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Relationship between profitability and type traits and derivation of economic values for reproduction and survival traits in Chianina beef cows

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ABSTRACT: The objectives of this study were 1) to propose a profit function for Italian Chianina beef cattle; 2) to derive economic values for some biological variables in beef cows, specifically, production expressed as the number of calves born alive per year (NACY), age at the insemination that resulted in the birth of the first calf (FI), and length of productive life (LPL); and 3) to investigate the relationship between the phenotypic profit function and type traits as early predictors of profitability in the Chianina beef cattle population. The average profit was 196€/cow·yr for the length of productive life (LPL) and was obtained as the difference between the average income of 1,375€/cow·yr for LPL and costs of 1,178€/cow·yr of LPL. The mean LPL was equal to 5.97 yr, so the average

total phenotypic profit per cow on a lifetime basis was 1,175€. A normative approach was used to derive the economic weights for the biological variables. The most important trait was the number of calves born alive (+4.03€/cow⁻¹·yr⁻¹ and +24.06€/cow). An increase of 1 d in LPL was associated with an increase of +0.19€/cow·yr and +1.65€/cow on a lifetime basis. Increasing FI by 1 d decreased profit by 0.42€/cow·yr and 2.51€/cow. Phenotypic profit per cow had a heritability of 0.29. Heritabilities for eight muscularity traits ranged from 0.16 to 0.23, and for the seven body size traits between 0.21 and 0.30. The conformation trait final score can be used as an early predictor of profitability. The sale price of the animal and differences in the revenue and costs of offspring due to muscularity should be included in a future profit function.

Key Words: Chianina, Economic Values, Genetic Analysis, Profit Function, Type Traits

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Introduction

The general breeding goal in beef cattle is to obtain a new generation of animals that are better adapted to the expected future production circumstances than their parents. When several traits are included in the breeding goal, economic values are used to combine EBV for the individual component traits into an overall EBV for economic merit. Different methods are available to calculate economic values. Two approaches of deriving economic weights can be distinguished: 1) a positive approach that involves the use of historical prices; and 2) a normative approach that involves the use of a profit function or bioeconomic model (Hazel, 1943; Groen, 1990; Van Arendonk, 1991; Wilton and

Goddard, 1996). In most studies that have addressed individual cow (predominantly dairy cattle) profitability (Van Arendonk, 1991; Pérez-Cabal and Alenda, 2002, 2003) or herd profitability (Veerkamp et al., 1994; Norman et al., 1996), the breeding objective was defined as a linear function of the major costs and returns (Wilton and Goddard, 1996).

Because lifetime profitability of a cow is a trait that can be recorded only after the cow has been culled, finding an early predictor of profitability is important for breeders (Forabosco et al., 2004). In dairy cattle, type traits are used as an early predictor of longevity (Vollema, 1998; Larroque and Ducrocq, 2001) and as indirect selection criteria for profitability (Norman et al., 1996; Vollema et al., 2000). For beef cattle, however, little is known about the relationships between profitability and type traits.

The aims of this study were to derive profit equations for the Chianina population, to determine the relative economic weights of reproduction and survival traits in Chianina cows and to investigate the genetic relation-

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ship between profit and type traits that can be used as early predictors of profitability. Both positive and normative approaches were used.

Materials and Methods

Profit

Data Used in the Positive Approach. In the positive approach, profit for each cow was calculated using real data from the Italian Chianina population. Those data were provided by ANABIC (the National Association of Italian Beef Cattle Breeders, Perugia, Italy) and consisted of information from 6,358 Chianina cows (8,382 before editing) with records on reproduction, production, and type traits. The cows were born between January 1, 1981, and December 31, 1996, and evaluated for type traits between 14 to 50 mo of age according to the breed's linear type trait evaluation system; however, type scoring data were collected continuously until 2003. Records from animals without information such as birth data, parity dates, and production data were excluded, as were data for cows changing herds during their productive lives. Age at first calving was required to be between 25 to 50 mo, and calving intervals had to be between 270 and 700 d long to be considered valid data. These wide ranges are common in Chianina and were included to account for different management systems. All parities up to the 12th were analyzed. Data from those herds with fewer than 10 cows were deleted from the analysis. Approximately 29% of the cows were daughters of the 66 AI sires, and the rest of the cows in the dataset were daughters of 783 natural service (NS) sires. The AI sires had an average of 24 daughters compared with an average of five daughters for the NS bulls. The data showed a high use of NS sires, which is understandable, given that almost 35% of the management systems involved in the study used summer grazing on pasture.

