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Postweaning growth of performance-tested buffaloes (*Bubalus bubalis,* Artiodactyla, Bovidae) reared under no-milking versus a dual-purpose system¤

Crecimiento posdestete de búfalos (**Bubalus bubalis,* Artiodactyla, Bovidae) sometidos a pruebas de desempeño provenientes de dos sistemas de manejo predestete: cría sin ordeño y doble propósito***

Crescimento pós-desmame para búfalo (**Bubalus bubalis,* Artiodactyla, Bovidae) emprovas de desempenho a partir dedois sistemas de manejo pré-desmame: sem ordenha e dupla aptidão***

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Summary

Objective: the objective of this study was to compare growth traits in buffaloes reared in farms using a pre-weaning management system with no milking (NM), or a dual-purpose system (DP: meat and milk production). **Methods:** performance tests were conducted at the Experimental Station of the University of Antioquia, located in Barbosa (Antioquia, Colombia). Buffaloes were confined and fed with fresh Maralfalfa grass (*Pennisetum* sp.) ad libitum, plus two kilograms of mixed plus two 2 kilograms of concentrate supplement per day. Weight, ultrasound, and bovinometric measurements were taken every 14 d. Bovinometric measurements were chest girth (CG), height at withers (HW), and height at sacrum (HS). Ultrasound measurements were Longissimus muscle area (REA) and rump fat thickness (RFT). Traits were analyzed using a linear regression and second order polynomial model using unstructured variance-covariance matrices and accounting for relationships among animals. **Results:** all the traits in DP animals, as well as RFT, HW, and HS in NM animals fit well with a second-order regression mixed model. Weight, CG, and REA in NM animals fit well with a first-order regression mixed model. The rate of increase for HW and HS declined at the end of the test in NM animals, while weight, CG, RFT, and REA did not. The DP buffaloes displayed an accelerated rate of increase for all traits towards the end of the evaluation. The non-zero estimates of genetic variances for random regression effects suggests that these characteristics may be improved genetically in Colombia. Environmental and genetic differences among farms may have influenced the high variability among individuals for the intercept. **Conclusions:** the linear regression variances were small for all traits,

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suggesting that although selection of animals within these performance tests is possible, expected changes in the buffalo population will be small.

Key words: *beef cattle, bovinometric, genetic improvement, growth, mixed models, performance test.*

Resumen

Objetivo: el objetivo de este estudio fue comparar características de crecimiento de búfalos sometidos a pruebas de desempeño, pertenecientes a dos sistemas de producción: cría sin ordeño (CSO) y doble propósito (DP). **Métodos:** las pruebas se realizaron en la Estación Experimental de la Universidad de Antioquia, ubicada en Barbosa, Colombia. Los animales fueron confinados y alimentados con pasto Maralfalfa (*Pennisetum* sp.) y dos kilogramos de un suplemento concentrado por día. El peso, las medidas de ultrasonido y bovinométricas fueron tomadas cada 14 días. Las medidas bovinométricas fueron perímetro torácico (PT), altura a la cruz (AC) y altura al sacro (AS). Las medidas por ultrasonido fueron área del músculo Longissimus (AOL) y espesor de grasa de la cadera (EGC). Las características fueron analizadas utilizando un modelo de regresión lineal mixto de primer orden y polinomial de segundo orden, con matrices de varianzas y covarianzas sin estructura, teniendo en cuenta la matriz de parentesco entre los animales. **Resultados:** todas las características en los animales provenientes del sistema DP y las caracteristicas EGC, AC y AS en animales de CSO, presentaron un mejor ajuste al modelo de regresión de segundo orden. El peso, PT y AOL en animales de CSO ajustaron mejor con un modelo de regresión de primer orden. La tasa de incremento de AC y AS en los búfalos de CSO declinó al final de la prueba, mientras que las otras características no presentaron disminución. Los búfalos del sistema DP aceleraron la tasa de incremento para todas las características al final de la evaluación. Las varianzas genéticas estimadas para los coeficientes de regresión fueron diferentes de cero, sugiriendo que estas características pueden ser mejoradas genéticamente en Colombia. Diferencias ambientales y genéticas entre fincas pueden haber influido en la alta variabilidad del intercepto entre los individuos. **Conclusiones:** las varianzas de los coeficientes de la regresión lineal fueron pequeñas para todas las características, sugiriendo que, aunque la selección de animales en pruebas de desempeño es posible, los cambios esperados en la población de búfalos serán pequeños.

