GENETIC PARAMETERS FOR GROWTH AND REPRODUCTIVE TRAITS OF BROWN SWISS CATTLE FROM MEXICO

Parámetros genéticos para caractéres de crecimiento y reproductivos del ganado pardo suizo europeo de México

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ABSTRACT. The aim of this study was to estimate the components of (co)variance and genetic parameters for birth weight (BW, n = 16 806), weaning weight adjusted to 240 d of age (WW240, n = 9 011), yearling weight (YW, n = 6 516), age at first calving (AFC, n = 5 974) and calving interval (CI, n = 8 873) of Brown Swiss cattle from Mexico. Retrospective data from 1982 to 2010 were used from 86 ranches, spread across the country, which belonged to the Mexican Association of Registered Brown Swiss Cattle Breeders. Two trivariate analyzes were used considering BW-WW240-YW and YW-AFC-CI traits. The animal model included the contemporary group, direct additive, maternal additive, permanent environmental effects and the error term, plus age of cow at calving, parity and purebred degree as covariates. In general, direct heritabilities ranged from 0.03 to 0.35 and maternal heritabilities from 0.02 to 0.10. Correlations between direct and maternal additive genetic effects for BW, WW240 and YW ranged from -0.29 to -0.70. The direct genetic correlations for BW-WW240, BW-YW and WW240-YW were 0.51, 0.44 and 0.84, respectively, whereas for YW-AFC, YW-CI and AFC-CI they were -0.34, 0.14 and -0.26, respectively. In conclusion, selection for yearling weight could reduce the age at first calving without altering the calving interval.
Key words: Brown Swiss, heritability, genetic correlation

RESUMEN. El objetivo del presente estudio fue estimar los componentes de (co)varianza y parámetros genéticos para peso al nacimiento (PN, n = 16,806), peso al destete ajustado a 240 d de edad (PD240, n = 9,011), peso al año (PA, n = 6,516), edad al primer parto (EPP, n = 5,974) e intervalo entre partos (IP, n = 8,873) de ganado Suizo Europeo en México. Se utilizaron datos retrospectivos de 1982 a 2010, correspondientes a 86 ranchos distribuidos en todo el país, los cuales estaban registrados en la Asociación Mexicana de Criadores de Ganado Suizo de Registro. Se utilizaron dos análisis trivariados considerando las características PN - PD240-PA y PA - EPP - IP. El modelo animal incluyó los efectos de grupo contemporáneo, aditivo directo, aditivo materno, ambiental permanente y el error; además de las covariables edad de la vaca al parto, número de parto y grado de encaste. En general, las heredabilidades directas variaron de 0.03 a 0.35 y las maternas de 0.02 a 0.10. Las correlaciones entre los efectos genéticos aditivos directos y maternos para PN, PD240 y PA variaron de -0.29 a -0.70. Las correlaciones genéticas directas para PN-PD240, PN-PA y PD240-PA fueron de 0.51, 0.44 y 0.84, respectivamente; y para PA-EPP, PA-IP y EPP-IP fueron -0.34, 0.14 y -0.26. En conclusión, la selección por peso al año reduciría la edad al primer parto sin modificar el intervalo entre partos. Palabras clave: Suizo Europeo, heredabilidad, correlación genética.
Palabras clave: Suizo Pardo, heredabilidad, correlaciones genéticas

INTRODUCTION

Beef cattle production is one of the most important livestock activities in Mexico. In arid areas, *Bos taurus* breeds are preferred and in the central and southern areas both *B. taurus* and *Bos indicus* cattle breeds are used. Among the *B. taurus* breeds, Brown Swiss cattle are widely distributed as pure or crossbreed (Pell *et al*. 2010). In recent years, many efforts have been made to improve environmental conditions to increase beef production (Zorrilla-Ríos *et al*. 2013). However, another alternative to increase cattle production is through the genetic selection of the best animals (Montaldo and Barría 1998).

