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Genetic parameters and genetic trends for age at first calving and calving interval in an Angus-Blanco Orejinegro-Zebu multibreed cattle population in Colombia[§]

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Abstract

Genetic parameters and genetic trends for age at first calving (AFC), interval between first and second calving (CI1), and interval between second and third calving (CI2) were estimated in a Colombian beef cattle population composed of Angus, Blanco Orejinegro, and Zebu straightbred and crossbred animals. Data were analyzed using a multiple trait mixed model procedures. Estimates of variance components and genetic parameters were obtained by Restricted Maximum Likelihood. The 3-trait model included the fixed effects of contemporary group (year-season of calving-sex of calf; sex of calf for CI1 and CI2 only), age at calving (CI1 and CI2 only), breed genetic effects (as a function of breed fractions of cows), and

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individual heterosis (as a function of cow heterozygosity). Random effects for AFC, CI1, and CI2 were cow and residual. Program AIREMLF90 was used to perform computations. Estimates of heritabilities for additive genetic effects were 0.15 ± 0.13 for AFC, 0.11 ± 0.06 for CI1, and 0.18 ± 0.11 for CI2. Low heritabilities suggested that nutrition and reproductive management should be improved to allow fuller expressions of these traits. The correlations between additive genetic effects for AFC and CI1 (0.33 ± 0.41) and for AFC and CI2 (0.40 ± 0.36) were moderate and favorable, suggesting that selection of heifers for AFC would also improve calving interval. Trends were negative for predicted cow yearly means for AFC, CI1, and CI2 from 1989 to 2004. The steepest negative trend was for cow AFC means likely due to the introduction of Angus and Blanco Orejinegro cattle into this population.

Keywords: Beef cattle; Criollo; Multibreed; Genetic trends; Reproduction

1. Introduction

Beef production in Colombia is largely extensive and primarily based on *Bos indicus* and *Bos taurus* x *Bos indicus* cattle (MADR, 2005), where *Bos indicus* is represented by Commercial Zebu and Brahman cattle, and *Bos taurus* breeds are Angus, Senepol, Simmental, and Criollo breeds (Blanco Orejinegro, Romosinuano, and Sanmartinero). Genetic evaluation and selection of animals for reproductive efficiency traits have not been conducted in Colombian multibreed populations despite their large potential impact on beef production costs under tropical conditions, particularly when temperate breeds are a major component of the breeding strategy. Two measurements of reproductive efficiency that are frequently taken in Colombian farms with extensive management systems are age at first calving and calving interval. Genetic improvement of these traits could have a major impact on beef productions costs. Shortening of age at first calving would decrease the cost of raising heifers for replacement and shortening of calving intervals would decrease production costs per calf produced per year.

A first step in the process of generating genetic evaluations for reproductive traits in Colombia would be to analyze existing datasets from large commercial beef enterprises. Thus, the objectives of this research were the estimation of genetic parameters and genetic trends for age at first calving, calving interval between the first and second calving, and calving interval between the second and third calving in a large commercial enterprise in the department of Antioquia in Colombia.

2. Materials and methods

2.1. Animals and data

This study used data collected from 1989 to 2004 at farm La Leyenda (municipality of Caucasia, department of Antioquia, Colombia). Cattle breeds present in the dataset were Angus, Blanco Orejinegro (Criollo breed), and Zebu. Zebu was primarily composed of commercial crossbred cattle of *Bos indicus* ancestry of various origins (Brahman, Guzerat, and Nellore), and by Brahman sires from the USA. The dataset contained a total of 2,301 Blanco Orejinegro, Zebu, and crossbred cows with records, of which 1,630 cows had ages at first calving (AFC), 1,221 cows had intervals between first and second calving (CI1), and 1,110 cows had intervals between second and third calving (CI2). Cows were daughters of 35 Zebu, 12 Angus, 4 Blanco Orejinegro, and 1 Angus x Zebu sires mated mostly to Zebu and Angus x Zebu dams. Table 1 presents numbers of cows with AFC, CI1, and CI2 records by breed-group-of-sire x breed-group-of-dam combination.

2.2. Management and feeding

Cows were rotated on pastures composed primarily of *Brachiaria decumbens*, *Brachiaria humidicola*, and *Brachiaria brizhanta*. Stocking rate ranged from 2.3 to 2.6 animals per hectare. Cattle were provided corn silage, and either sorghum (*Sorghum vulgare*) or guinea grass (*Pennisetum violaceum*) during the dry season. Cows and calves were managed together up to weaning at approximately 8 months of age.