Palabras clave: *bovinometría, crecimiento, ganado de carne, mejoramiento genético, modelos mixtos, pruebas de desempeño.*

Resumo

Objetivo: o objetivo deste estudo foi comparar as características de crescimento de búfalos submetidos em testes de desempenho. Estes búfalos foram provenientes de fazendas de gado de corte (CSO) ou dupla aptidão (DP). **Métodos:** as provas foram conduzidas na Estação Experimental da Universidade de Antioquia, localizada no município de Barbosa, na Colômbia. Os animais foram confinados e alimentados com capim Maralfalfa (*Pennisetum* sp.) e dois kg de suplemento por dia. Medidas morfométricas, de pesagem e ultrassom foram realizadas a cada 14 dias. As medidas morfométricas foram: perímetro torácico (PT), altura de cernelha (AC) e altura da garupa (AS). As mensurações de ultrassom foram: área do olho do lombo (AOL) e espessura de gordura na anca (EGA). As características foram analisadas utilizando um modelo de regressão linear misto de primeira ordem e polinomial de segunda ordem, com uma matriz de variância e covariância não estruturada, tendo em conta a matriz de parentesco entre os animais. **Resultados:** todas as características em búfalos provenientes do sistema DP e as características EGA, AC e AS em búfalos do sistema CSO, apresentaram um melhor ajuste em regressões de segunda ordem. O Peso, PT e AOL em animais provenientes do sistema CSO, ajustaram se melhor em regressões de primeira ordem. Em animais do sistema CSO a taxa de incremento da AC e AS diminuiu no final do período, as outras características não apresentaram diminuição. Os búfalos do sistema DP apresentaram um aumento considerável de todas as características ao final da avaliação. A variância genética estimada para os coeficientes de regressão foram diferentes de zero, o que sugere que estas características podem ser melhoradas geneticamente na Colômbia. Diferenças ambientais e genéticas entre as fazendas podem ter influenciado na alta variabilidade do intercepto entre os indivíduos. **Conclusões:** as variâncias do coeficiente de regressão linear foram pequenas para todas as características, sugerindo que, embora a seleção de animais em testes de desempenho seja possível, as mudanças esperadas na população de búfalos serão pequenas.

Palavras chave: *crescimento, gado de corte, melhoramento genético, modelos mistos, morfometría bufalina, testes de desempenho.*

Introduction

Performance tests are commonly used to initiate the evaluation process of economically important traits in beef cattle, particularly in countries where it is difficult to collect reliable information in the field. Performance tests evaluate animals under the same environmental conditions, thus performance differences among animals are highly associated to their genetic differences (Pereira *et al*., 1999; Nephawe*et al*., 2006). These tests play an important role when genetic evaluation systems are initially implemented in a population usually due to poor genetic connectivity among farms, which negatively affects genetic evaluations of animals across herds (Razook *et al*., 1997).

The first performance tests to evaluate postyearling growth in buffaloes from two preweaning rearing systems were recently conducted in Colombia. These preweaning rearing systems were: a) no-milking (NM), whose objective was to obtain a high weaning weight of the calf and a high slaughter weight at an early age, and b) dual purpose system (DP), where buffalo cows are milked once a day, thus calves attain lower weaning weights and reach slaughter weight at a later age, compared with the NM system.

Traits evaluated in buffalo performance tests included body weight, and bovinometric and ultrasound measurements. These traits can be used to statistically analyze growth in buffaloes as well as to determine the existence of variability among individual animal growth curves within a population (France *et al*., 1996; El Halimi, 2005).