Growth and reproduction are relevant economical traits that should be included in a sound breeding program. Therefore, the knowledge of the genetic parameters and the relationship between them are required before a selection program could be implemented (Falconer y Mackay 1996). Estimation of genetic parameters has been performed basically on pre-weaning growth traits, in several European breeds (Ríos-Utrera 2008, Torres-Vázquez *et al*. 2012). For Brown Swiss cattle, Segura-Correa *et al*. (2012) reported pre-weaning growth and age at first calving genetic parameters in the tropics of Mexico and Estrada-León *et al*. (2008) and Ríos-Utrera *et al*. (2010) reported the heritabilities for some reproductive traits in a herd managed under the tropical conditions of Mexico.

Although the genetic evaluation of Brows Swiss cattle in Mexico started in 2003 (Núñez *et al*. 2003), it has been focused on pre-weaning traits; therefore the amount of additive genetic variation of cow reproductive traits and their genetic relationship with growth traits is unknown. Age at first calving and calving interval are reproductive traits used as criteria for reproductive efficiency in all production systems and it could have a relevant impact on beef production cost, due to the impact on the cost of replacement heifers and the reduction in open days in cows. Meyer (2004) reported that cows with fast growing rates and high adult body weight tend to have poor reproductive performance, due to the genetic antagonism between those traits.

In Mexico, there is a lack of information on genetic parameter estimates on growth and reproductive traits for the Brown Swiss cattle breed, using multivariate models (Estrada-León *et al*. 2008, Segura-Correa *et al*. 2012). The objectives of this study were to estimate covariance and variance components and genetic parameters (heritability and genetic correlations) for growth traits (birth, weaning and yearling weights) and for yearling weight, age at first calving and calving interval.

MATERIALS AND METHODS

Origen, animal management and data structure

Records on 128 447 European Brown Swiss animals, born between 1982 and 2010, from 86 farms located in the tropics of Mexico were used. All the herds were registered in the breeding program of the Mexican Brown Swiss Cattle Breeders Association. The association registers animals at least 31/32 Brown Swiss.

Calves were weaned at approximately 8 months of age, and they were reared under grazing condition with minerals or commercial feed supplementation. Reproduction occurred throughout the year, based mainly on artificial insemination and controlled natural mating. Additional information on animal feed and reproductive management is given by Ruíz-Flores *et al*. (2006) and Ramírez-Valverde *et al*. (2007).

The traits used in this study were birth weight (BW, n=16 806), weaning weight adjusted to 240 d (WW240, n = 9 011), weight adjusted to a year of age (YW, n = 6 516), age at first calving (AFC, n = 5 974) and calving interval (CI, n = 3 914). Descriptive statistics and structure of the data used here is shown in Table 1. According to Maniatis and Pollott (2003), the data had an appropriate structure for partition of the variation in co and variance components, like direct additive, maternal additive and environmental permanent effects; nearly 10 % of the data had dams with records as calves, more than 1.5 calves per cow and more than seven calves per bull.

Statistical Analysis

To define the fixed effects to be used in the mixed models analysis, least-squares analyses were performed by the MIXED procedure of the SAS program (SAS 9.0®, SAS Institute, Cary, NC, USA). For each trait (BW, WW240, YW, AFC, CI), the assumptions for an analysis of variance were tested. Records with ± 3.5 standard deviations from the mean were deleted. The linear model for growth and reproductive traits included the fixed effects of contemporary group (GC) and the age of dam as covariate (linear and quadratic). GC were integrated by herd (81), year of birth or calving (1982 to 2010), season of birth or calving (rainy and dry) and sex of calf (female or male; only for growth traits). GG had at least seven records (Ramírez-Valverde *et al.* 2008). Connectedness of CG was evaluated using AMC program (Roso and Schenkel 2006).

Estimation of genetic parameters

Components of co variance, variance and genetic parameters were estimated using restricted maximum likelihood (REML) method, fitting two tri-variate animal models (BW-WW240, YW and YW-AFC-CI) using the MTDFREML software package (Boldman *et al.* 1995).

