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Weaning weight and post-weaning gain genetic parameters and genetic trends in a Blanco Orejinegro-Romosinuano-Angus-Zebu multibreed cattle population in Colombia[§]

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Abstract

Genetic parameters and genetic trends for weaning weight adjusted to 240 d of age (WW240), and weight gain from weaning to 24 mo of age (GW730) were estimated in a Colombian beef cattle population composed of Blanco Orejinegro, Romosinuano, Angus, and Zebu straightbred and crossbred animals. Calves were born and weaned in a single farm, and moved to 14 farms postweaning. Data were analyzed using a multiple trait mixed model procedures. Estimates of variance components and genetic parameters were obtained by Restricted Maximum Likelihood. The 2-trait model included the fixed effects of contemporary group (herd-year-season-sex), age

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of dam (WW240 only), breed direct genetic effects (as a function of breed fractions of calves), breed maternal genetic effects (as a function of breed fractions of dams; WW240 only), individual heterosis (as a function of calf heterozygosity), and maternal heterosis (as a function of dam heterozygosity; WW240 only). Random effects for WW240 were calf direct genetic, dam maternal genetic, permanent environmental maternal, and residual. Random effects for GW730 were calf direct genetic and residual. All relationships among animals were accounted for. Program AIREML was used to perform computations. Estimates of heritabilities for additive direct genetic effects were 0.20 ± 0.003 for WW240, and 0.32 ± 0.004 for GW730. Maternal heritability was 0.14 ± 0.002 for WW240. Estimates of heritability suggest that selection for preweaning and postweaning growth in this population is feasible. Low direct and maternal preweaning heritabilities suggest that nutrition and management should be improved to allow fuller expressions of calf direct growth and cow maternal ability. The genetic correlation between direct additive and maternal additive effects for WW240 was -0.42 ± 0.009, indicating an antagonistic relationship between these effects. The correlation between additive direct genetic effects for WW240 and GW730 was almost zero (-0.04 ± 0.009), suggesting that genes affecting growth preweaning may differ from those influencing growth postweaning. Trends were negative for direct WW240 and GW730 weighted yearly means of calves, sires, and dams from 1995 to 2006. Maternal WW240 showed near zero trends during these years. Trends for calf direct WW240 and GW730 followed sire trends closely, suggesting that more emphasis was placed on choosing sires than on dam replacements.

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

1. Introduction

Colombia has a great diversity of climates and ecological regions (IDEAM, 2008) that challenges the ability of one breed to be well adapted and productive in all environments. This has led producers to experiment with a variety of beef breeds in search of genotypes that are suitable to specific sets of environmental conditions. Cattle producers have tried Criollo breeds that have good adaptability and ability to produce meat (Romosinuano) or meat and milk (Blanco Orejinegro) under tough tropical environmental conditions. In addition, producers have imported semen and animals of various beef breeds (Angus, Brangus, Senepol) to increase growth and to improve carcass traits.

Economically relevant growth traits in the Colombian beef commercialization system are weaning weight and weight at 24 mo age. A fraction of calves is sold at weaning as feeders and the remaining ones are kept as replacement heifers and sires or sold as finished animals at 24 mo of age. There are also economic incentives to finish calves as 2-yr olds. This gives commercial producers additional motivation to keep ownership of their calves and to continue to collect performance data postweaning.

Commercial producers in Colombia would greatly benefit from timely genetic evaluations that include weaning weight and postweaning gains based on farm-collected information. Considering the multibreed nature of the beef cattle population in Colombia, genetic evaluations would need to include additive genetic and nonadditive genetic effects to permit the comparison of animals of diverse genetic composition (Elzo and Famula, 1985). Thus, the objectives of this research were to estimate genetic parameters and genetic trends for weaning weight and postweaning gain from weaning to 24 mo age in a multibreed population composed of Blanco Orejinegro, Romosinuano, Angus, and Zebu cattle in Colombia.

2. Materials and methods

2.1. Animals and data

This study used growth data collected in 14 farms located in the northern coastal and Antioquia regions of Colombia by a private cattle company (Custodiar S.A., Medellin, Colombia) from 1995 to 2007. The dataset consisted of 9,668 weaning weights and 1,357 2-yr old weights. Weaning weights were adjusted to 240-d of age (WW240), and 2-yr old weights were adjusted to 730 d of age using formulas similar to those used by the Beef Improvement Organization guidelines (BIF, 2002). Then, postweaning gain between weaning and 730 d age (GW730) was computed as the difference between adjusted weight to 730 d and WW240. The pedigree file included 13,763 calves, sires, and dams.