The objective of this study was to compare post-yearling growth in buffaloes coming from pre-weaning systems with and without cow milking using weight, ultrasound, and bovinometric measurements taken at a performance test station.

Materials and methods

Location

Performance tests were conducted at the Experimental Station of the University of Antioquia, located in Barbosa (Antioquia, Colombia), an area classified as subtropical wet forest (altitude: 1300 m above sea level, temperature: 23 °C, precipitation: 1800 mm / year).

Animals and Diets

A total of 122 animals from nine Colombian municipalities were evaluated at the Experimental Station. 45 animals came from NM herds located in Buenavista and Ayapel (both in Córdoba province), Cimitarra (Santander), and Norcasia (Caldas). The other 77 animals came from DP herds located in Montería, Buenavista, Montelíbano, Tierralta, Ayapel (all in Córdoba), Barrancabermeja (Santander), and Puerto Nare (Antioquia). Animals shared a high proportion of Murrah breed.

Four post-yearling performance tests were conducted, two for NM buffaloes (first: between July and October 2009; second: August and December 2010), and another two for DP buffaloes (first: between December 2009 and April 2010; second: February and May 2011). The number of buffaloes participating in each performance test, duration of each test, means and standard deviations for age, and initial and final weight are presented in table 1.

Animals were housed in individual pens (16 m^2), each equipped with a feeder and water dispenser. Pens had cement floor, no bedding, and were partially roofed (4 m^2). The diet consisted of fresh Maralfalfa grass (*Pennisetum* sp.) offered *ad libitum*, and 2 kg of a concentrate supplement per day. The supplement was composed of corn (50%), extruded soybean (15%), soybean (10%), extruded corn (10%), homogeneous mix of extruded corn and soybean meal (10%), mineral salt containing phosphorus (8%), calcium carbonate (1%), and 2% of a vitamin and mineral premix. Table 2 shows the chemical composition of Maralfalfa grass and the concentrate supplement.

Table 1. Age and weight averages and standard deviations during post-yearling performance tests of buffaloes reared under two different preweaning systems.

Trait	Production system			
	No-milking system		Dual purpose production system	
	PT_1	PT_2	PT_1	PT_2
Number of animals	26	19	33	44
Age at the beginning of test, d	285 ± 26	306 ± 18	426 ± 24	484 ± 23
Weight at the beginning of test, kg	261 ± 29	295 ± 26	240 ± 41	274 ± 51
Weight at the end of test, kg	342 ± 39	357 ± 26	314 ± 37	354 ± 45
Test length, d	116	112	126	111

PT_1: first performance test. PT_2: second performance test.

Table 2. Chemical composition of the diet offered during post-yearling performance tests of buffaloes reared under two different preweaning management systems.

Nutrient composition	Maralfalfa grass[1]				Feed supplement			
	NM		DP		NM		DP	
	PT_1	PT_2	PT_1	PT_2	PT_1	PT_2	PT_1	PT_2
Protein	7.46	8.49	5.88	7.60	13.98	14.20	14.63	16.48
Energy (Kcal/kg)	3866	3774	3857	3974	3813	3800	3846	4418
Acid detergent fiber (%)	48.10	47.89	44.68	43.79	12.53	9.19	9.50	8.14
Neutral detergent fiber (%)	71.56	64.79	71.29	63.47	18.55	20.14	17.15	15.20
Lignin (%)	11.92	11.66	12.61	11.59				
Total ash (%)					8.50	7.50	6.35	6.80
Calcium (%)					2.07	2.05	1.82	1.95
Ether extract (%EE)					1.53	1.95	2.41	2.00
Phosphorus (%)					0.19	0.20	0.21	0.20

[1] The composition of maralfalfa grass is the average of four samples taken each month, which were composed of three subsamples taken for three consecutive days before each measurement.

[2] NM: preweaning management system with no milking; DP: dual purpose preweaning management system.

PT_1: first performance test. PT_2: second performance test.