The general animal model included contemporary group as fixed effect, the age of dam as a covariate, direct additive (d) and maternal additive (m) genetic effects, permanent environmental effect (pe) and the residual term (e), with covariance of d and m $\neq$ 0, as suggested by Albuquerque and Meer (2001). In matrix notation the general animal model was:

$$y = X\beta + Z_1 d + Z_2 m + Z_3 pe + e$$

Where: y = vector of observations; β = vector of fixed effects associated with the incidence matrix X; d = vector of direct additive genetic effects associated with the incidence matrix Z_1; m = vector of maternal additive genetic effects associated with the incidence matrix Z_2; pe = vector of permanent environmental effect associated with the incidence matrix Z_3; and e = vector of residual effects.

The general model was fitted for the first tri-variate animal model for growth traits (BW-WW240-YW), excluding permanent environmental effect for YW, according to the likelihood ratio test previously performed.

The assumptions relating to distribution of y, d, m, pe and e were:

$$E = \begin{bmatrix} y \\ d \\ m \\ pe \\ e \end{bmatrix} = \begin{bmatrix} X\beta \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} ; Var = \begin{bmatrix} d \\ m \\ pe \\ e \end{bmatrix}$$

$$= \begin{bmatrix} G_d \otimes A & G_{dm} \otimes A & 0 & 0 \\ G_{dm} \otimes A & G_m \otimes A & 0 & 0 \\ 0 & 0 & P \otimes I_q & 0 \\ 0 & 0 & 0 & R \otimes I_0 \end{bmatrix}$$

Where:

G_d = 3x3 co variance matrix of direct additive genetic effects; G_m= 3x3 co variance matrix of maternal additive genetic effects; $G^{dm} = G^{md}$ = 3x3 co variance matrix of direct additive-maternal genetic effects; P= 3x3 co variance matrix of permanent environmental effects; R= 3x3 co variance matrix of residual effects; A= Numerator relationship matrix; I_q = Identity matrix whose order is equal to number of dams; I_0 = Identity matrix whose order is equal to number of individuals with observations; $\otimes$ = Kronecker operator (direct product between matrices). It is assumed that maternal additive genetic effects and permanent environment effects were not correlated. The convergent criterion used, was the variance of the values in the likelihood function (-2log L), considered to be smaller than 10^{-6}.

The second tri-variate animal model fitted (YW-AFC-CI), included the direct additive (d) and maternal additive (m) genetic effects, with covariance of a and m $\neq$ 0 for YW, direct addi-

Table 1. Structure and descriptive statistics of Brown Swiss cattle data in Mexico.

	BW	WW240	YW	AFC	CI
Number of paternal grandparents	221	183	162	162	156
Number of maternal grandparents	758	618	540	481	376
Number of sires	465	348	278	333	362
Number of dams	8 742	5 670	4 420	4 386	2 993
Number of dams with records	1 875	815	569	1 709	1 000
Number of records per dam (mean)	1.92	1.59	1.47	1.69	2.96
% of dams with 1 record	50.7	63.2	68,15	53.41	32.61
% of dams with 2 records	25.8	22.7	21,31	29.59	22.02
% of dams with ≥3 records	23.5	14.1	10,54	16.99	45.37
Mean ± SD	37.6 (5.2)	235.1 (43.1)	334.0 (58.3)	1 139.5 (248.2)	449.1 (83.9)
Coefficient of variation	14.0	18.3	17.5	21.8	18.7
% of males	51.5	51.5	51.8	–	–
Number of herds	82	71	62	75	61
Contemporary groups	965	611	456	480	522

BW = birth weight, WWA = weaning weight adjusted to 240 d of age, YW = yearling weight, AFC= age at first calving and CI = calving interval.

tive (d) genetic effect for AFC and direct additive (d) genetic effect and the environmental permanent effect (ep) for CI.

RESULTS

The values of the variance components, direct and maternal heritability estimates for BW, WW40 and YW are shown in Table 2. The correlations between direct and maternal genetic effects estimated in this study were negative and unfavorable (Table 3). Genetic and phenotypic correlations between BW, WW240 and YW are presented in Table 3. Genetic correlations between growth traits were positive and ranged from 0.44 to 0.84. The highest direct genetic correlation (0.84) was found between adjacent weights (WW240d and YW).