There were 2 seasons in this region: a dry one from December to March, and a wet one from April to November. Precipitation averaged 2,130 mm/yr, and temperature fluctuated between 27 °C to 30.2 °C. Mating occurred throughout the year. Estrous was detected visually by trained personnel twice a day (morning and afternoon). Heifers and cows were inseminated twice, then placed in a paddock with a natural service sire for 60 d. Heifers were inseminated for the first time when they reached a weight between 300 and 330 kg at an age of 28 to 30 months. Cows were rested for a period of 2 months after calving, and inseminated for the first time at the second visible estrous after the postpartum rest period.

2.3. Genetic predictions and genetic parameters

Multiple trait mixed model procedures (Henderson, 1976; Henderson and Quaas, 1976; Quaas and Pollak, 1980) were used to analyze data. Restricted maximum likelihood procedures (Harville, 1977) were used to obtain estimates of variances and covariances. Computations were carried out with software from the University of Georgia (AIREMLF90) that used an average information algorithm (Misztal, 1997; Tsuruta, 1999) and accounted for missing records using formulas developed by C. R. Henderson (Henderson, 1984).

The 3-trait (AFC, CI1, and CI2) animal model considered: 1) the environmental fixed effects of contemporary group (year-season of calving; year: 1989 to 2004; season: 1 = dry, 2 = wet), sex of calf (1 = male, and 2 = female; CI1 and CI2 only), and age at calving (CI1 and CI2 only); 2) breed fixed effects (1 = Angus, 2 = Blanco Orejinegro, and 3 = Zebu) as a function of expected breed fractions of cows (Robison et al., 1981; Elzo and Famula, 1985; Rodríguez-Almeida et al., 1997; Elzo and Wakeman, 1998), where expected breed fraction = prob (breed k), k = Angus, Blanco Orejinegro, Zebu; 3) heterosis fixed effects as a function of cow expected heterozygosities (Robison et al., 1981; Elzo and Famula, 1985; Rodríguez-Almeida et al., 1997; Elzo and Wakeman, 1998), where expected heterozygosity = prob (breed j sire of cow) × prob (breed k dam of cow) + prob (breed k sire of cow) × prob (breed j dam of cow), j ≠ k = Angus, Blanco Orejinegro, Zebu; 4) additive genetic random cow effects as deviations from genetic group effects; and 5) residual random effects. Genetic group effects were defined as a weighted sum of breed effects, thus the generalized least squares solution for genetic group i was equal to $g_i^0 = \sum_{i=1}^{B} p_{ij} b_i^0$, where B = number of breeds; p_{ij} = fraction of $breed_i$ in cow ij; and b_i^0 = generalized least squares solution for breed i.

Cow genetic effects were predicted as a weighted sum of breed genetic effects and random effects (Elzo and Wakeman, 1998). The EBV for cow ij was equal to $\hat{u}_{ij} = g_i^0 + \hat{c}_{ij}$, where $\hat{u}_{ij}$ = genetic prediction for cow ij; g_i^0 = generalized least squares solution for genetic group i; and $\hat{c}_{ij}$ = genetic prediction for cow ij as a deviation from genetic group i.

The variance-covariance matrix of the vector of random genetic effects was equal to G = A * G_0, where G_0 was a 3 x 3 matrix of variances and covariances among AFC, CI1, and CI2 additive genetic effects. The variance-covariance matrix of the vector of residuals was equal to $R = I * \sigma_e^2$, where σ_e^2 was the residual variance common to all animals in the population. Heritabilities for AFC, CI1, and CI2, and genetic and phenotypic correlations between AFC, CI1, and CI2 were computed using variances and covariances estimated with the AIREMLF90 program. The Delta method (Lindgren, 1976) was used to obtain standard errors of estimates of heritabilities and correlations.

Yearly means of EBV for cow AFC, CI1, and CI2 genetic effects were computed to study genetic trends between 1989 and 2004. Genetic trends were computed as a linear regression of yearly means on year using the procedure GLM of the Statistical Analysis System (SAS, 2007).

3. Results and discussion

3.1. Breed and heterosis effects

Breed effects (as deviations from Zebu) for AFC were negative for Angus (-281.2 ± 41.9 d; $P < 0.001$) and Blanco Orejinegro (-162.1 ± 31.9 d; $P < 0.001$). Similarly, AFC for Angus were also negative (-119.1 ± 30.3 d; $P < 0.001$) when compared to Blanco Orejinegro. These estimates of breed differences suggest that purebred Zebu and crossbred heifers with high proportion of Zebu took longer to calve for the first time than crossbred heifers with higher fractions of Angus or Blanco Orejinegro under the humid tropical conditions in Antioquia. The lower AFC found here for Angus and Blanco Orejinegro relative to Zebu was in agreement with the higher precocity of *Bos taurus* compared to *Bos indicus* breeds (Turner 1980; Nogueira, 2004). However, the breed effect for Angus should be taken with caution because there were no purebred Angus cows in this population. The Angus breed effect may have been underestimated because Angus was primarily represented by F1 Angus-Zebu cows and these crossbred cows are likely to be better adapted to tropical environmental conditions than purebred Angus cows.