Measured traits

Weight, ultrasound, and bovinometric measurements were taken every 14 d. Animals were weighted after a 12-hours fast. The bovinometric measurements were chest girth (CG), height at withers (HW), and height at sacrum (HS). A measuring tape and a bovinometric rule were used to measure height and chest girth. The ultrasound measurements taken were longissimus muscle area (REA) and rump fat thickness (RFT). Ultrasound measurements were taken using an Akila-Pro ultrasound equipment (Esaote Europe BV, Maastricht, The Netherlands) with a 3.5 MHz (18 cm) transducer. Images were measured with Eview software (Pie Medical, Maastricht, the Netherlands). To assess REA, an image was taken between the 12th and 13th rib, perpendicular to the loin muscle. To measure RFT the image was taken from the tip of the hip, towards the back region between the iliac and ischial tuberosities (Perkins *et al*., 1992; Realini *et al*., 2001; Jorge *et al*., 2005). All characteristics were measured by the same persons. Ultrasound data correspond to the average measured by two technicians.

Statistical Analysis

Traits were analyzed using animal mixed models with fixed and random first and second order regression effects. Models used unstructured variance and covariance matrices (different variances and covariances between random parameters), as described by Littell *et al.* (2004). Performance tests data for NM and DP preweaning systems were analyzed separately, because animals started their tests at substantially different ages. The mixed model was:

$$y_{ijk} = (\beta_0 + b_{0i:k}) + (\beta_1 + b_{1i:k})\, X_j + \beta_2\, X_j^2 + T_k + e_{ij}$$

Where, y_{ijk} = trait (weight, ultrasound and bovinometric) measured at the j-th age of the i-th animal in k-th test; β_0, β_1 and β_2= intercept, linear, and quadratic regression coefficients for all animals; X_j = is the j-th age; T_k = fixed effect of test (two tests by production system); and e_{ij} = residual associated with the individual variability of the observations not explained by the model, where $e_{ij} \sim N(0,\sigma_e^2)$; $b_{0i:k}$ and $b_{1i:k}$ = intercept and linear regression coefficient of the i-th animal, representing random deviations from β_0 and β_1 coefficients, respectively, where:

$$\begin{bmatrix} b_0 \\ b_1 \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix},\ A * \begin{bmatrix} \sigma_{b0}^2 & \sigma_{b01} \\ \sigma_{b10} & \sigma_{b1}^2 \end{bmatrix}\right)$$

The relationship matrix (A) between animals contained 120 animals in the NM analysis (10 half-siblings) and 192 animals in DP analysis (41 half-siblings). The $b_{2i:k}$ random effect of the i-th animal was not included in the final model because convergence was not achieved when this effect was included in preliminary runs. Computations were performed with the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). The relationship matrix was included in the mixed model equations using the option LData within the RANDOM statement of the MIXED procedure.

Results

Growth Curves

All traits in the DP system, as well as RFT, HW and HS in the NM system, showed a good fit with a second-order regression mixed-model. These traits showed a high significance level for parameters β_0 (P < 0.0001) and β_2(P < 0.0001); while β_1 was highly significant (P < 0.0001) for all traits, except RFT in NM system and RFT, HS and HW in the DP system (P > 0.05). On the other hand, weight, CG, and REA for the NM system fit well with a first-order regression mixed-model (β_2 had no significant effect with P > 0.05), and the estimated parameters (β_0 and β_1) were highly significant (P <0.0001). The correlation obtained between predicted and actual values fluctuated between 0.95 and 0.99 (P<0.0001), with distribution of residuals around zero. A normal distribution of residuals was obtained with these models, where most residuals showed a good fit.

Performance test results for bovinometric traits for NM animals were: CG = 173.6±5.68 cm, HW = 122.8±3.81 cm, and HS = 128.2±3.01 cm. The DP animals, which were older, had CG = 172.8±7.97 cm, HW =121.4±4.07 cm, and HS = 126.6±4.25 cm.

Animals from the NM system had a negative β_2 for HW (P<0.0001) and HS (P=0.0005), which indicates a deceleration in the rate of increase towards the end of the assessed period. On the other hand, CG continued to increase at a rate of 0.116 cm/d (P <0.0001) until the end of the performance test (Table 3, Figure 1).

