Breeding for improved calving performance in Piemontese cattle - genetic parameters for different parities

Andrea Albera[1], Ab F. Groen[2] and Paolo Carnier[3]

[1]ANABORAPI, Strada Trinità 32/A, 12061 Carrù (CN), Italy.
[2]Department of Animal Breeding, Wageningen Institute of Animal Science, P. O. Box 330, 6700 AH Wageningen, The Netherlands
[3]Department of Animal Science, University of Padova, Agripolis, 35020 Legnaro (PD), Italy.

Abstract

Estimates of heritability and genetic correlations for calving performance in different parities were obtained for the Italian Piemontese population using an animal model. Field data were 34.476 and 23.869 calving records of cows having records of first and second calving and first and third calving. Calving performance were scored in five categories and analysed using a bivariate linear model treating performance over parities as different traits. Genetic parameters were estimated using restricted maximum likelihood procedures and models including direct and maternal genetic effects. Estimates of variance components were heterogeneous over parities. Heritability of direct effect ranged from 0.18 to 0.14 in first parity and was 0.11 in second and third parity. Maternal heritabilities were similar in heifers and second parity cows and considerably lower in third parity cows. All genetic correlations between direct and maternal effects were strongly negative, ranging from -0.68 to -0.49. Genetic correlation between first and second parity was 0.998 for direct effects and 0.913 for maternal effects. When first and third parity calving performance were analysed, genetic correlations were 0.907 and 0.979 for direct and maternal effects. Genetic correlations among parities were very high. Nevertheless, preferential mating of young bulls to mature cows, which is widely used in the population in order to avoid calving problems could have affected these results. However, differences in variance components and heritabilities between heifers and cows were observed, indicating that calving performance in first and later parities should be treated as different traits and genetic evaluations performed accordingly.

1. Introduction

Calving performance is an important trait in beef cattle affecting profitability of herds, animal welfare and acceptability of the production system by the consumer (Jarrige and Beranger, 1992). Biological apects of calving performance are influenced by two components, the first related to the calf and the second to the dam (Philipsson, 1976). The calf component, often identified as direct effect, is mainly dependent on the size of the calf and is referred to as ability to be born easily. The dam component, identified as maternal or indirect effect, tends to depend mostly on the pelvic area dimension, the maternal preparation for calving and is referred to as ability to give birth easily (Meijering, 1984). From the genetic point of view the two effects generally show an antagonistic relationship, which is a complicating factor in the definition of breeding strategies (Dekkers, 1994).

Rates of dystocia are higher in first calving compared to later parities (Meijering, 1986), depending on the relative maturity of heifers at the moment of the calving. Genetic variance and heritability of dystocia tend to be higher in heifers compared to mature cows (Cue *et al.*, 1990; Gregory *et al.*, 1995). Genetic correlation between dystocia in first and other parities generally ranges from medium to high values (Thompson *et. al*, 1981; Cue and Hayes, 1985; Weller *et al*., 1988). Therefore, some authors suggested to consider calving difficulties in first and later parities as different traits and to adjust genetic evaluation accordingly (Cue and Hayes, 1990; Weller *et al*., 1988). In Italy, the Piemontese breed is actively selected for beef production characteristics. After own performance testing, selected young bulls are progeny tested, and for that purpose mated preferentially with mature cows in order to avoid calving problems. In latest years, the incidence of dystocia increased at a slow rate in the population (ANABORAPI, 1997), probably due to the negative genetic correlation of beef production traits with calving performance. Therefore, calving performance should be included in the breeding goal. Carnier *et al.* (1997) provided estimates of genetic parameters for calving performance in Piemontese heifers and second parity cows using an animal model.

The objective of this study was to estimate genetic parameters for calving performance using a bivariate linear model treating performance over parities as different traits both for direct and maternal effects.