Longevity was measured for the cows born before December 31, 1996, as length of productive life (LPL), defined as the number of years from the age at the insemination that resulted in the birth of the first calf to the date of culling or censoring. For the cows that were alive at the end of the study, the censoring date coincided with the date of the end of the study. Six months were added after the last date of calving to account for the time that the calf remains with the cow. The dataset included records from cows with complete (4,374 uncensored records) and incomplete (1,934 censored records) LPL.

Assumptions. All animals alive and dead (censored and uncensored cows) were included in the analysis, and no distinctions between data were made. For the censored animals, only cows with at least a 6-yr opportunity of survival were included. Otherwise, results corresponding to young sires would have been biased, because observed survival times would have been available only for the daughters that died early in life

(Cassandro et al., 1999; Forabosco et al., 2004). Data for censored cows are an important source of information because including only information for uncensored cows will decrease the accuracy of the indexes, increase the generation interval, and may decrease (drastically) the use of the young sires.

This study focused on reproduction and survival traits. Data on other traits, such as differences between animals in muscle conformation, marbling, and age and weight at slaughter, are not currently available for Chianina. Hence, conclusions for the relative economic importance of other traits (e.g., muscularity vs. reproduction and survival traits) cannot be drawn from the present study. The profit function and the economic weights should be updated when new information becomes available (Meuwissen and Goddard, 1997).

For the length of productive life, it was assumed that beef cows start to produce when they become pregnant, so the LPL was measured starting from the time of the insemination that resulted in the birth of the first calf (FI). For beef cattle, the most important source of income is the calf, which has an economic value that can be up to 10 times higher than that of a dairy calf of the same age. It is because of this high value of the calf that we decided to consider the productive life as starting from the date the cow became pregnant, rather than when she calved as is typically the case for dairy cattle.

Profit Functions. The profit function was expressed either as $\text{€}\cdot\text{cow}^{-1}\cdot\text{yr}^{-1}$ (**Py**) or as lifetime profit (**Pc**) in $\text{€}/\text{cow}$. In the first case, profit per cow was calculated as the difference between revenue (**R**) and yearly costs (**C**) per cow; in the second case, profit per cow (**Pc**) was expressed as the difference between lifetime revenue (**Rc**) and costs (**Cc**) per cow. The profit function described in this section is used for the positive as well as the normative approach for calculating economic weights. For the positive approach, **Py** and **Pc** were calculated for each cow in the dataset.

In the production system assumed in this study, which simulates the Italian system, beef cows were raised on pasture and the offspring (both males and females) that were born from these cows were sold to the market after weaning at an age of 6 mo. In many Italian beef production systems, young heifers are kept by breeders to replace culled cows, but in this work, the profit function assumed that all heifers were sold to the market at 6 mo, and the replacement females were bought from the market at the same age and for the same price. The calves that were not bought to replace culled cows were assumed to be sold to feedlots. All herds considered in this analysis were assumed to have the same market conditions and a similar production system. Analyses and results presented in this study refer to herds of cows, not to feedlots. In calculating **Py** and **Pc**, the cost of buying a single replacement heifer for a cow (independent of LPL) was included.

The economic information used to derive parameters for the study was based on the data collected in Italy by the National Institute of Economics (ISMEA). Economic

information, such as sale prices for cows, calves, and heifers, feed costs for cows, calves, and heifers, costs for housing, shelters, taxes, and other expenses were supplied by ISMEA (2002), ISMEA (2004), and the Research Center for Animal Production (CRPA, 2004). Bonuses and penalties (i.e., Regulation [EC] No. 2342/99 about rules concerning the beef market premium) were not considered in the analysis because they change independently of the market. Labor costs were excluded, so the net revenues were assumed to serve as compensation for the supplied labor. Reproductive information, such as number of calves born and heifers raised to given ages, LPL, and other reproductive information were collected by ANABIC and other local organizations (AIA, 2003) and integrated with the economic data.

