Breeding for longevity in Italian Chianina cattle

Promotor: **Prof. dr. ir. J.A.M. Van Arendonk**
Hoogleraar in de Fokkerij en Genetica
Wageningen Universiteit

Co-promotor: **Dr. ir. P. Bijma**
Universitair docent, Leerstoelgroep Fokkerij en Genetica,
Wageningen Universiteit
Dr. R. Bozzi
Dept. Animal Science
University of Florence - Italy

Promotiecommissie: **Dr. N. Gengler**
Dept. d’Agronomie, Economie et Développement
Unité de Zootechnie, Animal Breeding - Belgium
Prof.dr.ir. Alfons G.J.M. Oude Lansink
Leerstoelgroep Bedrijfseconomie
Wageningen Universiteit
Prof.dr.ir. Bas Kemp
Leerstoelgroep Adaptatiefysiologie
Wageningen Universiteit
Dr.ir.Theo Meuwissen
Norges Landbruksjhogskole
Institutt for husdyr og akvakulturvitenskap - Norway

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Flavio Forabosco

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Animal Breeding and Genetics Group
Department of Animal Science
Wageningen University, P. O. Box 338, 6700 AH, Wageningen, The Netherlands
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Abstract

The objective of this thesis was to evaluate genetic aspects of longevity (LPL) in the Chianina beef cattle population in order to define how to include this trait in selection criteria. The Chianina breed has been raised for over twenty-two centuries in Italy and today this breed is present in different countries across Europe, South and Central America, Australia, Canada and the USA. Its characteristics of somatic gigantism and rapid growth are combined with enormous resistance to harsh environmental conditions, great ease of calving and an excellent meat quality. In this breed longevity was recorded as the length of productive life (LPL), defined as years from the age at the insemination that resulted in the birth of the first calf to the date of culling or censoring. Six mo were added after the last date of calving to account for the time that the calf remains with the cow. The LPL was equal to 5.97 years on average. Heritability was equal to 0.11 when both censored and uncensored data were included to estimate longevity with the survival analysis. Type traits were used as an early predictor of profitability and muscularity traits were the most important parameters for longevity among the factors studied. Cows with approximately one calf per year remained in the herd longer than cows with fewer calves. Cows with a long LPL were more profitable than cows with short LPL. The final score could be used as an early predictor of profitability. An increase of one day unit in LPL was associated with an increase of +0.19 €/cow per year and +1.65 €/cow on a lifetime basis. Including longevity in both the Chianina breeding index and breeding goal either using empirical or economical weights has the positive effect of increasing the response (+2.97 and +4.92 days/year respectively). Beef breeding organizations should consider the opportunity to include longevity in a future breeding scheme to increase profit and to promote the well-being and welfare of the cows.

Contents

Chapter 1

General Introduction

Introduction

The longevity of a beef cow is a measurement of the time that she produces in a herd and it is determined by manifold factors such as production, fertility, health and workability (Vollema, 1998; Neerhof et al., 2000). Longevity is viewed as an important trait in many cattle breeds (Interbull, 1999). In a number of breeds, the trait is incorporated in the breeding program (Miglior, 2004). In the middle of the last century dairy cattle selection programmes started and aimed at increasing milk production (milk yield). Gradually emphasis was moved from milk yield towards protein and fat yield. In the last decade, interest has increased in broadening the selection objective to include other traits, called functional traits such as fertility, health and longevity (Pryce and Brotherstone, 1999; Beaudeau et al., 1999). Also in beef cattle, selection was initially aimed at traits related to the production such as daily gain, body weight and food conversion (Anabic, 2001). Since about ten years ago, selection emphasis has moved towards the conformation, including overall conformation expressed as final score, muscularity and body size. At the moment, functional traits are being looked into (Anabic, 2003). Functional traits are defined as those characteristics of an animal, which increase the efficiency by reducing costs of input (Groen et al., 1997; Kühn, 2003). This group of traits called "functional" traits include fertility, calving ease, temperament and longevity. For a long time these traits received little attention in beef cattle breeding. The aim of this thesis is to concentrate on longevity in Italian Chianina beef cattle.

The Chianina beef cattle

The Chianina is an ancient breed that has been raised for over twenty-two centuries in Italy and today it is present in multiple countries across Europe, South and Central America, Australia, Canada and the USA. Its characteristics of somatic gigantism and rapid growth are combined with good resistance to harsh environmental conditions and ease of calving. Chianina meat is lean with a superior commercial quality; a special meat cut called "*fiorentina*", which is taken from the loin, is famous in Italy.

The total beef cattle population in Italy, as registered at the National Herd Books, includes 281,191 head (Aia, 2003); the Italian Chianina population consists of approximately 33,000 head in 941 herds and it is one of the most important beef breeds in Italy. Cows and yearling heifers represent nearly 60% of the total population, calves represent 38.5% and bulls represent 1.5% (482 bulls) of the population (Anabic, 2003). The Chianina females are slaughtered at an age of 19 mo and at an average carcass weight of 330 kg; the bulls are slaughtered at an age of 20 mo and at an average carcass weight of 465 kg with a 64% net average dressing (Acciaioli et al., 1994; Mengoli, 2005). The meat produced in Italy from this breed comes mainly from fattened animals and replacement cows (Ismea, 2002) and it is mostly consumed in Italy. Important traits considered in the Chianina breeding goal are carcass yield, somatic development, reproductive efficiency and maternal ability.

The sires of Chianina breed are selected at the ANABIC (National Italian Beef Cattle Breeders Association) Genetic Center through the performance test (Anabic, 2001). Selection criteria include growth capacity and muscle development while respecting the traits typical of the breed. The data are collected (muscle development, growth rate before and during the performance) and summarized in a Bull Selection Index (BSI), which expresses the speed of the subject's growth rate and muscle development (Filippini, 1996). The bulls enter the test when they are 6 mo old and finish it (on average 36 per year which is 60% of the total number of bulls that enter the test) when they are 12 mo old. The 30% of bulls with the highest BSI are approved to be AI bulls and the rest of the bulls that finish the test are used as NS sires. Currently, in the Chianina tested bulls, the calves show an average daily gain of 1.432 kg/day before the performance test, while the growth reaches 1.700 kg/day during the performance test. In the last 10 years, muscularity increased from 325 to about 365 points, the average BSI of the tested sires increased from 104 to 117 and the weight at 365-days increased from 540 to about 600 kg (Canestrari, 2005).

The cows calve for the first time at an average age of 984±160.5 days and the mean calving interval is 418±81.2 days, calculated at the third parity (Filippini and Forabosco, 2000). Nearly 50% of the cows are bred by artificial insemination (AI) and 100% of the AI bulls used are tested at the Anabic performance testing station (Anabic, 2001). For the female population, production, reproduction and longevity data are routinely collected and integrated with pedigree information. Bull dams are selected only from the females that have a cow selection index (CSI) above 100 (the CSI index as μ=100 and σ=10) and a linear morphological evaluation score above 82 (Forabosco, 2002 and 2003). Among all progeny, only males born from bull dams have the opportunity to enter the performance testing station. At the end of it they become the fathers of the next offspring generation.

Longevity in cattle

Little attention has been paid to longevity in the past by beef and dairy breeders. In the last two decades a lot of attention was paid to longevity of dairy cattle, which is also relevant for beef cattle. Longevity is directly related to farm profit. Increased longevity reduces costs associated with raising or purchasing replacement females, increases the average herd production and the health and fitness of the animals (Hageman at al., 1991; Tempelman, 1998; Vukasinovic et al., 2001). Increased longevity enables increased selection response, because fewer animals have to be replaced involuntarily from a constant number of heifer calves born, resulting in higher selection intensity (Vukasinovic, 1999).

The introduction of appropriate statistical methods for genetic evaluation of longevity has taken a long time. This is due to the fact that analysis of survival data has a number of difficulties (Sölkner and Ducrocq, 1999): a) the distribution of the survival time is rarely known and in most cases extremely skewed, b) for part of the observations only a first part of the cows' life is known because the animals are still alive at the end of the study period, resulting in a large proportion of censored data c) the independent variables influencing survival time may themselves vary with time (i.e. age at first calving, herd size and conformation).

In beef cattle, particularly in Chianina, it will normally take a long time to obtain a reliable breeding value for longevity of beef bulls, because the length of productive life (LPL) of the cow is generally long. The longevity of the Chianina cow is longer than for dairy cows, which implies that it will take more time to get a reliable longevity estimate. To increase the reliability of the EBV information on relatives (full or half sisters and progeny) of the bull can be used. Most of the Chianina beef bulls use are NS (natural service) sires and they have offspring in a very limited number of herds. For this reason, the number of daughters and full or half sisters for each bull is low compared to dairy bulls where AI is used on almost all cows. Given these factors it is important for an effective selection for improved longevity to find alternatives to increase the reliability of breeding values of bulls. Attention will be paid in this thesis to traits recorded at a young age that can be used as early predictors of longevity. According to research on longevity in dairy cattle, it is possible to identify traits that can be used as early predictors of longevity. Little is known of the use of type traits to improve longevity in beef cattle.

Today, multiple dairy cattle breeding programs use type traits as early predictors of longevity (Vollema, 1998; Larroque and Ducrocq, 2001). Various studies have quantified the importance and the impact of type traits on longevity in dairy cattle (Boldman et al., 1992; Pasman and Reinhardt, 1999; Larroque and Ducrocq, 2001). Research indicates that dairy cows of moderate size, with functional udders and correct feet and legs are more likely to remain in the herd than cows that lack these characteristics.

In contrast to dairy cattle breeding programs, in which bull selection is based on progeny testing, in most beef breeding programs bull selection is based on testing of their own performance. Consequently, an imitation of the strategy applied in dairy cattle breeding would involve a major modification of beef breeding programs. One way to include longevity in the beef breeding programs without substantially modifying the breeding scheme is to implement selection based on early predictors of longevity such as the type traits of the cows. In Chianina beef cattle all the cows registered in the National Herd Book are evaluated for the type traits between 15 to 30 mo of age according to the linear type trait evaluation system (Anabic, 2001). Those beef cattle are evaluated for 26 traits, of which 22 are scored on a linear scale. The final score (FS) is obtained by combining four general traits: structure and legs, body size, muscular development and breed trait with an equal weight (25% each trait). Hence, data on type traits are currently available for the Chianina breed, and breeding for longevity based on type traits could commence in the near future with limited additional costs.

Breeding goals

Incorporation of longevity in breeding programs requires breeding organizations to quantify the relative importance of longevity in comparison to other traits. One can take two approaches to the decision on the relative weight given to longevity versus other traits; weights can either be based on models of economic profit ("economic values"), or weights can be based on the desired rates of genetic improvement (so-called "desired gains" or "empirical values").

The economic value of longevity or herd life in dairy cattle has been estimated in multiple studies (Van Arendonk, 1991; VanRaden and Wiggans, 1995), but little information is available for beef cattle. Most of the weights used in the overall selection index for beef breeds are empirical because profit functions are not available and consequently an accurate estimation of the economic values is not possible. Beef breeders would benefit from using economic indexes to optimize economic improvement in beef cattle populations when individual beef components (i.e., weight, muscularity, fat, dressing, longevity etc.) have separate values. Selection index procedures require a vector of known economic weights for the determination of the aggregate genotype. Economic weights are partial regression coefficients representing the marginal economic value of a unit additive genetic merit (Harris and Freeman, 1993). Methods for deriving economic weights can be divided into positive (data analysis) and normative (bioeconomic modelling) methods (Van Arendonk, 1991). Breeding objective should be defined according to future market values rather than from historical data.

The Chianina market is composed of two types of herds: the herds with suckled cows and the fattening herds. To estimate profit and to derive economic weights (e.g., for production, longevity etc.) only the suckled cow market was considered in this study. A decision was made to consider only the suckled cow system because: a) more information were available per cow (i.e., production, reproduction and morphological information) and per herd (i.e. input, output, level of production, market etc.) , b) most of these farms are under the control of National Organizations (i.e., Ana, Aia etc.) and c) most of these farms use tested bulls and potentially all of them have the possibility to submit the young calves to be tested at the performance test station (Anabic, 2001).

In suckling herds, the primary source of income for the breeder is the sale of calves after weaning, when they are 6 mo old. The calves are normally sold to fattening herds or as replacements to other suckled herds. On a single cow basis, production of one alive calf per year has a positive impact on the farm economy and reduces the risk of the cow being culled (Rogers et al., 2003). Increasing the length of productive life of the cow, increases the number of calves per cow and has a positive impact on the total farm profit.

An increase in longevity is also desirable from a general ethical point of view as it might increase consumer acceptance. Nielsen et al., (1999) demonstrated that the health traits (i.e., digestive disease, feet and legs disease, mastitis etc.) are the most important group of traits affecting longevity and profit for dairy cows. There is a growing concern about the well-being of cows and it is related to the sustainability of the production systems and welfare of the animals. Breeding for longevity is expected to improve the welfare of the animals (Vollema, 1998; Vukasinovic, 1999; Vukasinovic et al., 2001).

Due to the introduction of some communitarian laws, beef farms, including Chianina farms, are moving from an intensive production system (i.e., where the animals are tied in the stable) to a more extensive system where the animals are able to walk around. More and more consumers are looking for meat which comes from animals which are kept in systems that are considered more animal friendly (i.e., organic farms or farms with an extensive production system).

Analysis of longevity in beef cattle

Two different expressions for longevity are found in the literature: “corrected”, or “functional” longevity and “uncorrected” or “true” longevity. Functional longevity is corrected for the effect of production on culling decisions, and is thought to be a better measurement of a cows ability to withstand involuntary culling (Vollema, 1998; Dekkers, 1993). True longevity refers to the observed longevity not corrected for the effect of production (Boldman et al., 1992; Ducrocq et al., 1988). In addition, there are two definitions of longevity that relate to the moment of observation. “Lifetime” is used when the length of the complete lifespan of the cow is measured and for this trait it is necessary to wait till the cow is culled; “stayability” measures whether the cow is alive or dead at a specified point in time (e.g. 48 mo after first calving). Because stayability ignores variability in the precise time of culling, it does not contain complete information on a cow’s longevity (Vollema, 1998).

Culling reasons are often grouped into two categories: involuntary and voluntary. Voluntary culling refers to culling for productivity, whereas involuntary culling refers to culling for health and reproduction problems. When involuntarily culling rates are high, the opportunities for voluntarily replacement are limited (Van Arendonk, 1988; Rogers at al., 1988). Decisions to replace cows are mainly based on economic considerations; i.e., the breeder expects a higher profit by replacing the cow than by keeping her in the herd (Van Arendonk, 1986). The distinction between voluntary and involuntary culling is difficult, especially in beef cattle, as pointed out by Beaudeau et al. (1999). They noted that, except for emergency culling for acute health disorders (such as severe locomotive disorders, metritis, abortion, dystocia, or even death), all other culling decisions are technically decided and planned by the farmer. This system of culling also occurs in herds with Chianina cattle. It has to be emphasized that the Chianina breeders determine the actual longevity of the cows, and the culling decisions are completely embedded in the whole farming process. Whether or not to cull a Chianina cow depends not only on the individual factors (age at first calving, calving intervals, number of inseminations to get pregnant, abortions etc.) but also on herd factors (variation on herd size, availability of replacement heifers, beef market etc.) and all of these factors concur with the breeders’ decision to keep the Chianina cow in the herd or to replace it. For beef cattle, especially for the Chianina cattle, the best measurement of involuntarily culling, as pointed out before, can be considered the functional longevity.

Statistical data analysis

Three basic strategies have been suggested to evaluate longevity of cows. 1) Cows that survive to a specific age can be analyzed by linear, threshold or random regression models (Veerkamp et al., 2001; Visscher and Goddard, 1995; Vollema and Groen 1998). 2) Van Raden and Klaaskate (1993) suggested a method to predict the records for cows still alive. Estimates based on incomplete data are regressed toward the mean, and therefore have lower variance and heritability than complete records from cows whose lifespans are known. 3) The use of survival analysis to evaluate longevity. This method is increasingly used in dairy and beef cattle (Ducrocq et al., 1988; Smith and Quaas, 1994; Sölkner and Ducrocq, 1999; Damgaard et al., 2003).

With survival analyses, the hazard is modelled using models such as Weibull and Cox functions, instead of modelling longevity itself. The hazard function describes the probability of a cow being culled at a given time, given that she is still alive at that time. Because the hazard is modelled, it is possible to include uncensored as well as censored records (records from cows that are alive at the time of data collection). Mixed models can be featured and time dependent effects on the hazard rate can be considered. Time dependent effects permit more precise modelling of changes in culling policies over time. In survival analysis, either sire or animal models can be used (Ducrocq, 2001). With the sire model, (the animal model is feasible but still prohibitively expensive in terms of computer requirements) the sire variance σ_s^2 is estimated as the mode of its marginal posterior density which is approximated by Laplace integration. The "effective" heritability [$h^2 = 4 * \sigma_s^2 / (1 + \sigma_s^2)$] is calculated as proposed by Yazdi et al. (2002). The Weibull model is frequently used in animal breeding analysis (also for the Chianina data analysis) because of the simplicity of the survival function [$S(t)=\exp(-(\lambda t)^p)$] combined with its flexibility (Vollema and Groen, 1998). The disadvantage of survival analysis is that it is computationally very demanding relative to linear models, especially when the animal model is used.

Including longevity in breeding programs

Breeding organizations have to make many choices when they want to include longevity in their breeding goal.

First, breeding organizations have to decide which trait they want to use in their index for longevity. As indicated before, longevity itself is easily recorded, but it will take a long time before the information is available. It may be useful to use a predictor of longevity (Vollema, 1998) such as type traits that are measured early in life. From dairy cattle (Larroque and Ducrocq 2001; Vukasinovic et al., 2002) we already know that certain type traits have a correlation with functional longevity, and that including those traits in the selection index enables larger response in longevity.

Second, it has to be decided which statistical model to use for data analyses and breeding value estimation. Longevity can be defined as lifespan trait (all cows' life), as productive life trait or as stayability trait (whether or not the cow survives up to a certain point). Thereafter, different models can be used (i.e. linear and non-linear models). The optimum statistical model may differ for different definitions of longevity (Veerkamp et al., 2001).

Third, the breeding organization should decide on the optimum breeding scheme to be used. All traits affecting profitability should be included in the breeding goal of the organization. This means that longevity of beef cattle is part of the breeding goal. The breeding organization needs to decide on the amount and type of information to collect related to longevity (and other traits). Furthermore it has to decide on the weight to be given to different traits in the breeding goal. Finally a breeding organization has to determine the times and intensities of selection. Methods and software are available to evaluate the consequences of different breeding strategies (Wray and Hill, 19879; Villanueva et al., 1993, Rutten and Bijma). The results of these calculations can support the breeding organization in their decision making progress related to investments in data recording and/or a breeding scheme.

Objectives and outline of the thesis

This dissertation considers a number of aspects related to longevity in Chianina beef cattle breeding. The aspects are related to the choices of breeding organizations which are considering incorporating this trait in their breeding program. Firstly, Chapter 2 investigates the genetic background of longevity and some reproductive traits in Chianina cattle. In this Chapter the population structure was analyzed and shows a high use of natural service sires and a relatively low number of sires in multiple herds. Thereafter a preliminary analysis of longevity using the "Survival Kit" was presented. In Chapter 3, the phenotypic relationships between type traits and longevity shows that cow morphology influences the breeder's decision to keep the cow in the herd or to replace it. Besides, the relationship between production traits and longevity shows that longevity increases when the cow has one calf alive every year and decreases when the number calves per year is lower or higher. Chapter 4 deals with genetic analysis comparing different models (linear and non-linear models) to be used in a sire genetic evaluation. In beef cattle, longevity was better analyzed when the non-linear models were used. Improved genetic estimation including heritabilities, (co)variances and EBV were obtained when data from censored and uncensored cows were analyzed with the "Survival Kit".

Profit functions were presented in Chapter 5 in order to derive the economic weights of some biological traits. Furthermore, investigating the relationship between a phenotypic profit function and type traits as an early predictor of profitability it was found that the final score evaluated at an early age, is the best single early predictor of profitability.

A deterministic simulation was presented in Chapter 6 and the consequences of alternative selection strategies for longevity were discussed. The alternative selection strategies indicated that by including longevity in the Chianina breeding scheme the total profit could be increased. Excluding longevity from the breeding scheme decreased longevity and total profit and including longevity in both the Chianina breeding index and breeding goal, either using empirical or economic weights increased longevity.

Finally, in Chapter 7 the results of this thesis are discussed and issues concerning the incorporation of longevity in the breeding scheme are considered.

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Chapter 2

Preliminary study on longevity in Chianina beef cattle

Forabosco F., R. Bozzi, O. Franci and A.F. Groen

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Abstract

The genetic evaluation of the length of productive life (LPL) in the Chianina beef cattle breed has been investigated. The LPL was modelled with a Weibull model considering the herd-year of birth, age at first calving, year of parity and number of calves as a fixed effects and the sire effect as a random effect. The average LPL was equal to 4 years and 10 months, the sire variance was 0.0224 and the effective heritability was 8.7%.