2. Material and methods

2.1 Field data

Two datasets of 34,476 records of calving performance of cows having records of first and second calving and 23,869 records of calving performance of cows having records of first and third calving were used for this study. Calving performance in the Piemontese breed were scored by the farmers and records collected by technicians visiting the farms. Five classes were used for scoring: 1 (unassisted delivery), 2 (easy calving), 3 (difficult calving), 4 (Caesarean section), 5 (foetotomy).

The data covered a period of 9 years since 1989, when the present system of scoring calving performance was adopted, till 1997. A calving record consisted of calf and dam identity codes, date of the calving, sex of the calf, birth date and parity of the dam, herd code and calving performance score. Calves were required to have known sire, dam, maternal grandsire and maternal granddam. According to the data set dams were required to have calved in the same herd either in the first and second parity or in the first and third parity. Number of records in the pedigree files were 139,723 and 105,833 respectively for first and second parity and first and third parity data set.

2.2 Model

Variance components were estimated using a restricted maximum likelihood algorithm (REML) (Neumaier and Groeneveld, 1998). The same bivariate animal model was used for both datasets to investigate the relationship between first and later parities calving performance:

$$\begin{vmatrix} \mathbf{y}^h \\ \mathbf{y}^c \end{vmatrix} = \begin{vmatrix} \mathbf{X}^h & 0 \\ 0 & \mathbf{X}^c \end{vmatrix} \begin{vmatrix} \mathbf{b}^h \\ \mathbf{b}^c \end{vmatrix} + \begin{vmatrix} \mathbf{Z}_d^h & 0 & \mathbf{Z}_m^h & 0 \\ 0 & \mathbf{Z}_d^c & 0 & \mathbf{Z}_m^c \end{vmatrix} \begin{vmatrix} \mathbf{u}_d^h \\ \mathbf{u}_d^c \\ \mathbf{u}_m^h \\ \mathbf{u}_m^c \end{vmatrix} + \begin{vmatrix} \mathbf{e}^h \\ \mathbf{e}^c \end{vmatrix}$$

where $\mathbf{y}^h$ ($\mathbf{y}^c$) is a vector of observations on calving performance of heifers (cows), $\mathbf{b}^h$ ($\mathbf{b}^c$) is a vector of fixed effects for heifers (cows), $\mathbf{u}_d^h$ ($\mathbf{u}_d^c$) is an unknown random vector of additive direct genetic effects for heifers (cows), $\mathbf{u}_m^h$ ($\mathbf{u}_m^c$) is an unknown random vector of additive maternal genetic effects for heifers (cows), and $\mathbf{e}^h$ ($\mathbf{e}^c$) is a random vector of residuals for heifers (cows) data, and $\mathbf{X}^h, \mathbf{X}^c, \mathbf{Z}_d^h, \mathbf{Z}_d^c, \mathbf{Z}_m^h$, and $\mathbf{Z}_m^c$ are known matrices. All random effects were assumed to be normally distributed with null means and variance structure:

$$\mathbf{V}\begin{vmatrix} \mathbf{u}_d^h \\ \mathbf{u}_d^c \\ \mathbf{u}_m^h \\ \mathbf{u}_m^c \end{vmatrix} = \begin{vmatrix} \sigma_d^{2(h)} & \sigma_d^{(hc)} & \sigma_{dm}^{(h)} & \sigma_{dm}^{(hc)} \\ \sigma_d^{(hc)} & \sigma_d^{2(c)} & \sigma_{dm}^{(ch)} & \sigma_{dm}^{(c)} \\ \sigma_{dm}^{(h)} & \sigma_{dm}^{(ch)} & \sigma_m^{2(h)} & \sigma_m^{(hc)} \\ \sigma_{dm}^{(hc)} & \sigma_{dm}^{(c)} & \sigma_m^{(hc)} & \sigma_m^{2(c)} \end{vmatrix} \otimes \mathbf{A}$$

