Genetic selection strategies to improve longevity in Chianina beef cattle

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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 +2.97 d/yr 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.

RIASSUNTO

STRATEGIE GENETICHE DI SELEZIONE PER MIGLIORARE LA LONGEVITÀ NELLA RAZZA CHIANINA

La longevità nelle razze da carne è un carattere di importanza economica. Includere questo carattere all' interno di uno schema di selezione incrementa il profitto ed ha un impatto positivo sulla salute ed il benessere degli animali. Obiettivo del presente studio è stato quello di valutare l'effetto di strategie selettive alternative in cui la longevità è stata inserita in schemi selettivi diversi attraverso una simulazione di tipo deterministico. Sono stati messi a confronto diversi schemi in cui sono stati utilizzati sia pesi economici (EcW) che pesi empirici (EmW) e sono state valutate le risposte. I pesi empirici di accrescimento medio giornaliero (ADG) e muscolosità (MU) sono identici perché i due caratteri hanno per gli allevatori la stessa importanza, mentre i pesi economici sono stati derivati da equazioni di profitto. I caratteri utilizzati nei scenari di Base sono stati: incremento medio giornaliero pre-perfomance (ADG1), incremento medio giornaliero durante il performance (ADG2), e la muscolosità (MU); la longevità (L) è stata inclusa negli scenari alternativi. Quando le informazioni sulla longevità sono state incluse sia nell'indice che nell'obiettivo di selezione (scenario A-2) la risposta totale per la longevità usando sia gli EmW che gli EcW è stata rispettivamente di +2,97 e +4,92 giorni/anno. La rispo-

sta economica totale per lo scenario A-2 utilizzando EmW e EcW è stata rispettivamente di 3,020 €/anno e 3,342 €/anno, inoltre, la risposta totale in unità di BSI è stata di +0,699 e +0,678. Quando la longevità non è stata inclusa ne nell'indice ne nell'obiettivo di selezione (scenario Base), la risposta economica è stata la più bassa. I risultati ottenuti da questo studio indicano che la maggiore risposta totale, usando sia i pesi empirici che quelli economici, è stata ottenuta quando le informazioni sulla longevità sono state incluse sia nell'indice che nell'obiettivo di selezione (scenario A-2).

Parole chiave: *Chianina, Programma di selezione, Profitto, Longevità, Obiettivi selettivi.*

Introduction

In livestock production, including beef cattle, longevity is an important trait that affects profitability. Several studies (Jagannatha, 1998; Larroque and Ducrocq, 2001; Forabosco *et al.*, 2004a) have shown that this moderately heritable trait plays a considerable role in the farm economy by increasing the profit realised per cow. In addition, increased longevity enables a greater response in genetic selection for other traits, because fewer animals have to be replaced involuntarily, 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 Holstein cows is a trait well studied and already incorporated into many national selection indexes (Vollema et al., 2000; Powell and Van Raden, 2003; Miglior, 2004). 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). The same author found 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.*, 2004a; 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.