The results of the variance components, direct and maternal YW, AFC and CI heritabilities are shown in Table 4. The direct heritabilities for YW, AFC and CI were 0.35, 0.11 and 0.03, respectively. Maternal heritability for YW was 0.10. Table 5 shows the results of genetic and phenotypic correlations for YW, AFC and CI. Direct genetic correlations were negative for YW and AFC (-0.34) and between AFC and CI (-0.26) and positive for YW and CI (0.14).

DISCUSSION

The direct heritability for BW (0.19) is lower than the direct heritability (0.37) reported by Ríos-Utrera (2008) but it is within the range of estimates reviewed, without including Brown Swiss populations. Sahin *et al*. (2012), Tulki *et al*. (2008) and Kaygisiz *et al*. (2011) reported lower direct heritabilities for Brown Swiss populations in Turkey and in Pakistan, respectively.

The direct heritability for WW240 (0.27) is within the range of values reported by Ríos-Utrera (2008). The direct heritability (0.35) for YW was similar to the results published by different authors (Cucco *et al*. 2009, Costa *et al*. 2011). Maternal heritabilities were low (0.02 to 0.07), indicating this the little importance of the maternal effects for the three growth traits. These results are within the range of estimates reported in the literature for weaning traits (Ríos-Utrera 2008). The importance of maternal effects at different ages, has been documented (Robinson 1996a, b, Meyer 1997), with production of milk and the care of the cow's care of the calf (maternal ability) being the main effects (Meyer *et al*. 1994). Although the results revealed that estimates of direct heritability, for the three growth traits, were higher than the estimates of maternal heritability, the latter cannot be ignored in multi-trait genetic evaluations.

In general, the heritability estimates for the

Table 2. Components of covariance, variance, direct and maternal heritability for birth weight (BW), weaning weight adjusted to 240 d of age (WW240) and yearling weight (YW) using a trivariate animal model in Brown Swiss cattle in Mexico.

	Components of (Co)variance							
Variable	$\sigma^2{}_d$	$\sigma^2{}_m$	$\sigma^2{}_c$	σ_{dm}	$\sigma^2{}_e$	$\sigma^2{}_P$	$h^2{}_d$	$h^2{}_m$
BW	2.0	0.2	0.5	-0.3	8.2	10.7	0.19	0.02
WW240	165.0	28.7	1.9	-20.1	426.0	601.4	0.27	0.05
YW	287.3	59.5	–	-78.1	571.9	840.5	0.34	0.07

$\sigma^2{}_d$=direct additive genetic variance, $\sigma^2{}_m$=maternal additive genetic variance, $\sigma^2{}_c$=maternal permanent environmental variance, $\sigma^d{}_m$= direct-maternal additive genetic covariance, $\sigma^2{}_e$=residual variance, $\sigma^2{}_p$=phenotypic variance, $h^2{}_d$= direct heritability and $h^2{}_m$=maternal heritability.

Table 3. Genetic (above diagonal) and phenotypic correlations (below the diagonal) between birth weight (BW), weaning weight adjusted to 240 d of age (WW240) and yearling weight (YW) in Brown Swiss cattle in Mexico.

Traits	BWd	BWm	WW240d	WW240m	YWd	YWm
BWd	–	-0.43	0.51	0.00	0.44	0.00
BWm	–	–	-0.33	0.32	-0.60	0.09
WW240d	0.21	–	–	-0.29	0.84	-0.42
WW240m	–	–	–	–	-0.06	0.52
YWd	0.20	–	0.62	–	–	-0.60

BWd, WW240d, YWd = Direct genetic effects for BW, WW240, YW, respectively; BWm, WW240m, YWm = Maternal genetic effects for BW, WW240, YW, respectively.

Table 4. Components of covariance, variance, direct and maternal heritability for yearling weight (YW), age at first calving (AFC) and calving interval (CI) in Brown Swiss cattle in Mexico.