Four breeds were represented in the dataset: 2 Criollo breeds (Blanco Orejinegro and Romosinuano), Angus, and Zebu. Zebu included commercial crossbred *Bos indicus* cattle of Brahman, Guzerat, and Nellore origins, as well as Brahman sires imported from the USA. Records were from purebred animals from 3 breeds: Blanco Orejinegro, Romosinuano, Zebu, and from crossbred animals composed of 2, 3, and 4 breeds. Table 1 presents numbers of calves by breed-group-of-sire x breed-group-of-dam combination.

2. 2. Management and feeding

Calves were born and raised until weaning in a single farm owned by the Custodiar company. Farm La Leyenda is located in the municipality of Caucasia, Antioquia, Colombia. Approximately 12% of the yearly calf crop was kept postweaning and distributed among 14 farms in the departments of Antioquia and Cordoba, including La Leyenda; the remaining calves were sold to market.

Cows and preweaning calves at La Leyenda were maintained on pastures (*Brachiaria decumbens*, *Brachiaria humidicola*, *Brachiaria brizhanta cultivar*) in a rotational grazing system. During the dry season, cattle were fed corn silage, and either sorghum (*Sorghum vulgare*) or guinea grass (*Pennisetum violaceum*).

Postweaning management and nutrition were also based on rotational grazing on pastures (*Brachiaria decumbens*, *Brachiaria humidicola*, *Brachiaria brizhanta cultivar, Dichanthium aristatum*) throughout the year with supplementation of corn silage, and either sorghum (*Sorghum vulgare*) or *Pennisetum violaceum* during the dry season.

Yearly temperatures ranged from 27 °C to 30.2°C and precipitation fluctuated between 2,130 mm/yr and 2,500 mm/yr. Seasons were dry (December to March) and wet (April to November).

2.3. Genetic predictions and genetic parameters

Data were analyzed using multiple trait mixed model procedures (Henderson, 1976; Henderson and Quaas, 1976; Quaas and Pollak, 1980). Variance and covariance components were estimated using restricted maximum likelihood procedures (Harville, 1977), and computed with software from the University of Georgia using an average information algorithm (AIREMLF90; Misztal, 1997; Tsuruta, 1999).

The model for WW240 included direct and maternal genetic effects and maternal permanent environmental effects, whereas only direct genetic effects were assumed to be relevant for GW730. The 2-trait animal model was as follows:

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix}\begin{bmatrix} f_1 \\ f_2 \end{bmatrix} + \begin{bmatrix} Z_{bD1} & Z_{bM1} & \vdots & 0 \\ 0 & 0 & \vdots & Z_{bD2} \end{bmatrix}\begin{bmatrix} b_{D1} \\ b_{M1} \\ b_{D2} \end{bmatrix} + \begin{bmatrix} H_{D1} & H_{M1} & \vdots & 0 \\ 0 & 0 & \vdots & H_{D2} \end{bmatrix}\begin{bmatrix} h_{D1} \\ h_{M1} \\ h_{D2} \end{bmatrix}$$

$$+ \begin{bmatrix} \mathrm{Z}_{\mathrm{cD1}} & \mathrm{Z}_{\mathrm{dM1}} & \vdots & 0 \\ 0 & 0 & \vdots & \mathrm{Z}_{\mathrm{cD2}} \end{bmatrix}\begin{bmatrix} \mathrm{c}_{\mathrm{D1}} \\ \mathrm{d}_{\mathrm{M1}} \\ \mathrm{c}_{\mathrm{D2}} \end{bmatrix} + \begin{bmatrix} \mathrm{Z}_{\mathrm{peM1}} \\ 0 \end{bmatrix}\left[\mathrm{pe}_{\mathrm{M1}}\right] + \begin{bmatrix} \mathrm{e}_1 \\ \mathrm{e}_2 \end{bmatrix}$$

where:

y_i = vector of records for WW240 (i = 1) and GW730 (i = 2);

f_i = vector of fixed contemporary group (herd-year-season-sex) effects for WW240 and GW730, and age of dam (WW240 only); herd = 1 to 14; year = 1995 to 2007; season: 1 = dry, 2 = wet; sex: 1 = male, 2 = female;

b_{Di} = vector of direct breed fixed effects for WW240 and GW730; 4 breeds: Angus, Blanco Orejinegro, Romosinuano, Zebu;

b_{M1} = vector of maternal breed fixed effects for WW240; 4 breeds: Angus, Blanco Orejinegro, Romosinuano, Zebu;

h_{Di} = vector of direct heterosis fixed effects for WW240 and GW730;

h_{M1} = vector of maternal heterosis fixed effects for WW240;

c_{Di} = vectors of additive direct genetic random effects for WW240 and GW730;

d_{M1} = vector of maternal additive genetic random effects for WW240;

pe_{M1} = vector of permanent environmental maternal random effects for WW240;

e = vector of residuals for WW240 and GW730;

X_i = incidence matrices relating WW240 and GW730 to contemporary group effects;

Z_{bDi} = incidence matrix relating WW240 and GW730 to direct breed effects through the expected breed fractions of calves;