Revenue was calculated (Eq. [1]) as the sum of male calves sold, females calves sold, and cows sold, all expressed as €/cow·yr of the cow's LPL. Each cow produced $(1 - \text{DEP}) \times \text{NACY}$ offspring per year, with an equal probability of 0.5 for males and females. Revenue, expressed as €/cow·yr, was therefore equal to

$$R = 0.5 \times (1 - \text{DEP}) \times (\text{NACY} \times \text{CPR}) \\ + 0.5 \times (1 - \text{DEP}) \times (\text{NACY} \times \text{JCPR}) + \text{CCPR} / \text{LPL}$$

which simplifies to

$$R = [0.5 \times (1 - \text{DEP}) \times \text{NACY} \\ \times (\text{CPR} + \text{JCPR})] + \text{CCPR} / \text{LPL} \quad [1]$$

where DEP = proportion of dead animals (males and females) up to the sale of each cow assuming that the rate is the same for both sexes (2% each); NACY = number of calves born alive for each cow per yr of the cow's LPL; CPR = market price for males at weaning age (6 mo), €/male calf; JCPR = market price for females at weaning age (6 mo), €/female calf; CCPR = market price for cows at the end of their productive life, €/cow; and LPL = length of productive life, yr.

The annual number of cows born alive (NACY) was calculated as the total lifetime number of calves born alive for each cow (NAC) divided by the length of productive life, $\text{NACY} = \text{NAC} / \text{LPL}$. Lifetime revenue (Rc), expressed in €/cow, was calculated as follows:

$$\text{Rc} = [0.5 \times (1 - \text{DEP}) \times \text{NAC} \\ \times (\text{CPR} + \text{JCPR})] + \text{CCPR} \quad [2]$$

or equivalently,

$$\text{Rc} = R \times \text{LPL}$$

The beef price when the animals are sold to the market is affected by different parameters (e.g., destination of the animal, such as for replacement or for fattening, market conditions, etc.), but the data used in this study

did not include individual sale prices for each animal, and thus, no distinction was made in sale prices between animals. A distinction between feed and nonfeed costs was made to better understand the profit function. Feed cost included costs for concentrate, silage, forage (also from pasture), milk (for the calf), vitamins, minerals, etc. Nonfeed costs included the amortization of capital (housing, machines, land, and animals), interest, taxes, and general expenses (medicines, gas, electricity, and other costs).

Annual cost (C), expressed in €/(cow·yr), was calculated as follows:

$$C = \text{JCPR} / \text{LPL} + \text{RERHF} \times (\text{FI} - 0.5) / \text{LPL} \quad [3] \\ + \text{NACY} \times (\text{FCC} + \text{OCC}) + \text{FC} + \text{OC}$$

where RERHF = feed and non-feed costs for heifers until pregnancy, €/yr; FI = age at the first insemination that results in the first calf, yr; 0.5 = the age of purchased heifers (6 mo); FCC = average feed costs per calf (calculated from conception until 6 mo), €; OCC = average non-feed costs per calf until 6 mo of age, €; FC = average feed cost per cow after FI, €/yr; and OC = average non-feed costs per cow after FI, €/yr.

Lifetime cost (Cc) expressed in €/cow was as follows:

$$\text{Cc} = \{\text{JCPR} + [\text{RERHF} \times (\text{FI} - 0.5)] + \text{NAC} \\ \times (\text{FCC} + \text{OCC}) + \text{LPL} \times (\text{FC} + \text{OC})\} \quad [4]$$

or

$$\text{Cc} = C \times \text{LPL}$$

The FC and OC were assumed to be constant during the lifetime of the cow starting from when the cow became pregnant (immediately after the FI). No twins were considered in this analysis. The proportion of dead animals (DEP) was not included in the cost function because the majority of casualties occur when the animals are very young and are therefore not included in calculating costs for feeding and housing.

Aggregate Genotype and Derivation of Economic Values from the Profit Functions P_y and P_c

A profit equation representing the production system is used to derive the economic value for each trait in the aggregate genotype (Hazel, 1943; Brascamp et al., 1985; Groen, 1990). In this study, the aggregate genotype includes NACY, LPL, and FI. The aggregate genotype ($H_{(p)}$ and $H_{(pc)}$) is the weighted sum of the product of true breeding values and economic weights of NACY, LPL, and FI.