The rate of fat deposition continued to increase until the end of the test and had a positive β_2(P<0.0001). Similarly, muscle (REA) continued to grow linearly (P<0.0001) (Table 3, Figure 1).

Animals from the DP system had positive β_2 (P <0.0001 to P=0.0119) for all traits. This indicates that the animals had a positive rate of increase at the beginning of the performance test, associated to β_1, followed by an increased (not decrease, as occured with NM animals, despite their older age). At the end of the tests, animals from the first and second tests were 18 and 19 months old, respectively, and their rate of increase remained positive.

The DP buffaloes showed lower growth during the first 28 d of the performance test (Figure 2). When growth curves were analyzed without taking into account the measurements made during this period (results not shown), higher growth rates were observed for weight (478 g/d, P<0.0001), REA (0.04 cm2/d, P=0.0001), fat (0.009 mm/d, P=0.0044), HW (0.1163 cm/d, P<0.0001), and HS (0.1116 cm/d, P<0.0001).

Table 3. Growth, ultrasound, and bovinometric regression parameters for buffaloes reared under two different preweaning management systems in post-yearling performance tests.

Preweaning system[2]	Parameter[1] β_0	β_1	β_2
Weight, kg			
NM	244.9 ± 6.35	0.678 ± 0.02	
DP	235.9 ± 7.07	0.415 ± 0.03	0.0008 ± 0.0001
***Longissimus* muscle area, cm²**			
NM	31.77 ± 1.12	0.066 ± 0.003	
DP	27.96 ± 1.21	0.033 ± 0.008	0.0001 ± 0.000027
Rump fat thickness, mm			
NM	5.73 ± 0.38	0.0016 ± 0.0027	0.00004 ± 0.00001
DP	4.13 ± 0.34	0.0004 ± 0.0026	0.00005 ± 0.00008
Chest girth, cm			
NM	152.5 ± 1.18	0.1159 ± 0.0035	
DP	149.6 ± 1.60	0.1048 ± 0.0140	0.00013 ± 0.00005
Height at withers, cm			
NM	110.9 ± 0.99	0.111 ± 0.011	-0.00026 ± 0.00004
DP	112.1 ± 1.20	0.017 ± 0.012	0.00015 ± 0.00004
Height at sacrum, cm			
NM	116.8 ± 0.89	0.100 ± 0.009	-0.0002 ± 0.00004
DP	117.2 ± 1.21	0.0035 ± 0.010	0.0002 ± 0.00003

[1] β_0= intercept, corresponds to the initial value. β_1 and β_2= linear and quadratic regression coefficients associated to the prediction variable "age" during the performance test. β_0: P < 0.0001. β_1: P between 0.0675 and < 0.0001. β_2: P between 0.0393 and 0.0001.

[2] NM: pre-weaning system with no milking; DP: dual purpose pre-weaning system.