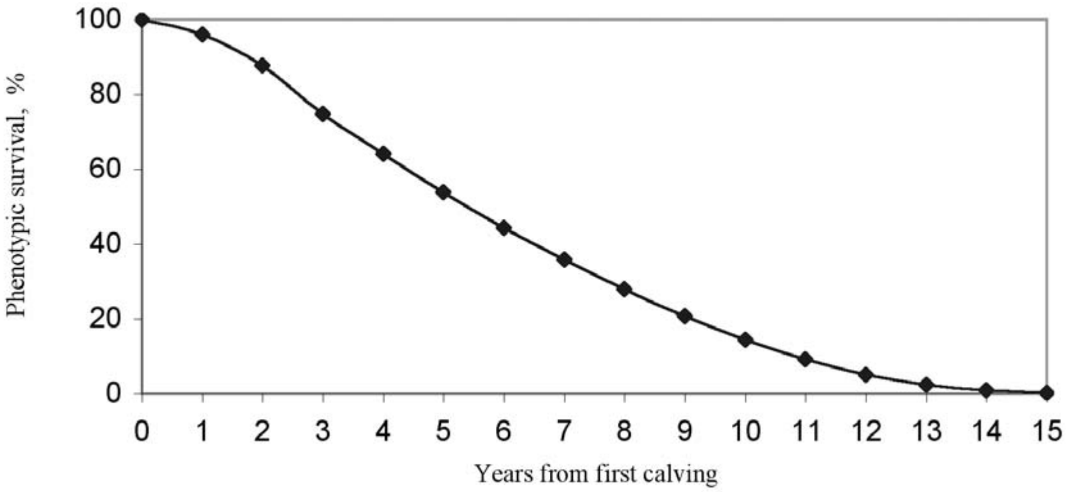
Material and methods

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.* (2004a) 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, a cow' s poor milk production, diseases, parturition problems and feet and leg disorders (Forabosco *et al.*, 2004a).

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 and 30 months 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

Figure 1. Survival curve of Chianina cows.



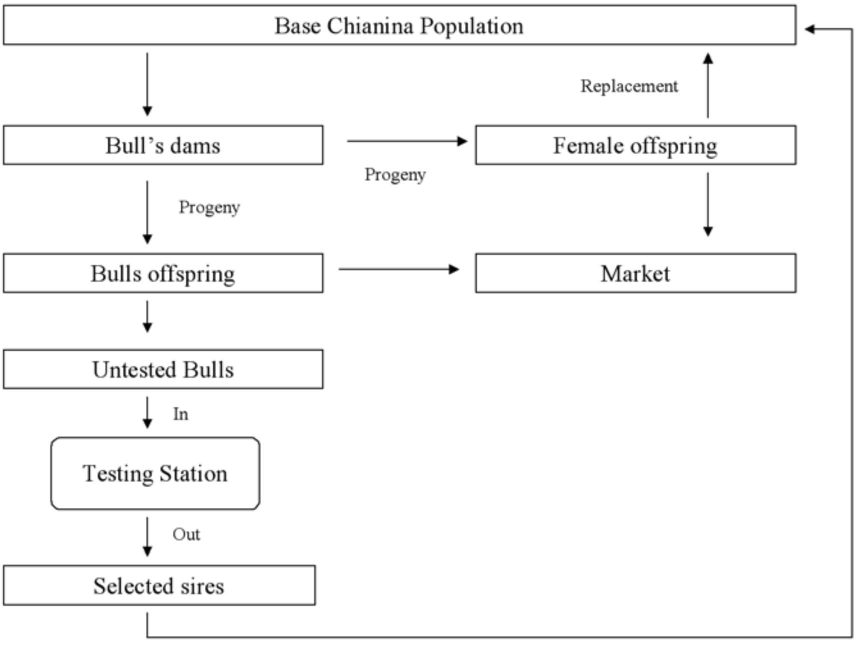
above 82. Selection of cows for replacement is mainly linked to the farmer' s decisions. Whether or not to select the cows for replacement or fattening depends not only on individual factors (age at first calving, calving intervals, number of inseminations to get pregnant, abortions etc.), but also on 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 months. 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-month test period begins. During the test period, the animals are weighed, measured and assessed morphologically. During that period, the bulls are weighed every 21 d, 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 months old and they are used as AI or NS sires. The 30% of 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 summarised 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

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



year to be the bull dams of the 60 males tested for growth and muscularity at the testing station. In the initial situation, 36 males per year (60% 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. 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 standardised 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 standardised 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 (Albera *et al.* , 2004; Forabosco *et al.*, 2004a). The EmW and EcW that were used in the present simulation study are presented in Table 1. The EcW used for ADG1 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 months) and period B (with ADG2 from 6 months to 18 months). 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).

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.

Due to an absence of EcW for MU trait for the Chianina breed, EcW for MU was derived from the Piemontese breed. The EcW used for 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 and 57.01 €/score expressed per cow per year the value for the MU found by Albera *et al.*, (2004). Score was expressed in percentage.