Estimates of breed deviations from Zebu for CI1 were -6.9 ± 51.5 d (P = 0.56) for Angus and -6.5 ± 39.4 d (P = 0.72) for Blanco Orejinegro. The difference between Angus and Blanco Orejinegro was -0.4 ± 37.9 d (P = 0.70). All breed differences for CI1 were non-significant. Estimates of breed differences for CI2 were negative for Angus minus Zebu (-94.9 ± 50.1 d; P = 0.08), positive for Blanco Orejinegro minus Zebu (18.4 ± 32.3 d; P = 0.55), and negative for Angus minus Blanco Orejinegro (-113.3 ± 40.9 d; P < 0.001). Zebu genes involved in adaptation may have helped Angus genes for precocity to be expressed in Angus-Zebu crossbreds. However, as indicated for AFC above, CI1 and CI2 values for Angus are likely to be underestimates because no purebred Angus cows existed in this population.

Estimates of heterosis were all non-significant, negative for AFC (-26.0 ± 21.0 d; P = 0.18) and for CI1 (-39.5 ± 25.6; P = 0.11), and positive for CI2 (16.0 ± 24.9 d; P = 0.49). The absolute value of heterosis for AFC here was lower than the absolute values of AFC heterosis reported in a Zebu-Holstein multibreed population in Brazil (-60 d; Martínez et al., 1988) and in an F1 Brown Swiss x Commercial Zebu cattle in Mexico (-76 ± 17 d; Magaña and Segura-Correa, 2001).

3.2. Heritabilities, genetic correlations, and phenotypic correlations

Estimates of additive genetic variances were 1,739.7 ± 1,483.4 d^2 for AFC, 899.1 ± 531.7 d^2 for CI1, and 1,316.8 ± 162.2 d^2 for CI2. Additive genetic covariance estimates were 410.8 ± 519.6 d^2 between AFC and CI1, 603.9 ± 542.1 d^2 between AFC and CI1, and 1,084.8 ± 605.2 d^2 between CI1 and CI2. Phenotypic variances were 11,295.1 ± 399.5 d^2 for AFC, 8,219.3 ± 328.2 d^2 for CI1, and 7,418.2 ± 317.8 d^2 for CI2. Table 2 shows the estimates of heritabilities, genetic correlations, and phenotypic correlations for AFC, CI1, and CI2. The value of heritability for AFC was low and had a high standard error. This suggests that AFC was heavily influenced by the extensive nutritional conditions, management, and tropical climate, and that genetic improvement for this trait would be slow. If nutrition and management of the cow-calf herd and replacement heifers were improved, this may permit fuller expression and potentially faster genetic progress for AFC in this population.

The estimate of heritability for AFC here was either similar or lower than most values reported for cattle in the tropics. Differences in breed composition, management, nutrition, and model used (sire vs. animal model) are likely to have contributed to these differences. The AFC heritability estimate here was higher than one obtained for Nellore cattle in Brazil (0.05; Silveira et al., 2004), but lower than those reported for Brahman-Nellore-Guzerat-Gir multibreed cattle in Mexico (0.46 ± 0.15; Magaña and Segura, 1997), Romosinuano in Costa Rica (0.28 ± 0.16; Casas and Tewolde, 2001), and Brahman in Mexico (0.46 ± 0.14; Estrada-León et al. 2008). However, the AFC heritability was similar to the ones estimated for Canchim in Brazil (0.13; Talhari et al., 2003), and for Romosinuano in Colombia (0.16 ± 0.09; Suárez et al., 2006). Thus, selection for AFC here and in most of the referenced populations would likely show some small decrease in AFC over time.

Estimates of heritabilities for CI1 and CI2 were also low, but with smaller standard errors than that for AFC. Low estimates of heritability for CI1 and CI2 indicate that these traits were greatly influenced by environmental conditions, thus improvements in nutrition and reproductive management would likely have a larger impact on reducing CI1 and CI2 than genetic selection. The heritability of CI2 was higher than CI1 because the genetic variance for CI2 was larger and the phenotypic variance smaller than those for CI1. This may have been influenced by lower growth nutritional demands after the second calving permitted cows to show estrous and get pregnant sooner than first calf heifers.

