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Estimates of genetic parameters for calving interval, body condition score, production and linear type traits in Italian Brown Swiss cattle.

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ABSTRACT

This study aimed to estimate genetic parameters for body condition score (BCS), calving interval (CI), linear type traits and milk yield (MY), using data of Italian Brown dairy cattle. A total of 32,359 records of first parity lactating cows collected from 2002 to 2004 in 4,885 Italian herds , were considered. The pedigree file included 96,661 animals. A multiple traits animal model REML analysis was performed in order to estimate (co)variance components without repeated observations (Groeneveld, 1998). The heritability of BCS (15%) was similar to that of MY. It ranged from 7 to 32% for linear type traits and was very low (5%) for CI. The genetic correlation between CI and MY was high and positive (56%), the one between CI and BCS was negative (-35%) and that between CI and most of type traits was positive, namely for angularity (0.46), body depth (0.41) and thurl width (0.43). Correlations of similar magnitude were found for udder traits. Due to the estimated correlations, the selection for MY and type exerts an unfavourable effect on reproduction ability of cows. To counterbalance this negative effect and to allow early prediction of bulls breeding values for fertility, inclusion of BCS in the breeding program is advisable. BCS and type traits information may also be used for animals that are either culled during the first lactation or that have not the opportunity of a further calving.

INTRODUCTION

The considerable genetic improvement of milk yield traits has reduced reproductive efficiency of dairy cattle (Grosshans et al., 1997; Dematawewa and Berger, 1998; Castillo-Juarez et al., 2000) and has increased the susceptibility to some diseases and the risk of culling due to health disorders or other abnormalities (Simianer et al., 1991; Dematawewa and Berger, 1998). Thus, functional traits as fertility should be included in the breeding goals, but the chance of using direct measures of reproduction efficiency for breeding is currently limited by a number of issues. Calving interval (CI) is traditionally the main fertility indicator during the productive life of an animal, particularly in dairy cattle (Rege and Famula, 1993). In comparison with other fertility traits such as days from calving to first service, days open, or non-return rate, it is easily and accurately recordable as the time between two subsequent calvings. However, CI might not be the most desirable direct measure of reproductive efficiency to be included in a breeding programme. First of all, CI is available only for the most fertile cows that calve for two or more times and not for the culled ones; it is not an early measure of fertility and, for this, it is not an adequate selection tool for breeding organizations which select bulls on the basis of the earliest information recorded on their female offspring. As a consequence, search of traits which exhibit genetic correlations with CI exploitable in selection is of interest. Studies on genetic relationships among body condition score (BCS), fertility, production and type traits in dairy cattle are quite scarce, particularly for Brown Swiss cattle.

In Italy, some research programs (the MTP project for Holstein Friesian cattle and the Superbrown project for Brown Swiss cattle) carried out at the Department of Animal Science of the University of Padova with the aim of including functional traits in breeding programs for dairy cattle and to increase economic efficiency through a reduction of producing costs (Cassandro et al., 1999; Dal Zotto et al., 2002) provided data on BCS and health related traits (e.g. mastitis, oedema, milk fever and lameness) on a large scale.

The objective of this study was to estimate genetic parameters for BCS, calving interval, linear type traits and milk yield traits for Brown Swiss cattle using officially recorded data collected in Italy.

MATERIALS AND METHODS

Data

Body condition score was recorded routinely by the National Association of Italian Brown Swiss cattle (ANARB) since September 2002 as an integration of the linear type classification scheme.

Eighteen linear type traits, including BCS, were recorded during the first lactation on herdbook registered animals. Type traits were recorded using a linear scoring system ranging from 1 to 50, whereas BCS was scored on a five-points scale with 0.25-unit increments according to Edmonson et al. (1989). Body condition scoring involved tactile and visual appraisal of the amount of fat tissue covering the lumbar region of the vertebrae and around the tail head (Gallo et al., 2001). CI was defined as the time in days between the first and the second calving. CI values lower than 200 d or greater than 800 d were not considered. Only records with a test day between 30 and 360 d of lactation were used.

The final database included information collected since September 2002 to June 2004. A total of 32,359 records on linear type traits, BCS, productive traits and somatic cell score (SCS) of first parity cows reared in 4,885 Italian herds were analysed. The pedigree file included 96,661 animals.