Selection strategies

The genetic and phenotypic parameters used in the simulations were based on previous

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

Scheme	Empirical weights (EmW) [1,2]				Economical weights (EcW)[2], €/y			
	ADG1	ADG2	MU	L	ADG1 g/d	ADG2 g/d	MU %	L d
Base	0.15 (0.026)	0.35 (0.059)	0.50 (0.278)	-	0.10	0.20	1.02	-
A-1	0.10 (0.018)	0.35 (0.059)	0.50 (0.278)	0.05 (0.018)	0.10	0.20	1.02	0.20
A-2	0.10 (0.018)	0.35 (0.059)	0.50 (0.278)	0.05 (0.018)	0.10	0.20	1.02	0.20
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 standardisation of the EBV to a standard deviation (σ=10);*
[2] *In the square 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*

research (Contiero *et al.*, 1997; Forabosco *et al.*, 2004a, 2004b) 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 actual 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.

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. The longevity data of the cows is recorded and simulated with the program (the 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.

Results

Empirical weights: Base and alternative scenarios

Table 3 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. However, 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) when compared with the dams (0.18). This 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 3), 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 longevi-

Table 2. Genetic and phenotypic parameters used in the simulation study. Genetic correlation above, phenotypic correlation below and heritabilities on the diagonal.

Trait	σ^2_P	ADG1	ADG2	MU	L
ADG1	27,225	0.38[1]	0.62[1]	0.74[1]	0.34[3]
ADG2	36,481	0.18[1]	0.32[1]	0.64[1]	-0.20[3]
MU	2798	0.36[1]	0.43[1]	0.37[1]	0.20[3]
L	729,316	-0.31[3]	0.07[3]	-0.21[3]	0.11[2]

σ^2_P = Phenotypic variance

[1] *Contiero et al., 1997.*

[2] *Forabosco et al., 2004a.*

[3] *Experimental data supplied by Forabosco.*

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

Scheme	Response for ADG1 g/d			Response for ADG2 g/d			Response for MU 1% score			Response for L d			Total response, in BSI units/yr (empirical)[1]	Total response, in €/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* $EcW_{€, ADG1}$ (0.10) + ADG2* $EcW_{€, ADG2}$ (0.20) + MU* $EcW_{€, MU}$ (1.02)+ L* $EcW_{€, L}$ (0.20) , expressed in €/yr.*

ty 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 was +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 4 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). 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 093 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. The difference in L between scenario *A-2* (29.5%) and *A-1* (6.8%) was due to the fact that in *A-2* longevity was included both in the breeding index and in the breeding goal while in *A-1* L was only included in the breeding goal.

Discussion

In beef cattle, longevity is not yet incorporated into any national selection index, as is already done in many countries for dairy cattle (Vollema *et al.*, 2000; Miglior, 2004). 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

Table 4. The effect of alternative scenarios on trait response for ADG1, ADG2, MU and L for the economic weights (EcW), expressed in trait units

Scheme	Econ. response for ADG1 g/d			Econ. response for ADG2 g/d			Econ. response for MU 1% score			Econ. response for L d			Total response, in BSI units/yr (empirical)[1]	Total response, in €/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 in 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.*

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 2).

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. In the future, type traits such as stature, size, feet and legs may be included in *A-1* and *A-2* scenarios and used as early predictors of longevity.

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 cattle, 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 decreases 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.

REFERENCES

Albera, A., Carnier, P., Groen, A.F., 2004. Definition of a breeding goal for the Piemontese breed: economic and biological values and their sensitivity to production circumstances. Livest. Prod. Sci. 89:67-