In the normative approach, the economic value of each breeding goal trait is found as the partial derivative of profit with respect to that trait. The economic weights are derived from the profit functions (such as P_y and P_c) as partial derivatives of the profit functions

Table 1. Prices and costs used in the profit function currently used in Italy

Prices and costs	Price, €	Source
Male calves at 6 mo	1,700	ISMEA (2002); ISMEA (2004)
Female calves at 6 mo	1,700	ISMEA (2002); ISMEA (2004)
Cow at slaughter age	600	ISMEA (2002); ISMEA (2004)
Feed and nonfeed costs for heifers (RERHF), per year	930.7	CRPA (2004)
Feed costs per mature cow (FC), per year	208.4	ISMEA (2002)
Nonfeed costs per mature cow (OCC), per year	336.0	ISMEA (2002)
Feed costs per calf (FC)	70.5	F. Forabosco (unpublished data)
Nonfeed costs per calf (OCC)	92.0	F. Forabosco (unpublished data)

(∂P and ∂Pc) with respect to the traits NACY, LPL, and FI (Moav and Moav, 1966; Brascamp et al., 1985; Weller, 1994).

For the profit equation (P_y), defined above as the difference between Eq. [1] and Eq. [3], the economic weights were as follows:

$$v_{NACY,P} = 0.5 \times (1 - DEP) \times (CPR + JCPR) - (FCC + OCC)$$

$$v_{LPL,P} = [-CCPR + JCPR + RERHF \times (FI - 0.5)] / LPL^2$$

$$v_{FI,P} = -RERHF/LPL$$

A derivation of economic weights for the profit equation (P_c), defined as the difference between Eq. [2] and Eq. [4], was obtained as follows:

$$v_{NACY,P_c} = [0.5 \times (1 - DEP) \times (CPR + JCPR) - (FCC + OCC)] \times LPL$$

$$v_{LPL,P_c} = 0.5 \times NACY \times (1 - DEP) \times (CPR + JCPR) - NACY (FCC + OCC) - (FC + OC)$$

$$v_{FI,P_c} = -RERHF$$

In the above derivations, the mean values have been used for the variables LPL, NACY, and FI.

Positive Approach

In the positive approach, an observation for profit of each cow was calculated by combining observations from the data set with the profit equations presented above. Subsequently, economic values were obtained as regression coefficients of profit on LPL, FI, or NACY using a multiple regression model in SAS (SAS Inst. Inc., Cary, NC). Those regression coefficients measure the relative contributions of each trait for phenotypic profit, either per year (P_y) or per lifetime (P_c). The profit functions P_y and P_c were corrected for the herd-year effect to account for differences between herds over the years.

Type Traits

Variables available for each cow were NACY, FI, LPL, phenotypic profit per cow (P_c), and 16 type traits. For the Italian Chianina, the type traits (ANABIC, 2001) consist of eight muscularity traits and seven body size traits, each of which is evaluated on a linear scale from 1 (very undesirable) to 5 (ideal). The final score (**FS**) is obtained by combining four general traits, structure and legs, body size, muscular development, and breed character, each with an equal weight (i.e., 25% for each trait). Scoring is performed by breed experts, who evaluate all animals present in each herd during a single yearly visit. For this study, only cows with complete type information were included. When cows were scored more than once, only the first conformation score was used.

Genetic and Phenotypic Parameters

A multiple-trait animal model was used to estimate the covariance components and EBV for NACY, FI, LPL, phenotypic profit per cow (P_c), the final score, and 16 type traits (20 traits in total). The model for the analysis was as follows:

$$Y_{ik} = HY_i + a_k + e_{ik} \quad [5]$$

where Y_{ik} = traits; HY_i = fixed effect of herd-year; a_k = random animal effect; and e_{ik} = residual error.

Computations were performed using the publicly available computer programs MTC (Misztal et al., 1995) and MTJAAM (Gengler et al., 1999). The covariance components were obtained through back transformation to the original scale (Misztal, 1990; Misztal et al., 1992). Convergence was assumed when mean squared differences between (co)variance matrices in consecutive rounds were $<10^{-7}$.