	Components of (Co)variance							
Variable	$\sigma^2{}_d$	$\sigma^2{}_m$	$\sigma^2{}_c$	σ_{dm}	$\sigma^2{}_e$	$\sigma^2{}_P$	$h^2{}_d$	$h^2{}_m$
YW	286.6	85.2	–	-108.6	553.8	816.9	0.35	0.10
AFC	5 052.5	–	–	–	39 955.6	45 008.1	0.11	–
CI	195.2	–	288.0	–	5 307.6	5 790.8	0.03	–

$\sigma^2{}_d$=direct additive genetic variance, $\sigma^2{}_m$=maternal additive genetic variance, $\sigma^2{}_c$=maternal permanent environmental variance, σdm= direct-maternal additive genetic covariance, $\sigma^2{}_e$=residual variance, $\sigma^2{}_P$=phenotypic variance, $h^2{}_d$= direct heritability, $h^2{}_m$=maternal heritability.

three traits were moderate; therefore, the inclusion of these traits is justified in a screening program for improving the production of the Brown Swiss breed in Mexico, and hopefully the genetic selection for any of these traits will result in a future improvement. The negative and unfavorable correlations between direct and maternal genetic effects (Table 3), should be of great interest to breeders, because the maternal effect on the phenotype of the progeny of cows selected, may negatively affect the genetic progress for weaning weight by up to 20 % or more (Robison 1981).

Negative genetic correlations between direct and maternal genetic effects are commonly encountered in the literature in beef cattle (Koots *et al.* 1994b, Meyer 1997, Eriksson *et al.* 2004). Beker (1980) suggested that high and negative genetic correlations between direct and maternal additive effects may be a consequence of the negative correlation between the cow and the calf, probably due to an adverse effect of the high nutrition during the rearing of heifers on weaning weight of the offspring.

Robinson (1996b) mentioned that the structure of the analyzed data could cause an important bias, as well as additional variation due to sire and sire x year interaction or negative covariance between mother-offspring, which is a real genetic antagonism between traits. However, in this study the bias that the structure of the data could produce is expected to be minimal, due to the adjustment made. In the analysis of the data at least seven animals per contemporary group and a minimum of five offspring per sire were considered. In addition, all possible effects were considered in the final statistical model for the estimation of genetic parameters, based on the criterion of the likelihood ratio test. The high and negative correlations between direct and maternal additive genetic effects for the three characteristics indicate an unfavorable synergy. Therefore, selection for direct additive genetic effects is expected to reduce maternal ability.

Table 5. Genetic (above diagonal) and phenotypic correlations (below the diagonal) between yearling weight (YW), age at first calving (AFC) and calving interval (CI) in Brown Swiss cattle in Mexico.

Traits	YWd	YWm	AFCd	CId
YWd	–	-0.70	-0.34	0.14
YWm	–	–	0.00	0.00
AFCd	-0.21	–	–	-0.26
CId	-0.65	–	-0.05	–

YWd, AFCd, CId = Direct genetic effects for YW, AFC, CI, respectively; YWm = Maternal genetic effects for YW.

The highest direct genetic correlation (0.84) found between adjacent weights (WW240d and YW, Table 3) suggests the presence of common genes that influence the three variables. Therefore, the selection of animals with high BW will increase WW240 and YW, and vice versa. But must be kept in mind that selection of animals with high PD240 or YW will increase the PN, which is not always desirable, as it can increase the frequency of calving difficulties (Zaborski *et al.* 2009), mainly in first calving cows. Unfavorable positive correlations between BW and the other two traits and positive correlation between WW240d and YW should be considered in selection programs for growth. Therefore, it is probably more effective to consider the BW and one of the other two traits in a selection index. In this sense, MacNeil (2003) evaluated the index, I = YW - BW 3.2, proposed by Dickerson *et al.* (1974), using a genetic correlation between BW and YW of 0.71, and they observed moderate genetic responses of 0.45, 3.42 and 7.74 kg^{-1} generation at birth, at 200 d and at one year of age, respectively.

