Calculating economic values for milk components in a pasture-based-dairy-system: the case of Argentina

L. Pruzzo, J. L. Danelón*, and R. J. C. Cantet

Departamento de Producción Animal, Facultad de Agronomía, Universidad de Buenos Aires, Argentina

ABSTRACT: Economic values (EV) of milk components (P: protein, F: fat and V: volume) were obtained for a dairy system based on pasture, where a large proportion of milk is sold to industry. The EV's were calculated using a profit function with a restriction in total feed supply. Economic value of protein (EVP) had the largest absolute and relative standardized values. Economic value of volume (EVV) was always small and negative. Multiple regression analyses of EV's showed all EV's to be affected ($P < 0.01$) by the ratio of price of protein to price of fat ($P:$F) and level of production. The effects of $P:$F were linear and quadratic, whereas those of level of production were linear. Prediction equations obtained in the study can be used to calculate EV's for different pricing systems and levels of milk production under grazing systems in Argentina.

Key words: Energetic costs, grazing systems, profit function, pricing systems, regression analysis, sensitivity analysis

Cálculo de valores económicos de componentes de la leche en lecherías basados en pastoreo: el caso de Argentina

RESUMEN: Los valores económicos (EV) de los componentes de la leche (P: proteína, F: grasa butirosa y V: volumen) se obtuvieron para un sistema lechero de base pastoril en el cual una gran proporción de la leche se vende a la industria. Los EV's se calcularon utilizando una función de beneficio con restricción en la oferta total de alimento. El mayor valor absoluto y relativo estandarizado fue el valor económico de la proteína (EVP). El valor económico del volumen (EVV) fue siempre pequeño y de signo negativo. Mediante análisis de regresión múltiple se demuestra que todos los EV's son afectados ($P < 0.01$) por la relación de precios proteína: grasa ($P:$F) y el nivel de producción. Los efectos de $P:$F fueron lineales y cuadráticos, en tanto que el efecto del nivel de producción fue lineal. Las ecuaciones de predicción obtenidas en este estudio pueden utilizarse para calcular EV's para diferentes sistemas de precios y niveles de producción de leche bajo sistemas pastoriles en Argentina.

Palabras clave: Análisis de regresión, análisis de sensibilidad, costo energético, función de beneficio, sistemas pastoriles, sistemas de precios

Introduction

In most countries in which dairying is an important enterprise the price of milk paid to producers is affected by the content of either protein (P), fat (F), volume (V) or a combination thereof. This is usually so as a result of a differential weighing applied by the local milk manufacturing industry (Gibson, 1989). In the case of Argentina, dairy farmers are paid for the contents of protein and fat. However, in accordance with world trends, a weighing based more on P is in-creasingly emerging as the preferred system. The relative importance of P, F, and V in the pricing system affects not only breeding decisions (Gibson *et al.,* 1992), but also a related issue, namely, the cost structure of producing one unit of P, F or V, as it becomes substantially different.

The end result of taking into account different prices and costs in the development of a multitrait selection goal is the calculation of the economic values (EV) through a profit function (Harris, 1970; Brascamp *et al.,* 1985). Visscher *et al.* (1994) developed a procedure that incorporates a restric-

tion due to total feed supply while deriving EV's, appropriate for pasture based dairy systems, which is the case for Argentina. In Argentina several milk pricing systems are in operation and there is great variability in the level of production among dairy farms. As a consequence, a single set of EV's is not adequate for use in all situations. Thus, there is a need to customize the indexes for individual producers (Bowman *et al.*, 1996). The objectives of this research were: 1) To obtain a profit function to calculate EV's for the most typical Argentine dairy farming system; 2) To test the sensitivity of those EV's to the pricing system and the level of production; and 3) To develop prediction equations for the EV's using different pricing systems and levels of production.

Material and Methods

The methodology first employed to calculate EV's was developed by Visscher *et al.* (1994) to model an Australian dairy system based on pasture. In his situation, the cost of feeding constitutes the largest portion of total production costs. Therefore, the yearly supply of feed was taken as a restriction for calculating EV's. Let profit (Pf) be equal to Revenue (R) minus cost (C). In an unrestricted feeding situation, the EV's are the first derivatives of Pf with respect to the trait of interest (x; Harris, 1970). In the present approach, the derivative of Pf incorporating the cost restriction for the EV is equal to:

$$\frac{dPf}{dx} = \frac{Pf}{x} - \frac{Pf}{Ft} \cdot \frac{Ft}{t} \qquad (1)$$

Expression (1) means that restricted EV for milk component i (EV_i), is equal to unrestricted EV_i minus profit per unit of feed requirement (Pf/Ft), times rate of change in the amount of feed required to produce milk component i (or the marginal revenue of producing such milk component). The ratio Pf/Ft is considered equal to the cost of the additional feed energy required to produce one extra unit of milk component i (or the marginal cost of producing that milk component). The rationale for this statement lies in economic theory: when market and production factors are purely competitive and in equilibrium, the market prices must equal marginal production cost. Detailed explanation of profit maximization can be found for example in Beattie and Taylor (1985, Chapter 4).