To evaluate the effect of the age at which the FS is taken, a second analysis was performed, using the same model and the same dataset described before, but cows were split into two groups depending on the age at which their FS was recorded. The first group had their FS score recorded at an age of less than 39 mo, whereas the second group at an age of greater than 39 mo. Thirty-nine months was chosen because it is the mean age at which the cows are scored.

Table 2. Descriptive statistics of profit function and the biological parameters considered

Traits	Mean	SD	CV
Profit function			
Phenotypic profit (Py), €/(cow·yr) of productive life	196	562.9	285.9
Return (R), €/(cow·yr) of productive life	1,375	607.0	44.1
Cost (C), €/(cow·yr) of productive life	1,178	92.2	7.8
Phenotypic profit (Pc), €/cow	1,175	3,361.7	285.9
Return (Rc), €/cow	8,214	3,625.2	44.1
Cost (Cc), €/cow	7,038	550.5	7.8
Parameters			
Age at the insemination (FI), yr	1.93	0.50	26.1
Length of productive life (LPL), yr ^a	5.97	2.52	42.3
No. of calves born per year of productive life (NACY)	0.78	0.37	47.6

^aCensored as well as uncensored data. The LPL was calculated from the insemination that results in the first calf up to the date of culling or censoring plus 6 mo, which is the normal time required for the cow to raise the calf.

Results and Discussion

Profit Functions

In a normative approach, the profit function and the derivation of economic weights presented in this article require that profit can be described by revenues and cost functions, all of which are subject to the same scaling factors such as the same number of animals in the enterprise, the same market conditions and a similar management system. Tables 1 and 2 show the basic descriptive statistics for the parameters used for the profit function. It is emphasized that those values are specific for the Italian Chianina population; values may differ for other populations. Average annual profit for a cow was 196€/(cow·yr) and was obtained as the difference between average income of (1,375 ± 623.3€·cow⁻¹·yr⁻¹ of LPL) and costs (1,178 ± 92.2€·cow⁻¹·yr⁻¹ of LPL). The total lifetime profit per cow (Pc) was 1,175€/cow and the LPL was equal to 5.97 ± 2.52 yr. Because a profit function is market-dependent, when the market circumstances change (i.e., from one country to another or inside the same country), the profit function must be adapted. The average LPL was higher than that found by Forabosco et al. (2004) for the same breed, which was due to the fact that the LPL included the first pregnancy plus 6 mo after the last parity. Average NACY was 0.78 ± 0.37 calves/yr.

Economic Weights

Table 3 reports the economic weights obtained with the normative approach for LPL, FI, and NACY. The highest economic value was found for NACY. An increase of one extra calf per year expressed as a revenue per day implied an increase of +4.03€/(cow·yr) and +24.06€/cow over the course of a lifetime. A 1 d increase in LPL was associated with an increase of +0.19€/(cow·yr) and +1.65 €/cow. An increase of 1 d of the age of insemination that resulted in the birth of the first calf (FI) decreases the profit respectively by 0.42€/(cow·yr) and 2.51€/cow. Genetically, NACY (0.907€·cow⁻¹·yr⁻¹) and LPL (0.169€·cow⁻¹·yr⁻¹) were found to be the most important economic traits for the Chianina beef cattle and the farmer should consider both in a breeding program for increased profit. Similar results were also found in dairy cattle by Van Arendonk (1991), Jagannatha (1998), and Perez-Cabal and Alenda (2003).

The relative size of the economic values of LPL on one hand, and FI and NACY on the other, differed between the two profit equations. This difference is already apparent when looking at the expressions for the economic values as given in the material and methods section. The economic value for FI and NACY derived from Py and Pc differ by a scaling factor, which is equal to the average LPL. For LPL, different elements come

Table 3. Absolute economic weights

Trait	Annual economic weight, €/(cow·yr)	Lifetime economic weight, €/cow	Genetic importance based on an economic weight, €/(cow·yr) ^a
Length of productive life (LPL), d	+0.19	+1.65	+0.169
Age at the insemination (FI), d	-0.42	-2.51	-0.134
Calves born alive per year (NACY), d ^b	+4.03	+24.06	+0.907

^aExpressed as $\sqrt{(h^2 * \sigma_\tau^2)} * v_{\tau,P}$, where: h^2 = heritability; σ_τ = phenotypic SD of trait τ (LPL, FI, and NACY); and $v_{\tau,P}$ = economic weight of trait τ (€·cow⁻¹·yr⁻¹).