Keywords: Longevity, Reproductive parameters, Chianina

Introduction

The Chianina is a beef cattle breed reared in centre Italy with extensive and semi-extensive systems. There are almost 28,000 animals registered in the Chianina Italian National Herd Book. Chianina is well known for its morphological muscle development and meat production. No analyses exists on the longevity of this breed. In livestock production, especially for beef cattle, longevity of breeding stock is highly desirable because it is an important way to increase the breeder's profit. The profit for the breeders comes from a reduction of the number of suckler cows to be replaced, an increased number of calves that can be sold at weaning or slaughter ages, an increase in voluntary culling and a reduction of costs in involuntary culling due to disease, low fertility and reproductive problems.

Longevity is a difficult trait in selection for various reasons: it takes time to have complete information for a cow, generation interval is long and a high percentage of cows are still alive at the time of genetic evaluation. In order to estimate the sires' EBV for longevity and to maximise the genetic progress, genetic merit of animals should be evaluated based on complete and incomplete information that are available during their life. For this reason genetic evaluation for longevity should utilise the records of cows that are alive (censored) or not alive (uncensored) at the time of data collection. At that time we do not know the lifespan of the animals that are still alive but their present age could be regarded as a minimum of the lifespan that they will achieve (Ducrocq, 1997).

Aim of this preliminary study is to calculate the phenotypic length of productive life (LPL) in Chianina cows, sire variance and heritability on LPL.

Material and Methods

Data were provided by the National Herd Book of the National Association of Italian Beef Cattle Breeders ANABIC. The data set consists of 11,712 Chianina cows born in the period from January 1985 to December 1995 and with at least one registered calving date. Herd Book technicians were visiting all farms every two months and recording culling date based on farmers' information with respect to dates of selling animals. LPL was defined as days between first calving and recorded culling date. Cows were considered uncensored (complete information) if the culling date was available before the end of the study period. Cows still alive at the end of the investigated period were considered as right censored data. No left censored data were used. A low percentage of cows changes herd during their lifetime and in this study all the cows were assigned to the herd of birth. Age at first calving had to be between 24 and 48 months and the calving intervals between 8.8 and 23 months otherwise the cow was deleted form the data. Only the sires with at least one daughter in two herds were considered. The pedigree file consists of 345 sires (table 1), 11.6% of them used for artificial insemination (AI) and mated with 38.53% of the cows on the data set. The AI sires have an average of 79 daughters distributed in 29 herds, whereas the NS sires have an average of ten daughters distributed in three herds. Data shows small herd size and relative high use of natural service sires which is complicating estimation of sire variance.

Table 1. Number of herds per AI and NS sire

hers per sire	AI sires		NS sires	
	# Sires	Mean	# Sires	Mean
2-3	14	2.5	248	2.2
4-5	1	4.0	38	4.3
6-7	2	6.5	10	6.4
8-9	1	8.0	4	8.5
10-19	2	10.5	4	13.5
20-39	9	28.0	1	26.0
40-59	3	47.6	0	0
60-79	4	68.0	0	0
80-99	2	94.5	0	0
100-149	2	133.0	0	0
Total	40	29.0	305	3.1

Survival of a beef cow, measured as length of productive life, was considered as the dependent variable. Survival analysis was performed using *The Survival Kit V3.01* by Ducrocq and Sölkner (1998). The following Weibull model was used:

$$\lambda (t) = \lambda_0(t) \ \exp \{ h_Y (t') + a_V (t') + l_O + c_N + s_S\}$$

where λ (t) is the hazard function of an individual depending on time t (days from first calving to culling), and $\lambda_0(t)$ is the baseline hazard function (related to the ageing process) which is assumed to follow a Weibull distribution with scale parameter λ and shape parameter ρ.

- h_Y (t') is the time-dependent effect of herd-year of birth. Herd-year of birth effects were assumed to follow a log-gamma distribution, which was algebraically integrated out during the analysis.
- a_V (t') is the time-dependent effect of year of former calving, assumed to be stepwise constant changing value at the beginning of every parity from first to 10th .
- l_O is the time-independent classes effect of age at first calving (25 classes).
- c_N is the time-independent classes effect of the total number of calves born of recorded lifespan (13 classes).
- s_S is the random time-independent effect of sire. Sire effect was assumed to follow a multinormal distribution A $\sigma^2{}_S$ where A is the relationship matrix between sires and $\sigma^2{}_S$ is the sire variance.

Results

The average length of productive life (LPL) is 1779 days, which corresponds to an interval of 4 years and 10 months (Table 2).

Table 2. Data characteristics.

		Min	Max
Records, no. after data selection	6047		
Herds, no.	345		
Right censored records, %	33,9		
Average LPL, d (uncensored records)	1779	3	5037
Age at first calving, d	964 ± 142.06	730	1457
First calving interval, d	431± 80.84	270	699
Average calving interval, d (from 1th to 4th parity)	418 ± 44.14	270	699

The age at first calving is 964 days and the average calving interval is 418 days; this is in accordance with what reported by Franci et al. (1998). There is also a high standard deviation from first (±80d) to the 10th (±70d) calving interval due to the management system and it is well described in the model where *hy* has a high significance ($P<0.0001$) before the integrate out of the model. The likelihood ratio tests for the fixed effects included in the model are all significant ($P<0.0001$) and the shape parameter ρ is 2.2 and the $\rho \log \lambda$ (intercept) equal to -19.47. The average number of parities is 5.2 with 8% of the cows that have more than 8 parities and the number of calves ranges from 0 and 13.

Almost 75% of the cows are alive at the age of 45.8 months due to a low percentage of animals that are culled for voluntary or involuntary reasons. The cows that pass throug the first parity without being culled have a high probability of staying alive until the fourth parity. The probability decreases when the number of parities are more than six.

The sire variance was equal to 0.0224 and was used to estimate the 'effective' heritability as proposed for proven sires (Yazdi et al., 2000; Ducrocq, 2001). The h^2_{EFF} calculated as $4*\sigma^2_S/(1+\sigma^2_S)$ was 0.087 similar to the values published for dairy cattle (Schneider, 2000).

Conclusions

Preliminary study on the Chianina shows that the phenotypic LPL in this breed is 1779 days with an heritability equal to 0.087. Further studies will analyse the sires EBV and the correlation between reproductive traits and type traits for longevity.

Acknowledgements

We would like to gratefully acknowledge the help of Schneider M. del P. who kindly answered our questions.

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Chapter 3

Phenotypic relationships between longevity, type traits and production in Chianina beef cattle

F. Forabosco, A.F. Groen, R. Bozzi, J.A.M. Van Arendonk, F. Filippini,
P. Boettcher and P. Bijma

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Abstract

Longevity is an increasingly important trait in beef cattle. Increased longevity reduces cost for the farmer and increases revenue. The objective of this research was to investigate the phenotypic relationship between type traits and longevity in Chianina beef cattle, and the relationship between production and longevity in order to analyze the effect of voluntary culling. Data included records on reproductive, productive and type traits provided by the National Association of Italian Beef Cattle Breeders from 6,395 Chianina cows. The average length of productive life was 1,829 days. The herd-year had a strong effect on the risk of culling. The effects of 22 type traits were analyzed. All the muscularity traits analyzed were highly significant and as a group had the largest impact on longevity followed by dimension, refinement and leg traits. Cows that calved before 35 mo of age had a lower probability of being culled than cows calving after 35 mo of age. Variation in herd size had a strong effect on risk ratio with lower risk for intermediate classes. Cows with approximately one calf per year remained in the herd longer than did cows with fewer calves. Straight-legged animals had a 59% greater probability of being replaced than cows with a moderate angle to the hock, whereas sickle-legged animals had only a 3% higher probability of being culled than average cows. Udder conformation had no effect on longevity. In summary, this study found that herd-year effects and muscularity traits were the most important parameters for longevity for Chianina cows among the factors studied.

Keywords: Beef Cattle, Chianina, Longevity, Survival

Introduction

In the European Union, where a quota system is applied for surplus meat production, the simplest way for a beef producer to increase income is to reduce costs. One way to do this is to increase length of productive life of cows. Increased longevity reduces the direct costs of raising or purchasing replacement females.

Longevity itself is an easy trait to record. A common way to measure it is as length of productive life, measured as the time from first calving to culling. One problem with recording longevity is that it requires a long time for the information to become available, decreasing the reliability of information for young animals. The use of indirect measures for longevity increases the reliability of proofs (EBV) for young bulls, and thus stimulates the use of younger bulls, decreasing generation intervals. One way to estimate longevity indirectly is to use information for type traits that are correlated with longevity.

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 herd life (Gutierrez and Goyache, 2002; Vukasinovic et al., 2002). Various studies have been conducted to quantify the importance and the impact of type traits on longevity in dairy cattle (Boldman et al., 1992; Pasman and Reinhardt, 1999; Larroque and Ducrocq, 2001). Research indicates that dairy cows of moderate size, with functional udders and correct feet and legs are more likely to remain in the herd than cows that lack these characteristics. In beef cattle little is known of the relationship between type traits and longevity and we have found no recent publications on this topic.

The aim of this study was to investigate the phenotypic relationships between type traits and longevity in Chianina beef cattle, and the relationship between production traits and longevity in order to analyze the effect of voluntary culling for production.

Materials and Methods

General

Data were provided by ANABIC (National Association of Italian Beef Cattle Breeders, Perugia) and consisted of 6,395 Chianina cows with records on reproductive, productive and type traits. Cows were born between January 1, 1981 and December 31, 1997. All cows had production data for at least the first parity and were scored for type traits. All parities up to the 12th were analyzed. Records from cows with more than 12 parities (0.07%) were truncated at the 12th parity. Longevity was measured as length of productive life (LPL) defined as days from first calving to the culling date. Data from 689 herds with one or more uncensored cows per herd were included in the analysis. Herds with only censored cows were deleted. Records from animals without information such as birth date, parity dates, and production data were not used. For cows changing herds during their productive life, only the part of the records corresponding to the original herd was included and records were censored at the date the cow moved to the second herd. If a culling date was not available (20%), cows with a final calving date greater than 18 mo prior to the end of the study were considered culled, and culling date was declared to be 180 d from the initiation of the last parity, because 6 mo is the normal time needed to wean a calf in the Chianina breed. Cows were sired by 817 bulls (Table 1). Approximately 5.3% of the sires were used for artificial insemination (AI) and mated with 35.2% of the cows in the data set. The AI sires had an average of 46 daughters distributed in an average of 27 herds, whereas the natural service (NS) sires had an average of five daughters distributed in 1.5 herds. The data shows a small average herd size and relatively high use of NS sires.

Reproduction and Production Traits

All reproductive information (such as age at first calving, birth date and number of calves) were collected by technicians from ANABIC. Calf weight was the weight of the calf at birth and was defined by six classes, ranging from 1 (low weight) to 6 (high weight). Each class had a range of 5 kg, or 1 phenotypic standard deviation. Calf weight was measured or estimated by a technician in collaboration with the breeder. Data from births with only single calves were considered; twins were excluded from the analyses. In addition to calf weight another production trait, number of calves born alive per year of reproductive life from first calving to culling, was considered (Table 2).

Table 1. Number of herds per AI and natural service (NS) sire

Herds	AI sires		NS sires	
	#	Mean	#	Mean
1	0	0.0	577	1.0
2 to 3	10	2.5	168	2.3
4 to 5	2	4.0	20	4.3
6 to 7	6	6.2	7	6.4
8 to 9	2	8.5	2	8.0
10 to 19	8	14.5	0	0.0
20 to 39	5	32.6	0	0.0
40 to 59	3	51.6	0	0.0
60 to 79	4	67.3	0	0.0
100 to 149	3	129.0	0	0.0
Total	43	27.4	774	1.5

Type Traits

Beef cattle in Italy are evaluated for 26 traits, of which 22 are scored on a linear scale The linear traits are described in Table 2. They consist of eight traits for muscle development, seven traits for body size, two traits for structure, two traits for refinement and one udder trait, each of which were evaluated on a linear scale from 1 (very bad) to 5 (very good). Six traits with intermediate optima describing leg conformation are scored from 1 (very bad) to 3 (optimum) and again 5 (very bad). Scoring is performed by breed experts who score all first and second parity animals present in each herd. In this analysis an average of 9.2 cows per herd were evaluated. 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.

Table 2. Summary statistics and description of production and type traits for 6,395 cows

Traits	Mean	SD	CV %	Optimum class	Description class 1	Description class 5
Production						
Weight of the calves (w_e), kg.	46.75	5.40	11.5			
N° of calves born per year of the cow's reproductive life (p_a)	0.97	0.30	30.0			
Muscle Development						
Withers width (MWW)	2.65	0.72	27.2	5	narrow	wide
Shoulders convexity (MSC)	2.76	0.72	26.3	5	flat	convex
Back width (MBW)	2.73	0.75	27.6	5	narrow	wide
Loins width (MLW)	3.21	0.70	21.9	5	thin	convex
Rump convexity (MRC)	2.93	0.67	22.7	5	meager	convex
Thighs width (MTW)	2.99	0.73	24.5	5	narrow	wide
Buttocks convexity (MBC)	2.93	0.68	23.1	5	concave	convex
Buttocks length (MBL)	3.07	0.70	22.8	5	short	long
Body Size						
Height at withers (BsHW)	3.22	0.84	26.0	5	short	tall
Trunk length (BsTL)	3.50	0.78	22.3	5	Short	long
Chest height (BsCH)	3.41	0.70	20.6	5	shallow	deep
Chest width (BsCW)	2.98	0.71	23.9	5	narrow	wide
Hip width (BsHw)	3.14	0.67	19.7	5	narrow	wide
Ischia (Pins) width (BsIW)	2.88	0.71	24.6	5	narrow	wide
Rump length (BsRL)	3.40	0.70	20.7	5	narrow	wide
Structure and Legs						
Rump angle (RA)	2.82	0.45	16.0	3	inclined	counter-inc.
Top line (TL)	2.83	0.40	14.3	3	concave	convex
Fore legs – Front view (FLFW)	3.12	0.40	12.8	3	twisted inward	t. outward
Fore legs – Side view (FLSW)	2.99	0.16	5.2	3	recurved	arched
Hind legs – Side view (HLSW)	2.66	0.56	20.9	3	sickle-legged	straight-leg.
Refinement						
Skeleton (Ske)	2.84	0.65	22.7	3	slender	heavy
Skin (Skin)	2.84	0.56	19.7	3	thin	thick

Model

Survival analysis was performed using *The Survival Kit V3.0* by Ducrocq and Sölkner (1998). A Weibull model was used because of the simplicity of the Weibull survival function $S(t) = \exp(-(\lambda t)^{p})$ combined with flexibility. Length of productive life was the dependent variable. The following model was used:

$$\lambda(t) = \lambda_0(t) \exp \{h_Y(t') + hv(t') + es + l_O + tt + p_a(t') + w_e(t')\};$$

where $\lambda(t)$ is the hazard function of an individual depending on time t (days from first calving to culling);

- $\lambda_0(t)$ is the baseline hazard function (related to the aging process) which is assumed to follow a Weibull distribution with scale parameter λ and shape parameter ρ;
- $h_Y(t')$ is the fixed time-dependent class effect of herd-year (calendar years) and,

$hv(t')$ is the fixed time-dependent class effect of variation in annual herd size (five classes; > +60%, + 60 through + 15%, + 15 through - 15%, - 15 through - 60% and < - 60%), assumed to be piece-wise constant, changing every year.

Fixed time-independent effects are:

- es is the expert who scored the cows;
- l_O is the age at first calving (26 classes);
- tt are the 22 type traits as described in Table 2;
- $p_a(t')$ is the fixed time-dependent class effect of the average number of calves born per year of reproductive life, assumed to be piecewise constant, changing every parity; 10 classes were created ranging from class 0.4 to 1.3 calves born per year of the cow's reproductive life. In the present study, only results for $p_a \leq 1$ are presented which excludes the cases of cows culled soon after first calving;
- $w_e(t')$ is the fixed time-dependent class effect of the weight class of the calf as described in the data section, changing every parity.

The traits included in this analysis were selected in the following manner. Initially all type and production (p_a and w_e) traits were analyzed simultaneously, and then non-significant traits were removed in a step wise manner. Pastern angle, rear view of hind feet and legs and udder were excluded from further analyses because they were not significant. Effects of all remaining traits were highly significant. This process resulted in the set of significant traits presented in Table 2 and used in furthers analysis.

The risk ratios of each type trait were then estimated one trait at a time without including production traits (p_a and w_e) in the model. Likewise, the risk ratios of each production trait (p_a and w_e) were estimated one trait at a time without including type traits in the model. Hence, estimated risk ratios refer to the effect of a trait on longevity, not corrected for the effects of other traits.

Results

In Chianina cows the average length of productive life was 1,829 days, which corresponds to an average of approximately 5 yr after first calving (see also Forabosco et al., 2002). In the data, 45% of the records were censored and are related to the fact that the collecting of type data began only in 1993.

Among the original 26 type traits, 22 had significant effects on longevity in the first analysis and were thus retained for subsequent analyses.

The estimated Weibull parameter ρ, considering production and all type traits simultaneously, was equal to 2.0 and the intercept $\rho\log(\lambda)$, was equal to –11.3. In subsequent analyses, the parameter ρ was fixed at 2.0 to reduce the computing time. These two parameters (ρ and intercept) fully describe the baseline hazard function and the baseline survival function $S(t) = \exp(-(\lambda\ t)^{\rho})$. A positive ρ (with $\rho > 1.0$) indicates a baseline hazard function for which risk of culling increases over time. The estimated baseline survival function S(t) and the baseline hazard function $\lambda_0(t)$ are shown in Figure 1. The baseline survival function S(t) corresponds to the fraction of cows that are expected to be alive t days after calving. The baseline hazard function $\lambda_0(t)$ shows the risk of a given cow being culled at a time t given that she is still alive at time $t - 1$. As indicated by the fact that $\rho > 1$, Figure 1 shows that the average risk of being culled increased as the age of the cow increased.

Effect of Longevity Adjusted for Productivity; the Contribution to the Likelihood

The contribution of individual traits to the likelihood was studied using the model where all traits were included simultaneously. The contribution to the likelihood (-2 log likelihood) of each trait is shown in Figure 2. The contribution for the herd-year as a time-dependent effect was equal to 4,260, which was the highest among all factors in the model. Contributions from the variation in annual herd size and the expert who scored the cows were lower than the contribution of the herd-year, but higher than the contribution from age at first calving and type traits.

All muscularity traits analyzed were highly significant, with a contribution to the likelihood ranging from 745 for muscularity at withers (MWW) to 389 for muscularity at buttocks length (MBL). Body size traits had smaller, but still significant contributions to the likelihood. Front and side view of fore legs (FLFW and FLSW), rear legs side view (HLSW), body refinement for skin (Skin) and skeleton (Ske) had moderate contributions to the likelihood.

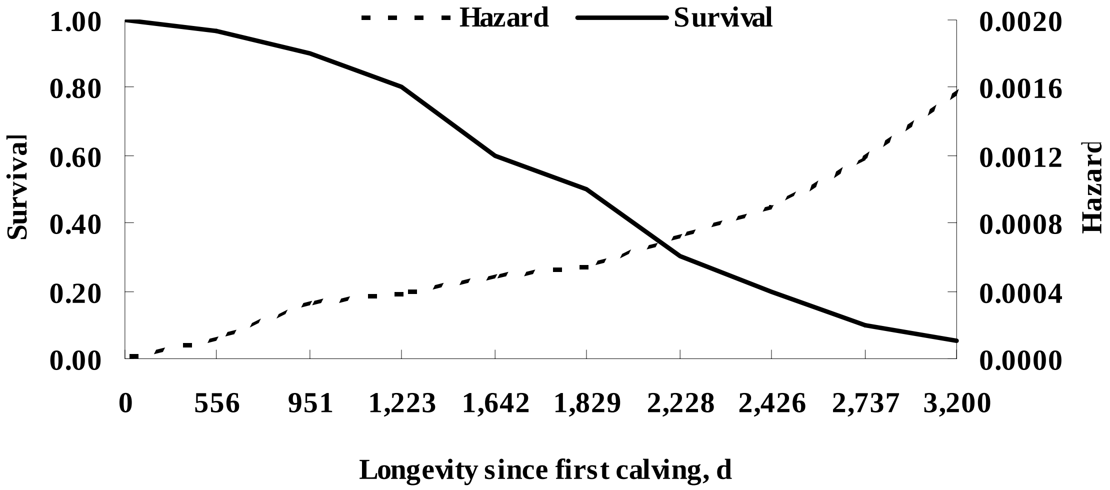

Figure 1. Baseline survival and baseline hazard function.

Effect of Age at First Calving and Variation in Herd Size

To be able to interpret fixed effects for each effect included in the model, the class containing the largest number of animals was used as a reference point, and the risk ratio for this class was set to 1. The effects from other classes were then expressed relative to this class. The effect of age at first calving of 25 mo (class 25), was used as a reference point (Figure 3). The risk ratio (RR) for age at first calving and herd variation were estimated without including production and the type traits information in the model. In this analysis, the 26 classes for age at first calving, ranging from 25 to 50 mo of age, were also considered to account for some differences in the management systems. This is because cows that were raised indoors usually calve earlier in life relative to cows raised outdoors with a seasonal calving.