Under profit maximization behavior and purely competitive markets, increases in revenues and normal profits, can be achieved by shifting the production function (i.e. the technical relationship converting feed into milk). In our context, this translates as genetic improvement.

To assess the relative EV of each trait included in the breeding goal it is necessary to have a full description of the production system and to set the profit equation from which the proper weight of each trait can be derived (Ponzoni, 1986).

The following modification of the Visscher *et al.* (1994) profit function was assumed for a typical Argentine dairy farm of Holstein cows:

$$Pf = N \sum_{k=1}^{3} (AC_k a_k Y_k) + N_d p_d + N_t p_t - cN - (c_c N_c + c_r N_r) \qquad (2)$$

where N is the number of milking cows, and AC_k is the scaling factor of the dairy herd with age groups $i = 2,..,l$. The values a_k (k = 1, 2, 3) are the prices of one kilogram of milk protein (P), or fat (F) or volume (V), and the mean production levels of mature (6 year-old) cows are the Y_k (k = P, F, V). N_d and p_d are the number and the price per cull cow, respectively; and N_t and p_t are similar values for male calves. The factor c represents non-feeding costs per milking cow; c_c is the rearing cost of female calves and N_c is the number of female calves. Finally, c_r and N_r are the feeding costs and the number of replacement heifers, respectively. For each milk component, AC_k was calculated using correction factors, with respect to mature cows:

$$AC_k = \frac{\sum_{i=1}^{n} CF_i N_i}{\sum_{i=1}^{n} N_i} \qquad (3)$$

In (3), N_i is the number of cows in age group i, and CF_i is the correction factor for age i from Beard (1992). The AC coefficient takes into account that milking cows are of different ages. Therefore, different levels of production in relation to a mature cow of the same breed, are to be expected. Expression (2) shows that the profit function consists of the difference between income and expenses. Milk components and culled animals are the income sources, and all but feeding costs are the expenses. Feeding costs are not included as they are taken into account on calculating the EV's. Thus, the derivative of Pf with respect to each component x is equal to:

$$\frac{Pf}{x} = N AC_x a_x \qquad (4)$$

which is no more than an adjusted marginal revenue of component x.

Then, in order to calculate Pf, a milking herd with 100 cows ages 2 to 11 was considered. The AC coefficients obtained using (3) were 0.90095, 0.90236, and 0.90095 for P, F, and V, respectively. The prices of P and F (US$2.505 and US$1.56 /kg respectively) were obtained from main Argentine dairy factories, and correspond to historic prices.

They are base prices without bonuses. The price was a weighed average between the value of milk produced from late fall to early spring, and the price of the remaining months. It was assumed that 25% of the total milk produced goes to the fluid market and 75% to manufacture (SAGyP, 1994). The proposed model sustains the idea that V (volume) has negative price (Dommerholt and Wilmink, 1986; Beard, 1988; Visscher *et al.*, 1994) due to the energetic cost of lactose synthesis and water caption; the price being even

more negative in case of water dilution (cryoscopy). Moreover, the Argentine milk industry pays for milk protein but not for lactose and, the negative price takes into account all costs associated with volume in terms of collection and transportation of milk. This charge was calculated as 5% of the price for milk with the same % of P (punishment for dillution), as currently applied by the milk processing industry, and it was equal to US $0.004 per liter. The annual levels of production for P, F, and V, were calculated for a mature cow with a calving interval of 395.4 days, a length of lactation of 297 days, and milk composition of 3.12% P and 3.5% F, which can be considered as average values for the country. The annual non-feeding costs per milking cow include AI, veterinary fees, maintenance of milking equipment and facilities, electricity and milk recording. The costs related to rearing calves and to growing replacement heifers were also included in Pf calculation.

Total metabolizable energy needs (ME, in MJ/year), were calculated for each age group and they include requirements for maintenance, pregnancy, growth, and milk production. The requirements of maintenance and growth were calculated as a function of metabolic body weight, which in turn was a function of time. Therefore, average body weight was calculated according to Beard (1992) as $W(t) = A\ h(t)$, where $h(t) = \{1 - [1 - (p_A)^{1/3}]\exp(-kt)\}^3$.