Estimates of heritability for CI1 and CI2 here were substantially larger than those reported in various purebred cattle populations. Small values of heritability for CI1 were estimated for Angus in the USA (0.01; Frazier et al., 1999), and for Nellore in Brazil (0.03 ± 0.14; Gressler et al., 2005), but a similar estimate was computed for Nellore in Brazil (0.10 ± 0.10; Gressler et al., 2000 and 0.10; Mercadante et al., 2000). The only estimate of heritability found in the literature for CI2 was near zero (0.01; Frazier et al., 1999) for Angus cattle in the USA. Heritability estimates for CI1 and CI2 here suggest that keeping cows with lower CI1 and CI2 may result in shorter calving intervals, and that the response could be faster than in other populations in tropical regions.

Estimates of additive genetic correlations between AFC and CI1, and between AFC and CI2 were positive and moderate suggesting that selection of heifers with low AFC may lead to shorter calving intervals. However, the large size of the standard errors of these correlation estimates prevents making concrete statements in this regard. Mercadante et al. (2000) estimated a positive value (0.53) whereas Gressler et al. (2005) estimated a negative value (-0.92) for the genetic correlation between AFC and CI1 for Nellore in Brazil, and Frazier et al. (1999) obtained near zero correlations between AFC and CI1 (-0.10) and between AFC and CI2 (-0.06) for Angus in the USA. Differences in sign and magnitude of genetic correlation estimates between AFC and calving interval traits may be due to differences in breed composition, environmental conditions, methods of estimation, and accuracies of variance and covariance components. However, they may also be an indication that the sets of genes affecting these traits differ across populations, and that genes present across populations of different breed composition have different additive genetic values.

The estimate of genetic correlation between CI1 and CI2 was positive, very high, and with a rather large standard error. Estimates of genetic correlations between CI1 and CI2 for beef cattle in tropical regions were unavailable. However, a similarly high and positive genetic correlation between CI1 and CI2 was found in Holstein Friesian cattle in Australia (0.88 ± 0.08; Haile-Mariam et al., 2003).

The estimate of phenotypic correlation between AFC and CI1 was positive, moderate, and had a low standard error. This indicates that cows with low ages at first calving tended to have relatively short first calving intervals, suggesting that these heifers had enough time to replenish their energy reserves and return to estrous quickly under the nutritional conditions in this multibreed population. This positive correlation was in contrast with the low negative phenotypic correlations between AFC and CI1 found in Nellore cattle in Brazil (-0.06; Mercadante et al., 2000; and -0.33; Gressler et al., 2005) suggesting that younger first calf heifers tended to return to estrous later than older ones, perhaps due to insufficient nutrition (Randel, 1990; Short et al., 1990).

Estimates of phenotypic correlations between AFC and CI2, and between CI1 and CI2 were positive, low, and with small standard errors indicating there was little association between phenotypic measurements of these traits. Phenotypic correlations between these traits were unavailable in the literature.

3.3. Weighted genetic means per year

Fig. 1 shows the trends for yearly means of cow EBV for AFC, CI1, and CI2 genetic effects that occurred from 1989 to 2004. Negative trends existed for yearly cow EBV means for AFC, CI1, and CI2 during this period. The negative slope of the trend between 1989 and 2004 for AFC was steeper (-6.26 ± 1.29 d/yr; $P < 0.001$) than for CI1 (-0.32 ± 0.09 d/yr; $P < 0.01$) and CI2 (-1.16 ± 0.48 d/yr; $P < 0.05$).

The decreasing trend of yearly cow EBV means for AFC began in 1991, coinciding with a major introduction of *Bos taurus* breeds (Angus and Blanco Orejinegro) in this population. This caused the composition of the population to change, increasing the proportion of *Bos taurus* in crossbred cattle (particularly Angus), and consequently lowering AFC in the population over time. Another factor that may have helped to lower AFC over time was the culling of heifers that failed to get pregnant at 30 months.

Although significant, the regression coefficient of yearly cow EBV means for CI1 between 1989 and 2004 was close to zero. Thus, CI1 was unaffected by the change in breed composition and culling practices in this population during this period. On the other hand, after an initial decline between 1990 and 1991, the trend for CI2 yearly cow means decreased little from 1991 to 2004 (slope = -0.33 ± 0.47 d/yr; $P = 0.49$) likely influenced by the influx of Angus and Blanco Orejinegro cattle in this population. This suggests that there was a limiting environmental factor that prevented further expression of this trait in this population. Management continued to be extensive and the composition of pastures remained essentially the same during this period. This extensive level of management and nutrition may have prevented crossbred Bos taurus x Zebu cows from achieving shorter CI2 during those years.