Z_{bM1} = incidence matrix relating WW240 to maternal breed effects through the expected breed fractions of dams;

H_{Di} = incidence matrix relating WW240 and GW730 to direct heterosis effects through expected heterozygosities in calves, where expected direct heterozygosity = prob (breed j sire) × prob(breed k dam) + prob(breed k sire) × prob(breed j dam), j ≠ k = Angus, Blanco Orejinegro, Romosinuano, Zebu;

H_{M1} = incidence matrix relating WW240 to maternal heterosis effects through expected heterozygosities in dams, where expected maternal heterozygosity = prob (breed j maternal grandsire) × prob(breed k maternal granddam) + prob(breed k maternal grandsire) × prob(breed j maternal granddam), j ≠ k = Angus, Blanco Orejinegro, Romosinuano, Zebu;

Z_{cDi} = incidence matrix relating WW240 and GW730 to additive direct genetic effects;

Z_{dM1} = incidence matrix relating WW240 to additive maternal genetic effects;

Z_{peM1} = incidence matrix relating WW240 to permanent environmental effects;

The variance of the vector of random genetic effects, G = A*G_0 where G_0 is a 3 x 3 matrix of additive variances and covariances among c_{D1}, d_{M1}, and c_{D2}. The variance of the vector of maternal permanent environmental effects pe_{M1}, R_{peM1} = I*σ_{peM1}^2. The variance of the vector of residuals, R = I* σ_e^2.

Genetic predictions were computed as a weighted sum of breed genetic effects and random effects (Elzo and Wakeman, 1998). Thus, the EBV for animal ij would be equal to:

$$\hat{u}_{ij} = g_i^0 + \hat{a}_{ij},$$

where:

$\hat{u}_{ij}$ = is the genetic prediction for animal ij,

g_i^0 = genetic group i, and

$\hat{a}_{ij}$ = genetic prediction for animal ij as a deviation from g_i.

Genetic groups in this multibreed population were defined as a weighted sum of breed effects, i.e.,

$$g_i^0 = \sum_{i=1}^{B} p_{ij} b_i^0$$

where:

B = number of breeds,

p_{ij} = fraction of breed_i in animal ij, and

b_i^0 = solution for breed i.

Estimates of variances and covariances were used to compute heritabilities for WW240 and GW730, and genetic and phenotypic correlations between WW240 and GW730. Standard errors of estimates of heritabilities and correlations were computed using the Delta method (Lindgren, 1976).

Weighted yearly means of EBV for calf, sire, and dam WW240 and GW730 direct genetic effects and for dam WW240 maternal were computed to study genetic trends between 1995 and 2006. Weights for calves and dams were equal to 1 and weights for sires were equal to the number of progeny per year. Genetic trends were computed as a linear regression of weighted yearly means on year using the procedure GLM of the Statistical Analysis System (SAS, 2007).

3. Results and discussion

3.1. Description of data

Means and standard deviations (SD) for the analyzed traits in this multibreed population were 177.6 kg and 29.0 kg for WW240, and 152.4 kg and 61.7 kg for GW730. The mean and SD for WW240 were higher than those reported for weaning weights at 244 d in a Venezuelan Holstein-Brahman crossbred population for animals predominantly *Bos taurus* (mean = 132 kg; SD = 21 kg) or *Bos indicus* (mean = 128 kg; SD = 23 kg) (Aranguren-Méndez et al., 2006). Contrarily, the mean WW240 here was lower than values reported for Tropicarne (63% Senepol, 23% Barzona, 9% Brahman, and 5% Charolais) cattle in Mexico (mean = 220.2 kg and SD = 19.4 kg at 240 d; Dominguez et al., 2003a), for Angus, Romosinuano, and Brahman crossbreds in USA (mean = 219.9 kg and SD = 35.2 kg at 229 d; Riley et al., 2007), and for Zebu, Angus, Holstein, Simmental, and Criollo crossbreds in Colombia (mean = 191 kg and SD = 32 kg at 240 d; Arboleda et al., 2007). Mean WW240 could be improved in this cattle by placing dams and calves in paddocks that have better quality pastures. Higher weaning weights would have an immediate economic impact on producers because most Colombian cow-calf producers sell over 70% of their calves at weaning based on weight. Higher weaning weights will also allow replacement heifers to breed earlier, thus reducing replacement costs, and perhaps resulting in longer productive lives.

The mean GW730 value was lower than the value published by Arboleda et al. (2007) for *Bos taurus-Bos indicus* crossbred cattle (225 kg at 858 d), and similar to those reported by Quijano (2002) for Blanco Orejinegro cattle (147 kg at 730 d). The low GW730 mean obtained here suggests that supplementation provided to cattle during the dry season was insufficient to meet their nutritional requirements for growth, thus resulting in low weight gains.