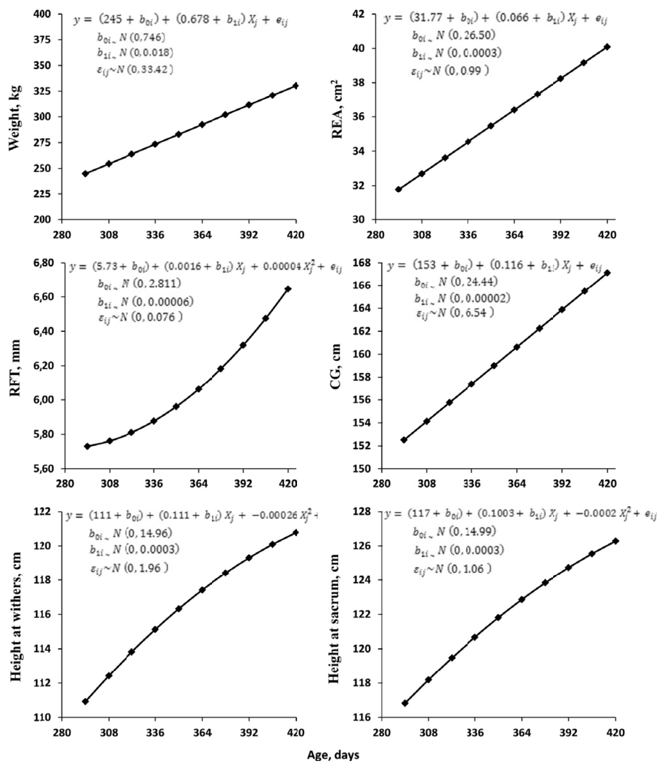

Figure 1. Growth plots of performance tests conducted with buffaloes from no-milking farms (data adjusted by a mixed linear regression and second order polynomial model). REA = longissimus muscle area. RFT = rump fat thickness. CG = chest girth. HW = height at withers. HS = height at sacrum.

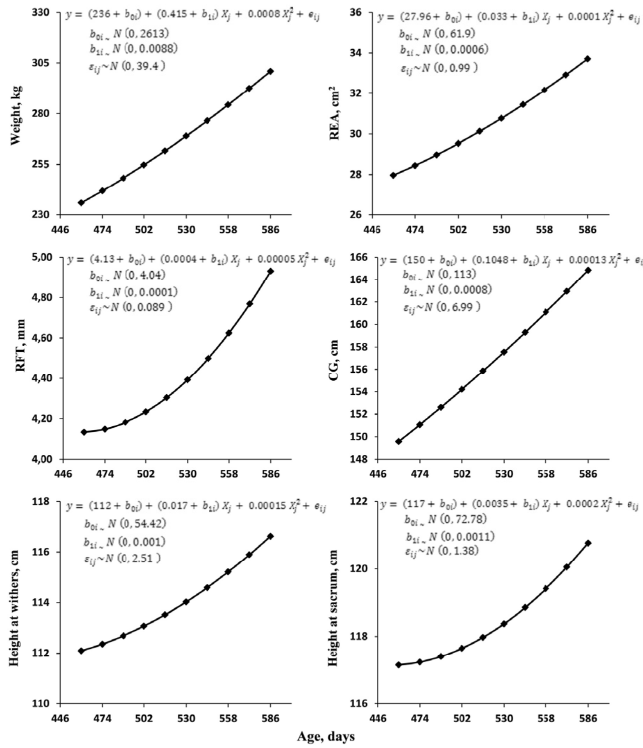

Figure 2. Growth plots of performance tests conducted with buffaloes from dual purpose farms (data adjusted by a mixed linear regression model and second order polynomial). REA = longissimus muscle area. RFT = rump fat thickness. CG = chest girth. HW = height at withers. HS = height at sacrum.

Genetic Variation

Variance components due to b_0, b_1, and residual effects, were estimated in order to obtain some information on the variability among animals in these four performance tests.

Table 4 presents the estimates of variance and covariance components obtained for growth, ultrasound, and bovinometric traits using data from the NM and DP performance tests. Estimates of animal variance components due to b_0 and b_1 were non-zero for all traits, which, according to the performance tests, suggests the existence of genetic variation among buffaloes. Negative correlations between b_{0i} and b_{1i} were estimated for all traits in both production systems (Table 5), indicating that animals entering the test with higher initial values had lower growth rates during the performance test.

Discussion

Growth Curves

All traits fit a first or second order regression mixed model. A normal distribution of residuals was obtained with these models, where most residuals fit well. There were some exceptions outside the curve, indicating they were either overestimated (at the beginning of the performance test) or underestimated (at the end of the test). The outliers could be caused by the heterogeneity among individuals.

Bovinometric measurements obtained at the end of the tests were lower than those reported by Lourenço *et al*. (2010) for animals submitted to two weight gain trials in Brazil, which resulted in CG = 183.07 and 178.58 cm, HW = 130.94 and 128.06 cm, and HS = 134.5 and 130.90 cm for the first and second tests, respectively. In contrast, DP animals in this study showed higher value for CG, HW and HS than those reported by Crudeli *et al.* (2007) in buffaloes grazing on native pastures, which at 18 months of age resulted in CG = 166.76, HS = 122.63 cm, and HW = 119.18 cm.