$$\mathbf{V}\begin{vmatrix} \mathbf{e}^h \\ \mathbf{e}^c \end{vmatrix} = \begin{vmatrix} \sigma_e^{2(h)} & \sigma_e^{(hc)} \\ \sigma_e^{(hc)} & \sigma_e^{2(c)} \end{vmatrix} \otimes \mathbf{I},$$

where $\sigma_d^{2(h)}$ ($\sigma_d^{2(c)}$) is the additive direct genetic variance for heifers (cows) calving performance, $\sigma_m^{2(h)}$ ($\sigma_m^{2(c)}$) is the additive maternal genetic variance for heifers (cows) , $\sigma_{dm}^{(h)}$ ($\sigma_{dm}^{(c)}$) is the additive genetic covariance between direct and maternal effects in heifers (cows), $\sigma_d^{(hc)}$ is the covariance between heifers and cows additive direct genetic effects, $\sigma_m^{(hc)}$ is the covariance between heifers and cows additive maternal genetic effects, $\sigma_{dm}^{(hc)}$ is the covariance between heifers additive direct and cows additive maternal genetic effects, $\sigma_{dm}^{(ch)}$ is the covariance between cows additive direct and heifers additive maternal genetic effects, $\sigma_e^{2(h)}$ ($\sigma_e^{2(c)}$) is the residual variance for calving performance in heifers (cows), and $\sigma_e^{(hc)}$ is the residual covariance between calving ease records of an animal calving as an heifers and as a cow, **I** is an identity matrix , and $\otimes$ denotes the Kronecker product (Searle, 1982).

Fixed effects included herd, year-season of calving, sex of the calf, age of the dam at the moment of the calving and the interaction between the sex of the calf and the age of the dam.

Due to the small herd size herd effect was kept separated from year-season effect. The age of the dam at calving was treated in classes: 8 classes from 21 to 37 months in heifers, 15 classes from 31 to 67 months in second parity cows and 10 classes from 42 to 84 months in third parity cows were used.

Because different calving for a cow occurred in different years and seasons originating calves that might have differed in sex, models used were unequal with respect to the definition of year-season and sex-age of the dam effects for different parities of the same cow.

Heritability for direct and maternal effects was computed as $h_d^2 = \sigma_d^2/(\sigma_d^2 + \sigma_m^2 + \sigma_{dm} + \sigma_e^2)$, and $h_m^2 = \sigma_m^2/(\sigma_d^2 + \sigma_m^2 + \sigma_{dm} + \sigma_e^2)$, respectively where σ_d^2 is the additive genetic variance for direct effects, σ_m^2 is the additive genetic variance for maternal effects, σ_{dm} is the genetic covariance between direct and maternal effects, and σ_e^2 is the residual variance.

Table 1. **Distribution of calving scores (%) per parity of dam**

Calving score	Dataset 1		Dataset 2	
	First parity	Second parity	First parity	Third parity
1 – Unassisted	12.4	19.9	12.7	21.2
2 – Easy	61.1	63.9	62.6	65.1
3 – Difficult	14.8	10.0	14.2	9.3
4 – Caesarean section	11.3	5.9	10.1	4.1
5 – Foetotomy	0.4	0.3	0.4	0.3

Table 2. **Estimates of genetic and residual (co)variances obtained with bivariate models treating calving performance in different parities as different traits**

Parameter[i]	First and second parity	First and third parity
$\sigma_{d}^{2(h)}$	.1080	.0774
$\sigma_{m}^{2(h)}$	.0738	.0525
$\sigma_{d}^{2(c)}$	.0538	.0468
$\sigma_{m}^{2(c)}$	.0599	.0197
$\sigma_{dm}^{(h)}$	-.0459	-.0311
$\sigma_{dm}^{(c)}$	-.0321	-.0206
$\sigma_{d}^{(hc)}$	.0761	.0546
$\sigma_{m}^{(hc)}$	.0607	.0315
$\sigma_{dm}^{(hc)}$	-.0443	-.0251
$\sigma_{dm}^{(ch)}$	-.0317	-.0254
$\sigma_{e}^{2(h)}$	.4662	.4654
$\sigma_{e}^{2(c)}$	.4120	.3797
$\sigma_{e}^{(hc)}$	.0556	.0255