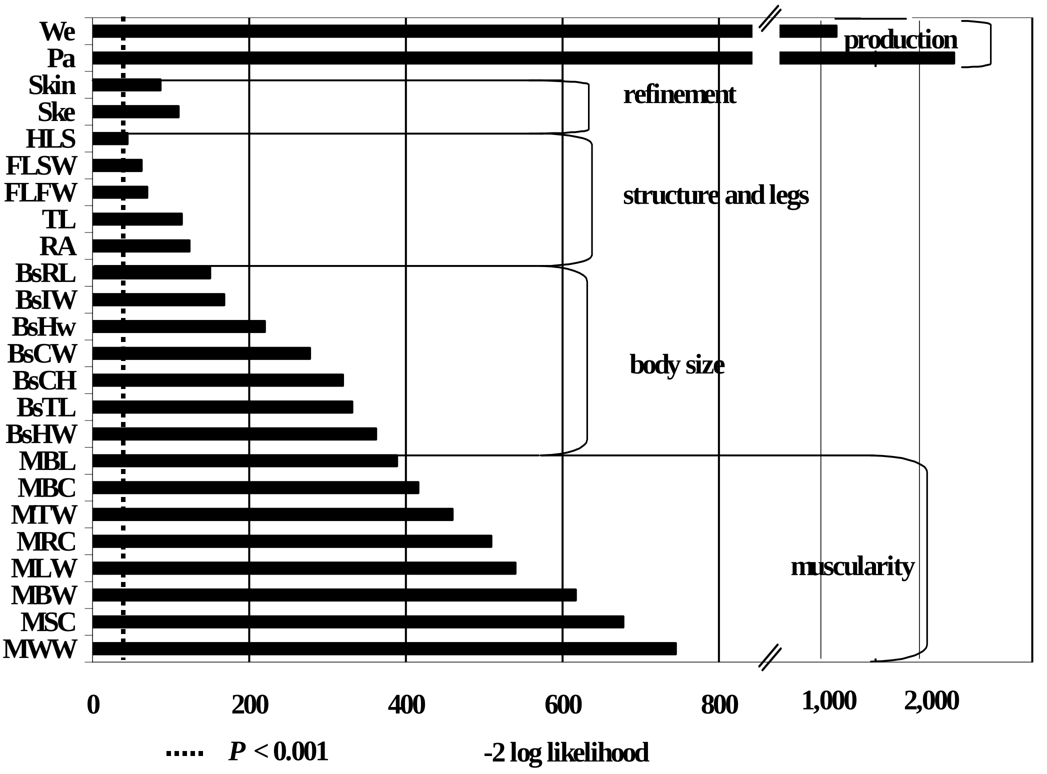

Figure 2. Contributions of individual traits to the likelihood for longevity.
See Table 1 for definition of abbreviations.

Age at first calving had a small effect on the RR. For a high age at first calving the RR was higher but the SE was large. After 38 mo, RR must be interpreted carefully due to a high SE, caused by a reduction in the number of older cows calving.

For variation in herd size, five classes were considered and the RR are shown in Figure 4. Animals in class 2, corresponding to a small increase in herd size, had a lower risk of being culled (8% less) than the animals in class 3, (stable herd size). Not surprisingly, decreasing herd size was associated with more risk of culling, as cows in class 4 had an 11% higher probability of being culled than animals in class 3, and for cows in shrinking herds (class 5) the probability of being culled was 73% higher than in a stable herd (class 3). Risk of culling in herds with large increases in size (class 1) was actually greater than in herds with small increases or stable size, but these differences were not significant.

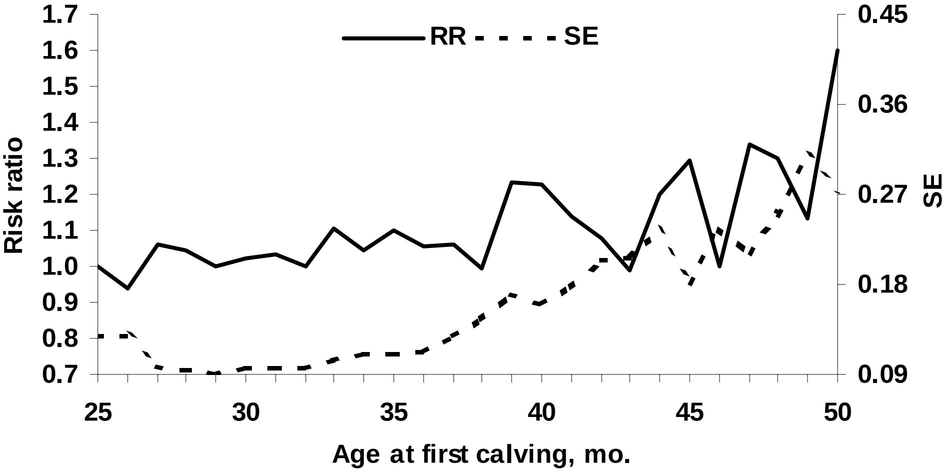

Figure 3. Risk ratio (RR) and SE for age at first calving.

Effect of Number of Calves and Weight

Longevity adjusted for production considered cow productivity as the number of calves born per year of the cow's reproductive life and the weight of the calves. No type traits were included in the model, and one effect at a time (either p_a or w_e) was analyzed. The RR of the class which corresponded to a single calf per year was set equal to 1.0 (Figure 5). Cows that calved only once every two years (class 0.5) had four times higher probability of being culled than cows in class 1.0. For cows belonging to classes below 0.7, the risk of being replaced increased drastically, probably due to health problems or voluntary culling associated with low fertility.

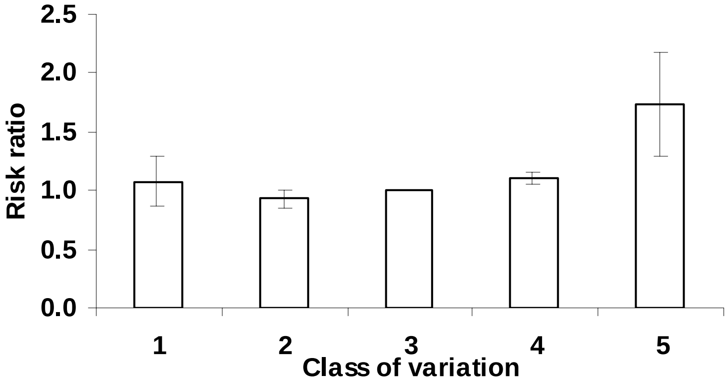

Figure 4. Risk ratios (RR) for variation in herd size(*).

(*) Classes are defined as (1) an increase of 60% or more in herd size, (2) an increase between 60 and 15%, (3) a change between 15 and -15%, (4) a reduction between –15 and -60%, and (5) a reduction of more than 60%.

Results for the effects of weight of calves (w_e) are presented in Figure 6. Six classes were considered from 1 (low weight) to 6 (high weight) and only single parity was considered in this analysis. Cows with their calves belonging to class 2 and 4 had respectively 0.85 and 0.79 probability of being culled. The weight of the calf had a smaller effect on longevity than the number of calves (Figure 6 vs 5).

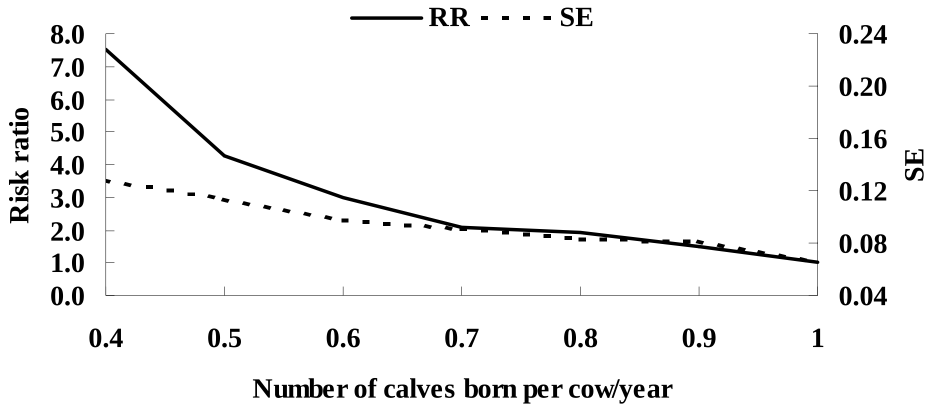

Figure 5. Risk ratio (RR) for number of calves born per cow per year of reproductive life.

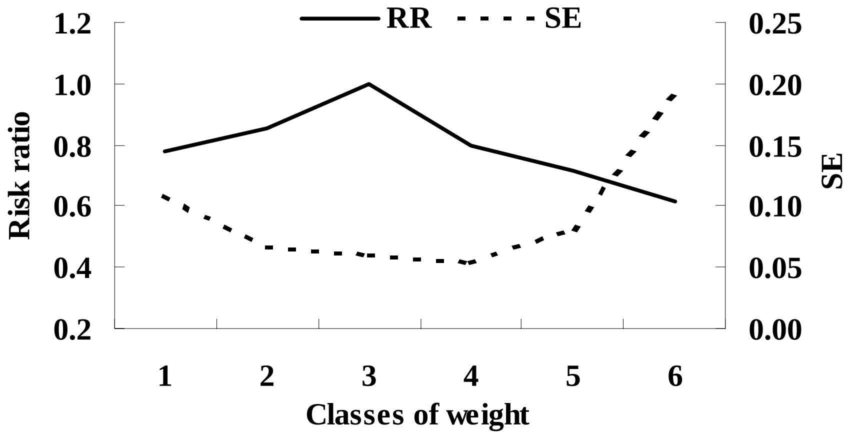

Figure 6. Risk ratio (RR) for weight of calf$^{(*)}$.

$^{(*)}$ Six classes are considered from 1 (low weight) to 6 (high weight). Each class is 1 standard deviation (5 kg), with an average of 47 kg per calf.

Effect of Type Traits

Risk ratios for muscularity traits are in Table 3. Looking at the muscularity traits as a whole, one can see a clear trend in the RR between class 1 and class 5. In all cases the RR in class 5 was less than in class 1, meaning that cows with high muscle development were more likely to remain in the herd. In some combinations of traits and classes, standard errors were large, but for all muscularity traits the trend for increased longevity for cows with more muscle development was consistent.

Risk ratios for body size traits are in Table 4. Results in Table 4 show that taller (class 4) Chianina cows with a long body and a deep and wide chest had a higher probability of survival. Results in Table 5 show that structure and leg traits were less informative for longevity than were muscularity and body size traits.

Table 3. Risk ratio for muscularity traits

	Muscularity traits[a]															
Class	MWW	SE	MSC	SE	MBW	SE	MLW	SE	MRC	SE	MTW	SE	MBC	SE	MBL	SE
1	1.62	*0.12*	1.92	*0.15*	1.39	*0.12*	1.20	*0.29*	1.43	*0.25*	1.80	*0.21*	1.44	*0.21*	2.01	*0.18*
2	1.15	*0.05*	1.06	*0.05*	1.11	*0.05*	1.12	*0.06*	1.27	*0.05*	1.34	*0.05*	1.15	*0.05*	1.08	*0.06*
3	1.00		1.00		1.00		1.00		1.00		1.00		1.00		1.00	
4	0.95	*0.08*	0.87	*0.07*	0.88	*0.07*	0.91	*0.05*	0.83	*0.06*	1.00	*0.06*	0.99	*0.06*	0.88	*0.06*
5	0.62	*0.41*	0.23	*0.30*	0.64	*0.30*	0.47	*0.22*	0.31	*0.35*	0.37	*0.25*	0.72	*0.25*	0.56	*0.23*

[a] MWW = Withers width, MSC = Shoulder convexity, MBW = Back width, MLW = Loins width, MRC = Rump convexity, MTW = Thighs width, MBC = Buttocks convexity, MBL = Buttocks length.

Table 4. Risk ratio for body size

	Body size[a]													
Class	BsHW	*SE*	BsTL	*SE*	BsCH	*SE*	BsCW	*SE*	BsHw	*SE*	BsIW	*SE*	BsRL	*SE*
1	1.49	*0.16*	1.15	*0.34*	1.09	*0.41*	1.66	*0.19*	1.14	*0.39*	2.57	*0.20*	1.03	*0.58*
2	1.04	*0.06*	1.26	*0.08*	1.09	*0.08*	1.16	*0.05*	1.18	*0.09*	1.15	*0.05*	1.24	*0.08*
3	1.00		1.00		1.00		1.00		1.00		1.00		1.00	
4	0.89	*0.05*	0.97	*0.05*	0.88	*0.05*	0.83	*0.06*	0.93	*0.05*	0.83	*0.07*	0.95	*0.05*
5	1.00	*0.09*	0.83	*0.09*	0.40	*0.14*	0.67	*0.20*	0.69	*0.12*	0.52	*0.20*	0.99	*0.11*

[a] BsHW = Height at withers, BsTL = Trunk length, BsCH = Chest height, BsCW = Chest width, BsHw = Hip width, BsIW = Ischia (Pins) width, BsRL = Rump length.

Table 5. Risk ratio for structure and legs

	Structure and legs[a]													
Class	RA	*SE*	TL	*SE*	FLFW	*SE*	FLSW	*SE*	HLSW	*SE*	SKE	*SE*	SKI	*SE*
1	1.05	*0.41*	0.91	*0.35*	0.97	*0.79*	*NE*	*NE*	1.32	*0.17*	1.46	*0.23*	1.09	*0.32*
2	0.99	*0.06*	1.03	*0.06*	1.27	*0.13*	1.77	*0.19*	1.03	*0.05*	1.21	*0.05*	1.02	*0.05*
3	1.00		1.00		1.00		1.00		1.00		1.00		1.00	
4	0.82	*0.14*	0.95	*0.32*	1.36	*0.06*	0.86	*0.38*	1.59	*0.16*	0.84	*0.06*	0.82	*0.08*
5	0.97	*0.30*	1.09	*1.14*	1.08	*0.33*	1.04	*0.86*	1.23	*0.92*	1.01	*0.30*	1.05	*0.69*

[a] RA = Rump angle, TL = Top line, FLFW = Fore legs - Front view, FLSW = Fore legs - Side view, HLSW = Hind legs - Side view, SKE = Skeleton, SKI = Skin, NE = Not estimable.

Discussion

The highest contribution to the likelihood was due to the herd-year effect followed by production traits, herd variation, age at first calving and type traits. Among the type traits, muscularity made the highest contribution to the likelihood followed by dimension, refinement and leg traits. Muscularity is logically the most important morphological trait for the breeder. Cows with good muscularity are thus more likely to avoid voluntary culling by the breeder than cows with poor muscularity. Among the dimension traits, stature (BsHW) was the strongest indicator trait for longevity. Bünger and Hermann (1999) reached similar conclusions for dairy cows, but this result differed from that of Larroque and Ducrocq (2001), who found a non-significant contribution of the stature to longevity for the non-registered Holstein population in France and a moderate contribution for the registered population. Wide hips and wide pins increase the probability of a cow remaining longer in the herd. The same results were found by Schneider et al. (1999), where dairy cows with wide pins had a 74% higher probability of avoiding culling than did cows with narrow pins. In this work it was found that animals in class 2 for pins (BsIW) had a 38% higher probability of being replaced than cows with wide pins (class 4). Rump length was a trait with an RR around 1.0 for all five classes. Similar results were found by Larroque and Ducrocq (2001) in dairy cattle.

No general trends were observed for the traits associated with structure and leg. When ignoring classes 1 and 5 due to their large SE, an intermediate optimum seemed to exist for FLFW and FLSW. For HLSW the situation was slightly different. Considering the HLSW (and excluding classes 1 and 5 that included few animals), animals in class 4 (straight-legged) had a 59% greater probability of being replaced than did animals in class 3. The RR for cows in class 2 (sickle-legged) was only 3% higher than the RR for class 3. In contrast, dairy cows with sickle-shaped legs have a much higher relative probability of being replaced than straight-legged cows (Burke and Funk, 1993; Schneider et al., 1999). This difference is likely due to differences in management and housing conditions. While most dairy cattle spend major proportions of their lives confined in barns, beef animals are raised mainly in pastures and straight-legged cows may have more problems walking in an open field.

Traits that show a moderate impact on longevity, such as the legs and refinement traits, suggest that beef producers do not consider these traits as very important for their culling policy.

Cows that have one calf per year are more profitable for the breeder so they remain in the herd longer than do cows that produce fewer calves. The majority of voluntary culling occurs between first and second calving and cows with even small problems at that period are often preferentially culled by the breeder who prefers to retain the older cows that have already proven themselves. When interest is in longevity itself (e.g., when estimating breeding values for functional longevity), the use of p_a as a productivity trait may be inappropriate for cows that give birth for the first time and die soon afterwards. Such cows have a high p_a due to their short LPL. Hence, the use of p_a to account for voluntary culling may cause a bias in the correct estimation of breeding values for longevity. For the purpose of breeding value estimation it may be better to use a binary time dependent fixed effect, which indicates whether or not the cow produced a calf. In the present study, where interest was in the effect of the number of calves on longevity, only results for $p_a \leq 1$ are presented (Figure 5), which excludes the cases of cows culled soon after first calving.

It is not easy to understand why cows that have calves with high weight (classes 4, 5 and 6) have a higher probability of surviving than animals in the average class. Large calves are generally associated with increased rates of calving problems. One of the reasons may be related to the fact that a significant proportion of Chianina cattle are raised outdoors and these cows calve without assistance from the respective breeders. Cows with heavy calves have a high probability of dystocia and stillbirth (Williamson and Humes, 1985; Nix et al., 1998), but because of the rearing management of the breed (extensive on pasture) stillborn calves are frequently not recorded and subsequently weighed. Thus the majority of the heavy calves registered were likely those that were born alive. If this is the case, a bias would be present for the animals in classes 4, 5 and 6. A solution for this bias might be to model the effect of calf weight within the breeding system in the model. In addition, effect of calving weight might be better modeled by accounting for the age of the dam.

Culling Reasons

In dairy cattle, culling reasons are grouped into two categories: involuntary and voluntary. Voluntary culling refers to culling for productivity, whereas involuntary culling refers to culling for health problems and reproduction. Longevity corrected for voluntary culling is called “functional longevity”, whereas actual observed longevity is called “true longevity” (Ducrocq et al., 1988). The reason for distinguishing between voluntary and involuntary culling is that the selection for true longevity is largely equivalent to selection for productivity (at least in dairy cattle) and does not necessarily lead to genetic improvement in the ability to withstand involuntary culling (Dekkers, 1993).

In this study we have used the number of calves born per year and the weight of calves as production traits, because the calf is the main source of income for the farmer. However, the weight of the calf may also be related to involuntary culling because of its relationship with calving difficulty. This distinction between voluntary and involuntary culling is particularly difficult in beef cattle as pointed out by Beaudeau et al. (1999). They noted that, except for emergency culling for acute health disorders (such as severe locomotive disorders, metritis, abortion, dystocia, or even death), all other culling decisions are technically decided and planned by the farmer. This system of culling also occurs in herds with Chianina cattle. In fact, muscularity traits appear to be important in culling decisions and the farmer seems to retain animals with better muscle development as pointed out by the results in Table 3.

Final Considerations

In order to allow an interpretation of the RR without being conditioned by all the other traits, one type trait at a time was considered in the model when calculating RR. However, because these traits are correlated, their effects can not be simply added. When choosing which traits to include in a breeding program, correlations between traits must be considered.

In this study, longevity was defined as LPL (i.e., from first calving to culling), whereas survival from birth to first calving was not considered. Obviously, survival from birth to first calving is also important, but survival during this period is probably a very different trait genetically than is survival after first calving, due to biological differences and differences in management policies of the farmers. For this reason, a single Weibull survival function may not properly fit a definition of survival that combines both the periods prior to first calving and LPL after first calving. In a breeding program a sensible approach would be useful to treat survival until first calving and LPL as two separate but correlated traits that are both included in the breeding goal.

Implications

This study found that herd-year effects and muscularity traits were the most important parameters for longevity for Chianina cows among the factors studied. Not surprisingly, notable differences were observed in the relationship between conformation and survival for beef cattle from previous studies on dairy cows. In beef cattle, traits such as muscularity and longevity must be considered in a future implementation of a beef cattle breeding scheme and can not be simply extrapolated from dairy cattle. For the purpose of genetic evaluation for productive life in beef cattle a single Weibull function may not properly fit survival from birth to culling. It could be useful to treat survival until first calving and length of productive life as two separate but correlated traits that are both included in the breeding goal.