4. Conclusions

The low heritabilities for AFC, CI1, and CI2 estimated here indicate that genetic improvement for these traits would be slow in this multibreed population. Genetic trends were favorable for all traits. However, genetic changes were primarily due to introduction of animals and semen from Angus and Blanco Orejinegro breeds to the Zebu base population rather than selection. Although estimates of heritabilities for AFC, CI1, and CI2 were low, it would be advantageous to implement a multibreed genetic evaluation system for these traits. This could help stimulate much needed higher levels of data collection.

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Table 1

Number of cows by breed-group-of-sire x breed-group-of-dam combination[1] for AFC, CI1, and CI2

Breed group of dam	Trait	Breed group of sire			
		A	B	Z	A x Z
B	AFC		10		
	CI1		5		
	CI2		8		
Z	AFC	788	53	638	
	CI1	634	22	493	
	CI2	555	22	498	
AxZ	AFC	3	18	108	9
	CI1	2	3	57	5
	CI2			27	
¾Z x ¼A	AFC	3			

[1] A = Angus; B = Blanco Orejinegro; Z = Zebu.

Table 2

Heritabilities (diagonal), genetic correlations (above diagonal), and phenotypic correlations (below diagonal) for AFC, CI1, and CI2

Trait	AFC	CI1	CI2
AFC	0.15 ± 0.13	0.33 ± 0.41	0.40 ± 0.36
CI1	0.40 ± 0.04	0.11 ± 0.06	0.99 ± 0.54
CI2	0.09 ± 0.05	0.09 ± 0.05	0.18 ± 0.11

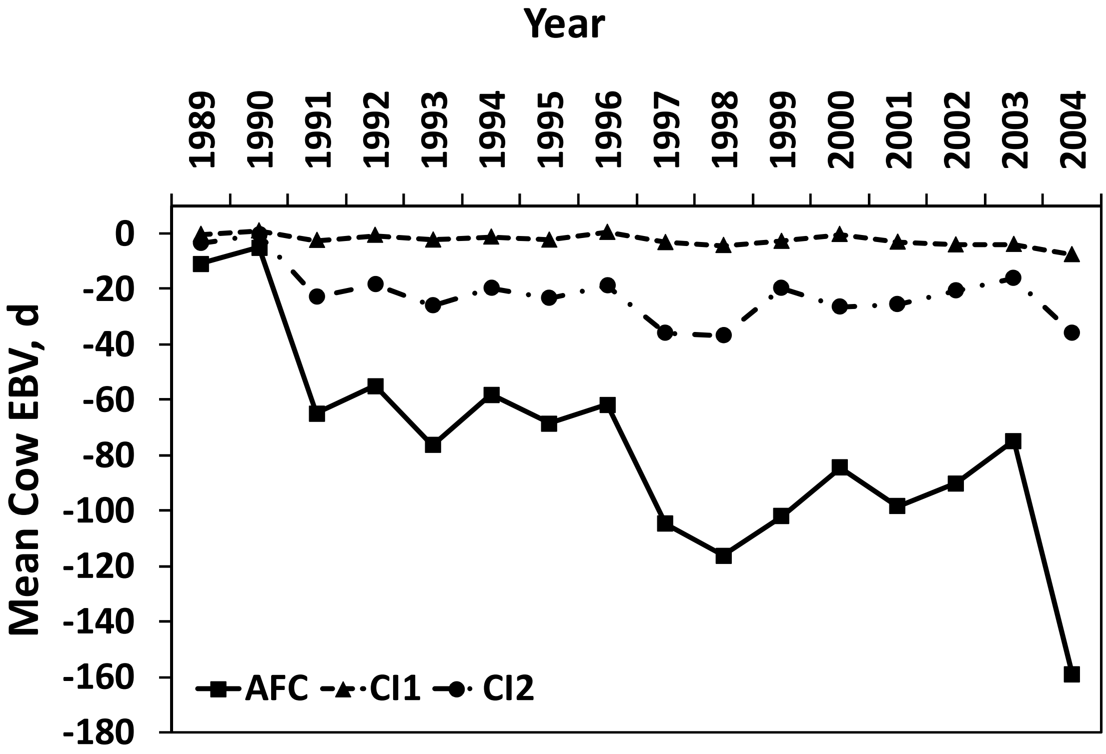

Fig. 1. Yearly means of cow EBV for AFC, CI1, and CI2