[i]The term $\sigma_{d}^{2(h)}$ is the direct genetic variance for first parity, $\sigma_{m}^{2(h)}$ is the maternal genetic variance for first parity, $\sigma_{d}^{2(c)}$ is the direct genetic variance for second or third parity, $\sigma_{m}^{2(c)}$ is the maternal genetic variance for second or third parity, $\sigma_{dm}^{(h)}$ is the genetic covariance between direct and maternal effects for first parity, $\sigma_{dm}^{(c)}$ is the genetic covariance between direct and maternal effects for second or third parity, $\sigma_{d}^{(hc)}$ is the genetic covariance between direct effects for first parity and direct effects for second or third parity, $\sigma_{m}^{(hc)}$ is the genetic covariance between maternal effects for first parity and maternal effects for second or third parity, $\sigma_{dm}^{(hc)}$ is the genetic covariance between direct effects for first parity and maternal effects for second or third parity, $\sigma_{dm}^{(ch)}$ is the genetic covariance between direct effects for second or third parity and maternal effects for first parity.
The term $\sigma_{e}^{2(h)}$ is the residual variance for first parity, $\sigma_{e}^{2(c)}$ is the residual variance for first parity, $\sigma_{e}^{(hc)}$ is the residual covariance between first and second or third parity.

Table 3. **Estimates of heritability and genetic correlations (± approximated SE) obtained with bivariate models treating calving performance in different parities as different traits**

Parameter[i]	First and second parity	First and third parity
$h_{d}^{2(h)}$	.179 ± .013	.137 ± .016
$h_{m}^{2(h)}$	.123 ± .012	.093 ± .015
$h_{d}^{2(c)}$	.109 ± .012	.110 ± .015
$h_{m}^{2(c)}$	.121 ± .012	.046 ± .014
$r_{dm}^{(h)}$	-.514 ± .044	-.487 ± .074
$r_{dm}^{(c)}$	-.566 ± .050	-.676 ± .078
$r_{d}^{(hc)}$	.998 ± .000	.907 ± .016
$r_{m}^{(hc)}$	.913 ± .012	.979 ± .007
$r_{dm}^{(hc)}$	-.551 ± .042	-.643 ± .078
$r_{dm}^{(ch)}$	-.503 ± .055	-.511 ± .077
$r_{e}^{(hc)}$	.1269	.0707

[i]The term $h_{d}^{2(h)}$ is the direct heritability for first parity, $h_{m}^{2(h)}$ is the maternal heritability for first parity, $h_{d}^{2(c)}$ is the direct heritability for second or third parity, $h_{m}^{2(c)}$ is the maternal heritability for second or third parity, $r_{dm}^{(h)}$ is the genetic correlation between direct and maternal effects for first parity, $r_{dm}^{(c)}$ is the genetic correlation between direct and maternal effects for second or third parity, $r_{d}^{(hc)}$ is the genetic correlation between direct effects for first parity and direct effects for second or third parity, $r_{m}^{(hc)}$ is the genetic correlation between maternal effects for first parity and maternal effects for second or third parity, $r_{dm}^{(hc)}$ is the genetic correlation between direct effects for first parity and maternal effects for second or third parity, $r_{dm}^{(ch)}$ is the genetic correlation between direct effects for second or third parity and maternal effects for first parity and $r_{e}^{(hc)}$ is the residual correlation between first and second or third parity.

3. Results and discussion

Table 1 shows the distribution of calving scores according parity. Incidence of dystocia (assisted difficult calvings, caesarean sections and foetotomy) was almost two times greater in heifers than in later parities. Occurrence of calving difficulties in third parity cows was slightly reduced compared to second parity cows.