The values A and p_A are maturity weight and birth weight (as a proportion of maturity weight), respectively; t is age expressed in days and k is a constant. Maturity weight was assumed to be equal to 600 kg, and p_A and k were respectively equal to 0.067 and 0.0025.

Maintenance and growth requirements were calculated according to AFRC (1993), as shown in Appendix 1. The requirement for pregnancy was assumed to be equal and constant for each cow within a given age group (SCA, 1990). Finally, the requirements for production (R_p) were calculated as suggested by Visscher et al.,1994):

$$R_p = N_m (AC_p\ k_p\ P_m + AC_f\ k_f\ F_m + AC_v\ k_v\ V_m) \quad (5)$$

where N_m is the number of milking cows; P_m, F_m and V_m, respectively, are the production levels for a mature cow of P, F and V; and k_p, k_F and k_v are the metabolizable energy required per kg of P, F and V, respectively. The values used for the energy requirements were: 35.6 MJ/kg for P, 69.9 MJ/kg for F, and 25.1 MJ/kg for lactose (Dommerholt and Wilmink, 1986; Beard, 1988). The energy required to produce 1 kg of milk volume containing 3.12% of P, 3.5% of F, 4.73% of lactose, 8.6% of NFS, and 11.7% of TS was equal to $(25.1)(0.0473)(1000) / (1\,000 - 0.035 - 0.0312) = 1.1872$ MJ. Of this total requirement, 60.4% was employed for maintenance, 12.3% for growth and pregnancy, and 27.3% for milk production. Corresponding values from Visscher et al. (1994) were 52.6%, 10.8%, and 36.6 %. The difference reflects a higher level of milk production in the Australian study.

Dividing the calculated values of total profit by total energy required gave a Pf/Ft ratio of US$4.70 / GJ. The factors k_p, k_F and k_v are the additional requirements to produce a unit of P, F and V, respectively, formally:

$$\frac{Ft}{P}\ k_p \quad \frac{Ft}{F}\ k_f \quad \frac{Ft}{V}\ k_v \quad (6)$$

Finally, the EV's were obtained by substituting (4) and (6) in (1), such that:

$$\frac{dPf}{dx}\ N\ AC_x\ a_x\ k_x\ \frac{Pf}{Ft} \quad (7)$$

which if the farmer is maximizing profit becomes

$$\frac{dPf}{dx}\ N\ AC_x\ MR_x\ MR_{cx} k_x \quad (8)$$

where $MR_x - Mc_x$, represents the marginal revenue and the marginal cost of the component x. If the farmer is maximizing profits, it should be equal to zero.

Results and Discussion

Economic values: Table 1 shows the EV's both in US$ per milking cow per year and in standardized form. The values of the genetic standard deviations used for standardizing EV's were 14.4, 19 and 475 kg for P, F and V, respectively (Musi, D., personal communication).

Using the second column in Table 1, the resulting index is equal to:

$$I_j = 2.1131 aP_j + 1.1250 aF_j - 0.083 aV_j \quad (9)$$

and using the last column is:

$$I_j = aP_j + 0.5545 aF_j - 0.1172 aV_j \quad (10)$$

In (9) and (10), aP_j, aF_j and aV_j are the best available predictions of the breeding values for P, F and V, respectively, of sire j. With values for P:F:V of 1:0.55:-0.11, the standardized EV for P almost doubled that of F, whereas V was close to a tenth of P but opposite in sign. Visscher et al. (1994) reported corresponding values of 1:0.41:-0.40. Therefore, their standardized EV's were similar in sign to the ones estimated in this study but different in magnitude. This reflects the protein to fat price ratio ($P:$F) of.6:1 in the present investigation. The smaller negative standardized EV for V (EVV) obtained in our study, indicates a lower penalty for volume in Argentina, where costs of collection and transportation of milk have so far not been charged to the dairyman. Moreover, Argentina does not yet have a quota system to limit the volume. Rather, farmers producing larger volumes of milk receive an extra bonus.

Table 1.   Economic values of EV milk components.