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Chapter 4

Linear model vs survival analysis for genetic evaluation of sires in Chianina beef cattle

F. Forabosco, R. Bozzi, F. Filippini, P. Boettcher, J. A. M. Van Arendonk, and P. Bijma

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Abstract

The objective of this study was to compare EBV for longevity in Chianina beef cows estimated with linear and non-linear sire models. The non-linear analyses were based on a survival model and separate datasets were created that considered all data (SURVall) and only uncensored (SURVun) records. The linear models were used to analyze longevity measured as dichotomous (yes/no) measures of survival in the first three parities (LIN-S3) and an overall measure of lifespan in months (LIN-LPL). The survival analyses considered time dependent effects of herd-year and variation in herd size, time independent effects of year-season and age at first calving. Linear models considered herd-year effects and age at first calving; in the LIN-LPL model the herd-year was considered at 1st calving. (Co)variance components and correlations between EBV were estimated. Correlation between EBV from the two survival analyses was 0.85. For LIN-S3 the correlations of EBV across parities were approximately 1. Medium correlations were found (from 0.50 to 0.62) when only uncensored data (SURVun) were compared to the linear model (LIN-S3). Higher correlations were found (from 0.71 to 0.93) when EBV based on both censored and uncensored data (SURVall) were compared to LIN-S3. The risk of being culled increased with a concurrent reduction in the herd size. Heritability was estimated at 0.11, 0.09 and 0.08 respectively for SURVall, SURVun and LIN-LPL; and 0.05, 0.02 and 0.02, respectively, for survival in the first three parities according to LIN-S3. Linear and non-linear models differed in many aspects; the most precise EBV are obtained when all data are used in the evaluation.

Key Words: Beef Cattle, Chianina, Genetic Analysis, Longevity

Introduction

In livestock production, including beef cattle, longevity is a highly important trait that affects profitability. Increased longevity of beef cows affects the average herd production due to an increase in the number of productive cows and a decrease in rearing heifers.

Genetic evaluation of longevity and incorporation of this trait in beef cattle breeding programs is hindered by three factors. First, longevity is not an easy trait to measure because a complete observation is not available when selection decisions are to be made. Given that the productive life of beef cows can easily exceed five years, this necessitates waiting until culling to record longevity and increases the generation interval considerably. This problem can be partially addressed by using survival analysis (Ducrocq et al., 1988; Vukasinovic et al., 2001; Meuwissen et al., 2002). Longevity has been well studied in dairy cattle and many countries currently have implemented genetic evaluations and include longevity in the breeding program. Second, although longevity is recorded and evaluated in many countries, there is no common way to define the trait and analyze the phenotypic data collected. For example, for dairy cattle in USA, UK and Canada longevity is analyzed with a linear model, in France, Austria, Germany, Italy, Denmark, Spain and the Netherlands, a survival analysis is used (Interbull, 2004). The third factor is the lack of information regarding estimates of genetic parameters for longevity of beef cattle, which are necessary for most genetic evaluation methods.

The objective of this paper was to estimate genetic parameters to be used in a genetic evaluation and to compare results of different approaches from a practical perspective. Genetic parameters, including (co)variances and EBV were estimated from linear and non-linear models for longevity. Correlations among EBV were calculated to evaluate differences between different models.

Materials and Methods

Data

Data were provided by ANABIC (National Association of Italian Beef Cattle Breeders, Perugia) and consisted of 13,257 Chianina cows with records on reproductive traits collected from January 1, 1974 until December 31, 2000. For the analyses, the cows born after December 31, 1990 were excluded from the dataset. This decision was made to give all the cows at least a 10 year opportunity to express longevity. Otherwise, results corresponding to young sires would have been biased because observed survival times would have been available only for daughters that died early in life due to a lack of sufficient recording time for the daughters that remained in the herd (Cassandro et al., 1999; Forabosco et al., 2004). Table 1 shows the distribution of the records across different parities. All the cows had at least the first parity registered and an age at first calving between 25 and 50 months. Only sires with at least 6 daughters were included in this analysis. Because of the high number of natural service sires (Table 2), and a relatively small average herd size, herds with fewer than 20 cows were grouped according to homogeneous geographical areas and the management system (tie stall, loose housing and summer grazing) employed. The grouping involved 19.5% of the cows that were assigned to 50 different groups with an average of 51.7±38.3 cows per group. The total number of "groups" and herds was 191 spread over 20 provinces.

Table 1. Number of records per parity used in the analysis.

Parity *n*	Culled[1]	Survived[2]	Total	Culled, %
1[a]	2,645	10,612	13,257	20.2
2[a]	1,882	8,730	10,612	17.7
3[a]	1,439	7,291	8,730	16.5
4	1,222	6,069	7,291	16.8
5	1,110	4,959	6,069	18.3
6	996	3,963	4,959	20.1
7	938	3,025	3,963	23.7
≥ 8	920	2,105	3,025	30.4

[1] Culled cows have not been registered for parity $n + 1$;

[2] Survived cows have been registered for parity $n + 1$ and still alive;

[a] Records used in the EM REML analysis;

Table 2. Daughters per sire.

Number of daughters per sire	Number of sires			
	Natural Service		Artificial Insemination	
	Sires	Mean ± std	Sires	Mean ± std
< = 20	451	10.7 ± 3.9	3	13.3 ± 4.5
21 to 50	100	29.3 ± 6.3	19	43.7 ± 5.3
> 50	5	57.2 ± 4.1	33	131.0 ± 122.7
Total	556 (91.0 %)	14.5 ± 9.4	55 (9.0 %)	94.8 ± 105.6

Survival Analysis

Longevity was recorded as the length of productive life (LPL), defined as days between first calving to culling or censoring. For 11.9% of the cows, precise culling dates were not recorded and in these cases the culling date was estimated as the last registered date of parturition plus 180 days, as 180 days is the average time for weaning the calf in the Chianina breed. Cows that were sold, rented or exported for commercial or non-commercial purposes from one herd to another, or to a different destination were treated as right censored. No left censored records were used in this analysis and 13.4% of the cows (1,780) were still alive on December 31, 2000 (i.e. right censored data).

Survival analysis was performed using *The Survival Kit V3.0* by Ducrocq and Sölkner (1998). Two different analyses were implemented; the first analysis (SURVall) considered both censored and uncensored records (13,257) and the second (SURVun) used only uncensored records (11,477) to facilitate comparison with linear model analysis (see later).

The following Weibull model was used:

$$\lambda (t) = \lambda_0(t) \exp \{ h_Y (t') + h_{var} (t') + l_O + y_s + s_e \}; \qquad [1]$$

where

- $\lambda (t)$ is the hazard function of an individual depending on time t (days from first calving to culling),

- $\lambda_0(t)$ is the baseline hazard function (related to the aging process) which is assumed to follow a Weibull distribution with scale parameter λ and shape parameter ρ.

- $h_Y(t')$ is the random time-dependent effect of herd-year. Herd-year effect (reassigned every year on January 1) was assumed to follow a log-gamma distribution, which was algebraically integrated out from the joint posterior density.

- $h_{var}(t')$ is the fixed time-dependent class effect of change in herd size (5 classes; >+60% , +60 through +15%, +15 through -15%, -15 through -60% and <-60%); this variable was assumed to be piecewise constant, changing on January 1 of each year.

- l_O is the continuous time-independent class effect of age at first calving ;

- y_s is the fixed time-independent class effect of year-season at first calving;

- s_e is the random sire effect.

A sire model was used to estimate the sire variance (σ_s^2) and the sire effect was assumed to follow a multivariate normal distribution. The Weibull model was used because of the simplicity of the Weibull survival function $S(t)=\exp(-(\lambda t)^{\rho})$ combined with flexibility (Forabosco et al., 2004; Vollema and Groen, 1998). The sire variance σ^2_s was estimated as the mode of its marginal posterior density which is approximated by Laplace integration.

In a preliminary analysis, the significance of all factors used in the analysis was tested by comparing the likelihood for the full model with models excluding the factor in question. This procedure was done for each effect and all effects in the model (Equation [1]) were highly significant ($P<0.001$). The "effective" heritability was calculated as proposed by Yazdi et al. (2002).

$$h^2 = 4 * \sigma_s^2 / (1 + \sigma_s^2) \qquad [2]$$

Where σ_s^2 = sire variance

Reliability of a sire's EBV was computed based on the exact number of uncensored progeny (N_i) for each sire (i) as proposed by Yazdi et al. (2002):

$$R_{i\,\mathrm{appr.}} = \frac{N_i}{N_i + \left(\dfrac{4 - h^2}{h^2}\right)} \qquad [3]$$

Where h^2 is the heritability of the trait.

Linear model

A linear sire model was applied to estimate the heritability and breeding values (EBV). Two different analyses were implemented: in the first approach (LIN-S3 analysis) a multiple-trait model was applied to analyze longevity measured as dichotomous (yes/no) measures of survival in the first three parities and the second approach (LIN-LPL) considered the length of productive life (LPL) of the cow. Productive life (LPL) for the LIN-LPL was counted as months from first calving to culling.

For the LIN-S3 model the herd-year random effect (HY) was fitted considering the effect of the herd and year of parity of the cow; for each cow a maximum of three herd-years were considered. A cow was considered to have survived parity *n* if she had a registered parity *n* +1. In this case the survival trait for *n* was coded as 1.When the cow did not calve for the n^{th} time, information on survival for parity *n* was coded as missing. For the LIN-LPL model the herd-year random effect (HY) was fitted considering the HY at the first calving. The linear models were performed using the EM REML (Expectation Maximization Restricted Maximum Likelihood) with acceleration (Misztal, 2002).

The following model was used:

$$Y_{lki} = h_{Yl} + l_{Ok} + s_i + e_{lki} \qquad [4]$$

where:

Y_{lki} = animal alive (1) or dead (0) after *n* + 1 parities for the LIN-S3 model; months since first calving to culling for the LIN-LPL model ;

h_{Yl} = random effect of herd-year for each parity for the LIN-S3; random effect of herd-year of the first parity for the LIN-LPL model;

l_{Ok} = fixed effect of age at first calving, 25 classes;

s_i = random sire effect;

e_{lki} = error.

Heritability was calculated from the sire variance (Falconer and Mackay, 1996):

$$h^2 = \frac{4 * \sigma_s^2}{\sigma_s^2 + \sigma_e^2} \qquad [5]$$

where σ_e^2 is the environmental variance.

Reliability (r_{REML}) for animal *i* for parity *p* and for survival was calculated as

$$r^2_{REML\,i} = (G_i - PEV_i) / G_i \qquad [6]$$

where:

PEV_i is the diagonal element of the coefficient matrix for the LIN-S3 dataset pertaining to animal *i* and parity *p* (1, 2 and 3). For LIN-LPL dataset, PEV_i is the diagonal element of the coefficient matrix pertaining to animal *i* and the overall measure of LPL. The G_i was the diagonal of the **G** matrix. Where $\mathbf{G} = \mathbf{A}\sigma_s^2 = \text{var(s)}$ for the additive genetic (sire) variance effect.

Correlations

Only the sires present in the linear and non-linear analysis with at least 25 uncensored daughters were used to calculate correlations among EBV; 25 was chosen because it was the average number of daughters per sire in the most representative provinces. Because the dataset used for the survival analysis (SURVun and SURVall) were different from the dataset used for the linear analysis (LIN-LPL and LIN-S3), a correction of the sires EBV for the genetic trend was made as suggested by Calo et al. (1973). A correction for the genetic trend was also needed because sires were born in different years.

The approximated genetic correlation was calculated as:

$$Cg = \frac{s_{EBV}}{(r_{REML} * r_{LPL})^{0.5}} \qquad [7]$$

Where:

Cg = correlation between sire's EBV corrected for the effect of the genetic trend;

s_{EBV} = expressing sire's EBV as a deviation from the birth year mean;

r_{REML} = reliability for the sire's EBV from the linear model;
r_{LPL} = reliability for the sire's EBV from the non-linear model;

In this way it was possible to correlate the sires EBV from linear and non-linear models accounting for the genetic progress over the years. Possible differences between EBV were thus related to the model and the method of analysis, rather than differences in genetic trend. In particular, the EBV of natural service sires with daughters in one or a few herds was probably biased because less information was available for the correct estimation (and for the reliability) of these bulls. One of the objectives of this study was to examine the effects of using only data from uncensored animals for the Survival analysis (SURVun) that probably better mimics the data used for the non-linear model (LIN-LPL).

Results

Survival analysis

Model parameters. Estimates of effects for the sire model with censored and uncensored data (SURVall) and for the uncensored data only (SURVun) are presented in Table 3. In these analyses, the Weibull parameter ρ was equal to 1.98 and 2.00 for SURVall and SURVun, respectively. Therefore, the parameter ρ was fixed at 1.98 for SURVall and 2.00 for SURVun when sire variance was estimated to reduce the amount of computing time. A value of $\rho > 1$ indicates that the baseline hazard risk increases as age increases. The intercept $\rho\log(\lambda)$ was equal to –14.66 and –14.32 for SURVall and SURVun, respectively. These two parameters (ρ and intercept) fully describe the survival function $S(t)= \exp(-(\lambda t)^{\rho})$, which is given in Figure 1. The first derivative $dS(t)/d(t)$ of the S(t) changes convexity at 2,075 days. This change in the shape of the survival curve is possibly due to changes in the relative emphasis of voluntary versus involuntary culling. Most of the voluntary culling in beef cattle occurs early in life and the cows that have already surpassed 2,075 days since first calving were probably able to delay involuntary culling (disease, parturition problems i.e. dystocia and morphological problems) from that point forward. For SURVall the effective heritability [2] was slightly higher (11.2%) compared to the SURVun (9.3%), probably due to an inclusion of additional information from censored cows (old cows). Moreover, for the same reason, reliability [3] for the sires BV for SURVall was 0.28 ± 0.16 higher than for the SURVun (0.24 ± 0.15).

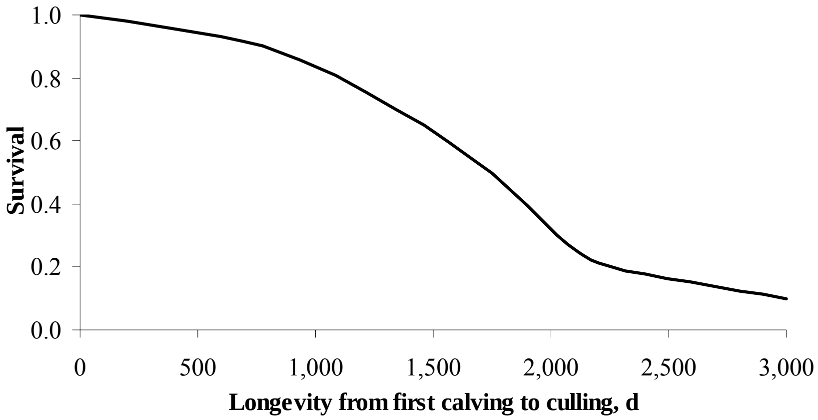

Figure 1. SURVun and SURVall survival function(1).

(1)Because the censored cows in the SURVun and SURVall were exactly the same, the same slope of the survival function was found for both models.

Table 3. Parameters estimated for non-linear sire model.

Parameters	SURVun	SURVall
Gamma (γ)	1.12	1.94
Rho (ρ)	2.00	1.98
Intercept [$\rho \log(\lambda)$]	-14.32	-14.66
Sire variance (σ_s^2)	0.024	0.029
h^2 (effective)	0.093	0.112

Non-genetic effects. Risk ratios for variation in herd size are presented in Table 4. To be able to interpret the effect of variation in herd size for the SURVall, the class containing the largest number of animals was used as a reference point, and the risk ratio (RR) for this class was set to 1. When the number of cows in the herd increased between +15% to +60%, the RR for culling was 0.55, i.e. lower than for cows in a herd of stable size (±15%, of herd variation). Cows present in shrinking herds (-15% to -60%) had 3.14 times greater probability of being culled than cows in herds of a constant size.

Sire effects. Sire solutions expressed as relative culling rate for the SURVun ranged between 0.14 and 3.97 with a mean of 1.25±1.07. For SURVall, results were similar with a relative culling rate ranging between 0.07 and 3.88, with a mean of 1.21±0.99. A low value indicates a relatively low risk of culling. To improve longevity a sire with a relative low risk of culling is desirable.

Table 4. Risk ratios (RR) for variation in herd size.

Classes[1]	LPL all	
	RR	SE
5	2.98	*0.108*
4	3.14	*0.047*
3	1.00	
2	0.55	*0.033*
1	0.27	*0.171*

[1] Classes are defined as (1) an increase of 60% or more in herd size, (2) an increase between 60 and 15%, (3) a change between 15 and -15%, (4) a reduction between –15 and -60%, and (5) a reduction of more than 60%.

Linear model

Estimates of heritability and genetic correlation for longevity in first, second and third parities from the linear sire model (LIN-S3) are presented in Table 5. Heritability ranged between 2.5% and 5.3%. Genetic correlation between first and second parity was 0.93, which was higher than the correlation between second and third parity (0.84). This higher correlation suggests that the genetic factors that affect culling in parities 1 and 2 were similar. The moderate genetic correlation (0.69) between first and third parities suggests that greater differences exist between early and later survival in Chianina beef cattle.

Reliabilities for the sires BV for LIN-S3 was 0.23±0.14 for first parity, 0.20±0.11 for second parity and 0.23±0.08 for third parity.

From the linear sire LIN-LPL with the same dataset as that used for the SURVun, heritability was equal to 7.7 %, which was the highest estimate obtained by the various linear models.

Approximate genetic correlations

Approximate genetic correlations between the EBV are shown in Table 6. In this way it was possible to compare 103 sires with relatively high reliabilities. Correlations between EBV from the survival analysis and the linear model corrected for the genetic trend were moderate to high, ranging between 0.50 to 0.93. The highest correlation between linear and non-linear models was found between SURVall and parity 3 from LIN-S3 at 0.93. Linear and non-linear models differed in many aspects; better results were found when all available data (censored and uncensored data) were used.

Table 5. Heritability (diagonal), genetic correlation (below diagonal) for LIN-S3 model.

	Parity		
Parity	1	2	3
1	0.053		
2	0.93	0.025	
3	0.69	0.84	0.025

Table 6. Approximated genetic correlation (corrected by method of Calo et al., 1973) between estimated breeding value from linear sire model for the LIN-S3 and LIN-LPL and EBV's from survival analysis for censored and uncensored data (SURVall) and uncensored data only (SURVun).

	Non-linear model[1]		Linear model[1]		
Survival analysis[1]	SURVun	SURVall	Parity 1	Parity 2	Parity 3
SURVun	1.00				
SURVall	0.85	1.00			
Linear LIN-S3 model[1]					
Parity 1	0.50	0.71	1.00		
Parity 2	0.60	0.86	0.99	1.00	
Parity 3	0.62	0.93	0.96	0.98	1.00
Linear LIN-LPL model[1]					
LIN-LPL	0.63	0.66	0.95	0.93	0.89

[1] 103 sires with ≥ 25 uncensored daughters.

Discussion

A sire model was used for the survival analysis because the approach used to estimate the variances is not well suited to the animal model that tends to overestimate the genetic variances (Ducrocq, personal communication; Ducrocq et al., 2001a; Ducrocq, 2001b). To facilitate a comparison between non-linear and linear models, a sire model was also used for the linear model. As pointed out by Ramirez-Valverde et al. (2001) and Snelling et al. (1995), comparing sire models and animal models might lead to a different ranking of the sires. The effective heritability for the SURVall was the highest found in this study. This is similar to what Boettcher et al. (1999) and Ducrocq et al. (1988) found when making similar comparisons with longevity data for dairy cattle. The effective heritability from the survival analysis was slightly lower when only uncensored records were used, perhaps some genetic variance was lost by elimination of censored daughters. Heritability calculated with the LIN-S3 model at the first parity was similar to what was found by Vollema and Groen (1998) for dairy cattle. However, the estimate was lower than might have been expected based on the results of Snelling et al. (1995) for beef cows, who found a heritability (stayability) equal to 8%. Heritabilities for the second and third parity calculated with the LIN-S3 were low but the LIN-LPL heritability was similar to what was found by Snelling et al. (1995) in beef cattle and by Boettcher et al. (1999) in dairy cattle. Heritabilities obtained from linear and non-linear models can be used as criteria of comparison (Ducrocq, personal communication) as can reliability. Correlation coefficients between the linear and non-linear models in particular between SURVall and LIN-S3 were similar to the values reported by Vollema and Groen (1998) and Boettcher et al. (1999) for dairy cattle, who found a high correlation between EBV from these models. Reliability was slightly higher for non-linear than linear model probably because the linear model is an approximation of the survival model (Veerkamp et al., 2001). For their relatively high standard error found in this work, reliabilities may not be use as a good criteria of comparison between models. One way to increase reliability of EBV for survival is to include an earlier predictor of longevity and the type traits as pointed out by Larroque and Ducrocq (2001) and Vukasinovic et al. (2002). In Chianina beef cattle, muscularity traits are the most important type traits for longevity (Forabosco et al., 2004).

Each of the approaches used for the analysis had some advantages as well as disadvantages. The linear model was simple to implement and required less computing resources. The LIN-LPL model and the LIN-S3 have some important differences; in the LIN-LPL we assume that a single sire affects longevity of the daughters and in the multiple traits LIN-S3 for each parity (1, 2 and 3) the sires (1, 2 and 3) are considered. Although the LIN-S3 and LIN-LPL models account, respectively for genetic variability in survival among sires from one parity to another and in genetic variability among sires from all LPL of their daughters. The differences in the sire variances between LIN-LPL, LIN-S3 and the model used affects heritability and BV. Possible differences between BV were thus related to the model (fixed, random, dependent and independent variables) and the method of analysis (linear and non-linear).