Estimated genetic and residual (co)variances are in Table 2, corresponding heritabilities, genetic and residual correlations are reported in Table 3. In heifers the variance of the direct effect was higher then the variance of maternal effect, as a consequence also heritability was higher. Dystocia showed more genetic variation as a trait of the calf than as a trait of dam. Varona *et al.* (1999) in Gelbvieh and Carnier *et al.* (1997) in Piemontese, using an animal model, obtained a larger variance for direct then for maternal effects. In dairy cattle Thompson *et al*. (1981) and Groen *et al*. (1998) reported higher variances for direct effect compared to maternal effect, while Cue and Hayes (1985) and Cue *et al*. (1990) found variances for the direct effect slightly lower than maternal effect variances in Holstein heifers.

Analysis of calving performance for Piemontese cows yielded variance estimates, which were consistently smaller than those obtained for heifers. Variance and heritability of direct genetic effects exhibited a marked decrease from heifers to second and third parity cows. For third parity females also maternal variance dropped dramatically. Same results were obtained by Carnier *et al.* (1997) in first and second parity Piemontese cows. Gregory *et al.* (1995a, 1995b) reported estimates of direct heritability for calving performance in beef cattle to be higher for calves born from 2-year-old dams than for calves born from older dams. Also most studies dealing with calving ease scores in dairy cattle reported higher estimates of heritability for heifers than for cows.

Estimated heritabilities obtained in the present study were lower than those reported by Trus and Wilton (1988) for five beef breeds, but were higher than the estimates computed by Kemp *et al.* (1988) in Simmental cattle or by McGuirk *et al.* (1998) for some beef breeds used in crossbreeding with Holstein cows.

Estimated genetic covariances between direct and maternal genetic effects were negative both for heifers and cows. As a consequence, all genetic correlations between direct and maternal effects were negative ranging from -0.68 to -0.49, indicating that females born easily tend to have more difficulties in giving birth. Thompson *et al.* (1981) suggested that small calves born with less difficulties may result in small cows with more calving problems than larger dam.

Genetic correlations between direct effects for first and second parity and for first and third parity were 0.998 and 0.907, respectively. Thus, ranking of sires for direct effects on heifer calving performance is expected to be very similar to that based on calving performance of later parities. In literature, estimates of genetic correlations between parities are scarce and limited to sire models. Thompson *et al*. (1981) and Cue and Hayes (1985) investigated the relationship between direct effects for Holstein heifers and cows using a linear sire model and reported a correlation between direct effects of 0.84 and 0.995, respectively. Lower estimates were obtained by Cue (1990) who investigated genetic aspects of calving performance over parities in Ayrshires cattle. Weller *et al*. (1988) reported low correlations between first and later parity sire evaluations for calving ease in Israeli Holsteins either when using a threshold or a linear model analysis.

Genetic relationships between maternal effects over parities were high and correlations ranged from 0.91 for first and second parity to 0.98 for first and third parity. These results suggest that prediction of breeding values for maternal effects using performance of first-parity daughters would provide at an earlier stage the same information provided by daughters at later calving.

However, preferential mating of young bulls to adult females, which is widely practised in the Piemontese population to reduce calving problems, might have affected the estimate of the genetic correlation.

4. Conclusions

Variances and heritabilities found in this study indicate that the introduction of calving ease in the breeding goal of the Piemontese and the selection for this trait are feasible. Genetic correlations between calving performance in different parities were very high but variance components and heritabilities were heterogeneous between heifers and cows. This suggests that subsequent calving should be considered as different traits in the genetic evaluations.

Specific breeding strategies, taking into account negative genetic relationship between direct and maternal effects and involving also beef production traits, need to be studied.

References

ANABORAPI. 1997. Statistiche di Libro Genealogico. Associazione Nazionale Allevatori Bovini di Razza Piemontese, Carru' (CN).