The rate of increase for HW and HS declined at the end of the test in the NM system, while weight, CG, RFT, and REA did not. This is consistent with the growth waves previously described for cattle (Bergand Butterfield, 1976). The B wave (from the limbs towards the back), which corresponds to growth in height, develops early. On the contrary, the C wave (from the back towards the sternum) is delayed. In addition, the muscle and fat deposition occur at a later age, where fat tissue is the last to accumulate in the animal (Berg and Butterfield, 1976).

The DP buffaloes accelerated the rate of increase for all the traits towards the end of the evaluation (not decreased, as it happened to NM animals), despite of the older age (18 and 19 months in the first and second test, respectively). These animals showed little growth during the first 28 d of the performance test. This could have happened for two reasons: firstly, DP buffaloes were accustomed to a different production system, managed under grazing conditions, with different climate and forage species, thus they needed to get accustomed to a new system (confinement, cut grass, climate) and a new group of animals; secondly, the first performance test for DP animals started at the beginning of the drought season, which was particularly intense. The total precipitation during the four months of the test was less than half of that in previous years (199 mm vs. 584 mm; Institute of Hydrology, Meteorology and Environmental Studies -IDEAM; station 27015150, El Progreso, Barbosa, Antioquia, Colombia). These conditions negatively affected the production and nutritional quality of the grass.

Table 4. Variance components for post-yearling growth, ultrasound, and bovinometric traits in performance tests for buffaloes reared under two different preweaning management systems.

System	Traits[1]							
	Weight, kg				**Longissimus muscle area, cm²**			
	σ^2_{bo}	σ^2_{b1}	σ_{b01}	σ^2_e	σ^2_{bo}	σ^2_{b1}	σ_{b01}	σ^2_e
DP	2613±453	0.0088±0.002	-3.493±0.839	39.40±2.27	61.90±10.80	0.0006±0.0001	-0.114±0.030	0.99±0.06
NM	746±176	0.0178±0.004	-0.668±0.866	33.42±2.56	26.50±5.91	0.0003±0.00009	-0.043±0.018	0.99±0.08
	Rump fat thickness, mm				**Chest girth, cm**			
	σ^2_{bo}	σ^2_{b1}	σ_{b01}	σ^2_e	σ^2_{bo}	σ^2_{b1}	σ_{b01}	σ^2_e
DP	4.036±0.717	0.0001±0.00002	-0.009±0.0029	0.089±0.005	113.8±22.34	0.0008±0.0002	-0.258±0.067	6.99±0.44
NM	2.811±0.599	0.00006±0.00001	-0.006±0.0023	0.085±0.007	24.44±6.99	0.00002±0.0001	-0.017±0.024	6.54±0.55
	Height withers, cm				**Height at sacrum, cm**			
	σ^2_{bo}	σ^2_{b1}	σ_{b01}	σ^2_e	σ^2_{bo}	σ^2_{b1}	σ_{b01}	σ^2_e
DP	54.42±13.11	0.0011±0.0003	-0.193±0.053	2.51±0.17	72.78±16.88	0.0011±0.0002	-0.246±0.058	1.38±0.09
NM	14.96±3.99	0.0003±0.0001	-0.043±0.019	1.96±0.17	14.99±3.88	0.0003±0.00008	-0.044±0.015	1.06±0.09

[1] NM= preweaning system with no milking; DP= dual purpose preweaning system.

σ^2_{b0}: intercept variance; σ^2_{b1}: growth rate variance; σ_{b01}: covariance between intercept and growth rate; σ^2_e : residual variance

Table 5. Correlations between b_{0i} and b_{1i} for growth, ultrasound, and bovinometric traits during post-yearling performance tests for buffaloes reared under two different preweaning management systems.

