Genotype × Environment Interaction for Age at First Calving in Brazilian and Colombian Holsteins

M. F. Cerón-Muñoz,¹ H. Tonhati,² C. N. Costa,³
J. Maldonado-Estrada,⁴ and D. Rojas-Sarmiento⁵

¹GRICA-FCA-Universidad de Antioquia, Colombia

²FCAV-Universidade Estadual Paulista, Jaboticabal, SP, Brazil

³Embrapa Gado de Leite, Juiz de Fora, MG, Brazil

⁴Centauro-FCA-Universidad de Antioquia, Medellín, Colombia

⁵Asociación Holstein de Colombia

ABSTRACT

The objective was to determine whether there is a genotype × environment interaction for age at first calving (AFC) in Holstein cattle in Brazil and Colombia. Data included 51,239 and 25,569 first-lactation records from Brazil and Colombia, respectively. Of 4230 sires in the data, 530 were North American sires used in both countries. Analyses were done using the REML bi-trait animal model, and AFC was considered as a distinct characteristic in each country. Fixed effects of contemporary group (herd-calving year), sire genetic group, and cow genetic group, and random effects of animal and residual variation were included in the model. Average AFC in Brazil and Colombia were 29.5 ± 4.0 and 32.1 ± 3.5 mo, respectively. Additive and residual genetic components and heritability coefficient for AFC in Brazil were 2.21 mo^2 , 9.41 mo^2 , and 0.19, respectively, whereas for Colombia, they were 1.02 mo^2 , 6.84 mo^2 , and 0.13, respectively. The genetic correlation of AFC between Brazil and Colombia was 0.78, indicating differences in ranking of sires consistent with a genotype × environment interaction. Therefore, in countries with differing environments, progeny of Holstein sires may calve at relatively younger or older ages compared with contemporary herdmates in one environment versus another.

(**Key words:** calving age, genetics, environment, interaction)

Abbreviation key: $G \times E$ = genotype × environment.

INTRODUCTION

Selection methods in dairy cattle often include reproductive and productive traits, and possible influence of

genetic progress in milk yield on reproductive performance. Cows having a great genetic potential for milk yield often exhibit reproductive problems, particularly when subjected to climatic stress, especially such as that of (sub)tropical climates (Campos et al., 1994).

Animal fertility is a determining factor in genetic gains of different production systems (Olds et al., 1979; Esslemont and Peeler, 1993). Although heritability estimates for most reproductive traits are usually low, there is sufficient genetic variation to obtain genetic gain by selection of these characteristics (Philipsson, 1981; Thaller and Aumann, 1996), and, as such, it can be effective on long-term production cost reduction (Shook, 1989; Campos et al., 1994).

Oltenacu et al. (1991) reported an antagonistic association between production and conception rate for heifers and cows. However, for AFC, Seykora and McDaniel (1983) stated that selection for milk yield resulted in a favorable reduction in AFC in heifers, in agreement with the reports by McDaniel and El-Sayed (1980), and Hansen et al. (1983a, 1983b). Abubakar et al. (1986) and Pearson de Vaccaro (1974) reported that Holstein cattle were older at first calving in South America than in other countries, and suggested nutritional differences as a main cause.

Animal productive and reproductive potentials are expressed only as much as their environmental conditions allow. The environment does not change the genetic constitution of the individual. However, environmental factors determine the extent to which the phenotype is expressed; therefore, it is possible that the best genotype in one environment may not be in others (Warwick and Legates, 1980). This phenomenon is known as genotype × environment interaction ($G \times E$). Falconer (1952) defined $G \times E$ as the change in relative performance of a characteristic expressed in 2 or more genotypes, measured in 2 or more environments. Thus, interactions can involve changes in genotype classification or changes in magnitude of genetic, environmental, and phenotypic variances in differing environments.

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Corresponding author: M. Cerón-Muñoz; e-mail: mceronm@universia.net.co.

Table 1. Number of sires¹ heifers and average at first calving (AFC) by genetic group of sire in Brazil and Colombia.²

Brazil				Colombia			
Genetic group	Sires	Heifers	AFC (mo)	Genetic group	Sires	Heifers	AFC (mo)
Br (≤1979)	334	2782	30.66	Co (≤1979)	84	1241	32.69
Br (1980–1984)	592	5005	30.20	Co (1980–1984)	123	1935	32.80
Br (1985–1993)	1019	3758	29.82	Co (1985–1993)	142	1678	31.81
Ca (≤1976)	100	2897	29.89	Ca (≤1976)	82	926	31.99
Ca (1977–1981)	45	3329	29.09	Ca (1977–1981)	66	2080	31.90
Ca (1982–1993)	111	2522	28.56	Ca (1982–1993)	102	1734	31.85
US (≤1971)	117	1688	30.37	US (≤1971)	145	796	32.38
US (1972–1976)	204	8015	29.82	US (1972–1976)	318	5584	32.18
US (1977–1981)	216	12,298	29.57	US (1977–1981)	315	4946	32.04
US (1982–1993)	281	8945	28.37	US (1982–1993)	364	4649	31.69
Total	3019	51,239			1741	25,569	

¹530 sires commons in the 2 countries.²Br = Brazilian sires; Ca = Canadian sires; Co = Colombian sires; US = American sires.

Comparative reproductive characteristics and G×E studies in cattle populations located in different regions or countries are needed to determine whether imported genotypes exhibit reproductive problems in (sub)tropical countries. For Lytton and Legates (1966), G×E can be observed in reproductive characteristics and such variables could be weighted along with production traits in animal selection programs. The objective of this study was to determine the genotype × environment interaction of age at first calving of Holstein cattle between Brazil and Colombia.