Trait	$/year	$/milking cow-year	Standardized
P	211.31	2.1131	1.0
F	112.50	1.1250	0.5545
V	-0.8314	-0.0083	-0.1172

Table 2.   The effect of $P:$F and level of production on economic value (EV)

Production Level	Milk Component	Protein: Fat Price ratios ($P:$F)							
		1.6:1	2:1	5:1	10:1	1.6:1	2:1	5:1	10:1
		$/cow-year				Standardized			
1 150	P	2.113	2.227	2.965	3.444	1	1	1	1
	F	1.125	0.919	0.349	0.065	0.555	0.430	0.123	0.020
	V	-0.008	-0.008	-0.009	-0.011	-0.117	-0.109	-0.095	-0.092
1 440	P	2.067	2.182	2.919	3.397	1	1	1	1
	F	1.034	0.831	0.259	-0.028	0.521	0.397	0.092	-0.009
	V	-0.010	-0.010	-0.011	-0.012	-0.142	-0.132	-0.112	-0.107
1 725	P	2.026	2.143	2.873	3.350	1	1	1	1
	F	0.954	0.754	0.180	-0.110	0.490	0.366	0.065	-0.034
	V	-0.011	-0.011	-0.012	-0.014	-0.165	-0.152	-0.128	-0.121
2 012	P	1.990	2.108	2.844	3.318	1	1	1	1
	F	0.883	0.685	0.111	-0.183	0.462	0.339	0.041	-0.057
	V	-0.012	-0.012	-0.014	-0.015	-0.186	-0.171	-0.142	-0.133

Sensitivity analysis: The sensitivity of the calculated EV's was analized considering multiple scenarios differing in level of production and $P:$F ratio, as one can expect the latter to be higher in the near future in Argentina. EV' s were calculated for seven different $P:$F ratios (1.6, 2, 5, 6.8, 7.8, 8.2, and 10 to 1) and four mean levels of production (base level and 25%, 50% or 75% in excess of the base), in order to test the effects of these variations on EV' s by means of linear regression analysis. The scenarios included in the sensitivity analysis were based on previous research conducted in USA and New Zealand, since there is no previously published research on EV's for milk components in Argentina.

A condensed summary of the results including four $P:$F ratios is presented in Table 2. For the range of variation analyzed, the EV's for P (EVP) always had the greatest absolute and relative values. Leitch (1994) noted that P had the highest EV in Canada, continental Europe, Israel, New Zealand, UK and USA. Results presented in Table 2 also show that EVV was always negative. Similar results were obtained for EVP and EVV in New Zealand, where pastures are the main nutritional resource, as in Argentina.

In a study conducted in Australia, Bowman *et al.* (1996) found that EVV' s were negative where milk mostly goes to manufacturing, again in accordance with the situation in Argentina. The ratio EVP/EVF changed more than did the ratio of absolute values ($P:$F). For example, for the base production level, changing $P:$F from 2:1 to 5:1 resulted in a change in standardized EVP/EVF from 1: 0.043 (ratio value of 2.32) to 1:0.123 (ratio of 8.13). Thus, a 2.5-fold increase in $P:$F produced a 3.5-fold increase in standardized EVP/EVF. This result, which is due to the higher ME cost of producing F than P, justifies the use of economic values instead of component prices only. Beard (1988)

noted that the differential energy requirements to produce P, F and V, induce small changes in prices to render large changes in EV' s. The EVF became negative when $P:$F increased to 10:1, and was equal to -0.028, -0.110, and -0.183, for daily production levels of 14.40, 17.25, and 20.12 kg/cow, respectively. Under such conditions, the price of F was not high enough to compensate the cost of producing more of it. This finding was also reported by L. I. C. (1996).

Regression analysis of sensitivity: A regression analysis was conducted in order to: 1) test the effects of $P:$F ratio and level of production on EV values and 2) obtain prediction equations for future calculation of EV's. For EVP and EVF, the models that gave the best fit included linear and quadratic effects of $P:$F (P < 0.01) and linear effects of level of production (P < 0.01). For EVV, linear effects of both $P:$F and level of production (P < 0.01) were present in the model with the best fit. Durbin-Watson statistics to test first-order autocorrelation, i.e. the hypothesis being 'the autocorrelation parameter is equal to zero' (Ho: ro= 0), as described in Ramanathan (1989) and Goldberger (1991), did not reject the null hypothesis in all three models. The prediction equations were:

$$\hat{E}VP = 1.8 + 0.328533239\,(\$P:\$F) - 0.01519587\,(\$):\$F)^2 - 0.014257499(PL)$$

$$\hat{E}VF = 1.83093858 - 0.30437109\,(\$P:\$F) + 0.01620026\,(\$P:F)^2 - 0.02791823(PL)$$

$$\hat{E}VV = -0.0021657967 - 0.0003128185\,(\$P:\$F) - 0.000477754\,(PL)$$

where PL is level of production. In USA, Harris and Freeman (1993) observed that changes in $P:$F had a small impact on EVV, but a large effect on the ratio EVP/EVF. This effect was larger the greater the proportion of milk sent to industry. In Canada, Gibson *et al.* (1992) found that EV' s

of production traits, and the corresponding indeces, were relatively insensitive to level of production and feeding costs. However, they were sensitive to pricing system, which involved \$P:\$F.