However, the linear model is statistically less appropriate for censored and categorical data (Boettcher et al., 1999; Veerkamp et al., 2001), probably a threshold model would be more appropriate (Boettcher et al., 1999).

Survival analysis is able to give an estimation of survival for each day during the entire productive life and not only in some specific moments, given by the linear model, sires will always rank the same across all stages of productive life. Survival analysis can analyse all the information available from both live and dead cows and give a more precise

EBV. Approximately 14% of the cows were censored and almost 69% were alive after the third parity. The linear model is not able to readily include the information on these cows beyond the fact that they survived at least three parities. The only way to include this variability in survival at an advanced age is to analyse the parities up to the last one observed in the data. For the Chianina breed analysed in this study, such an analysis would have to include up to the 12th parity and, therefore, 12 traits. However, such an analysis would require too many computing resources and probably would not reach a convergence due to the high proportion of missing records in later parities. Survival analysis is able to include all the information (censored and uncensored cows) at the same time without losing useful information. Herd-year and variation in herd size are time dependent variables that correct the cow's longevity, accounting for specific events occurring during the cow's life.

Implications

Heritabilities estimated were different using linear or non-linear models. The highest estimates were obtained with the survival analysis including both uncensored and censored data (11%). Within a herd, the risk of being culled increased with a reduction in the herd size from one year to another. Censored as well as uncensored data are optimally combined using survival analysis which was specifically designed to deal with time dependent events and censoring. Based on the literature and our results, the Italian beef breeding organizations are initiating the development of a survival analysis for the genetic evaluation of longevity.

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Chapter 5

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

F. Forabosco, R. Bozzi, P. Boettcher, F.Filippini, P. Bijma and
J.A.M.Van Arendonk

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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 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 per year for the length of productive life (LPL) and was obtained as the difference between average income of 1,375 €/cow per year of LPL and costs of 1,178 €/cow per year of LPL. The mean LPL was equal to 5.97 years, 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 per year and +24.06 €/cow). An increase of one day unit in LPL was associated with an increase of +0.19 €/cow per year and +1.65 €/cow on a lifetime basis. Increasing FI by one day decreased profit by 0.42 €/cow per year 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: Profit function, Economic values, Type traits, Genetic analysis, Chianina

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 the estimated breeding values (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 which involves the use of a profit function or bio-economic model (Groen, 1990; Hazel, 1943; Van Arendonk, 1991; Wilton and Goddard, 1996). In most studies that have addressed individual cow (predominantly dairy cattle) profitability (Pérez-Cabal and Alenda, 2002; Pérez-Cabal and Alenda, 2003; Van Arendonk, 1991) or herd profitability (Norman et al., 1996; Veerkamp et al., 1994), 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 relationship between profit and type traits that can be used as early predictors of profitability. Both a positive and a normative approach 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 of 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 1st, 1981 and December 31st, 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 was collected continuously until 2003. Records from animals without information such as birth date, parity dates, and production data were excluded, as well as 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 in length 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 to 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 31st, 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 year 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 is an important source of information, because including only information for uncensored cows will reduce the accuracy of the indexes, increase the generation interval and has the potential to reduce (drastically) the use of the young sires.

This study focuses on reproduction and survival traits. Data on other traits such as differences between animals in muscle conformation, marbling, age and weight at slaughter are not available for Chianina at present. Hence, conclusions for the relative economic importance of other traits (e.g. muscularity versus 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 live, 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 €/cow per year (P) or as lifetime profit (Pc) in €/cow. In the first case, profit per cow was calculated as the difference between revenue (R) and costs (C) per cow per year; 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, P and Pc were calculated for each cow in the dataset.

In the production system assumed in this study, that 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 P 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) n° 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 (R) was calculated [1] as the sum of sold males calves, sold females calves and sold cows, all expressed as €/cow per year of the cow's LPL. Each cow produced (1-DE)*NACY offspring per year with an equal probability of 0.5 for males and females. Revenue (R), €/cow per year, was therefore equal to:

$$R = 0.5 \times (1 - DE) \times (NACY \times CP) + 0.5 \times (1 - DE) \times (NACY \times JCP) + CCP/ LPL;$$

which simplifies to

$$R = [\, 0.5 \times (1 - DE) \times NACY \times (CP + JCP)] + CCP/ LPL \qquad [1]$$

Where:

DE = proportion of dead animals (males and females) up to the sale of each cow. We assumed that the rate is the same for both sexes (2% each);
NACY = number of calves born alive for each cow per year of the cow's LPL;
CP = market price for males at weaning age (6 mo), € per male calf;
JCP = market price for females at weaning age (6 mo), € per female calf;
CCP = market price for cows at the end of their productive life, € per cow;
LPL = length of productive life, years.

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, NACY= NAC/LPL. Lifetime revenue (Rc), expressed in € / per cow, was:

$$Rc= [\, 0.5 \times (1 - DE) \times NAC \times (CP + JCP)] + CCP \qquad [2]$$

or equivalently,

$$Rc = R \times LPL$$

The beef price when the animals are sold to the market is affected by different parameters (e.g., destination of the animal, i.e. 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 non-feed 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. Non-feed costs included the amortization of capital (housing, machines, land and animals), interest, taxes, general expenses (medicines, gas, electricity and other costs).

Annual cost (C), expressed in € / cow per year, were calculated as:

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

Where:

RERHF = feed and non-feed costs for heifers until pregnancy, € per year;
FI = age at the first insemination that results in the first calf, year;
0.5 = the age of purchased heifers (6 mo.);
FCC = average feed costs per calf (is 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, € per year;
OC = average non-feed costs per cow after FI, € per year;

Lifetime cost (Cc) expressed in € per cow were,

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

or,

$$Cc = C \times LPL$$

The FC and OC were assumed to be constant during the lifetime of the cow starting from when the cow becames pregnant (immediately after the FI). No twins were considered in this analysis. The proportion of dead animals (DE) were 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 and Pc

A profit equation representing the production system is used to derive the economic value for each trait in the aggregate genotype (Brascamp et al., 1985; Groen, 1990; Hazel, 1943). 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 and Pc) as partial derivatives of the profit functions (∂P and ∂Pc) with respect to the traits NACY, LPL and FI (Brascamp et al., 1985; Moav and Moav, 1966; Weller, 1994).

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

$v_{NACY,P} = 0.5 \times (1 - DE) \times (CP + JCP) - (FCC + OCC)$;

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

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

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

$v_{NACY,Pc} = [0.5 \times (1 - DE) \times (CP + JCP) - (FCC + OCC)] \times LPL$;

$v_{LPL,Pc} = 0.5 \times NACY \times (1 - DE) \times (CP + JCP) - NACY (FCC + OCC) - (FC + OC)$;

$v_{FI,Pc} = - RERHF$;

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) or per lifetime (Pc). The profit functions P and Pc 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 (Pc) 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 (Pc), the final score and 16 type traits (20 traits in total). The model for the analysis was:

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

where:

Y_{ik} = traits;

HY_i = fixed effect of herd-year;

a_k = random animal effect;

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 impact of the age at which the final score (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 below 39 mo; the second group at an age above 39 mo. Thirty-nine mo was chosen because it is the mean age at which the cows are scored.

Results and Discussion

Profit functions

In a normative approach, the profit function and the derivation of economic weights presented in this paper 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 per year and was obtained as the difference between average income of (1,375 ± 623.3 €/cow per year of LPL) and costs (1,178 ± 92.2 €/cow per year of LPL). The total lifetime profit per cow (Pc) was 1,175 €/cow and the length of productive life (LPL) was equal to 5.97 ± 2.52 years. Because a profit function is market dependent, when the market circumstances change (i.e., from one country to an other 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 per year .

Economic weights

Table 3 reports the economic weights obtained with the normative approach for length of productive life (LPL), age at the insemination that resulted in the birth of the first calf (FI) and calves born alive per year expressed per year and per cow (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 € per cow per year and +24.06 € per cow over the course of a lifetime. A single day increase in LPL was associated with an increase of +0.19 € per cow per year and +1.65 € per cow. An increase of one day of the age of insemination that resulted in the birth of the first calf (FI) decreases the profit respectively by 0.42 € per cow per year and 2.51 € per cow. Genetically, NACY (0.907 € per cow per year) and LPL (0.169 € per cow per year) 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 Jagannatha (1998), Perez-Cabal and Alenda (2003) and Van Arendonk (1991).

The relative size of the economic values of LPL on one hand and FI and NACY on the other differs 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 P and Pc differs by a scaling factor which is equal to the average LPL. For LPL, different elements come into the expression derived from P and Pc, respectively. This result is also found in other studies and reflects the importance of choosing appropriate scaling factor for the enterprise (Smith et al., 1986). Economic values derived from P 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.

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 non-feed costs for heifers (RERHF), per year	930.7	CRPA (2004)
Feed costs per mature cow (FC), per year	208.4	ISMEA (2002)
Non-feed costs per mature cow (OCC), per year	336.0	ISMEA (2002)
Feed costs per calf (FC)	70.5	F. Forabosco (unpublished data)
Non-feed costs per calf (OCC)	92.0	F. Forabosco (unpublished data)

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

Traits	Mean	SD	CV
Profit function			
Phenotypic profit (P), €/cow per year of productive life	196	562.9	285.9
Return (R), €/cow per year of productive life	1,375	607.0	44.1
Cost (C), €/cow per year 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), years	1.93	0.50	26.1
Length of productive life (LPL), years [a]	5.97	2.52	42.3
Calves born per year of productive life (NACY), n	0.78	0.37	47.6

[a] Censored 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.

Table 3. Absolute economic weights.

Traits	Annual economic weight (€/cow per year)	Life time economic weight (€/cow)	Genetic importance based on an economic weight [a] (€/cow per year)
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

[a] expressed as $\sqrt{\left(h^2 * \sigma^2{}_\tau\right)} * v_{\tau,P}$, where: h^2= heritability σ_τ = phenotypic std. dev. of trait τ (LPL, FI and NACY), $v_{\tau,P}$=economic weight of trait τ (€/cow per year).

[b] economic weight expressed per day for one extra calf per year.

Positive approach

Results from the multiple regression model for both profit functions, the profit per cow per year (P) and per cow (Pc), are in Table 4. Those traits, corrected for the herd-year effect, explained 98% and 78% of the total variation (R- square) in Pc and P respectively. The relative importance of LPL to the production (NACY) was calculated as the value of one additional day of LPL expressed per unit of calf born and was equal to +0.10 € per d per unit of calf born for P which was higher if compared with Pc (+0.08 € per d per unit of calf born).

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 of this paper.

Table 4. Regression coefficients for phenotypic profit (P and Pc) corrected for the herd-year effect [a]

Trait [b]	Regression coefficients			Relative importance[c]
	LPL	FI	NACY	
Pc	+2.16	-2.26	+27.39	+0.08
P	+0.48	-0.34	+4.77	+0.10

[a] correction for the herd-year effect was made using the General Linear Models (SAS, 2000). The outputs (predicted values from the GLM) of P and Pc were used as inputs for the regression analysis (SAS, 2000).

[b] P= phenotypic profit per cow per year; Pc= phenotypic profit per cow.

[c] value of one extra d of productive life expressed per unit of calf born.

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 (FS) was the only type trait with a different mean (82.7±1.9) and a scale between 74 to 91.

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

Traits	Mean	SD	CV	Optimum class	Description class 1	Description class 5
Final Score (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

[a] Anabic, 2001; [b] 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 between 0.62 to 0.85. Genetic correlations among the seven dimensional traits ranged between 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, genetic correlation ranged from 0.63 for MSC to 0.86 for BsCW.

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	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	0.12	-0.08	0.20
BsIW														0.74	0.81	0.08	0.16	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

See Tables 2 and 5 for definition of abbreviations.

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 the phenotypic profit function per cow per year (P) and 19 type traits are shown in Table 7. The highest heritability was observed for FI (0.41) followed by FS (0.34) and BsTL (0.30). Phenotypic profit (P) 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 P 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 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 P 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 (P) 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 (P) 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 P and FSbe (FS collected at a cow aged below or equal to 39 mo) 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 the cows have been evaluated at an age below 31 mo.

Table 7. Heritability 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 year (NACY), length of productive life (LPL) and the phenotypic function of profit (P)

Traits	Profit (P)	
	h^2	Genetic correlations
Profit per cow per year (P)	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

Final considerations

From these results (Table 7) muscularity traits seem to have an important impact on profit and the final score, particularly the FSbe, summarizes all of this information. Profit per cow per year 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 versus 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 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 profit per cow per year 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 and thus information on variability in this 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 profit per cow per year as a trait per se in future breeding programs.

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Chapter 6

Genetic selection strategies to improve longevity in Chianina beef cattle

F. Forabosco, P. Boettcher, R. Bozzi, F. Filippini and P. Bijma

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Abstract

Longevity in beef cattle is an important economic trait. Including this trait in a breeding scheme increases profit and has a positive impact on the well-being and welfare of the animals. The aim of the present study was to evaluate the consequences of alternative selection strategies to include longevity in different breeding schemes using deterministic simulation. Different schemes were compared and economic (EcW) and empirical weights (EmW) were used to evaluate the responses. The empirical weights of average daily gain (ADG) and muscularity (MU), were identical because both traits have an identical importance for the breeders. Economic weights have been derived from profit equations. Traits used in the *Base* scenarios were: average daily gain pre-performance test (ADG1), average daily gain during the performance test (ADG2) and muscularity (MU); longevity (L) was included in the alternative schemes. When longevity was included both in the breeding index and in the breeding goal (scenario A-2), the total longevity response using EmW and EcW was +2.97d/y and +4.92 d/yr respectively. The total economic response for scenario *A-2* using EmW and EcW were 3.020 €/yr and 3.342 €/yr respectively, and the total response in units of Bull Selection Index were +0.699 and +0.678 respectively. Longevity decreased when it was not included in either the breeding goal or in the breeding index (scenario *Base*), and economic response was the lowest found. The results of the current study indicate that the highest total response using either economic weights or empirical weights was found when information on longevity was included both in the breeding index and in the breeding goal (scenario *A-2*).

Key Words: Chianina, Selection program, Profit, Longevity, Breeding goals

Introduction

In livestock production, including beef cattle, longevity is an important trait that affects profitability. Several studies (Forabosco et al., 2004; Larroque and Doucrocq, 2001; Jagannatha, 1998) have shown that this moderately heritable trait plays a considerable role in the farm economy by increasing the profit realized per cow. In addition, increased longevity enables a greater response in genetic selection for other traits, because fewer animals have to be replaced involuntarily and thus higher selection intensity of females is possible. Moreover, breeding for longevity is considered to have ethical benefits, because direct selection for longevity results indirectly in an improvement of health and fitness, (i.e., the well-being of the cow, Vukasinovic et al., 2001). Longevity in Black-and-White cattle is a trait well studied and already incorporated into many national selection indexes (Powell and Van Raden, 2003; Miglior, 2004; Vollema et al., 2000). Miglior, (2004) in the same study found, for the same breed, an average economic weight for longevity equal to 10% (relative weight for this trait in the national selection indexes). For some countries, such as The Netherlands, Germany and Ireland, the weight of longevity is respectively 26%, 25% and 23% (relative weight for this trait in the national selection indexes). This shows the importance of longevity in some national selection indexes.

In beef cattle, particularly in the Italian Chianina breed, longevity has not been extensively studied (Forabosco *et al*., 2004; Rogers et al., 2004) and few publications are available on the inclusion of this trait in a beef cattle breeding program. In the present paper, a deterministic simulation was implemented in order to examine the benefits of incorporating longevity into the Chianina beef cattle breeding scheme. Longevity, productive and reproductive data are collected by the National Italian Beef Cattle Breeders Association (Anabic, 2001), which is the breeding organization for Chianina in Italy. Several selection schemes were compared based on the selection response for daily gain, muscularity and longevity. Different breeding goals were implemented in order to investigate the effect of breeding goal definition on selection response for longevity.

Materials and Methods

The Italian Chianina Population

The Italian Chianina population consists of approximately 33,000 animals in 941 herds (i.e., mean = 35 head/herd). Cows and yearling heifers represent nearly 60% of the total population, calves 38.5% and bulls represent 1.5% (482 bulls) of the population. The primary source of income for breeders is the sale of calves. Cows that produce one calf per year are the most profitable and breeders tend to keep these animals. Forabosco et al. (2004) reported an average productive life for the Italian Chianina of approximately 5 years, but some cows reached more than 15 years of productive life (Figure 1). The main reasons for culling of cows are calves with low vitality, cow's poor milk production, diseases, parturition problems and feet and leg disorders (Forabosco et al., 2004).

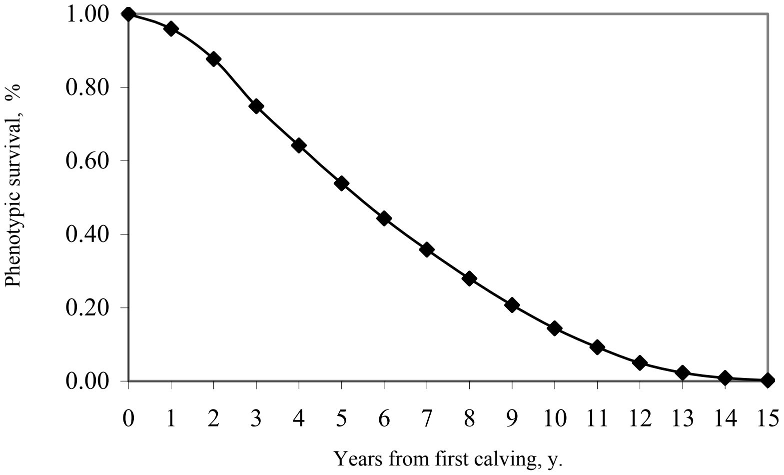

Figure 1. Survival curve of Chianina cows.

Cow selection: The cows calve for the first time at an average age of 964 d and the mean calving interval is 418 d, calculated as an average from first to the fourth parity (Forabosco et al., 2002). All females are evaluated for conformation between 15 to 30 mo of age, according to the linear morphological evaluation system (Anabic, 2001). Nearly 50% of the cows are bred by artificial insemination (AI) and 100% of the AI bulls used are tested at the Anabic performance testing station (Anabic, 2001). Bull dams are selected only from the females that have a cow selection index (CSI) above 100 (the CSI index as μ=100 and σ=10) and a linear morphological evaluation score above 82. Among all progeny, only males born from bull dams have the opportunity to enter the performance testing station. Selection of cows for replacement is mainly linked to the farmer's decisions. Whether or not to select the cows for replacement or fattening depends not only on individual factors (age at first calving, calving intervals, number of inseminations to get pregnant, abortions etc.), but also on herd factors (variation on herd size, availability of replacement heifers, beef market etc.) and all of these factors are completely embedded in the whole farming process.

Bull selection: Selection of the male line for the Italian Chianina is based on the results of a performance test (Anabic, 2001). The young male calves are sent to the testing station when they reach an age of five mo. Animals are admitted to the testing station only after all subjects of the same age available in the population have been assessed, giving careful consideration to the traits of each animal as well as those of its parents. The stay at the testing station starts with a one-month adaptation period, at the end of which the six months test period begins. During the test period, the animals are weighed, measured and assessed morphologically. During that period, every 21 d the bulls are weighed, and they are measured twice (at the start and at the end of the test period). At the end of the period three breed experts evaluate the bulls' morphology. The bulls finish the test (on average 36 per year which is 60% of the total number of bulls that enter the test) when they are 12 mo old and they are used as AI or NS sires. The 30% percent bulls with the highest bull selection index (BSI) are approved to be AI bulls and the rest of the bulls that finish the test are used as NS sires. All the data are collected (muscle development, growth rate before and during the performance) and summarized in a BSI, which expresses the speed of the subject's growth rate and muscle development (Filippini, 1996).

Simulation

Population structure: A population that mimicked the actual population was produced using deterministic simulation. This population had overlapping generations and a fixed number of sires and dams selected out of specific age classes. The population structure is shown in Figure 2. Each year, animals were ranked according to a selection index that differed according to the scenario simulated. From a total of 20,000 Chianina females (cows and heifers), the top 50% (based on the CSI index) were considered as candidates each year to be the bull dams of the 60 males tested for growth and muscularity at the testing station.