MATERIALS AND METHODS

Data from 76,808 first calvings of Holstein cows from 7 regions in Brazil and 5 regions in Colombia were obtained for Holstein cows calving from 1980 through 1997. Data were from the Brazilian Association of Holstein Cattle Ranchers, available from the National Animal Sciences Database, from EMBRAPA Gado de Leite, Juiz de Fora, MG, Brazil, and from the Colombian Holstein Association (Table 1). Contemporary groups were made up by herd-year, and groups with fewer than 5 cows were discarded. For the analysis there were considered 6742 and 3219 herd-year from 1287 and 374 herds in Brazil and Colombia, respectively. In addition, sires were excluded if they did not have at least 2 daughters in each 1 of 2 herds from Brazil and Colombia. Genetic groups of sires were made by considering origin of sire (Brazil, Canada, Colombia, and United States) and dates of birth within each origin, as described in Table 1. Also, cows were grouped by genetic background according to the classification of the Holstein associations in each country. Only purebred Holsteins and cows with ≥31/32 Holstein genetics were included.

Bivariate analysis was done with an animal model, using the derivative-free restricted maximum likelihood method. The (co)variance components were estimated with the MTDFREML (Boldman et al., 1993) program. The fixed effects of contemporary group, the genetic group of the sire, and the genetic group of the cow, as well as the random effects of animal and residual, were included. The model of bi-trait analysis for the AFC between the 2 countries can be represented in a matrix notation as:

$$y_i = X_i b_i + Z_i a_i + e_i$$

with

$$y = \begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} + \begin{bmatrix} Z_1 & 0 \\ 0 & Z_2 \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \end{bmatrix}$$

where:

Vector of observations for the *i*th age at first calving, *i* = 1 = Brazil, and 2 = Colombia

Vector of fixed effects of herd year, cow genetic group and sire genetic group for the *i*th characteristic;

Vector of random additive genetic effect of animal for the *i*th characteristic;

Vector of random residual effect for the *i*th characteristic. X_i is the incidence matrix related to the fixed effects b_i , and Z_i is the incidence matrix related to the random additive genetic effect of animal (a_i).

The assumptions in relation to 1st and 2nd moments were:

$$\begin{bmatrix} a \\ e \end{bmatrix} \sim NMV \left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} G & 0 \\ 0 & R \end{bmatrix} \right)$$

Table 2. Estimates of (co)variance, heritabilities, and genetic correlations of age at first calving of Brazilian and Colombian Holstein cattle.

	Brazil	Colombia
Average age of the cows at first calving (months)	29.50	32.07
Standard deviation	3.97	3.50
Coefficient of variation (%)	13.46	10.93
Additive genetic variance (mo ²)	2.21	1.02
Residual variance (mo ²)	9.41	6.84
Heritability	0.19	0.13
	Brazil-Colombia	
Genetic covariance between Brazil and Colombia	1.17	
Genetic correlation between Brazil and Colombia	0.78	

where:

$G = A \otimes G_0$ is the (co) variance additive genetic matrix for the characteristics and

$$G_0 = \begin{bmatrix} \sigma_{a_{11}}^2 & \sigma_{a_{12}} \\ \sigma_{a_{21}} & \sigma_{a_{22}}^2 \end{bmatrix};$$

$\sigma_{a_{ii}}^2$ is the additive genetic variance of characteristic $i = 1, 2$, and $\sigma_{a_{12}}$ is the additive genetic covariance between characteristics 1 and 2;

A is the relationship matrix and $\otimes$ is the direct product; and

$R = I \otimes R_0$ is the residual (co)variance matrix between the characteristics, and

$$R_0 = \begin{bmatrix} \sigma_{e_{11}}^2 & 0 \\ 0 & \sigma_{e_{22}}^2 \end{bmatrix};$$

$\sigma_{e_{ii}}^2$ is the residual variance for characteristic $i = 1, 2$.

RESULTS AND DISCUSSION

The average AFC were 29.5 ± 4.0 and 32.1 ± 3.5 mo for Brazil and Colombia, respectively (Table 2). The difference in average AFC between countries reflects the different reproductive performance of heifers. It is likely that weather and management conditions particular to each country are determinant in their reproductive performance. These values are similar to those found in other Latin American countries. In a literature review by Pearson de Vaccaro (1974), the AFC among Holstein-Friesian in South American countries varied from 30 to 36 mo. Because AFC for Holstein dairy herds in Brazil and Colombia are at the lower end of that range in the current report, there appears to have been some improvement from the earlier data.

The components of additive genetic and residual variances and the heritability coefficient were 2.21 mo²,

9.41 mo², and 0.19, respectively for Brazil, and 1.02 mo², 6.84 mo², and 0.13, respectively, for Colombia. Heritability values were similar to the 0.26 estimated by Shanks et al. (1981) and 0.16 estimated by Hansen et al. (1983b), but greater than that of 0.05 ± 0.03 estimated by Seykora and McDaniel (1983). In contrast, Abubakar et al. (1986) found an abnormal heritability value of 2.19 for AFC in Colombian Holstein cattle.

The genetic correlation of AFC between Brazil and Colombia was 0.78, suggesting that $G \times E$ would have an important impact on animal performance (Robertson, 1959). It also highlights that progeny of North American sires had different performance in these 2 countries, leading to changes in the rank of the sires as a consequence of this interaction. Apparently, expression of genes responsible for age at first calving varies across environments.

In conclusion, we suggest that care should be taken in considering sires when comparing progeny in different dairy production systems in the tropics because of the possibility of $G \times E$ for relative rankings.

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