3.2. Breed effects

All direct and maternal breed effects for Angus, Blanco Orejinegro, and Zebu were estimated as deviations from Romosinuano. Direct breed effects for WW240 were negative for Angus (-0.24 ± 4.61 kg; P = 0.69) and Blanco Orejinegro (-0.39 ± 4.74 kg; P = 0.21), and positive for Zebu (14.71 ± 4.52 kg; P = 0.0001). Zebu was clearly superior for WW240 direct effects, and the two Criollo breeds and Angus behaved similarly. This indicates that, under the tropical environmental conditions of this population, purebred Zebu and crossbred calves with a high Zebu fraction had higher preweaning growth ability than that of crossbred calves with higher fractions of the other three breeds. Similar outcomes were obtained for weaning weight (mean calf age = 229 d) in an Angus-Romosinuano-Brahman multibreed herd in the USA (Riley et al., 2007), where breed deviations from Romosinuano for direct weaning weight effects were 24.2 kg for Angus and 35.0 kg for Brahman.

Maternal breed effects for WW240 were 9.56 ± 4.32 kg (P = 0.0001) for Angus, 9.35 ± 4.33 kg (P = 0.003) for Blanco Orejinegro, and 15.74 ± 3.97 kg (P = 0.0001) for Zebu. Thus, purebred Blanco Orejinegro, Zebu, and crossbred dams with large fractions of these breeds or Angus had better maternal ability than purebred Romosinuano and high percentage Romosinuano dams. However, the maternal breed effect for Angus should be taken with caution because there were no purebred Angus dams in this population. Angus was primarily represented by F1 Angus-Zebu and ¾ Angus ¼ Zebu dams. Because these crossbred dams are likely to be better adapted to the hot and humid conditions in this region, Angus maternal ability may have been overestimated.

Zebu had the best maternal ability of all breeds in this population. Similar results were found in other tropical and subtropical regions. Zebu was superior to

Belmont Adaptaur for maternal effects (13.3 ± 2.4 kg at 193 d) in Rockhampton, Australia (Prayaga, 2003). Franke et al. (2001) reported that Brahman had better maternal ability than Angus in Baton Rouge, Louisiana (12.9 ± 5.3 kg; 205 d), and Riley et al. (2007) found Brahman to have superior maternal ability to Angus (40.2 kg; 229 d) and Romosinuano (5.3 kg; 229 d) in Brooksville, Florida.

Estimates of direct breed effects for GW730 were positive for Angus (19.61 ± 13.08 kg; $P = 0.0001$) and Zebu (63.54 ± 14.07 kg; $P = 0.0001$), and negative for Blanco Orejinegro (-7.07 ± 12.56 kg; $P = 0.19$). Criollo breeds had substantially lower performance for postweaning gain than Angus and Zebu. As with preweaning direct and maternal breed effects, Zebu had the best performance of all breeds in this population. Studies considering weight gains between weaning and two years of age were unavailable for comparison. However, Zebu was superior to Belmont Adaptaur for direct postweaning gain between 193 d and 524 d of age in Rockhampton, Australia (27.3 kg; Prayaga, 2003).

3. 3. Heterosis effects

Direct and maternal heterosis here were defined in terms of intralocus interbreed interactions between alleles from any two different breeds. Thus, heterosis estimates are averages of interbreed interactions of all available parental breed combinations.

Estimates of heterosis were 17.28 ± 1.28 kg ($P < 0.0001$) for WW240 direct genetic effects, 4.49 ± 1.77 kg ($P < 0.30$) for WW240 maternal genetic effects, and 31.00 ± 7.16 kg ($P < 0.003$) for GW730 direct genetic effects.

The estimate of direct heterosis for WW240 was over three times the value of maternal heterosis. This may be an indication that maternal milk was substantially less influenced by non-additive interbreed genetic effects than direct preweaning growth. Alternatively, it may be imply that the level of nutrition prevented crossbred cows from fully expressing their heterosis potential for milk production. The high and significant value of direct heterosis for GW730 suggests that it would be economically advantageous to consider expected heterozygosis of the progeny when planning matings in this population.

The estimate of direct heterosis for WW240 was lower than the average (21.0 kg) of three direct heterosis estimates for weaning weight (mean calf age = 229 d) in Florida (Romosinuano-Brahman = 20.5 ±1.5 kg; Romosinuano-Angus = 14.6 ± 1.4 kg; Brahman-Angus = 27.8 ± 1.7 kg; Riley et al., 2007). This value was also lower than the estimate for Angus x Brahman in Louisiana (38.6 ± 5.7 kg; 205 d; Franke et al., 2001), but higher than that of an Angus x Nellore population in Brazil (4.0 to 12.6 kg; 205 d; Kippert et al., 2008), and a range of direct heterosis estimates for three *Bos taurus x Bos taurus* crossbred populations in Nebraska (3.5 ± 10.9 to 14.2 ± 2.7 kg; 200 d; Rodriguez et al., 1997).