^bEconomic weight expressed per day for one extra calf per year.

Table 4. Regression coefficients for phenotypic profit (Py and Pc) corrected for the herd-year effect^a

Trait ^b	Regression coefficients ^c			Relative importance ^d
	LPL, €/d	FI, €/d	NACY, €/d	
Pc	+2.16	-2.26	+27.39	+0.08
Py	+0.48	-0.34	+4.77	+0.10

^aCorrection for the herd-year effect was made using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). The outputs (predicted values from GLM) of Py and Pc were used as inputs for the regression analysis using SAS.

^bPy = phenotypic profit/(cow·yr); and Pc = phenotypic profit per cow.

^cLPL = length of productive life; FI = age at the insemination; and NACY = No. of calves born per year of productive life.

^dValue of increasing productive life by 1 d expressed per unit of calf born.

into the expression derived from Py and Pc, respectively. This result also has been found in other studies and reflects the importance of choosing appropriate scaling factor for the enterprise (Smith et al., 1986). Economic values derived from Py correspond to a situation where the number of cows per year is constant, whereas Pc corresponds to a situation with a constant number of replacement heifers entering the herd. Equivalently, Pc may be interpreted as the profit per heifer entering the herd. In the later case, replacement heifer costs are not included in the economic weight of LPL because these costs are equal before and after the genetic change of LPL.

Positive Approach

Results from the multiple regression model for both profit functions, the Py and the Pc, are given in Table

4. Those traits, corrected for the herd-year effect, explained 98 and 78% of the total variation (R^2) in Pc and Py respectively. The relative importance of LPL to the production (NACY) was calculated as the value of 1 d of LPL expressed per unit of calf born and was equal to +0.10 $\text{€}\cdot\text{d}^{-1}\cdot\text{unit of calf born}^{-1}$ for Py, which was higher than Pc (+0.08 $\text{€}\cdot\text{d}^{-1}\cdot\text{unit of calf born}^{-1}$).

The economic weights derived from the regression analysis (i.e., the regression coefficients) were in good agreement with the results obtained in the normative approach. The differences in the values obtained for LPL could have resulted from censoring in the real data. The effect was relatively small, however. This close agreement makes it worthwhile to look at the value of predictor traits in an analysis of data as reported in the next section.

Type Traits

Table 5 shows descriptive statistics of the type traits, all of which had similar means near the midpoints of their respective ranges, as expected. Final score was the only type trait with a different mean (82.7 ± 1.9) and a scale between 74 to 91. Genetic correlations among the 15 type traits, FS, FI, NACY, and LPL are shown in Table 6. Genetic correlations between all pairs of the eight muscularity traits were high and positive, ranging from 0.62 to 0.85. Genetic correlations among the seven dimensional traits ranged from 0.59 to 0.90. Correlations between muscularity and dimensional traits were always positive. Final score was moderately to highly associated genetically with all muscularity and dimensional traits; the genetic correlation ranged from 0.63 for MSC to 0.86 for chest width (BsCW).

Table 5. Summary statistics and description of 15 type traits and the final score (FS) for 6,358 cows^a