78.
ANABIC, 2001. The Chianina Breed. Taurus 1 (Suppl. 1): 4-45.
Bulmer, M.G., 1971. The effect of selection on genetic variability. Am. Nat. 105:201-211.
Contiero, B., Mantovani, R., Cassandro, M., Gallo, L., Bittante, G., 1997. Parametri genetici dell'accrescimento, della muscolosità e di alcune misure somatiche rilevati su torelli di razza Marchigiana, Chianina e Romagnola in performance test. Taurus 6: 17-28.
Filippini, F., 1996. New genetic indexes for the performance-tested bulls. Taurus International. 3:6-10.
Forabosco, F., Bozzi, R., Filippini, F., Franci, O., Groen, A.F., 2002. Preliminary study on longevity in Chianina beef cattle. Proc. 7th World Cong. Genet. Appl. Livest. Prod., Montpellier, France CD-ROM Comm. N. 2-66.
Forabosco, F., Groen, A.F., Bozzi, R., Van Arendonk, J.A.M., Filippini, F., Boettcher, P., Bijma P., 2004a. Phenotypic relationships between longevity, type traits and production in Chianina beef cattle. J. Anim. Sci. 82:1572-1580.
Forabosco, F., Bozzi, R., Filippini, F., Boettcher, P., Van Arendonk, J.A.M., Bijma, P., 2004b. Linear model vs survival analysis for genetic evaluation of sires in Chianina beef cattle breed. Livest. Prod. Sci. (In press).
Jagannatha, S., Keown J.F., Van Vleck, L.D., 1998. Estimation of relative economic value for herd life of dairy cattle from profit equations. J. Dairy Sci. 81:1702-1708.
Larroque, H., Ducrocq, V., 2001. Relationship between type and longevity in the Holstein breed. Genet. Select Evol. 33:39-59.
Meuwissen, T.H.E., 1991. Reduction of selection differentials in finite populations with a nested full-half sib family structure. Biometrics 47:195-203.
Miglior, F., 2004. Overview of different breeding objective in various countries. pp 7-11, Session 4, in Proc. 11th World Holstein-Frisian Federation Meet., Guelph, Ontario, Canada.
Powell, R.L., Vanraden, P.M., 2003. Correlation of longevity evaluation with other trait evaluations from 14 countries. In Proc. Interbull technical workshop, Beltsville, MD, USA. Interbull bulletin 30: 5-19.
Rogers, P.L., Gaskins, C.T., Johnson, K.A., Macneil, M.D., 2004. Evaluating longevity of composite beef females using survival analysis techniques. J. Anim. Sci. 82:860-866.
Rutten, M.J.M., Bijma, P., Wolliams, J.A., Van Arendonk, J.A., 2002. SelAction: Software to predict selection response and rate of inbreeding in livestock breeding programs. J. Hered. 93:456-458.
Villanueva, B., Wray, N.R., Thompson, R., 1993. Prediction of asymptotic rates of response from selection on multiple traits using univariate and multivariate best linear unbiased prediction. Anim. Prod. 57:1-13.
Vollema, A. R., 1998. Selection for longevity in dairy cattle. Ph.D. Degree, Wageningen Agriculture University, The Netherlands.
Vollema, A.R., Van der Beek, S., Harbers, A.G.F., de Jong, G., 2000. Genetic evaluation for longevity of Dutch dairy bulls. J. Dairy Sci. 83:2629-2639.
Vukasinovic, N., 1999. Application of survival analysis in breeding for longevity. Proc. 4th Int. Workshop on Genetic Improvement on functional traits in cattle, Jouy-en-Josas, France. Interbull bulletin N. 21, pp 3-10.
Vukasinovic, N., Moll, J., Casanova, L., 2001. Implementation of a routine genetic evaluation for longevity based on survival analysis techniques in dairy cattle populations in Switzerland. J. Dairy Sci. 84:2073-2080.
Wray, N.R., Hill, W.G., 1989. Asymptotic rates of response from the index selection. Anim. Prod. 49: 217-227.

Appendix 1. Derivation of EmW from EmWi.

Trait	σ^2_P	σ^2_A	r_{IH}	σ^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	3130.00	10	0.15	0.026	0.10	0.018
ADG2, g	$(191.0)^2$	11,674	0.55	3531.00	10	0.35	0.059	0.35	0.059
MU, score(1)	$(52.9)^2$	1035	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 standardised EBV; EmW = empirical weight before derivation; EmW^i = empirical weight after derivation; ADG1= average daily gain pre-performance; ADG2=average daily gain during the performance; MU = muscle development; L = longevity.

(1) *Score = σ_P *100;*

(2) *EmW^i for Base scenario;*

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

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

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

Appendix 2. 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=covariance.

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

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

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

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; σ^2_{Hem} = 0.7328; Cov ($H_€$, H_{em}) = 1.0618;

ρ = 0.97