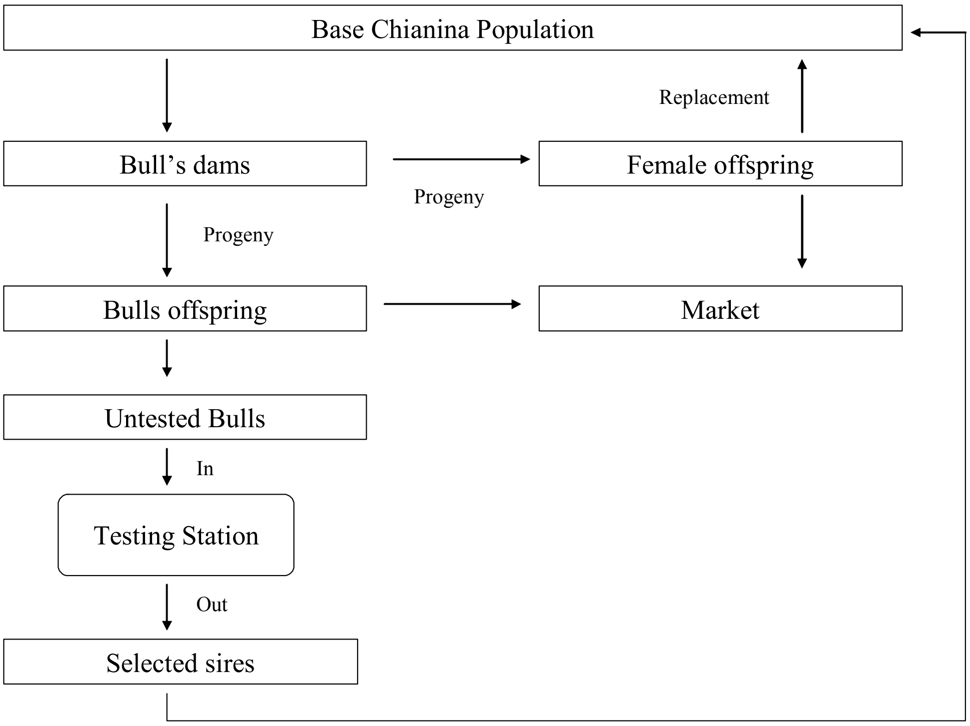

Figure 2. Structure of population and breeding scheme, per year.

In the initial situation, 36 males per year (60% out of the 60 males that enter the test) were selected to be the sires of the next generation and 3,125 cows per year were used as replacement cows out of the 10,000 cows (the number of replacement cows was obtained as: 10,000 cows/8 years of length of life/0.4 offspring per cow). The number of offspring per dam was assumed to be 0.4 male and 0.4 females per year. Ten yearly age classes were simulated, starting with 751 cows in age class 3 and ending in class 10 with 225 cows with a 10% culling per age classes and a selected proportion equal to 0.8 starting from age class 3 up to age class 10. Each age class was equal to 1 year. Sixty sires per age class were considered as candidates with a selected proportion equal to 0.6 starting from age class 2 to age class 8. Total longevity was measured only on the female population from age class 3 to 10, own performance, pedigree and half sibs information was also included.

Breeding goals

Current breeding goal: The performance test is used to evaluate the beef bulls. The BSI (Bull Selection Index) used in practice is a weighted sum of the standardized EBV (μ=100, σ=10) of gain until test (ADG1), gain during test (ADG2) and muscularity (MU).
The traits ADG1 and ADG2 were calculated as linear regressions of weight over age. ADG1(kg/d) was calculated as weight at the start of the performance test minus weight at birth divided by age at the start of the test; ADG2 (kg/d) was calculated as weight at the end of the test minus weight at the start of the test divided by the duration of the test. The trait MU was a score derived from three evaluations made by breed experts according to the Anabic regulations (Filippini, 1996; Anabic, 2001).

Alternative breeding goal: The alternative breeding goal included the longevity (L) of the beef cows. Longevity was the only trait that was not measured directly from the performance of the bulls in the station, but was instead obtained based on longevity of the cows. Taking this new trait into consideration, the alternative breeding goal (or aggregate genotype, H) was a combination of four traits: average daily gain pre-performance (ADG1), average daily gain during the performance (ADG2), muscle development (MU) and longevity (L), and was expressed as a weighted sum of the true breeding values for the four traits (BV_{ADG1} , BV_{ADG2} , BV_{MU} , BV_L) and their respective economic weights (EW_{ADG1} , $EW_{ADG2,}$ EW_{MU} , EW_L).

$$H = EW_{ADG1} * BV_{ADG1} + EW_{ADG2} * BV_{ADG2} + EW_{MU} * BV_{MU} + EW_L * BV_L$$

Economic and empirical weights: Two different sets of “weights” were used; “economic weights” (EcW) and “empirical weights” (EmW). The EmW are those currently used in Italy. The EmW for ADG2 was higher than ADG1 because the information available for ADG2 is more reliable since it was collected during the performance test. The EmW of ADG (ADG1 + ADG2) and MU were identical because the opinion is that both traits have an identical importance for the breeders. Each of these EmW was applied to standardized EBV. To be able to include and compare all traits (ADG1, ADG2, MU and L), which have different scaling factors in breeding schemes for different scenarios, a conversion to trait units is needed for the deterministic simulation. This conversion and the resulting weights are presented in appendix 1. The EcW are based on previous studies on Italian beef cattle (Forabosco et al., 2004; Albera et al., 2004), and the results are shown in appendix 2. The

EmW and EcW that were used in the present simulation study are presented in Table 1. The EcW used for ADG2 was double the weight for ADG1 due to the major expense related to the increase in the amount of feed needed for the growing animals (see appendix 2 for more details).

Selection strategies

The genetic and phenotypic parameters used in the simulations were based on previous research (Forabosco et al., 2004, 2004a; Contiero et al., 1997) and are shown in Table 2. Predictions of genetic changes were performed by the program SelAction (Rutten et al., 2002). This program predicts the rate of genetic gain using an accurate approximation of a stochastic simulation with selection on BLUP EBV from an animal model (Wray and Hill, 1989; Villanueva et al., 1993) and selection differentials were calculated using the method of Meuwissen (1991). The selection response is expressed per year, in trait units, in economic units, as the contribution due to each sex and as total response. A hierarchical mating structure was used where dams were nested within sires and random mating of selected animals was applied (Rutten et al., 2002). A population with overlapping generations and a fixed number of sires and dams was simulated. In SelAction, animals are assumed to be selected on an index I which equals their expected value for the aggregate genotype [I = Exp.(H)]. This corresponds to an index: $I = EW_{ADG1} * EBV_{ADG1} + EW_{ADG2} * EBV_{ADG2} + EW_{MU} * EBV_{MU} + EW_{L} * EBV_{L}$, as used in practise.

Scenarios: Three different scenarios were compared;

BASE : This scenario simulated the current breeding scheme for Italian Chianina bulls, where the animal subject to selection is measured directly for daily gain (ADG1 and ADG2) and muscularity (MU). Selection on the female population was simulated only for bull dams. These three traits were then included in both the index and in the breeding goal. Longevity (L), was not included in either the breeding index or the breeding goal. Both the EcW and EmW were used in all scenarios. The aim of the scenario was to simulate the current status and to establish a basis for comparison with other scenarios that considered L.

Table 1. Empirical and economical weights used in different schemes.

Scheme	Empirical weights (EmW) $^{(1, 3)}$				Economical weights (EcW) $^{(2, 3),}$, €*y			
	ADG 1	ADG 2	MU	L	ADG 1 g/d	ADG 2 g/d	MU %	L d
Base	0.15	0.35	0.50	-	0.10	0.20	1.02	-
	(0.026)	(0.059)	(0.278)					
A-1	0.10	0.35	0.50	0.05	0.10	0.20	1.02	0.20
	(0.018)	(0.059)	(0.278)	(0.018)				
A-2	0.10	0.35	0.50	0.05	0.10	0.20	1.02	0.20
	(0.018)	(0.059)	(0.278)	(0.018)				
Base	[1.023]	[6.284]	[1.137]	-	[0.029]	[0.132]	[0.305]	-
A-1	[0.425]	[5.874]	[1.063]	[0.824]	[0.014]	[0.063]	[0.145]	[0.432]
A-2	[0.427]	[5.896]	[1.067]	[0.827]	[0.014]	[0.064]	[0.147]	[0.439]

(1) See appendix 1 for the derivation of EmW. In the brackets ( ) the corresponding value (EmW) of the trait. Outside the brackets the weight per std of EBV applied after standardization of the EBV to a standard deviation (σ=10);

(2) See appendix 2 for the derivation of EcW;

(3) In the brackets [ ] the value of the variance ($\sigma^2_{H,T}$) that the trait (T) explains: $\sigma^2_{H,T} = EW^2 * \sigma^2_A / \sigma^2_H$ where: $\sigma^2_A = \sigma^2_P * h^2$ and $EW^2 = EmW^2$ and EcW^2

A-1 : The second scenario (A-1) was simply the BASE scenario, but with the addition of (L) in the breeding goal, but not in the breeding index. In the breeding goal, the relative weights on ADG1, ADG2 and MU were kept the same, but the relative emphasis applied to the combination of these three traits was decreased, to accommodate the addition of L. The aim of applying this scenario was to investigate the benefit of including L in the breeding goal without having to record it, and compare results to the BASE and A-2 scenarios.

A-2 : In the second alternative scenario (A-2), L was included in both the breeding goal and in the breeding index. Cow's longevity data is recorded and simulated with the program (cows own performances and pedigree information were included). Results obtained were compared with BASE and A-1 scenarios, the average cohort interval was 5.3 years.

Table 2. Genetic and phenotypic parameters used in the simulation study.

Trait	$^{(1)}\sigma^2_p$	ADG 1	ADG 2	MU	L
ADG1	27,225	**0.38**$^{(2A)}$	0.62$^{(2A)}$	0.74$^{(2A)}$	0.34$^{(2C)}$
ADG2	36,481	0.18$^{(2A)}$	**0.32**$^{(2A)}$	0.64$^{(2A)}$	-0.20$^{(2C)}$
MU	2,798	0.36$^{(2A)}$	0.43$^{(2A)}$	**0.37**$^{(2A)}$	0.20$^{(2C)}$
L	729,316	-0.31$^{(2C)}$	0.07$^{(2C)}$	-0.21$^{(2C)}$	**0.11**$^{(2B)}$

$^{(1)}\sigma^2_p$ = Phenotypic variance

$^{(2)}$ Genetic correlation above, phenotypic correlation below and heritabilities are on the diagonal.

$^{(2A)}$ Contiero et al., 1997; $^{(2B)}$ Forabosco et al., 2004; $^{(2C)}$ Forabosco, unpublished.

Results

Empirical weights: Base and alternative scenarios

Table 3a gives the response for traits ADG1, ADG2, MU and L for the base and alternative scenarios for both sexes using empirical weights (EmW). In the base situation, where longevity is not considered in either the breeding index or in the breeding goal, the total response was 0.658 units of BSI (UBSI)/yr and 2.362 €/yr; but because longevity was not included in both the breeding index and the breeding goal the true total response was reduced by -0.003 UBSI/yr and -0.038 €/yr, so the final response was 0.654 UBSI/yr and 2.324 €/yr respectively. Ignoring longevity in both the breeding index and the breeding goal deteriorated the total profit because it reduced longevity by 0.19 d/yr per animal.

The trait in the breeding goal that had the greatest proportion of the total economic response was MU (50.1%), followed by ADG2 (37.3%) and ADG1 (12.6%). The average accuracy of the indexes for the sires was relatively high (0.62) if compared with the dams (0.18) and this

Table 3a. The effect of alternative scenarios on trait response for ADG1, ADG2, MU and L for the empirical weights (EmW), expressed in trait units.

Scheme	Res. for ADG 1 g/d			Res. for ADG 2 g/d			Res. for MU 1% score			Res. for L d			Total response, in BSI units/yr (empirical)[(1)]	Total response, in euro/yr [(2)]
	Male	Female	Tot.	Male	Female	Tot.	Male	Female	Tot.	Male	Female	Tot.		
Base	2.775	0.408	3.183	3.334	0.834	4.168	1.072	0.114	1.186	0.459	-0.649	-0.190	0.654	2.324
A-1	2.768	0.605	3.373	3.113	1.177	4.289	1.096	0.177	1.273	0.900	-0.834	0.066	0.669	2.507
A-2	2.798	0.736	3.534	3.076	0.618	3.695	1.096	0.211	1.307	1.255	1.719	2.974	0.699	3.020

(1) Calculated as: ADG1* EmW_{ADG1} (0.026 for Base and 0.018 for *A-1* and *A-2*) + ADG2* EmW_{ADG2} (0.059 for *A-1* and *A-2*) + MU* EmW_{MU}
(0.278 for *A-1* and *A-2*) + L* EmW_{L} (0.018 for *A-1*, *A-2* and 0.018 for Base as reduction of trait response), expressed in BSI units/yr.;
(2) Calculated as: ADG1* $\text{EcW}_{€,\text{ADG1}}$ (0.10) + ADG2* $\text{EcW}_{€,\text{ADG2}}$ (0.20) + MU* $\text{EcW}_{€,\text{MU}}$ (1.02)+ L* $\text{EcW}_{€,\text{L}}$ (0.20) , expressed in €/yr;

Table 3b. The effect of alternative scenarios on trait response for ADG 1, ADG 2, MU and L for the economic weights (EcW), expressed in trait units.

Scheme	Ec. Res. for ADG 1 g/d			Ec. Res. for ADG 2 g/d			Ec. Res. for MU 1% score			Ec. Res. for L d			Total response, in BSI units/yr (empirical)(1)	Total response, in euro/yr (2)
	Male	Female	Tot.	Male	Female	Tot.	Male	Female	Tot.	Male	Female	Tot.		
Base	2.781	0.411	3.192	3.277	0.849	4.126	1.082	0.114	1.196	0.592	-0.669	-0.077	0.657	2.580
A-1	2.685	0.492	3.178	2.636	0.985	3.621	1.111	0.141	1.252	1.670	-0.736	0.933	0.661	2.731
A-2	2.686	0.593	3.279	2.563	0.113	2.676	1.095	0.150	1.245	2.068	2.858	4.925	0.678	3.342

(1) Calculated as: ADG1* EmW_{ADG1} (0.026 for Base and 0.018 for *A-1* and *A-2*) + ADG2* EmW_{ADG2} (0.059 for *A-1* and *A-2*) + MU* EmW_{MU}
(0.278 for *A-1* and *A-2*) + L* EmW_{L} (0.018 for *A-1*, *A-2* and 0.018 for Base as reduction of trait response), expressed as BSI units/yr;

(2) Calculated as: ADG1* $EcW_{€,ADG1}$ (0.10) + ADG2* $EcW_{€,ADG2}$ (0.20) + MU* $EcW_{€,MU}$ (1.02)+ L* $EcW_{€,L}$ (0.20) , expressed in €/yr;

was due to the fact that the traits analysed (ADG1, ADG2, MU) were measured directly from the male population, whereas dams were selected based on pedigree information.

In scenario A-1, longevity was included in the breeding goal with a weight equal to 0.10 (Table 2) but not in the breeding index. The total response was 0.669 per UBSI/yr and 2.507 €/yr (Table 3a), which was respectively 2.2% and 7.9% higher than in the Base scenario where longevity was not included in either the breeding index or the breeding goal. In other words, including longevity in the actual breeding goal has the positive effect of increasing the total response, even though longevity does not need to be recorded in this case. Longevity affects profit in two ways: directly with a positive impact on the total profit (+0.0132 €/yr and +0.001 UBSI/yr) and on the cohort total longevity (+0.066 d/yr), and indirectly increasing response for the correlated traits (ADG1 and ADG2). The trait that in the breeding goal had the strongest economic response was again MU (52.9%), followed by ADG2 (37.8%), ADG1 (9.1%) and L (0.2%). The impact of the total response was +0.554 per UBSI/yr for sires and +0.115 per UBSI/yr for dams. The average accuracy of the indexes for the sires (0.58) and dams (0.17) was similar to the Base scenario.

In scenario A-2, all the traits ADG1, ADG2, MU and L were included in both the index and in the breeding goal. The total response for this scenario were +0.699 per UBSI/yr and +3.020 €/yr, which was respectively 7% and 30% higher than in the Base scenario. Those values were the highest found across all scenarios. When longevity was included in the breeding index and in the breeding goal, total longevity increased by +2.77 d/yr. The ADG1 per animal increased 3.5g, ADG2 3.7g and the MU 1.3% of the score. The sires contribution was +0.559 UBSI/yr and the dams contribution was +0.096 UBSI/yr. The highest total response was found for MU (52.0%) followed by ADG2 (31.2%), ADG1 (9.1%) and L (7.7%). The average accuracy of the indexes was 0.59 for the sires and 0.25 for the dams.

Economic weights: Base and alternative scenarios

Table 3b gives the economic response for ADG1, ADG2, MU and L for the base and alternative scenarios using economic weights (EcW). In the base situation, where economic weights were used and longevity was not included in the breeding goal nor in the breeding index, the total response was +0.658 UBSI/yr and +2.580 €/yr. But because longevity was included in neither the breeding goal nor in the breeding index, the total response was reduced by -0.001 UBSI/yr and –0.016 €/yr and the final total response was +0.657 UBSI/yr and +2.564 €/yr. Not including longevity in the breeding goal and the breeding index reduces the total longevity of the cohort by -0.08 d/yr. The trait that in the breeding goal had the highest economic response was MU (55.7%), followed by ADG2

(31.9%) and ADG1 (12.4%). The accuracy of the index for the sires was (0.62) equal to that found in the Base situation with empirical weights.

In scenario A-1, the total responses including longevity were +0.661 UBSI/yr and +2.731 €/yr corresponding to +0.93 d/yr; higher than in the Base situation (+0.004 UBSI/yr and +0.151 €/yr), see Table 3b. The highest total economic response was found for the sires (+2.463 €/yr) with an increase of +3.178 g/d at ADG1, +3.621 g/d at ADG2, 1.252 1% score and 0.93 d/yr. The strongest economic response was found for MU (55.0%), followed by ADG2 (26.5%), ADG1 (11.6%) and L (6.8%). The average accuracy of the indexes was 0.47 for the sires and 0.10 for the dams.

In scenario A-2 the total responses were the highest found across all scenarios for the (EcW) and were +0.678 UBSI/yr and +3.342 €/yr. Longevity had a positive impact on the cohort +4.9 d/yr that was respectively +2.068 d/yr for the sires and +2.858 d/yr for the dams. The difference between the Base scenario and scenario A-2 were +0.021 UBSI/yr and +0.762€/yr respectively. The trait that in the breeding goal had the strongest economic response was MU (44.7%), followed by L (29.5%), ADG2 (16.0%) and ADG1 (9.8). The average accuracy of the indexes was 0.48 for the sires and 0.30 for the dams.

Discussion

In beef cattle, longevity is not yet incorporated into any national selection index, as is already done in many countries for dairy cattle (Miglior, 2004; Vollema et al., 2000). In order to simulate selection for longevity in beef cattle, six different scenarios were compared using deterministic simulation. In all scenarios using EmW and EcW, a Base situation with ADG1, ADG2 and MU was used as reference information. Including longevity in the breeding schemes either in scenario A-1 or scenario A-2 for EmW and EcW increased the total response. Slight differences between UBSI were found between A-1 and A-2 scenarios when results from EmW and EcW where compared. Better results were obtained when EmW were used in either A-1 (+ 0.669 UBSI/yr) and A-2 (+0.699 UBSI/yr) scenarios. The total economic response using the EcW in Base scenario was +0.256 €/yr higher than the total response when EmW were used and similar results were found when A-1 (+ 0.224 €/yr) and A-2 (+0.322 €/yr) where compared. More precise differences were found when the total economic response was considered. From these results we can conclude that EmW are better when only total response in UBSI was considered, and EcW are more appropriate when only total economic response was considered. However, differences in responses between both sets of weights were relatively small. A more general conclusion can be drawn from these results considering the correlation (ρ) between breeding goals (H) using EmW and EcW. The high correlation (ρ=0.97) between H suggests that both approaches give similar results (see appendix 3).

Thereafter, the results of the current study indicate that the highest total response found in this work, using either economic weights or empirical weights was found when longevity information was included in both the breeding index and in the breeding goal (scenario A-2). To be able to use the A-2 scenario, it is necessary to collect longevity information from the female population and integrate it with the sire information. This process could be long and expensive due to the high costs, and could sometimes be impeded by various practical problems (i.e., impossibility to control the female population, absence or inadequacy of a system to collect longevity information, data analysis etc.). In dairy cattle, where the animals are tied and milked daily, an A-2 scenario is feasible. For most beef cattle breeds when collecting longevity data is not possible scenario A-1 could be a good alternative.

Ethical considerations

In this work, ethical “profit” was not included, but we already know that ethical issues play an important role in the whole market economy (Vukasinovic et al., 2001). There is growing concern about the well-being and welfare of cows, not only amongst the farmers but in particular amongst the consumers. Therefore, breeding for longevity is considered more ethical because selection is aimed at the improvement of health and fitness of the animals and not only production (Vollema, 1998; Vukasinovic, 1999; Vukasinovic et al., 2001). In Chianina, an increase in longevity from a general ethical point of view may increase consumer acceptance, increase meat market request and have a positive impact on the whole economy. An important future step would be to calculate the correlated response between longevity and health and fitness of the animals to be able to estimate the impact of those “ethical” traits in the EBV.

Conclusions

The results of the current study show that selection for longevity in beef cattle is possible and has a positive impact on profit. We have considered alternative selection schemes for longevity. The alternative selection strategies indicated that by including longevity in the Chianina breeding scheme the total profit is increased. Excluding longevity from the breeding scheme decrease longevity and total profit. Including longevity in both the Chianina breeding index and breeding goal, either using empirical or economic weights in the breeding goal increased longevity by +2.97 and +4.92 d/yr respectively. When collecting information on longevity is not feasible, a scenario where longevity is included only in the breeding goal is a good alternative. Beef breeding organizations should consider the opportunity to include longevity in a future breeding scheme to increase profit and the well-being and welfare of the cows.