Carnier, P., Dal Zotto, R., Albera, A., Bona, M., 1997. Direct and maternal effects on calving ease in heifers and second parity Piemontese cows. *Proceedings International Workshop on Genetic Improvement of Functional Traits in cattle (GIFT) - Fertility and Reproduction, Grub. INTERBULl bulletin 18: 12-16.*

Cue, R.I., Hayes, J.F, 1985. Correlations of various direct and maternal effects for calving ease. *J. Dairy Sci.* 68:374-381.

Cue, R.I., 1990. Genetic parameter for calving ease in Ayrshires. *Can. J. Anim. Sci.* 70:67-71.

Cue, R.I., Monardes, H.G., Hayes, J.F, 1990. Relationships of calving ease with type traits. *J. Dairy Sci.* 73:3586-3590.

Dekkers, J.C.M., 1994. Optimal breeding strategies for calving ease. *J. Dairy Sci* 77:3441-3453.

Gregory, K.E., Cundiff, L.V., Koch, R.M., 1995a. Genetic and phenotypic (co)variances for production traits of intact male populations of purebred and composite beef cattle. *J. Anim. Sci.* 73:2227-2234.

Gregory, K.E., Cundiff, L.V., Koch, R.M., 1995b. Genetic and phenotypic (co)variance for production traits of female populations of purebred and composite beef cattle. *J. Anim. Sci.* 73:2235-2242.

Groen, A.F., Van Aubel, J.P.J.M., Hulzebosch, A.A, 1998. Calving performance in dairy cattle - influence of maturity of dam on the correlation between direct and indirect effects. *Proceedings 6th World Congress on Genetics Applied to Livestock Production, Januari 12-16, Armidale.* Vol 23: 387-390.

Jarrige R., Beranger C., 1992. World animal science. C5. Beef cattle production. Elsevier, New York.

Kemp, R.A., Wilton, J.W., Schaeffer, L. R., 1988. Phenotypic and genetic parameters for gestation lenght, calving ease and birth weight in Simmental cattle. *Can. J. Anim. Sci.* 68:291-294.

McGuirk, B.J., Going, I., Gilmour, A.R., 1998. The genetic evaluation of beef sires used for crossing with dairy cows in the UK. 2. Genetic parameters and sire merit predictions for calving survey traits. *Anim. Sci.* 66:47-54.

Meijering, A., 1984. Dystocia and stillbirth in cattle - a review of causes, relations and implications. *Livest. Prod. Sci.* 11:143-177.

Meijering, A., 1986. Dystocia in dairy cattle breeding with special attention to sire evaluation for categorical traits. *Ph.D. Diss., Wageningen Agric. Univ., Wageningen, The Netherlands.*

Neumaier, A., Groeneveld, E., 1998. Restricted maximum likelihood estimation of covariances in sparse linear models. *Genet. Sel. Evol.* 30:3-26.

Philipsson, J., 1976. Studies on calving difficulty, stillbirth and associated factors in Swedish cattle breeds. III. Genetic Parameters. *Acta Agric. Scand.* 26:211-220.

Searle, S.R., 1982. Matrix algebra useful for statistics. John Wiley & Sons Inc., New York.

Thompson, J.R., Freeman, A.E., Berger, P. J., 1981. Age of dam and maternal effect for dystocia in Holstein. *J. Dairy Sci.* 64:1603-1609.

Trus, D., Wilton, J.W., 1988. Genetic parameters for maternal traits in beef cattle. *Can. J. Anim. Sci.* 68:119-128.

Weller, J. I., Misztal, I., Gianola, D., 1988. Genetic analysis of dystocia and calf mortality in Israeli-Holstein by threshold and linear models. *J. Dairy Sci.* 71:2491-2501.

Varona L., Misztal, I., Bertrand, J.K., 1999. Threshold-linear versus linear-linear analysis of birth weight and calving ease using an animal model: I. Variance component estimation. *J. Anim. Sci.* 77:1994-2002.