Regarding the heritabilities estimated for reproductive traits, generally in the literature they have low heritability (Koots *et al.* 1994a), except AFC. Roughsedge *et al.* (2005) and Estrada-León *et al.* (2008) reported values for AFC from 0.17 to 0.26 and 0.28, respectively. Therefore, it seems possible to improve the AFC through selection. However, Koots *et al.* (1994a) reported a heritability average of 0.06 for the AFC and Roughsedge *et al.* (2005) found a value of 0.05 for South Devon cattle, suggesting that in some breeds, this feature is strongly influenced by environmental factors. In this study, taking into account the heritability estimated (0.11), the improvement of the AFC would have better results if better management practices were implemented.

For CI, the heritability (0.03) estimated in this study is very low but similar to the estimates from other studies. Based on three estimates, Koots *et al.* (1994a) reported a mean heritability of 0.10 for CI. Roughsedge *et al.* (2005) estimated values ranging from 0.04 to 0.13 for four breeds of beef cattle and Estrada-León *et al.* (2008) found a value of 0.11 in a herd of Brown Swiss cattle in the tropics of Mexico. The results, in this study, indicate that the improvement of CI had to be through better and sound management practices.

The negative but favorable correlation (Table 5) between YW-AFC and positive between YW-CI indicates that the heaviest females at one year of age will have their first calving at an early age but the CI will increase. As a result, the selection based on YW may result in a reduction in the AFC but in longer calving intervals. Therefore, in the long term, this selection can increase mature weight (Grossi *et al.* 2008, Costa *et al.* 2011), which in a pasture based production system is undesirable and will also likely increase calving difficulty (Núñez-Domínguez *et al*. 1991, Martin *et al*. 1992). The moderate association between AFC and YW shows the importance of body weight of the heifer to the start of the reproductive life. Part of the genetic variation of AFC may be due to the variation in body weight (Núnez-Domínguez *et al*. 1991, Martin *et al*. 1992). However, the response to selection would be low, reducing AFC when only YW is considered in a breeding program. Thus, the inclusion of AFC in a selection index could improve sexual precocity of females (Roughsedge *et al*. 2005). Genetic correlations between weights at different ages and reproductive traits have been reported by several authors. A study reported genetic correlations between -0.06 to -0.18 for three breeds, indicating that selection for weight at 400 d of age results in a low AFC (Roughsedge *et al*. 2005). This result is similar to the correlation of -0.11 between YW and age at puberty reported by Gregory *et al*. (1995).

The estimated direct genetic correlation between YW and CI was positive and unfavorable, indicating that selection for YW would increase CI. Genetic correlations between weights at different ages and reproductive traits were estimated by Gutiérrez *et al*. (2007), indicating a negative association (-0.14) but positive between YW and CI, which disagrees with what was found in this study. The age at first mating and consequently the AFC is more a function of body weight and the age of the animal; therefore, the common practice, in many herds, of adopting the minimum weight for mating heifers may cause the favorable relationship between the YW and AFC (Mercadante *et al*. 2003). As a result, high AFC is caused, in part by low growth rates due to poor nutritional status of replacement heifers (Renquist *et al*. 2006). In contrast, the unfavorable relationship between YW and CI, is largely due to the fact that CI is mainly affected by age, regardless of body weight, because cows with AFC at two years of age have longer CI compared with cows calving for the first time at three years of age. After three years of age, there is little difference between the intervals of two subsequent calvings. The long first CI is probably due to dystocia problems and delayed uterine involution associated with the age at first calving (Renquist *et al*. 2006). In addition, the poor performance of first calving cows is, partly because they are still growing and the demand for milk from the offspring subjected them to stress, causing a delay in ovarian activity.

CONCLUSIONS

The results indicate that selection for growth traits can result in joint and several favorable responses because of moderate heritabilities and positive association between them; however, the unfavorable genetic correlation between direct and maternal additive genetic effects must be taken into account. Selection for YW may have moderate positive effects on AFC. Correlation information may be required in the assessment of multi-trait reproductive variables to assist in the selection of bulls to produce replacement heifers for the herds.

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