The estimate of maternal heterosis for WW240 was lower than that reported for an Angus-Brahman multibreed population in Florida (21.0 ± 3.6 kg; 205 d; Elzo et al., 1990a), but higher than another estimate for these same two breeds in Louisiana (-1.1 ± 5.1 kg; 205 d; Franke et al., 2001). Maternal heterosis here was also lower than values estimated for Red Angus x Nellore in Brazil (27.2 ± 4.0 kg; 205 d; Perotto et al., 1999), and for three *Bos taurus x Bos taurus* crossbred populations in the USA (5.5 ± 1.4 kg to 9.9 ± 1.8 kg; 200 d; Rodriguez et al., 1997).

Estimates of direct heterosis for weight gain from weaning to two years of age were unavailable in the literature. However, the estimate of direct heterosis for GW730 was lower than the average of direct heterosis for weight gain between 205 d and 550 d of age for bulls and heifers in an Angus-Brahman multibreed population in Florida (44.2 kg; Elzo et al., 1990b). On the other hand, Kippert et al. (2008) estimated an heterosis value of 0.065 kg/d for postweaning average daily gain (205 d to 550 d of age) in an Angus x Nellore multibreed population in Brazil, a comparable value to the one obtained here from 240 d to 730 d of age 0.063 kg/d (= 31.0 kg/(730 d – 240 d)).

3. 4. Genetic variances and covariances

The estimates of direct additive genetic variances were 96.44 ± 1.16 kg^2 for WW240 and 497.87 ± 6.00 kg^2 for GW730. Maternal additive genetic and permanent environmental variances for WW240 were 69.40 ± 0.21 kg^2 and 27.15 ± 0.33 kg^2. Phenotypic variances were 484.95 ± 4.64 kg^2 for WW240 and 1559.27 ± 16.42 kg^2 for GW730.

The estimate for additive direct genetic variance for WW240 in this population was higher than that for Romosinuano (72 kg^2), but lower than that for Zebu (108.2 kg^2) in a Colombian Romosinuano-Zebu multibreed population (Elzo et al., 1998). Further, this WW240 additive direct genetic estimate was larger than corresponding estimates for Sanmartinero (52.8 kg^2), and Zebu (49.1kg^2) in a Colombian Sanmartinero-Zebu multibreed population (Elzo et al., 2001).

The estimate of maternal genetic variance for WW240 was similar to those reported by Elzo et al. (1998) for Romosinuano (73.6 kg^2) and by Quintero et al. (2007) in a population composed by Brahman and commercial Zebu cattle (65.2 kg^2). Lower estimates of maternal genetic variances were found in a Sanmartinero-Zebu cattle population in Colombia (61.8 kg^2 for Sanmartinero, and 61.7 kg^2 for Zebu; Elzo et al., 2001). Similarly, lower maternal genetic variances were obtained in three *Bos* *taurus* multibreed populations in the USA for weaning weights adjusted to 200 d (36.9 to 63.5 kg^2; Rodriguez et al., 1997).

Estimates of additive genetic variances for weight gains between weaning at 240 d age and two years age were unavailable in the literature. However, estimates of additive genetic variances for weight gains between 240 d age and 550 d age were reported for Tropicarne cattle in Mexico (136.6 kg^2; Dominguez et al., 2003b), and between 240 d and 480 d of age in a Sanmartinero-Zebu Colombian multibreed population (146.0 kg^2 for Sanmartinero and 147.3 kg^2 for Zebu; Elzo et al., 2001). The number of days between 240 d and 730 d age here is approximately twice the number of days between 240 d and 480 d in the Sanmartinero-Zebu study. Thus, postweaning additive genetic variances for calves between 240 d and 730 d of age in the Sanmartinero-Zebu population would approximately be four times the additive genetic variances estimated by Elzo et al. (2001). These estimates (584 kg^2 for Sanmartinero and 589.2 kg^2 for Zebu) were somewhat higher than the estimate of 497.87 ± 6.00 kg^2 for GW730 obtained here.

The estimate of additive genetic covariance between additive direct and maternal effects for WW240 was negative (-34.06 ± 0.76 kg^2), which is consistent with values reported in the literature (Meyer, 1992; Waldron et al., 1993; Elzo and Wakeman, 1998; Elzo et al., 2001). Negative estimates of additive genetic covariances were also obtained between direct genetic effects for WW240 and GW730 (-8.97 ± 1.87 kg^2), and between maternal genetic effects for WW240 and direct genetic effects for GW730 (-17.92 ± 1.59 kg^2). Negative estimates of covariances between direct and maternal genetic effects for WW240 and postweaning gains from 240 to 480 d of age were obtained in Colombian

Romosinuano-Zebu (Elzo et al., 1998) and Sanmartinero-Zebu (Elzo et al., 2001) multibreed populations.