Estimation of Genetic Parameters

Multivariate Restricted maximum likelihood (REML) was used to estimate genetic parameters. (Co)variance components were obtained using the VCE package (Groeneveld, 1998).
The linear mixed models used to estimate (co)variance components were:

$$P_{ijkl} = \mu + HYM_i + age_j + dCF_k + a_l + e_{ijkl}$$

$$T_{ijkl} = \mu + HYM_i + age_j + dCT_k + off_l + a_m + e_{ijklm}$$

where P was a measure on CI, milk, fat or protein yield or SCS; T was a measure on BCS or a linear type trait; μ = intercept; HYM = herd-year-month of calving (4780 herds, 4 years and 12 months levels); age = age at calving (4 levels); off = type classifier (37 levels); dCF = days in milk at the milk test day; dCT = days in milk at linear type and BCS scoring; a = additive genetic effect of animal; e=random residual error term.

In addition, milk yield was included (9 levels) in the model for BCS and the time between the last milking and the linear type traits scoring was considered in the model for udder traits. Because of large memory requirements, the analysis was performed using a series of four-traits models that always included CI and BCS.

Predicted Transmitting Ability Estimation and Response to Selection

Breeding values for BCS, CI, production and linear type traits were estimated using PEST (Groeneveld, 1998) and the estimated (co)variance components obtained in the REML analysis.
All estimated breeding values (EBV) were standardized using mean and standard deviation of EBV of cows born in 2000 and then rescaled to a 100 mean and 10 standard deviation.
Responses to selection were calculated using selection index theory (Smith, 1936; Hazel, 1943). It was assumed that selection of breeding candidated was based on information derived by 1 lactation with a progeny test of 200 or 50 daughters per sire of bull (SB) or sire of cow (SC), respectively, and 2 records per dam of bull (DB) and dam of cow (DC), except for CI where it was assumed 1 records for DB and CD pathsways. Assumed selected fractions (i) were: top 1% for SB and DB, 5% for SB and no selection on SC. Generation intervals (N) were 8 yr for SB and 5 years of the other three selection pathways, except for CI where it was assumed a longer large increment of N (+0.77

year). Responses and correlated responses to selection were initially calculated using only single trait selection indexes. Later, responses and correlated responses to selection were also computed using different relative importance for milk yield and BCS in the index. These two traits were considered together for investigating indirect response exhibited by CI. The genetic response (Rg), after 10 years of selection, was estimated as:

$$Rg = i\, b'G / \sqrt{(b'Pb)}$$

where b is the vector of the index weights, G is an m x n matrix of genetic covariances among the m index observations and the n traits in the aggregate genotype and P is an m x m matrix of phenotypic covariances among the observations in the selection index.

RESULTS AND DISCUSSION

Descriptive statistics for traits considered in this study are presented in Table 1. Average test day milk yield and fat and protein contents were 22.3 kg/d, 3.89 and 3.43%, respectively. Average CI an was close to 420 d indicating an undesirable fertility condition in Italian Brown Swiss cattle. All these values are in agreement with those reported by Dal Zotto et al. (2002). As known, milk production level is negatively related with fertility and BCS (Pryce et al., 2000; Gallo et al., 2001). Dairy cows use a quota of body reserves (from 3 to 10%) as a source of energy to sustain production and this is mostly evident in the early 150 days after calving. Scored BCS during lactation was on average 3.20 with values ranging between 1.75 and 5 and a variation coefficient greater than 10%.

Additive genetic variance and heritability estimates are reported in Table 2. BCS exhibited a moderate heritability (15%) which was similar to that of test day milk yield (14%) whereas CI showed a very low h^2 (5%). For linear type traits heritability estimates ranged from 8% to 32%.

Estimated genetic correlations between all traits and BCS or CI are in Table 2.

As expected, genetic correlations between milk, fat or protein yield and CI were high and positive (from 0.53 to 0.56), indicating that top producing cows have longer CI. Selection to enhance milk yield has led to a greater dependence on body tissue mobilization to support milk production in early lactation, as intake is not sufficient to sustain lactation in this period (Veerkamp, 1998). Dairy cows with a high genetic merit are more predisposed to body tissue mobilization and reproductive performances are more sensitive to changes in BCS (Pryce et al, 2001).

A negative energy balance and an excess of body tissue mobilization are associated to a higher incidence of metabolic disorders and poor fertility (Veerkamp, 2000). Cows which are genetically disposed to have a higher BCS at calving exhibit limited changes in BCS in early lactation in comparison with genetically thin animal (Dechow et al., 2002). Conversely, cows with genetically low BCS may not maintain sufficient energy levels to activate ovarian function or display estrous.

Genetic correlation of CI with body depth, thurl width and angularity were moderate (from 0.41 to 0.46), indicating that deeper, thurler and more angular cows have longer CI.

