder depth[iv] | 5.49 | 1.49 |

[i] first lactation, [ii] (scale 62 to 90); [iii] (scale 1 to 18); [iv] (scale 1 to 9)

Table 2. **Heritabilities and their standard errors in parenthesis of true profit, longevity, production and type traits used in the analysis**

| | $h^2$ (SD) | |
|---|---|---|
| True profit | 0.091 | (0.014) |
| Productive life (PL) | 0.034 | (0.008) |
| Total days in milk | 0.044 | (0.011) |
| Milk per day of PL | 0.117 | (0.017) |
| Milk | 0.321 | (0.032) |
| Fat | 0.205 | (0.022) |
| Protein | 0.290 | (0.024) |
| Fat% | 0.347 | (0.028) |
| Protein% | 0.324 | (0.025) |
| Final Class | 0.288 | (0.021) |
| Feet and Legs | 0.159 | (0.018) |
| Stature | 0.394 | (0.012) |
| Body depth | 0.318 | (0.013) |
| Foot angle | 0.107 | (0.015) |
| Leg side view | 0.160 | (0.016) |
| Fore udder attachment | 0.152 | (0.019) |
| Rear udder height | 0.271 | (0.022) |
| Udder cleft | 0.187 | (0.021) |
| Udder depth | 0.280 | (0.024) |

Genetic correlations between true profit and productive life, production and type traits are in Table 3. True profit shows largest genetic correlation with milk per day of productive life (0.92) because it is composed of productive life and milk production in all lactation. This result is in agreement with results of Haan *et al.* (1992). Beaudry *et al.* (1987) affirm that correlation between lifetime production traits and relative net income changes considerably with prices of milk and food.

Correlations with productive life and yield traits were high and similar, being slightly larger with protein yield. Cassel *et al.* (1993) and Visscher and Goddard (1995a) also reported large genetic correlations. As expected, highest profits come from high yielding cows. The large bonus for protein level given by the milk payment system and the moderate marginal food cost of protein explains why protein shows the largest genetic correlation with true profit among yield traits.

Table 3. **Genetic correlations between true profit and longevity, production and type traits used in the analysis, and their standard errors (in parenthesis)**

| | Genetic correlation (SD) | |
|---|---|---|
| Productive life (PL) | 0.760 | (0.063) |
| Total days in milk | 0.760 | (0.057) |
| Milk per day of PL | 0.921 | (0.014) |
| Milk | 0.764 | (0.054) |
| Fat | 0.761 | (0.057) |
| Protein | 0.833 | (0.046) |
| Fat% | -0.160 | (0.080) |
| Protein% | 0.068 | (0.097) |
| Final Class | -0.005 | (0.105) |
| Feet and Legs | 0.164 | (0.096) |
| Stature | -0.048 | (0.093) |
| Body depth | -0.247 | (0.107) |
| Foot angle | 0.208 | (0.113) |
| Leg side view | -0.330 | (0.089) |
| Fore udder attachment | -0.081 | (0.119) |
| Rear udder height | -0.028 | (0.090) |
| Udder cleft | 0.158 | (0.103) |
| Udder depth | -0.302 | (0.053) |

Genetic correlations between true profit and type traits were negative except with feet and legs, foot angle and udder cleft, and ranged from -0.33 with leg side view to 0.21 with foot angle.

Final class has a genetic correlation with true profit near zero (-0.005). In Spanish type program, final class takes an overall value of the animal conformation and for many dairymen it is an important reference at the time of breeding. The null correlation with true profit suggests that final class is not a good breeding criterion for profit.

True profit has unfavourable moderate correlations with capacity traits (stature and body depth), because larger cows require more energy for maintenance, what means more cost and less profit.

Feet and legs and foot angle show a moderate positive correlation with true profit. In contrast, rear leg side view has a negative correlation. Feet and legs is a composite trait, which considers the locomotive disorders in addition to legs traits, what is a serious reason for involuntary culling (McDaniel, 1997). McDaniel (1997) defines foot angle as the best predictor of survival rate, given that cows with larger claw angle seem to be more profitable. Rear leg side view is an intermediate optimum trait, and, therefore it is difficult to explain the relationship between this trait and true profit. Dekkers *et al.* (1994) found that on the desirability scale rear leg side view had a significant positive effect on profitability.

Udder cleft shows moderate favourable correlation with true profit. It suggests that more profitable cows tend to have tight udder clefts. However, udder depth shows a negative correlation with true profit. This correlation could be misleading because of the influence of milk production. Haan *et al.* (1992) found also, a negative phenotypic correlation between relative net income and udder depth, however, when they considered cows with the same level of production the sign of the correlation was positive. This result can be interpreted by the fact that more shallow udders tend to be associated with lower production, which is less profitable.

### 3.2. Stepwise regression analysis

Coefficients of determination for prediction of true profit using sires estimated breeding values for first lactation traits (milk, fat, protein, fat% and protein%), and type traits (final class, feet and legs, stature, body depth, foot angle, rear leg side view, udder depth, fore udder attachment, rear udder attachment, udder cleft) are in Table 4. Protein is the unique production trait included as significant in the model. It alone accounts for 30% of the variation in true profit. Rear leg side view, udder cleft and body depth were the following traits included.