Trait	Mean	SD	CV	Optimum class	Description	
					Class 1	Class 5
FS ^b	82.67	1.93	2.34			
Muscle development						
Wither width (MWW)	2.63	0.71	26.8	5	Narrow	Wide
Shoulder convexity (MSC)	2.73	0.71	25.8	5	Flat	Convex
Back width (MBW)	2.71	0.74	27.2	5	Narrow	Wide
Loins width (MLW)	3.18	0.70	22.0	5	Thin	Convex
Rump convexity (MRC)	2.91	0.66	22.7	5	Concave	Convex
Thigh width (MTW)	2.98	0.72	24.2	5	Narrow	Wide
Buttock convexity (MBC)	2.91	0.66	22.6	5	Concave	Convex
Buttock length (MBL)	3.04	0.68	22.5	5	Short	Long
Body size						
Height at withers (BsHW)	3.22	0.84	26.0	5	Short	Tall
Trunk length (BsTL)	3.51	0.78	22.3	5	Short	Long
Chest height (BsCH)	3.42	0.71	20.7	5	Shallow	Deep
Chest width (BsCW)	2.98	0.71	23.7	5	Narrow	Wide
Hip width (BsHw)	3.41	0.67	19.8	5	Narrow	Wide
Ischia (Pins) width (BsIW)	2.89	0.69	24.0	5	Narrow	Wide
Rump length (BsRL)	3.39	0.71	20.8	5	Narrow	Wide

^aANABIC (2001).

^bScale between 74 to 91.

Table 6. Genetic correlation between type traits, final score (FS), age at the insemination that resulted in the birth of the first calf (FI), calves born alive per year (NACY), and length of productive life (LPL)

Traits ^a	MSC	MBW	MLW	MRC	MTW	MBC	MBL	BsHW	BsTL	BsCH	BsCW	BsHw	BsIW	BsRL	FS	FI	NACY	LPL
MWW	0.82	0.80	0.76	0.73	0.71	0.69	0.80	0.34	0.37	0.52	0.70	0.53	0.60	0.35	0.72	-0.19	0.22	0.04
MSC		0.70	0.82	0.79	0.75	0.77	0.75	0.40	0.42	0.60	0.73	0.61	0.77	0.47	0.77	-0.12	0.39	0.04
MBW			0.84	0.71	0.69	0.62	0.71	0.28	0.25	0.48	0.54	0.44	0.58	0.33	0.63	-0.01	0.16	-0.01
MLW				0.81	0.74	0.73	0.80	0.45	0.47	0.56	0.67	0.68	0.75	0.57	0.80	-0.04	0.15	0.04
MRC					0.85	0.79	0.78	0.42	0.50	0.62	0.67	0.62	0.76	0.56	0.81	-0.03	0.30	0.12
MTW						0.82	0.84	0.23	0.29	0.45	0.64	0.52	0.74	0.40	0.73	-0.06	0.39	0.08
MBC							0.79	0.30	0.41	0.52	0.72	0.52	0.66	0.40	0.75	-0.15	0.27	0.10
MBL								0.47	0.52	0.61	0.76	0.64	0.77	0.57	0.81	-0.18	0.15	0.12
BsHW									0.89	0.81	0.67	0.62	0.59	0.79	0.67	0.04	-0.05	0.03
BsTL										0.77	0.73	0.65	0.61	0.90	0.71	0.00	-0.13	0.15
BsCH											0.82	0.79	0.77	0.74	0.81	0.08	0.03	0.20
BsCW												0.80	0.80	0.69	0.86	-0.06	0.11	0.12
BsHw													0.82	0.73	0.76	-0.08	0.20	0.20
BsIW														0.74	0.81	0.16	0.15	0.15
BsRL															0.71	-0.01	-0.05	0.17
FS																-0.02	0.20	0.06
FI																	-0.37	0.11
NACY																		0.27

^aSee Tables 2 and 5 for definition of abbreviations.

Table 7. Heritability (h^2) and genetic correlation between type traits, final score (FS), age at the insemination that resulted in the birth of the first calf (FI), calves born alive per yr (NACY), length of productive life (LPL) and the phenotypic function of profit (Py)

Trait	h^2	Genetic correlation
Profit·cow ⁻¹ ·yr ⁻¹ (Py)	0.29	—
Wither width (MWW)	0.22	0.25
Shoulder convexity (MSC)	0.23	0.36
Back width (MBW)	0.21	0.15
Loins width (MLW)	0.20	0.19
Rump convexity (MRC)	0.19	0.37
Thigh width (MTW)	0.18	0.35
Buttock convexity (MBC)	0.21	0.35
Buttock length (MBL)	0.16	0.22
Height at withers (BsHW)	0.32	0.00
Trunk length (BsTL)	0.30	0.09
Chest height (BsCH)	0.24	0.27
Chest width (BsCW)	0.26	0.17
Hip width (BsHw)	0.23	0.11
Ischia (Pins) width (BsIW)	0.21	0.20
Rump length (BsRL)	0.24	0.16
Final score (FS)	0.34	0.25
Age the insemination (FI)	0.41	-0.42
Calves born alive per year (NACY)	0.12	0.35
Length of productive life (LPL)	0.14	0.51