Udder attach type traits (fore udder attach, rear udder height and width) showed a positive and moderate genetic correlation with CI (from 0.26 to 0.50) indicating that cows with a good morphological udder have longer CI.

The genetic correlations of BCS with the traits previously mentioned were of opposite sign but of the same magnitude of those for CI. Genetically, thinner cows have longer CI (-0.35) and are more productive (-0.40) than cows with higher BCS. A noticeable genetic correlation has been estimated between BCS and angularity (-0.87). Lighter cows are expected to be in a greater negative energy balance because of the contribution of BCS to live weight (Price et al., 2000) and cows classified as 'dairy' have a higher incidence of reproductive disorders. The positive genetic correlation between linear type traits and CI might be attributed to more opportunities to conceive given to cows with better morphological characteristics.

As fertility is difficult to measure and exhibits low heritability, BCS might be useful as an indirect trait for improving fertility in dairy cattle.

In a national dataset, where BCS was recorded once in first parity cows, the relationship between CI and BCS was greatest when BCS scoring was performed in early lactation (Price et al., 2000).

BCS recorded once in early lactation is more markedly related to reproductive performance than the change in BCS from week in milk 1 to week in milk 10. Moreover, BCS is easy to measure and can be used both for management and for breeding purposes as an indirect selection criterion for fertility. Results from this study show that it is possible to improve CI by exploiting favourable genetic relationships with some type traits (e.g. angularity) and BCS, which measures are available for in early lactation and also for cows culled before the second calving.

Table 3 shows average estimated breeding values for investigated traits in cows grouped on the basis of their calving interval EBV. Cows with shorter CI (EBV < 90) evidenced a higher value of BCS and lower values of production traits than the other two CI EBV groups. These results are in agreement with studies by Price et al. (2000; 2001). With respect to size type traits, there were not consistent differences among the three CI EBV groups with the exception of angularity and thurl width. Cows with the highest CI EBV showed higher average EBV (113) for angularity than the other groups. For udder traits EBV, noticeable differences were found for different CI EBV groups. Cows with favourable EBV values for CI showed the lowest EBV values for fore udder attach and rear udder height but EBV for udder depth and teat length were on average.

Results reported in Table 4 evidence that, because of the negative genetic correlation between MY and CI or BCS, when selection is only for CI or BCS, the correlated response in MY is unfavourable. The selection for BCS implies a negative correlated response in CI that means a reduction of CI.

When the goal was the increase of MY, an increment of about 5 kg/d of milk, of 25 d in CI and a decrease of 0.13 points in BCS were obtained in ten years of selection. When direct (CI) and indirect (BCS) selection for fertility was considered, results were different. Particularly, selection for only CI leaded to the best response for fertility but to the worst for milk yield traits. When selection considered only BCS, response was favourable but smaller than when selecting directly for CI. Moreover, because of the tight and negative genetic correlation between BCS and angularity (ANG), a loss of 6.63 points in the latter trait was obtained when selecting to increase BCS.

A simulation in which MY and BCS were simultaneously included in the index (Table 5) with variable weights showed that the best weights for not worsening fertility and, at the same time, for not decreasing production was 30% for MY and 70% for BCS.

CONCLUSIONS

Milk yield and linear type traits resulted negatively correlated with fertility of Italian Brown cows. To avoid an excessive loss in reproductive performance it appears useful to include BCS in the breeding program to allow early prediction of bulls breeding values for fertility. BCS and type traits information may be used for animals which do not have for culling or other causes the opportunity of a further calving. Further investigations on other fertility traits other than CI should be conducted to confirm these results and to better define selection indexes to improve fertility of Italian Brown cows.

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Table 1. Descriptive statistics of investigated traits

	Type traits score			
	1	50	Mean	SD
Calving interval (CI), d			421.0	86.0
BCS, points			3.20	0.35
Milk yield, kg/d			22.3	5.60
Fat yield, kg/d			0.86	0.26
Protein yield, kg/d			0.76	0.20
SCS			2.22	2.05
Stature, points	Small	Tall	31.85	8.02
Strength, points	Narrow	Wide	25.75	8.19
Body depth, points	Shallow	Deep	28.90	7.22
Angularity, points	Coarse	Angular	26.78	7.40
Top line, points	Weak	Strong	24.77	4.58
Rump angle, points	High pins	Low pins	25.79	5.36
Thurl width, points	Narrow	Wide	23.37	7.03
Rear leg set, points	Postly	Sickled	26.90	7.07
Hock quality, points	Coarse	Modelled	23.42	8.07
Pastern, points	Weak	Strong	24.61	8.56
Hell height, points	Low	High	23.77	8.50
Fore udder attach, points	Loose	Tight	24.30	8.77
Rear udder height, points	Low	High	24.37	7.09
Rear udder width, points	Narrow	Wide	28.85	10.06
Udder support, points	Broken	Strong	26.06	7.83
Udder depth, points	Shallow	Deep	27.98	7.59
Teat direction, points	Diverge	Converge	25.21	6.37
Teat length, points	Short	Long	26.82	7.47