3. 5. Heritabilities and genetic correlations

Estimates of heritabilities for WW240 were 0.20 ± 0.003 for additive direct genetic effects and 0.14 ± 0.002 for maternal genetic effects. The higher value of heritability for WW240 additive direct indicates that calves' own ability to grow had a higher influence on their weights at weaning than the maternal ability of their dams. Because maternal ability is largely due to maternal milk, this suggests that the amount of milk dams provided to their calves was insufficient to meet their growth demands. Low milk production in this cow population may be due to low genetic milking ability, or, more likely to insufficient nutrition to achieve their milk genetic potential.

Estimates of direct and maternal heritabilities for WW240 were higher than those obtained in three Colombian multibreed populations: Romosinuano-Zebu (0.09 to 0.10 for direct; 0.09 to 0.13 for maternal; Elzo et al., 1998), Sanmartinero-Zebu (0.08 to 0.10 for direct; 0.10 to 0.11 for maternal; Elzo et al., 2001), and a Zebu-Angus-Holstein-Simmental-Criollo (0.08 for direct; 0.08 for maternal; Arboleda et al., 2007). The value of direct heritability for WW240 was also higher than the ones estimated for Tropicarne in Mexico (0.11 ± 0.06; Dominguez et al., 2003a) and for Romosinuano in Colombia (0.14 ± 0.05; Ossa et al., 2005). The estimate for maternal heritability was similar to that of Tropicarne (0.15 ± 0.06) and Romosinuano (0.12 ± 0.03).

The estimate of heritability for direct genetic effects for GW730 was 0.32 ± 0.004. This value of heritability suggests that the postweaning feeding and management system allowed a moderate level of expression of the genetic growth potential of calves, thus selection for GW730 would be expected to be effective in this population. As indicated above, no comparable studies were found for this trait. However, heritability estimates for postweaning gains from 240 d to 480 d of age were 0.14 in Romosinuano, 0.44 in Sanmartinero, and it ranged from 0.14 to 0.37 in Zebu in 2 Colombian multibreed populations (Elzo et al., 1998, 2001). Heritability estimates for weight gains from 240 d to 550 d were 0.22 in a Zebu-Angus-Holstein-Simmental-Criollo population in Colombia (Arboleda et al., 2007), and 0.17 ± 0.08 for Tropicarne in Mexico (Dominguez et al., 2003a).

The estimate of the genetic correlation between direct additive and maternal additive genetic effects for WW240 was negative (-0.42 ± 0.009) indicating an antagonistic relationship between these effects. However, the negative correlation was medium, thus there was a sizable number of animals (22%) whose EBV was above the population mean for both traits. Thus, selection of sires and dams with positive direct and maternal EBV for WW240 is feasible in this population.

The correlation between maternal additive genetic effects for WW240 and direct additive genetic effects for GW730 was low and negative (-0.10 ± 0.009). Thus, calves whose dams provided greater care and quantities of milk in the preweaning period tended to have lower postweaning gains. This suggests that calves that received more milk from their dams may have been less prepared to cope with the postweaning nutritional conditions than calves that consumed less milk preweaning. As with direct and maternal WW240, a large fraction of this population (25%) had positive EBV for maternal WW240 and direct GW730.

Lastly, the genetic correlation between direct additive effects for WW240 and GW730 was nearly zero (-0.04 ± 0.009). It appears that genes affecting calves own ability to grow under the nutritional conditions before weaning differed substantially from those responsible for growth under the postweaning nutritional environment. This suggests that selection of animals for direct WW240 would have essentially no impact on GW730 in this population. A near zero correlation between WW240 and weight gain from 240 d to 480 d of age was also found for Sanmartinero (-0.01), Zebu (0.02 to 0.05), whereas a somewhat higher negative correlation existed for Romosinuano (-0.24), in two Colombian multibreed populations (Elzo et al., 1998, 2001).

Environmental and phenotypic correlations between WW240 and GW730 were also low negative (environmental = -0.19 ± 0.01; phenotypic = -0.16 ± 0.007). These negative values reconfirm the negative impact that lower quality pastures after weaning had on calf growth from weaning to two years of age.

3. 4. Weighted genetic means per year

Fig. 1 shows the trends for yearly EBV means of calves, their sires, and their dams for WW240 and GW730 direct genetic effects from 1995 to 2006. Negative trends existed for yearly means of calves, sires, and dams for both WW240 direct and GW730 direct during this period. The negative slope of the trend for WW240 direct was steeper for calves (-0.52 ± 0.19 kg/yr; $P < 0.05$) and for sires (-0.69 ± 0.35 kg/yr; $P > 0.05$) than for dams (-0.38 ± 0.06 kg/yr; $P < 0.01$). Similarly, the slope of the trend for GW730 direct was more negatively inclined for sires (-3.64 ± 1.00 kg/yr; $P < 0.01$) and calves (-2.58 ± 0.51 kg/yr; $P < 0.01$) than for dams (-1.51 ± 0.19 kg/yr; $P < 0.01$).