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Appendix 1

Derivation of EmW from EmW^i.

Trait	σ^2_P	σ^2_A	r_{IH}	$\sigma^2_{EBV} = \sigma^2_A * r_{IH}^2$	σ_I	$^{(2)}$ EmW$^i_{BASE}$	$^{(4)}$ EmW$_{BASE}$	$^{(3)}$ EmW$^i_{A-1,A-2}$	$^{(5)}$ EmW$_{A-1,A-2}$
ADG1, g	$(165.0)^2$	10,346	0.55	3,130.00	10	0.15	0.026	0.10	0.018
ADG2, g	$(191.0)^2$	11,674	0.55	3,531.00	10	0.35	0.059	0.35	0.059
MU, score$^{(1)}$	$(52.9)^2$	1,035	0.55	313.00	10	0.50	0.278	0.50	0.278
L, d	$(854.0)^2$	80,224	0.10	802.24	10	-	-	0.05	0.018

Where $\sigma^2_A = \sigma^2_p * h^2$ and σ^2_A=additive variance for each trait, r_{IH} = accuracy of the indexes, σ_I= standard deviation of the standardize EBV;

$^{(1)}$ Score = σ_P *100;

$^{(2)}$ EmW^i for Base scenario;

(3) EmW^i for A-1 and A-2 scenarios;

(4) $EmW_{BASE} = [1 / (\surd \sigma^2_A * r_{IH}^2)] * EmW^i_{BASE} * \sigma_I$;

(5) $EmW_{A-1,A-2} = [1 / (\surd \sigma^2_A * r_{IH}^2)] * EmW^i_{A-1,A-2} * \sigma_I$;

Appendix 2

EcW used in the different scenarios.

Trait	€*animal*y	Source
ADG1, g/d	0.10	Forabosco (1)
ADG2, g/d	0.20	Albera et al., 2004
MU, % of score	1.02	Forabosco (2)
L, d	0.20	Forabosco et al., not published yet

(1) Was calculated considering the revenue generated during 18 months of the bull's life. Two lengths of life (periods) were considered: period A (with ADG1 from birth to 6 mo) and period B (with ADG2 from 6 mo to 18 mo). Assuming that inside each period the ADG is constant; for 1g increase in weight a total of 180 g was obtained in period A and 360 g in period B. As a derivative of period B (0.20 g/d) period A was equal to half of period B (0.10 g/d).

(2) MU was calculated as [(57.01*9)/5]*0.01. Where: 9 were the classes from the linear score evaluation system from the Anaborapi linear evaluation system (Albera et al., 2004) and 5 the classes from the linear score evaluation system from Anabic. Albera et al., (2004) found for the MU a value of 57.01 €/score expressed per cow per year. Similar CV was found between Anaborapi and Anabic. The score was expressed in % .

Appendix 3

Correlation (ρ) between breeding goals (H) using empirical (H_{em}) and economical ($H_{€}$) weights. Where : $\sigma^2_{H€}$, σ^2_{Hem} = variance of the H_{em} , $H_{€}$; C= matrix of genetic variances for traits ADG1, ADG2, MU and L; $\delta_{€}$, δ_{em} = economical and empirical weights for traits ADG1, ADG2, MU and L.

Cov ($H_{€}$, H_{em}) = $\delta_{€}{}' C \delta_{em}$

$\sigma^2_{H€} = \delta_{€}{}' C \delta_{€}$ and $\sigma^2_{Hem} = \delta_{em}{}' C \delta_{em}$

$$\rho = \frac{Cov(H_{€}, H_{em})}{\sqrt{\sigma^2_{H€} * \sigma^2_{H\,em}}}$$

Where:

$$\delta'_{€} = \begin{vmatrix} 0.1 & 0.2 & 1.02 & 0.2 \end{vmatrix}$$

$$\delta_{em} = \begin{vmatrix} 0.10 \\ 0.35 \\ 0.50 \\ 0.05 \end{vmatrix}$$

$$C = \begin{vmatrix} 1.00 & 0.62 & 0.74 & 0.34 \\ 0.62 & 1.00 & 0.64 & -0.20 \\ 0.74 & 0.64 & 1.00 & 0.20 \\ 0.34 & -0.20 & 0.20 & 1.00 \end{vmatrix}$$

Resulting in:

$\sigma^2_{H€} = 1.6465$; $\sigma^2_{Hem} = 0.7328$; Cov ($H_{€}$, H_{em}) = 1.0618;

$\rho = 0.97$

Chapter 7

General Discussion

Brief introduction

In beef cattle, longevity is an important trait because it affects cow profitability. Longevity has been the central theme in this thesis. In summary, the results in this thesis show that information on type traits, collected when the animals are young, can be used as an early predictor of longevity (Chapter 3) and profitability (Chapter 5). Muscularity traits have the largest impact on profit and the final score is the best single early predictor of profitability in Chianina cattle (Chapter 5).

Estimating the breeding values for longevity is an important step in a genetic selection program. In Chapter 4 we showed that the survival analysis (non-linear model) is appropriate to analyse longevity in Chianina cattle, because it uses all the information available from both alive and dead cows (censored and uncensored cows).

Breeding companies world-wide have been very successful in increasing meat production (i.e., mainly growth), but they can also contribute to an increase in the longevity of beef cows by including this trait in their breeding programs (Chapter 6). Including longevity in the breeding goal and in the breeding index, using either economic or empirical weights, increases the total selection response (Chapter 6).

The general discussion focuses on the current situation with respect to longevity in Chianina cattle and on aspects associated with the implementation of breeding for longevity in this breed such as breeding goal definition, breeding value estimation, data recording and strategies for breeding organizations.

Longevity in Chianina: the current situation

Chianina is a breed well-known in Italy for its somatic gigantism, rapid growth, ease of calving and high meat quality. It is one of five breeds controlled by ANABIC (ANABIC, 2001) and it is second in number of animals registered in the National Herd Book, preceded only by the Marchigiana breed. Chianina is one of the breeds that didn’t suffer from the BSE crises. On the contrary, it increased its market share and the price of meat increased. Thereafter, with the approval of Regulation EC 2081/92, the EU granted Protected Geographical Identification (PGI) to the Chianina breed. PGI is one of the systems adopted by the EU to recognize and protect agro-food products from the various areas of the European Union destined for human consumption. The system (PGI) indicates the origin, the rearing system, the feeding system, and traces the path followed by each and every head, from its birth to the shelves of the butcher shop to the consumer. Thanks to this system, Chianina (and its meat) is more prominent today than in the past. Despite the rapid increase in the number of animals and in the market price, the average herd size is relatively small (33 heads per herd) and the farming economy relies partly on EU support.

Data on longevity in Chianina cattle have been collected at a provincial level in Italy since 1965. A regular flow of data from the provinces to the national database has been implemented. Longevity data (i.e., ages at birth, at first insemination, at first calving, at culling etc.) are integrated with productive and reproductive information in the national database. All this information is available for research and is used for various national purposes, such as services for farmers and for breeding organizations. However, longevity has not yet been included in any genetic evaluation nor in breeding schemes. This is probably due to the fact that, in the past, selection in beef cattle focused mainly on production (such as daily gain, body weight and food conversion) and only in recent years has the attention shifted to functional traits (such as longevity).

The estimated baseline survival function and the baseline hazard function for the Chianina breed are shown in Figure 1. The mean LPL in Chianina cows was 1,829 days, which corresponds to an average of approximately 5 yrs after first calving (Chapter 3).

Longevity in beef cattle is a relatively new topic and except for a limited number of publications in this field, there is little information on the actual situation regarding longevity in most beef breeds world wide. In the future, a better recording of beef breeds must be implemented in order to enable proper monitoring of the situation.

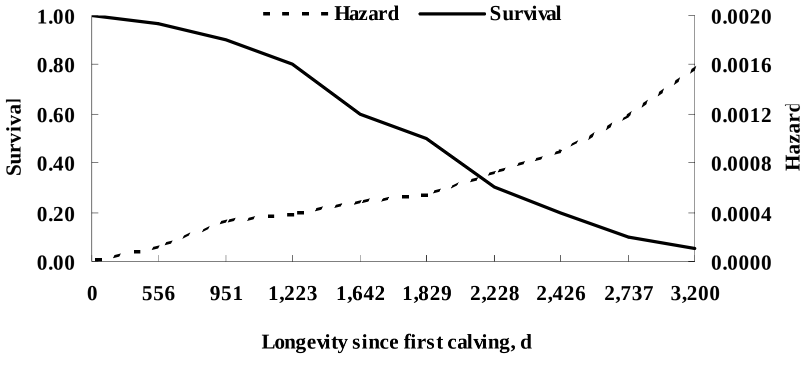

Figure 1. Baseline survival and baseline hazard function.

All Chianina cows in the National Herd Book are evaluated for type traits between 15 to 30 mo, and this information is used to calculate the Cow Selection Index (CSI). The CSI (Forabosco, 2002, 2003a, 2003b) is a breeding index that includes morphological information from different type traits (muscularity, dimension and legs) and productive information (from the Bull Selection Index). According to the CSI, only the cows with a positive index become bull dams, and they (the bull dams) have an impact on the genetic progress of the population. Thereafter, the indexes and type traits information were used by ANABIC to develop mating programs to help the farmer to find the best bull for the cows in the herd. Muscularity is an important predictor trait for longevity (Chapter 3) and because muscularity is incorporated into the BSI (50% of the total index), this affects the bulls' longevity in a positive manner (Chapter 6).

How to implement longevity in beef cattle breeding

To implement longevity in beef breeding schemes, breeding organizations have to make four major decisions. These major decisions are not independent from each other, as each decision will influence the others. These decisions are:

1) To include longevity in the breeding goal and decide on its weight

2) To estimate breeding values for longevity

3) To record the relevant data

4) Strategy and optimization of the breeding program

1) To include longevity in the breeding goal and decide on its weight

Longevity corrected for production (i.e., number of calves born) is called functional longevity and uncorrected longevity is also known as true longevity. Longevity in a breeding goal can be included as true or functional longevity. Does the breeding goal change if we use a different definition of longevity? To be able to illustrate this point in a simple manner, a genetic correction using only two traits, production (P) and true longevity (TL) is presented and discussed.

The breeding goal including true longevity (H_{TL}) is expressed as a weighted sum of the breeding values (A_P and A_{TL}) for the two traits (P and TL) and their respective economic weights (V_P, V_{TL}),

$$H_{TL} = V_P * A_P + V_{TL} * A_{TL}$$

Functional longevity (FL) is defined as:

$$FL = TL - b_{TL,P} * P$$

where the regression coefficient ($b_{TL,P}$) is :

$$b_{TL,P} = \frac{\mathrm{Cov}\ (P, TL)}{\sigma_P^2}$$

and A_{FL} is the part of the longevity that is genetically independent of production

$$A_{FL} = A_{TL} - \frac{\mathrm{Cov}\ (A_{TL}, A_P)}{\sigma^2_{AP}} * A_P$$

Where :
H_{TL} = breeding goal for true longevity; FL = functional longevity; TL = true longevity; V_P = economic weight for P (production); A_P = breeding value for P; V_{TL} = economic weight for TL; A_L = breeding value for TL; $b_{TL,P}$ = regression coefficient of TL for P; σ_P^2 = variance of P; A_{FL} = breeding value for FL;

The breeding goal of functional longevity (H_{TL}) is expressed as a weighted sum of the breeding values (A_P and A_{TL}) for the two traits (P and FL) and their respective economic weights (V_P, V_{FL}).

$$H_{FL} = f_P * A_P + f_{FL} * A_{FL}$$

By substituting A_{FL} we can express H_{FL} in terms of P and TL, which leads to a modification of economic weights (V_P and V_{TL}).

$H_{FL} = f_P * A_P + f_{FL} * (A_{TL} - b_{TL,P} * A_P)$

$H_{FL} = (f_P – f_{FL} * b_{TL,P}) * A_P + f_{FL} * A_{TL}$

$V_P = f_P – f_{FL} * b_{TL,P}$ [1]

$V_{TL} = f_{FL}$ [2]

Where :
H_{FL} = breeding goal for functional longevity; f_P = economic weight for P (production); A_P = breeding value for P; f_L = economic weight for TL; A_{TL} = breeding value for TL; $b_{TL,P}$ = regression coefficient of TL for P; σ_P^2 = variance of P; A_{FL} = breeding value for FL;

From this demonstration we can conclude that the breeding goals for true and functional longevity (H_{TL}, H_{FL}) are equivalent when the appropriate economic weights are used (Equation [1] and [2]). What is going to change are the economic values V_P ,V_{TL}, f_P and f_{FL}. In Chapter 5 of this thesis, economic weights for functional longevity were derived from a profit function. The derivation of economic weights for functional longevity (Chapter 5) was possible because longevity was corrected by the production (i.e., number of calves born) and it was included in the profit equation.

In Chapter 5 two different approaches were used to define the Chianina profit functions and the derivation of economic weights: the normative and the positive approach. In the normative approach profit is described by return and cost functions, all of which are subject to the same scaling factors such as, for example, the same number of animals in the herd, the same market conditions and a similar management system. Results from a positive approach were also calculated with a multiple regression model for both profit functions, the profit per cow per year (P) and per cow (Pc). The regression coefficients, derived from the regression analysis using the positive approach, were in agreement with the results obtained in the normative approach (Chapter 5). The differences in the values obtained for LPL could have resulted from censoring in the real data. However, the effect was relatively small. An increasing number of censored animals (i.e., because mainly young cows are used) could have a biased effect on the average profit and a negative impact on the derivation of the economic value. In this case, careful consideration of the use of economic factors should be made and a positive approach would probably be a good alternative. If the number of censored animals is not relevant, the use of a normative or a positive approach to estimate the economic factors is indifferent.

The economic value of functional longevity depends on the production circumstances, on the market and the criteria used for the economic evaluation (Kahi et al., 1998). In the future more information related to important traits such as muscularity must be provided as the lack of this information has limited our work. Another important source of information is the market price of the animals, which should be recorded on an individual basis and included in future calculations of the profit function (Amer et al., 1997; Perez-Cabal and Alenda, 2002 and 2003).

A way to look at profit using type traits as an early predictor of profitability is presented in Chapter 5. From the results of this study it was found that profit was positively correlated with early predictors of profitability such as muscularity traits. Muscularity seems to have an important impact on profit and the final score is considered the best single early predictor of profitability in Chianina beef cattle.

Raising Chianina is economically more profitable today (Chapter 5) than in the past thanks to a good market for meat and a high meat price that puts this breed at the top of the meat quality list. But, profitability remains an important target for breeders and increased longevity will substantially facilitate the achievement of this target.

2) To estimate breeding values for longevity

In Chapter 4, survival analysis was found to be better adapted to analyzing continuous data than a linear model because it can give an estimation of survival for each day during the entire productive life of the Chianina cow and not only at some specific points as given by the linear model (Sölkner and Ducrocq, 1999). Meuwissen et al., 2002 found that linear and non-linear models give similar results and this is possibly due to the fact that the linear model mimics the survival analysis. Using the survival analysis (Chapter 4) the accuracy of EBV for sires is high compared to a linear model but the accuracy of the BV is still low if it is compared to traits that have a high heritability (i.e., weight). In this case, particularly for the young bulls, one solution is to publish the index of longevity only when a certain accuracy of the index is reached or when the bulls have a certain number of uncensored daughters and sisters. In this way the bull indexes are more stable and this fact affects breeders and organizations positively. The disadvantage of survival analysis is the very demanding computation that drastically increases when an animal model is used for a single trait model (multiple trait analyses are not supported). In the future it will be desirable to have a multiple trait evaluation where correlated and uncorrelated traits can also be included (i.g., type traits). Beef breeding organizations should use the survival analysis to analyze survival data.

3) To record the relevant data

As indicated before, longevity itself is easily recorded, but a long time is required before the information is available. It may be more useful to use an index of type traits that are measured early in life as a predictor of longevity. Type traits, especially muscularity and dimension, can be used as a reasonably informative “measurement” of cow longevity (Chapter 3). In the Chianina breed, both kinds of information are available, and the best choice would be the use of the type traits that are collected when the cows are young. Two limitations are related to the use of early predictors of longevity: the first is that the collection of information on type traits began only two decades ago, while longevity information has been collected for almost fifty years, and second, survival analysis is not yet able to support multiple trait analysis. For this reason the best choice would be to use longevity information until a multiple trait survival analysis is available to support multiple traits (i.e., type traits).

An important step in a correct longevity analysis is an accurate recording of the culling reasons. Not only must the date of culling be collected, but also the reasons for culling. From experience with dairy cattle, culling reasons are grouped into two categories: involuntary and voluntary. Voluntary culling refers to culling for productivity, whereas involuntary culling refers to culling for health or reproduction problems. Longevity corrected for voluntary culling is called “functional longevity”, whereas actual observed longevity is called “true longevity” (Ducrocq et al., 1988). The reason for distinguishing between voluntary and involuntary culling is that the selection for true longevity is largely equivalent to selection for productivity (at least in dairy cattle) and does not necessarily lead to genetic improvement in the ability to withstand involuntary culling (Dekkers, 1993).

This distinction between voluntary and involuntary culling is particularly difficult in beef cattle as pointed out by Beaudeau et al. (1999) and this is manly due to a lack of information. To reduce the gap between beef and dairy cattle, it is fundamental that we are able to collect the information related to the reasons for culling in the future. Setting up a system that collects this type of information together with productive and reproductive information is vital for a better understanding of longevity in beef cattle. To do that, all the organizations involved in collecting, analysing and using the data must be made aware of the importance of this delicate step. A precise and correct data collection is an important step that will positively affect breeders, organizations and commercial companies.

4) Strategy and optimization of the breeding program

For a better profit function the market price of individual animals must be included in the profit equations. In the future, productive, reproductive, culling reasons and the market price of the animals should be collected as soon as possible and made available for genetic analysis. Another important issue is the type traits that can be use as early predictors of longevity. For this reason the Chianina breeding organization should be able to continue to collect type traits information from all the cows registered at the National Herd Book. In Chapter 6, predictions of genetic change were performed by using the program SelAction (Rutten et al., 2002). Three different scenarios were compared and economic and empirical weights were used (Gibson, 1989). The results indicated that the highest total economic response found in this work, using either economic weights or empirical weights was found when information about the longevity trait was included in both the breeding index and the breeding goal (scenario A-2). Both empirical and economic weights can be used, but the best results were obtained when economic weights were employed. Last but not least, an important issue to consider is the communication of the bulls' longevity to the breeder. Another important aspect that must be taken into account is the bulls' rank fluctuation. This is due to the low accuracy of the index, especially when the bulls have not yet been proven. To reduce this problem, sire longevity must be published only when the sires accuracy is above a minimum value. Because the time needed to get a precise breeding value could be long, one way to optimize the breeding program is to collect and store an adequate amount of semen from all bulls. When BV for longevity is below a minimum value cows must not be used for reproduction and they certainly may not become bull dams.

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Summary

This thesis focuses on genetic improvement of longevity in Chianina beef cattle. Increasing longevity increases production (i.e. number of calves alive), reduces the costs (rearing, feeding, health, reproduction and housing) and increases the total farm profit. For those reasons, longevity can be considered an important trait in beef cattle.

Chapter 2 consists of a study on Chianina longevity, where the phenotypic and genetic background of longevity was investigated using survival analyses. In this Chapter, the population structure was analyzed, showing high use of natural service sires and a relatively low number of sires that are used in multiple herds. The sire variance was 0.0224 and the effective heritability was 8.7%.

Chapter 3 investigates the phenotypic relationship between type traits and longevity in Chianina beef cattle, and the relationship between production traits and longevity. Results indicate that the highest effect on longevity is due to the herd-year effect, followed by production traits, variation in herd size, age at first calving and finally type traits. Muscularity is the most important morphological trait for the breeder. Cows with good muscularity are more likely to avoid voluntary culling than cows with poor muscularity. Among the dimension traits, stature had the largest effect on longevity. Wide hips and wide pins decrease the probability of culling. Cows that have one calf per year are more profitable for the breeder and remain longer in the herd than cows producing fewer calves. The majority of voluntary culling occurs between the first and second calving and cows with problems at that stage, even if it are small problems, are often culled by the breeder, who prefers to retain the older cows that have already proven themselves.

The distinction between voluntary and involuntary culling in Chianina cattle is difficult, mainly due to a lack of information on culling reasons. Except for emergency culling for acute health disorders (such as severe locomotive disorders, metritis, abortion, dystocia, or even death), all other culling decisions are technically decided and planned by the farmer.