Table 4. **Coefficients of determination ($R^2$) of the stepwise regression for prediction of true profit using sires estimated breeding values for production and type traits**

| Trait | $R^2$ |
|---|---|
| Protein | 0.3032 |
| Rear leg side view | 0.3412 |
| Udder cleft | 0.3639 |
| Body depth | 0.3972 |

Table 5 shows coefficients of determination of the stepwise regression for prediction of true profit, using in addition of sires breeding values for production and type traits, the type-production combined index (ICO) and the net merit index (MEG) defined by Charfeddine (1998). As in the previous analysis, few traits were significant. The net merit index is the most significant trait, followed by Rear leg side view, Body depth and Udder cleft, increasing $R^2$ by 3.5 %, 2.7% and 2.5%, respectively.

Table 5. **Coefficients of determination ($R^2$) of the stepwise regression for prediction of true profit using sires estimated breeding values for production and type traits, and official combined index (ICO), and net merit index (MEG)**

| Trait | $R^2$ |
|---|---|
| Net merit index (MEG) | 0.3167 |
| Rear leg side view | 0.3515 |
| Body depth | 0.3789 |
| Udder cleft | 0.4041 |

## 4. Conclusions

If profit could be recorded on individual animals, the breeding objective would be the single trait profit (Goddard, 1998). But as a longevity trait, true profit will be recorded at the end of the productive life of a cow, showing also a low heritability. All the recent methodology applied in predicting the breeding value of longevity could be applied to predict the true profit.

True profit can be used to quantify the current indexes used to rank animals for profit. In this study, the set of data was small and conclusions should be taken carefully. Net merit index is the best predictor of true profit, but this study suggest that more information from type traits (Rear leg side view, Udder cleft and Body depth) should be added in the index. Type traits were included in the net merit index to improve longevity, but genetic correlations between type traits and longevity are in general low. Probably, the inclusion of a direct prediction of the longevity BV into the net merit index would improve the prediction of the true profit.

## References


Andrus, D. F. and McGilliard, L.D. 1975. Selection of dairy cattle for overall excellence. J. Dairy Sci. 58:1876.

Balaine, D. S., Pearson, R. E., Miller, R. H. 1981. Profit functions in dairy cattle and effect of measures of efficiency and prices. J. Dairy Sci. 64: 87.

Beaudry, T. F., Cassell, B. G., Norman, H. D. and Pearson, R. E., 1988. Impact of prices on profit functions in dairy cattle. J. Dairy Sci. 71: 485.

Cassell, B. G., Smith, B. B. and Pearson, R. E., 1993. Influence of herd-life opportunity and characteristics of cows and herds on different net income functions. J. Dairy Sci. 76: 1182.

Charfeddine, N., 1998. Selección por mérito económico global en el ganado vacuno frisón en España. Tesis doctoral, Dpto. Producción Animal, E.T.S.I. Agrónomos Madrid.

Charfeddine, N., Alenda, R., and M.J. Carabaño, 1997. Relationships Between Somatic Cell Score and Longevity, Production and Type Traits in Spanish Holstein-Friesian Cows. 48th Ann. Meet. of EAAP, Vienna, Austria.

Dekkers, J. C. M., Jairath, L. K. And Laurance, B. H., 1994. Relationships between sire genetic evaluation for conformation and functional herd life of daughters. J. Dairy Sci., 77: 844.

Goddard, M. E. 1998. Consensus and debate in the definition of breeding objectives. J. Dairy Sci., 81(2):6-18.

Groeneveld, E., Kovac, M. and Wang, T. 1993. PEST user's manual. Version 3.1. University of Illinois..

Groeneveld, E. and García Cortés, L. A. 1998. VCE 4.0, a (co)variance component package for frequentists and Bayesians. Proc. 6th World Congress on Genetics Applied to Livestock Production. Vol. 27: 455-456.

Haan, M. H. A., Cassell, B. G., Pearson, R. E. and B. B. Smith, 1992. Relationships between net income, days of productive life, production, and linear type traits in grade and registered Holsteins. J. Dairy Sci. 75: 3353.

McDaniel, B. T., 1997. Breeding Programs to reduce foot and legs problems. Proc. International Workshop on Genetic Improvement of Functional traits in cattle; Health. Uppsala, Sweden p. 115.

Tigges, R. J., Pearson, R. E., Vinson, W. E. 1984. Use of dairy herd improvement variables to predict Lifetime Profitability. J. Dairy Sci. 67: 180.

Visscher, P. M., and Goddard, M. E. 1995a. Genetic parameters for milk yield, survival, workability and type traits for Australian dairy cattle. J. Dairy Sci. 78: 205.

Visscher, P. M. and Goddard, M. E. 1995b. Genetic analyses of profit for Australian dairy cattle. Animal Science 61: 9.