The pattern of yearly means for calves and sires showed a closer association than between calves and dams. Correlations between calf and sire yearly means were equal to 0.98 (P < 0.001) for WW240 direct and for GW730, whereas the correlation between calf and dam yearly means was 0.69 (P < 0.01) for WW240 and 0.81 (P < 0.002) for GW730. The closer association between sire and calf yearly means suggests that criteria used to choose bulls as sires had a substantially greater influence on progeny genetic values for WW240 direct and GW730 direct than criteria used to choose replacement dams. The large fluctuations in sire yearly means for WW240 and GW730 were due to changes in the breeds of sires used in this population over time. Low sire EBV for WW240 and GW730 direct were due to extensive use of sires of various breed groups whose EBV were below the mean of sires used from 1995 to 2006. In particular, imported Angus and Zebu sires were responsible for the low mean sire EBV in 1997, and Romosinuano, Blanco Orejinegro, Angus-Zebu crossbred sires caused the low means in 2002, 2003, and 2004. On the other hand, Brahman sires raised sire mean EBV for WW240 and GW730 in 2000 and 2001, and were also instrumental in the recovery of sire means in 2005 and 2006.

Yearly means for dam WW240 maternal had only minor changes from 1995 to 2006. The trend for dam WW240 maternal was essentially zero (-0.013 ± 0.020; P < 0.0001). This trend suggests that replacement heifers in this population were primarily chosen based on the maternal performance of their dams. Use of this criterion decreased the impact of inferior sires for direct WW240 and GW730 on replacement heifers, and hence the low negative trend for yearly means of dams for these traits.

4. Conclusions

Estimates of heritability for direct and maternal WW240 and for direct GW730 suggest that selection for these traits is feasible in this population. However, heritability estimates for direct and maternal WW240 were low indicating that the level of nutrition and management preweaning needs to be improved to allow fuller expression of these traits in calves and cows. Although heritability for GW730 was medium, postweaning gains were low. Thus, postweaning nutrition and management also needs improvement. Higher quality pastures and additional supplementation would help calves achieve their growth potential, particularly high percent Angus crossbred calves. Implementation of these management and nutritional measures would need to be counterbalanced with additional economic returns from calf sales at weaning and at two years of age.

Genetic trends were negative for all traits and effects, except for maternal WW240. This suggests that a genetic evaluation system for all animals in the population needs to be implemented. Animals would need to be evaluated not only for economically relevant growth traits, but also for reproduction and carcass traits. Genetic predictions from these evaluations should be used to select superior sires and dams to be used in carefully planned mating systems. Crossbred matings exploiting direct heterosis would be advantageous, particularly *Bos taurus* x Zebu matings.

The low performance of the Romosinuano and Blanco Orejinegro breeds in this multibreed population was likely due to lack of culling and selection in these breeds due to low population numbers (less than 3,000 animals each; Quijano, 2002; Ossa, 2007). The Ministry of Agriculture and Rural Development in Colombia initiated a promotion program of Criollo cattle in 2005 with the purpose of increasing population numbers (MADR, 2008). Larger population sizes, genetic evaluation, and appropriate culling and selection programs should help improve the genetic worth and commercial value of Romosinuano and Blanco Orejinegro cattle. This would increase their competitiveness in straightbred and crossbred mating programs.

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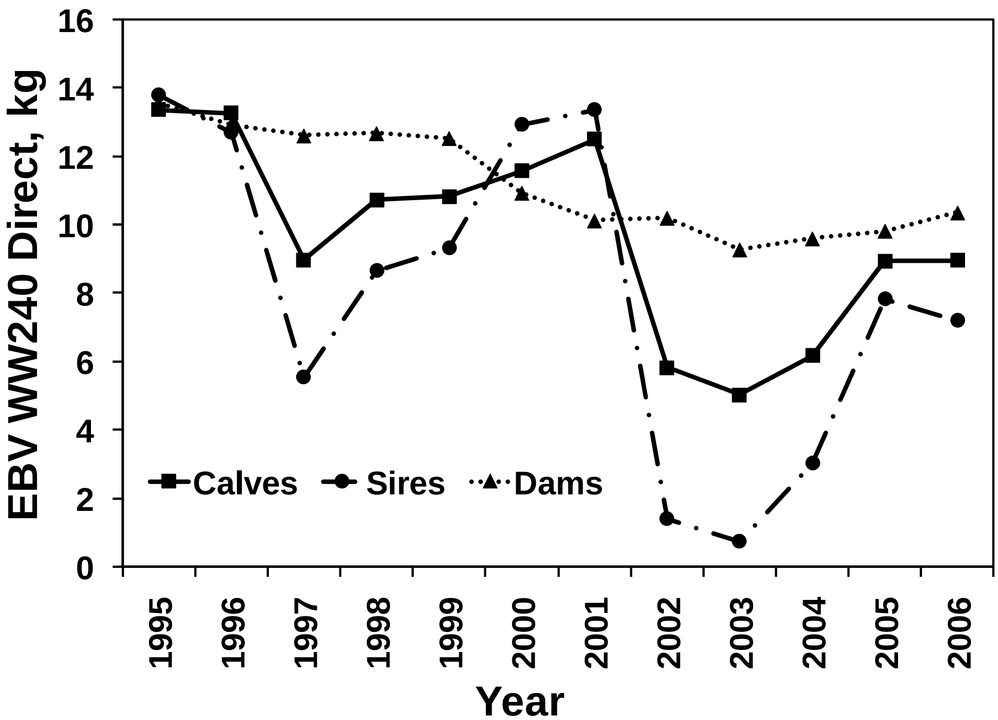
Table 1