The present prediction equations for the EV's allow Argentine dairy farmers to set up their own economic indeces for selection, taking into account differences in pricing system (\$P:\$F) and level of production. The economical significance of the EV's so calculated becomes more important as the \$P:\$F ratio increases.

Literature Cited

AFRC. 1993. Energy and Protein Requirements for Ruminants. Agriculture and Food Research Council. Technical Committee on Responses to Nutrients. CAB International, Wallingford, UK.

Beard, K. T. 1988. Efficiency of index selection for dairy cattle using economic weights for major milk constituents. Aust. J. Agric. Res. 38: 273.

Beard, K. T. 1992. Studies on breeding objectives and selection indices applicable to the Australian dairy cattle industry. PhD thesis, Univ. of NSW, Australia.

Beattie, B. R. and C. R. Taylor. 1985. The Economics of Production. J. Wiley & Sons. New York.

Bowman, P. J., P. M. Visscher, and M. E. Goddard. 1996. Customized selection indices for dairy bulls in Australia. Anim. Sci. 62:393.

Brascamp, E. W., C. Smith, and D. R. Guy. 1985. Derivation of economic weights from profit functions. Anim. Prod. 40: 175.

Dommerholt, J. and J. B. M. Wilmink. 1986. Optimal selection response under varying milk prices and margins for milk production. Liv. Prod. Sci. 14:109.

Gibson, J. P. 1989. Selection on the major components of milk: alternative methods of deriving economic weights. J. Dairy. Sci. 72:3176.

Gibson, J. P., N. Graham, and E. B. Burnside. 1992. Selection indexes for production traits of Canadian dairy sires. Can. J. Anim. Sci. 72: 477.

Goldberger, A. S. 1991. A Course in Econometrics. Harvard University Press, Cambridge, MA.

Harris, B. L. and A. E. Freeman. 1993. Economic weights for milk yield traits and herd life under various economic conditions and production quotas. J. Dairy Sci. 76: 868.

Harris, D. 1970. Breeding for efficiency in livestock production: defining the economic objectives. J. Anim. Sci., 30: 860.

Leitch, H.W. 1994. Comparison of international selection indices for dairy cattle breeding. Proc. Interbull Annual Meeting, Ottawa, Canada. 1-8.

Livestock Improvement Corporation. 1996. Animal Evaluation Technical Advisory Committee Report, 1st. Ed. 26 p.

Ponzoni, R.W. 1986. A profit equation for the definition of the breeding objective of Australian Merino sheep. J. Anim. Breed. Genet. 103:342.

Ramanathan, R. 1989. Introductory Econometrics with Applications. HBJ Publishers, Florida. pp 329-366.

Secretaría de Agricultura, Ganadería y Pesca (SAGyP). 1994. Estadísticas Agropecuarias y Pesqueras. Buenos Aires.

SCA, 1990. Feeding Standards for Australian Livestock: Ruminants. CSIRO Publications, Melbourne.

Visscher, P. M., P. J. Bowman, and M. E. Goddard. 1994. Breeding objectives for pasture based dairy production systems. Liv. Prod. Sci. 40:123.

Appendix 1

Requirements for maintenance

The maintenance requirements of each age group were calculated using a slight modification of the AFRC (1993) procedure:

$$MJ_i / day = \frac{0.53 \left(\frac{W_i}{1.08}\right)^{0.67} 1.2}{k_m},$$

where W_i is the live weight of a cow in age-group i, and $k_m = 0.35q + 0.503$, with q being the diet metabolizability at maintenance. The numerator of the above expression corresponds to the requirements for fasting metabolism plus an allowance for voluntary activity. Total requirements (R_m) are the sum of annual requirements for all age-groups (i=0,..,n):

$$R_m = \sum_{i=0}^{n} (N_i MJ / day \; 365)$$

The value of N_i corresponds to the number of animals in age-group *i*.

Requirements for growth

The metabolizable energy required per animal and per day was calculated for each age group, using AFRC (1993), as:

$$ME_i / day = \frac{W_i E_i}{k_e}$$

where W_i is daily gain (in grams) for each age-group and E_i is the energetic value of one kg of live weight gain calculated as:

$$E_i, MJ/kg = \frac{C_2 (4.1 + 0.0332 W_i - 0,000009 W_i^2)}{(1 - C_i 0.1475 + W_i)},$$

where $C_1 = 1$ and $C_2 = 1.15$ for heifers.

Total requirements for growth (Rg) were calculated as:

$$R_g = \sum_{i=0}^{n} (ME_i / day \; 365 N_i)$$