Chapter 4 compares estimated breeding values (EBVs) for longevity in Chianina beef cows estimated with either linear or non-linear sire models. The non-linear analyses used a survival model. Separate datasets were created that considered all data (SURVall) or only uncensored (SURVun) records. Two linear models were used to analyze longevity measured as dichotomous (yes/no) measurements of survival in the first three parities (LIN-S3) and an overall measurement of lifespan in months (LIN-LPL). For SURVall, the effective heritability was slightly higher (11.2%) compared to the SURVun (9.3%), probably due to the inclusion of additional information from censored cows (old cows). Moreover, for the same reason, reliability for the sires BV for SURVall was 0.28±0.16, higher than for the

SURVun (0.24±0.15). Sire solutions expressed as a relative culling rate for the SURVun ranged between 0.14 and 3.97, with a mean of 1.25±1.07. For SURVall, results were similar with a relative culling rate ranging between 0.07 and 3.88, with a mean of 1.21±0.99. A low value indicates a relatively low risk of culling. Heritability for longevity in first, second and third parities from the linear sire model (LIN-S3) ranged between 2.5% and 5.3%. Reliabilities for the sires BV for LIN-S3 was 0.23±0.14 for first parity, 0.20±0.11 for second parity and 0.23±0.08 for third parity. For the linear sire LIN-LPL with the same dataset as was used for the SURVun, heritability was equal to 7.7%, which was the highest estimate obtained by the various linear models. Correlations between EBVs' from the survival analysis and the linear model, corrected for the genetic trend, were moderate to high, ranging between 0.50 to 0.93.

Chapter 5 shows two different approaches for defining profit functions and deriving economic weights; a normative and a positive approach. In the normative approach a profit function is derived in which profit is described by return (sold male calves, sold female calves and sold cows) and cost (feed costs such as concentrate, silage, forage vitamins, minerals, etc. and non-feed costs such as housing, machines, land, interest, taxes etc.) functions. In the positive approach economic values of traits were calculated using multiple regression for profit function expressed as €/cow per year of LPL (P) and as lifetime profit (Pc) in €/cow. Economic values were obtained as regression coefficients of profit on length of productive life, age at first insemination and number of calves born per cow per year using a multiple regression model. Those regression coefficients measure the relative contributions of each trait for phenotypic profit, either per year (P) or per lifetime (Pc). The regression coefficients obtained from the positive approach, were in concordance with the results of the normative approach.

In the normative approach the average profit for a cow was 196 €/cow per year of LPL and was obtained as the difference between return (1,375 €/cow per year of LPL) and cost (1,179 €/cow per year of LPL). The total lifetime phenotypic profit per cow (Pc) was 1,175 €/cow and average length of productive life (LPL) was equal to 5.97 years. The average number of calves born per year (NACY) was equal to 0.78. Number of calves born per year and LPL were the most important economic traits in Chianina beef cattle. Phenotypic profit per cow (Pc) had one of the highest heritabilities (0.29). The genetic correlation between Pc and LPL (0.51) was the highest found among the traits evaluated. Profit was positively correlated with early predictors of profitability like muscularity traits. The genetic correlation between muscularity and profitability ranged from 0.15 to 0.37. Genetic correlations were lower but positive between profit and the dimensional traits (between 0 and 0.27).

Chapter 6 evaluates alternative selection strategies for longevity using deterministic simulation. Three different breeding schemes were compared based on the selection responses. Both economic and empirical weights were used to evaluate the responses. Empirical weights are the weights currently used in Italy. Results indicate that the highest total response, using either economic or empirical weights, was found when information on longevity was included both in the breeding index and in the breeding goal. To be able to model this scenario, it is necessary to collect longevity information on the female population and integrate it with the sire information. This process could be long and expensive. When collecting longevity data is not possible, a scenario where longevity is included in the breeding goal but it is not recorded nor used in the selection index could be a good alternative. In conclusion, including longevity in the Chianina breeding scheme, using either empirical or economic weights increased total economic response. Therefore, it is important that breeding companies include longevity in their breeding goal, which requires limited effort and investment.

Sommario

Obiettivo della presente tesi è lo studio della longevità nella razza Chianina. L'incremento della longevità porta ad un aumento della produzione (numero di vitelli vivi), una riduzione dei costi (allevamento, alimentazione, sanitari, riproduttivi e gestionali) ed una crescita del profitto aziendale. Per tutte queste ragioni la longevità deve essere considerata un importante carattere per le razze da carne.

Nel *Capitolo 2* viene presentato il primo studio sulla longevità condotto sulla razza Chianina. Grazie all'uso della Survival Analysis viene analizzato il comportamento fenotipico e genetico della longevità. In questo capitolo la struttura della popolazione è stata analizzata ed è emerso l'uso in popolazione di un alto numero di tori abilitati alla fecondazione naturale ed un uso limitato di tori che operano in più allevamenti (tori di connessione). La varianza toro è risultata pari a 0.0224 mentre l'ereditabilità effettiva è dell' 8.7%.

Nel *Capitolo 3* sono state studiate le relazioni fenotipiche tra caratteri morfologici, produttivi e di longevità nella razza Chianina. I risultati indicano che l'effetto azienda-anno è quello che incide maggiormente sulla longevità delle vacche, seguito dai caratteri produttivi, dalla variazione delle dimensioni aziendali, dall'età al primo parto e dai caratteri morfologici. Per l'allevatore la muscolosità è risultata essere il più importante carattere morfologico. Vacche con buona muscolosità hanno una minore probabilità d'essere riformate rispetto a vacche poco muscolose. Tra i caratteri dimensionali la statura ha il maggior effetto sulla longevità. Vacche che partoriscono un vitello all'anno sono economicamente più convenienti per l'allevatore e rimangono mediamente di più in allevamento rispetto a vacche che partoriscono di più o di meno. La maggior parte delle riforme volontarie avvengono tra il primo ed il secondo parto. Se la vacca giovane ha dei problemi in questo periodo, anche di poco conto, viene eliminata, poiché l'allevatore preferisce vacche più vecchie ma di provata affidabilità. La distinzione tra riforma volontaria ed involontaria nella razza Chianina è di difficile determinazione e ciò è principalmente legato ad una carenza di informazioni relative alle causa di riforma. Eccezion fatta per le riforma di "emergenza" causata da acuti problemi sanitari (es. problemi di locomozione, metriti, aborti, distocia o perfino morte), tutte le altre decisioni di riformare o di tenere la vacca in allevamento sono prese e pianificate dall'allevatore.

Nel *Capitolo 4* vengono confrontati i valori genetici (EBVs) della longevità per la razza Chianina stimati con modelli toro lineari e non lineari. L'analisi non lineare è stata condotta utilizzando un modello di sopravvivenza. Separati set di dati sono stati creati dove tutte le informazioni disponibili (SURVall) o solo quelle con animali a carriera chiusa (SURVun) sono stati analizzati. Due modelli lineari sono stati usati per analizzare la longevità; un

modello che considera la sopravvivenza misurata come presenza/assenza (si/no) nei primi tre parti (LIN-S3) ed un secondo modello dove la longevità media è stata misurata in mesi (LIN-LPL). L'ereditabilità effettiva calcolata con il modello non lineare SURVall è stata leggermente superiore (11.2%) a SURVun (9.3%) e ciò è probabilmente da attribuirsi all'inclusioni di informazioni addizionali quali appunto quelle derivate da animali a carriera aperta. Inoltre, per lo stesso motivo, l'attendibilità dei BV dei tori per SURVall è stata di 0.28±0.16, superiore a quella ottenuta da SURVun (0.24±0.15). Il rischio di riforma dei tori per il modello SURVun è variato da 0.14 a 3.97, con una media di 1.25±1.07. Per SURVall i risultati sono simili ai precedenti con un rischio di riforma tra 0.07 e 3.88 ed una media di 1.21±0.99. L'ereditabilità del carattere longevità in primo, secondo e terzo parto per il modello lineare (LIN-S3) è variata passando da 2.5% a 5.3%. L'attendibilità dei BV dei tori è stata di 0.23±0.14 per il primo parto, 0.20±0.11 per il secondo parto e 0.23±0.08 per il terzo parto. Per il modello lineare toro (LIN-LPL), con lo stesso set di dati utilizzati per il modello SURVun, l'ereditabilità è stata di 7.7%, la più alta riscontrata tra i modelli lineari. Correlazioni da moderate ad alte (da 0.50 a 0.93) sono state ottenute tra EBV di modelli lineari e non lineari corretti per il trend genetico.

Nel *Capitolo 5* vengono presentate le funzioni di profitto e la derivazione dei pesi economici attraverso due differenti approcci; normativo e positivo. Nell'approccio normativo la funzione di profitto è descritta come differenza tra ricavi (vendita di vitelli, vitelle e vacche a fine carriera), costi alimentari (concentrati, silo mais, foraggi, vitamine, minerali etc.) e costi non alimentari (carburanti, tasse, spese varie, ammortamento del capitale terra, macchine, ricoveri, etc.). Nell'approccio positivo i valori economici sono stati calcolati come regressioni multiple sulle funzione di profitto ed espresse in €/vacca per anno di LPL (P) ed €/vacca (Pc). I valori economici sono quindi stati ottenuti come coefficienti di regressione del profitto sulla lunghezza della carriera produttiva, sull'età alla prima inseminazione, sul numero medio di vitelli nati vivi per vacca per anno, ed è stato utilizzato un modello a regressione multipla. I coefficienti di regressione esprimono il contributo relativo di ciascun carattere in funzione del profitto e sono espressi in anni (P) o in carriera produttiva (Pc). I coefficienti di regressione ottenuti con l'approccio positivo sono risultati simili a quelli ottenuti con l'approccio normativo.

Nell'approccio normativo il profitto medio per vacca è risultato pari a 196 €/vacca per anno di LPL ed è stato ottenuto come differenza tra ricavi (1375 €/vacca per anno di LPL) e costi (1179 €/vacca per anno di LPL). Il profitto fenotipico medio (Pc) calcolato su tutta la carriera produttiva della vacca è stato di 1175 €/vacca e la lunghezza media della carriera produttiva è risultata pari a 5.97 anni. Il numero medio di vitelli nati per vacca per anno (NACY) è di 0.78. NACY e LPL sono risultati essere i caratteri economicamente più importanti nella razza Chianina. Il profitto fenotipico per vacca (Pc) ha mostrato uno dei più alti valori di ereditabilità (0.29). La correlazione genetica tra Pc e LPL (0.51) è risultata la più altra tra i caratteri presi in considerazione. Le correlazioni genetiche tra muscolosità e profitto (Pc) oscillano da 0.15 a 0.37 mentre quelle tra i caratteri dimensionali ed il profitto (da 0 a 0.27) hanno mostrato valori più bassi.

Nel *Capitolo 6* vengono presentate e discusse diverse strategie selettive per la longevità attraverso una simulazione di tipo deterministico. Tre differenti schemi selettivi sono stati messi a confronto sulla base delle rispettive risposte selettive. Sono stati utilizzati sia pesi empirici che pesi economici. I pesi empirici sono quelli correntemente utilizzati in Italia. La massima risposta selettiva, usando sia i pesi economici che quelli empirici, è stata ottenuta quando le informazioni sulla longevità sono state incluse sia nell'indice genetico che nell'obiettivo di selezione. Per modellizzare questo scenario è necessario raccogliere le informazioni sulla longevità femminile ed integrarle con le informazioni dei riproduttori. Questo processo può risultare lungo e costoso. Se non fosse possibile raccogliere questo tipo di informazioni, lo scenario dove la longevità è inclusa nell'obiettivo di selezione ma non nell'indice genetico può essere una buona alternativa. Concludendo possiamo dire che se la longevità viene inclusa nello schema selettivo per la razza Chianina, utilizzando i pesi empirici o quelli economici, abbiamo un incremento della risposta economica totale. E' inoltre importante che le organizzazioni che si occupano di selezione includano la longevità tra gli obiettivi di selezione. Così facendo con un minimo sforzo ed un basso investimento è possibile incrementare il profitto dell'allevatore.

Samenvatting

Dit proefschrift richt zich op de erfelijke verbetering van levensduur in Chianina vleesvee. Verbetering van de levensduur in vleesvee verhoogt de opbrengsten, zoals het aantal kalveren geboren per koe, en verlaagt de kosten voor bijvoorbeeld voeding en huisvesting. Verbetering van levensduur draagt daarmee bij een de bedrijfswinst, waardoor levensduur een belangrijk kenmerk is in de vleesveefokkerij.

Hoofdstuk 2 beschrijft de fenotypische en genetische achtergrond van levensduur in Chianina, gebruikmakend van de zogenaamde "suvival analyse" methode. Resultaten in dit hoofdstuk tonen aan dat er relatief veel gebruik wordt gemaakt van natuurlijke paring en dat slechts een klein aantal stieren dochters heeft op meerdere bedrijven. De stiervariantie in levensduur bedroeg 0,0224, en de geschatte erfelijkheidsgraad van levensduur was 8,7%.

Hoofdstuk 3 beschrijft de fenotypische relatie van levensduur met exterieur- en productiekenmerken. Levensduur werd het sterkst beinvloed door het bedrijf-jaar effect, gevolgd door het wel of niet afkalven, variatie in bedrijfsomvang, leeftijd bij eerste keer afkalven en exterieurkenmerken. Binnen de exterieurkenmerken hadden bespieringskenmerken de meeste invloed op levensduur. Koeien met goede bespiering worden minder snel afgevoerd dan koeien met matige bespiering. Daarnaast had hoogtemaat invloed op levensduur. Grote koeien met brede kruizen bleken minder snel te worden afgevoerd. Koeien die ieder jaar een kalf geven leveren een hogere bijdrage aan de bedrijfswinst, en worden minder snel afgevoerd dan koeien die minder kalveren produceren. Het grootste deel van de vrijwillige afvoer treedt op tussen eerste en tweede afkalven. Koeien die in deze periode problemen vertonen worden vaak afgevoerd omdat boeren bij voorkeur oudere koeien aanhouden die zichzelf al bewezen hebben.

Het is moeilijk om een onderscheid te maken tussen gedwongen afvoer en vrijwillige afvoer in Chianina, metname omdat er geen informatie over afvoerredenen beschikbaar is. Met uitzondering van afvoer ten gevolge van acute gezondheidsproblemen, zoals abortus, geboorteproblemen, of ernstige beenproblemen, zijn afvoerbeslissingen een combinatie van vrijwillige en gedwongen afvoer die door de boer van tevoren gepland wordt.

Hoofdstuk 4 maakt een vergelijking tussen fokwaardes voor levensduur geschat met een lineair stier-model of met een zogenaamd "survival stier-model". Hiertoe werden twee datasets gemaakt. De eerste dataset bevatte levensduurgegeven van alle dieren, ook van koeien waarvan de levensduur nog niet bekend was. De tweede dataset bevatte alleen gegevens aan koeien met bekende levensduur. In de lineaire analyse werd levensduur als 0/1 kenmerk in de eerste drie lactaties geanalyseerd, en tevens werd totale levensduur geanalyseerd. De geschatte erfelijkheidsgraad voor totale levensduur, geanalyseerd met het survivalmodel, was iets hoger in de dataset met alle koeien (11,2%) dan in de set van koeien met bekende levensduur (9,3%). De betrouwbaarheid van de geschatte fokwaarden van stieren was ook iets hoger wanneer de set met alle koeien werd gebruikt (0,28 ± 0,16 versus 0,24 ± 0,15). In de dataset met alle koeien varieerden de geschatte fokwaardes voor stieren, uitgedrukt als de kans op afvoer, van 0,14 tot 3,97, met een gemiddelde van 1,25 ± 1,07. In de set van koeien met bekende levensduur varieerden de geschatte fokwaardes voor stieren van 0,07 tot 3,88, met een gemiddelde van 1,21 ± 0,99. (Een lage fokwaarde betekent een kleine kans op afvoer, dus een hogere verwachtte levensduur). Erfelijkheidsgraden voor levensduur in de eerste, tweede en derde pariteit, geschat met het lineaire model, lagen tussen de 2,5 en 5,3%. Bijbehorende betrouwbaarheden voor de fokwaardes van stieren bedroegen 0,23±0,14 voor de eerste lactatie, 0,20±0,11 voor de tweede lactatie, en 0,23±0,08 voor de derde lactatie. De erfelijkheidsgraad van totale levensduur, geschat met het lineaire model op de dataset van koeien met bekende levensduur, bedroeg 7,7%. Dit was de hoogste waarde gevonden met het lineaire model. Correlaties tussen geschatte fokwaardes van het lineaire en het survivalmodel varieerden tussen de 0,53 en 0,93.

Hoofdstuk 5 vergelijkt twee methoden voor het bepalen van zogenaamde “profit fuctions” en de daarvan afgeleide economische waarden van kenmerken. De eerste methode, een zogenaamde normatieve methode, beschrijft winst als een wiskundige functie van inkomsten (verkochte kalveren) en kosten (kosten voor voer, huisvesting en kapitaal). Economische waardes worden vervolgens bepaald als de partiële eerste afgeleide van profit naar de onderliggende kenmerken. De tweede methode, een zogenaamde positieve methode, berekent economische waardes gebruik makend van multiple regressie van winst op de onderliggende kenmerken. De economische waarden van levensduur, leeftijd bij eerste afkalven, en van het aantal kalveren geboren per jaar zijn gelijk aan de regressiecoëfficienten van winst op die kenmerken. De economische waarden verkregen met de normatieve en positieve methoden kwamen goed met elkaar overeen.

In de normatieve methode bedroeg de winst 196 Euro per koe per jaar. Deze winst was het verschil tussen 1.375 Euro aan opbrengsten en 1.179 Euro aan kosten per koe per jaar. De gemiddelde levensduur bedroeg 5,97 jaar, en de totale winst over het gehele leven van een koe bedroeg 1.175 Euro per koe. Gemiddeld werden er 0,78 kalveren per koe per jaar geboren. Het aantal geboren kalveren, per jaar dan wel in het gehele leven, was economisch het meest belangrijke kenmerk in Chianina. Winst per koe had een hoge erfelijkheidsgraad van 0,29. De genetische correlatie tussen winst en levensduur bedroeg 0,51 en was een van de hoogste gevonden waardes voor de genetische correlaties. Voorspellende kenmerken, zoals bespiering, hadden een positieve correlatie met levensduur. De genetische correlatie tussen bespieringskenmerken en winst varieerde van 0,15 tot 0,37. Genetische correlaties tussen skeletmaten en winst varieerden van nul tot 0,27.

Hoofdstuk 6 vergelijkt drie alternatieve fokprogramma's voor het verbeteren van levensduur. Bij de beoordeling van de fokprogramma's is gebruik gemaakt van zowel de economische waarden uit hoofdstuk 5, als van de empirische waardes die op dit moment in Italie worden gehanteerd. De hoogste selectierespons werd gevonden als levensduur zowel in het fokdoel als in de selectie-index werd opgenomen. Om dit scenario in de praktijk te kunnen uitvoeren is het nodig dat levensduur aan de koeien wordt gemeten, en dat deze informatie wordt geintegreerd met de gegevens aan stieren. Dat is niet eenvoudig in de huidige omstandigheden. Als dit niet mogelijk is, is het een goed alternatief om levensduur op te nemen in het fokdoel zonder het kenmerk als zodanig te meten. Het opnemen van levensduur in het Chianina fokprogramma verhoogt de totale selectierespons, zowel bij gebruikmaking van economische als empirische waardes. Het is daarom van belang dat fokkerij-organisaties overgaan tot het opnemen van levensduur in hun fokdoel. Dit vereist slechts een beperkte inspanning en investering.

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Abbreviation Key

ADG1	Average daily gain pre-performance
ADG2	Average daily gain during the performance
AI	Artificial insemination
BSI	Bull selection index
C	Cost per cow per year
Cc	Cost per cow
CSI	Cow selection index
EBV	Estimated breeding value
EcW	Economic weight
EmW	Empirical weight
FI	Age at the insemination that resulted in the birth of the first calf
FS	Final score
H	Aggregate genotype
I	Index
L	Longevity
LIN-LPL	Linear model for the overall measurement of lifespan
LIN-S3	Linear model measurements of survival in the first three parities
LPL	Length of productive life
MU	Muscularity
NACY	Number of calves born alive per year
NS	Natural insemination
P	Profit per cow per year
Pc	Profit per cow
R	Revenue per cow per year
Rc	Revenue per cow
RR	Risk ratio
SURVall	Survival model with all records
SURVun	Survival model with only uncensored records
UBSI	Units of bull selection index

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Curriculum Vitae

Flavio Forabosco, was born on January 24th, 1970 in Gemona del Friuli, Italy. He attended a scientific secondary education and in 1996 he completed his Degree in Tropical and Subtropical Agricultural Science with distinction. During and after his studies, he travelled, worked and studied in Brasil, the USA and various countries within Europe. After graduating he worked as an officer in the Italian army. At the end of 1999 he was awarded a fellowship to study abroad. He joined the Animal Breeding and Genetic Group at the Wageningen University and he studied there for 10 months under the supervision of Prof. Johan Van Arendonk. After he left university he was employed by the National Association of Italian Beef Cattle Breeders (ANABIC) in Perugia to work in the Breeding Evaluation Office. He is now a recognised Chianina national breed expert and since 2001 he has been an advisor to two technical magazines and one scientific journal in the field. He combined his activities at ANABIC with his PhD studies. In 2001 he joined the Animal Breeding and Genetic Group at Wageningen University. The subject of his research work was “Breeding for longevity in Italian Chianina cattle”. During his PhD he spent several months each year at the University of Wageningen under the supervision of Prof. Johan Van Arendonk and Dr. ir. P. Bijma. He completed his PhD in 4 years.

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