Number of animals by breed-group-of-sire x breed-group-of-dam combination[1] for WW240 and GW730

Breed group of dam	Trait	Breed group of sire											
		A	B	R	Z	AxB	AxZ	BxA	ZxA	Rx(AxZ)	5/8Ax3/8Z	¾Ax¼Z	¾Zx¼A
B	WW240	3	46		13								
	GW730		6		1								
R	WW240	9	9	23	7				1				
	GW730		2	6	3								
Z	WW240	2211	197	260	2294						7		9
	GW730	274	43	73	161								2
AxZ	WW240	284	697	539	1778	132	355	4			38		
	GW730	23	210	127	196	11	6						
BxZ	WW240	120	19	14	42		5		9				
	GW730	38	2	1	4								
RxZ	WW240	24	12	12	37	3							
	GW730	4	1	1		1							
Ax(BxZ)	WW240				1								
Bx(AxZ)	WW240	8	3	1	9								
	GW730	2	1										
Rx(AxZ)	WW240	4	2	1	7				2				
¾Ax¼Z	WW240		2		3	1	482						
	GW730		1				112						
¾Zx¼A	WW240		32	43	60	5			13	6		7	
	GW730		8	11	10							1	

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



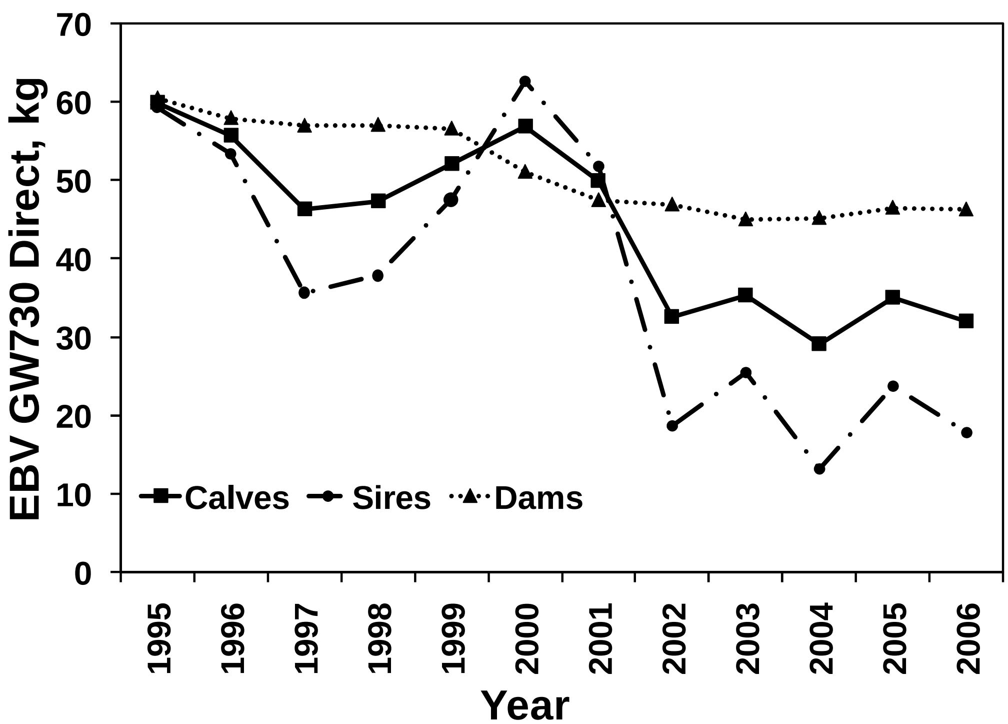


Fig. 1. Yearly EBV means for WW240 and GW730 for calves, sires, and dams