Genetic correlations with FI were around zero for most of the traits, with the exception of NACY, for which a moderate negative genetic correlation (-0.37) was observed. Weak genetic correlations were found for LPL along with muscularity and dimensional traits, as well as the other biological variables.

The heritabilities of the various traits and genetic correlations with Py and 19 type traits are shown in Table 7. The highest heritability was observed for FI (0.41) followed by FS (0.34) and trunk length (BsTL; 0.30). Phenotypic profit (Py) had a heritability of 0.29. Similar heritability values were reported for dairy cattle by Perez-Cabal and Alenda (2002) and Visscher and Goddard (1995). Among the individual type traits, heritabilities for the eight muscularity traits ranged between 0.16 to 0.23. Heritabilities for the seven body size traits were on average a little higher (between 0.21 to 0.30) than for the muscularity traits. Genetic correlations between Py and the other traits were positive except for FI (-0.42). Forabosco et al. (2004) found that, for this breed, an increase of age at first calving increased the risk of the cow being culled and that increased age at first calving was associated with decreased productive life for the cow. Cows with genetic factors associated with increased FI tended to have decreased genetic potential for profit. The genetic correlations indicate that cows with longer LPL were more profitable than cows with short LPL. The genetic correlation between Py and LPL (0.51) was the highest correlation found for the traits evaluated in this work. It is important to note that LPL was used directly in calculating the profit.

Profit (Py) was positively correlated with early predictor traits like muscularity traits. The genetic correlation between muscularity traits and profitability ranged between 0.15 to 0.37. Genetic correlations were lower but positive between profit (Py) and dimensional traits (between 0 and 0.27) and moderate (0.25 and 0.17) for FS and FSab (FS collected at a cow aged above 39 mo) respectively. The highest genetic correlation was found between Py and the FS collected at a cow aged below or equal to 39 mo (**FSbe**) and was equal to 0.36, indicating that the final score evaluated at an early age (FSbe) is the best single early predictor of profitability. The high correlation between P and FSbe is probably due to the fact that during the years of this study the age at which the cows were scored went down, and since 2001, almost all of the cows have been evaluated at an age of less than 31 mo.

Final Considerations

From these results (Table 7), muscularity traits seem to have an important effect on profit and the final score, particularly the FSbe, summarizes all this information. Yearly profit per cow was only calculated from LPL, FI, and NACY, and important traits like muscularity were not included in the revenue and cost functions. This study, therefore, does not provide information on the relative economic importance of LPL, FI, and NACY vs. other important traits, such as muscularity. In the future, differences in revenue and costs due to the cow morphology (i.e., mainly muscularity but also dimensions) need to be included. Another important source of information is the market price of the animals, which should be recorded on an individual basis and included in a future calculation of the profit function (Amer et al., 1997). As soon as all of this information is available, it will be possible to calculate the total farm profit. This important information, which is affected mainly by the number of animals per herd and the market condition (i.e., real price of the animals), could be used to identify the farms that are able to remain in the market and the farms that are at risk of exclusion. A specific selection program could be implemented to help the farms at risk to become competitive by improving their management and the genetics of their livestock.

Implications

Estimated heritability for yearly profit per cow was moderate (0.29), suggesting that direct selection for this trait would produce a significant improvement of profitability in Chianina beef cows. Profit is a trait that can be recorded accurately only at an advanced age. Results showed that profit could be predicted, however, by using information from the linear type evaluation system. The final score evaluated at an early age, was found to be the best single early predictor of profitability. One limitation of this study was that individual information on sale prices was not available; thus, infor-

mation on variability in these data due to genetic differences in body conformation and carcass yield and quality could not be calculated. It is recommended that the beef cattle organizations start to record the sale price and implement the genetic evaluation of the yearly profit per cow as a trait per se in future breeding programs.

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