Table 2. Heritability of traits and genetic correlations with calving interval and BCS[1]

	h^2	Genetic correlation with CI	Genetic correlation with BCS
Calving interval (CI), d	0.05	-	-
BCS, points	0.15	-0.35	-
Milk yield, kg/d	0.14	0.56	-0.40
Fat yield, kg/d	0.09	0.53	-0.31
Protein yield, kg/d	0.13	0.55	-0.22
SCS	0.06	0.19	-0.26
Stature, points	0.32	0.15	-0.18
Strength, points	0.17	0.17	0.22
Body depth, points	0.10	0.41	-0.18
Angularity, points	0.19	0.46	-0.87
Top line, points	0.10	0.06	-0.80
Rump angle, points	0.24	-0.01	0.11
Thurl width, points	0.14	0.43	-0.29
Rear leg set, points	0.14	0.12	-0.39
Hock quality, points	0.08	0.19	-0.73
Pastern, points	0.09	-0.09	0.19
Hell height, points	0.07	0.03	0.35
Fore udder attach, points	0.14	0.42	-0.31
Rear udder height, points	0.17	0.26	-0.58
Rear udder width, points	0.17	0.50	-0.47
Udder support, points	0.13	0.15	-0.27
Udder depth, points	0.23	-0.21	-0.07
Teat direction, points	0.15	0.17	-0.29
Teat length, points	0.32	0.03	0.10

[1]Standard errors of heritability estimates ranged from 0.006 to 0.017; standard errors of correlations estimates ranged from 0.006 to 0.076.

Table 3. Average estimated breeding values (EBV) for investigated traits in cows grouped on the basis of their calving interval EBV.

Trait	Base SD[1]	Calving interval EBV		
		<90 (favourable)	90-110	>110 (unfavourable)
CI	7.90	85	100	115
BCS	0.05	109	98	89
Milk	0.72	89	100	112
Kg fat	0.03	92	99	109
Kg protein	0.02	91	99	109
SCS	0.22	95	102	106
Stature	2.50	96	101	107
Strength	1.66	96	100	105
Body depth	1.57	92	100	111
Angularity	1.53	90	101	113
Top line	0.69	98	101	102
Rump angle	1.21	102	101	97
Thurl width	1.24	91	100	111
Rear leg set	0.89	101	101	104
Hock quality	0.97	96	102	106
Pastern	0.96	102	100	99
Hell height	0.85	100	99	101
Fore udder attach	1.63	89	100	107
Rear udder height	1.77	88	100	111
Rear udder width	1.58	93	101	107
Udder support	1.42	95	100	104
Udder depth	1.85	101	100	97
Teat direction	1.14	93	100	105
Teat length	2.26	102	101	98

[1]Estimated breeding values standard deviation for base cows (cows born in 2000)

Table 4. Direct and correlated response of milk yield (MY), angularity (ANG), BCS and calving interval (CI) to 10-years selection for different single trait breeding goals.

Trait	Goal			
	MY	ANG	BCS	CI
MY, kg/d	4.9	1.84	-1.98	-1.86
ANG, points	2.71	7.88	-6.63	-2.35
BCS, points	-0.13	-0.29	0.32	0.08
CI, d	25.2	21.6	-15.9	-30.5

Table 5. Indirect response on fertility (CI) and correlated response of milk yield (MY), angularity (ANG) and BCS, after 10-years selection based on selection indexes with different relative weights for MY-BCS.

	MY to BCS index weights										
	100÷0	90÷10	80÷20	70÷30	60÷40	50÷50	40÷60	**30÷70**	20÷80	10÷90	0÷100
MY, kg/d	4.90	4.58	4.17	3.61	2.87	1.97	0.99	**0.06**	-0.75	-1.42	-1.98
ANG, points	2.71	1.92	0.97	-0.18	-1.47	-2.80	-3.99	**-4.95**	-5.68	-6.22	-6.63
BCS, points	-0.13	-0.09	-0.04	0.01	0.07	0.14	0.20	**0.24**	0.28	0.30	0.32
CI, d	25.20	22.90	20.00	16.30	11.60	6.10	0.40	**-4.84**	-9.28	-12.90	-15.90