	Traits[2]					
System[1]	Weight	REA	RFT	CG	HW	HS
DP	-0.69	-0.59	-0.45	-0.86	-0.81	-0.88
NM	-0.18	-0.44	-0.46	-0.70	-0.60	-0.65

[1]NM = preweaning system with no milking. DP = dual purpose preweaning system.

[2]REA = *longissimus* muscle area. RFT = rump fat thickness. CG = chest girth. HW = height at withers. HS = height at sacrum.

A key factor to consider during a performance test is the quality of the diet. The intention of these four performance tests was to offer a diet with a nutritional value similar to the medium-quality grass, so it would not greatly diverge from grasses generally used in Colombia. This was aimed to reduce the probability of a genotype-environment interaction (when the offspring of the best animals chosen under particular feeding conditions do not perform well under different conditions). However, pasture quality declined substantially at the first performance test for DP buffaloes (Table 2), mainly reflected in its lower protein and high lignin contents.

During the performance tests with NM animals, an adequate growth was observed from the outset of the tests, indicating that the diet was adequate. These animals entered the tests at a younger age and had recently been weaned and therefore required a higher quality diet. Precipitation was adequate during the time the tests were conducted, resulting in adequate grass quality and animal growth. On the other hand, the DP animals were older and had already overcomed the weaning stress, therefore, they required a lower quality diet. For this reason, fast growth was expected from the beginning of the tests. However, results showed that the diet provided to DP buffaloes was not adequate, reflecting an insufficient production and pasture quality during their first performance test, due to the low precipitation observed during that period. These results demonstrate the importance of providing homogenized rations to ensure a consistent nutritional intake, independent of weather conditions.

The initial weight of NM buffaloes (261 and 294 kg, for first and second test, respectively) was similar to that reported by Lourenço *et al*. (2010) for Murrah buffaloes in two weight-gain trials conducted by the Eastern Amazon Embrapa in Belém (Pará, Brazil). Their animals belonged to farms that had genetic improvement programs, and initial weights averaged 265 kg and 273 kg during the first and second tests, while age ranged from 213 d to 303 d. Considering that Brazil is one of the top buffalo producers and that it has conducted extensive breeding research, it could be argued that animals in the first test had high genetic potential. The initial weight estimated in the present study for NM animals was lower (245 kg) than that reported by Lourenço *et al*. (2010), because the initial age considered was the minimum age (235 d). The initial weight of DP buffaloes in the present work was lower (240 and 274 kg, for the first and second test, respectively), and the animals were also older (first test: 426 d; second test: 484 d) compared with those reported by Lourenço *et al*. (2010), because they were managed under a different production system (with cow-milking), which led to lower weights and older weaning ages.

Crudeli *et al*. (2007) reported a mean weaning weight of 282.4 kg at seven months of age for 170 Mediterranean buffaloes in Argentina, which is higher than the weight at the begining of the performance tests in the present study. However, they also reported 335.9 kg at 18 months of age, which was lower to that of the performance tests for NM buffaloes at 13 and 14 months of age (342 and 357 kg, Table 1). This is a good indicator of the genetic growth potential of NM animals and of the adequate handling offered during the performance test. At the end of the first test, DP animals (18 months of age) continued to show lower weights (314 kg, Table 1) than NM animals. Malhado *et al*. (2008) reported lower average weight for yearling Murrah buffaloes (229.65kg), but a similar average weight for DP animals at 18 months of age (317.17 kg). Mean weight at the end of second test for DP animals was higher than the weight reported for Malhado *et al*. (2008).

The daily gain obtained by Lourenço *et al*. (2010) was 911 and 969 g/d for the first and second weight-gain trials (224 d, excluding the adaptation period), which was higher to that obtained for NM (678 g) and DP (415 g) buffaloes. These results can be explained by the diet used (similar nutritional value of medium-quality grass). The daily gains obtained by Lourenço *et al*. (2010) during the adaptation period of their two trials (70 d) were also low (257 and 285 g), reaffirming the importance of taking this period into account.

Genetic Variation

Non-zero estimates of genetic variances for b_0 and b_1 suggested that growth, ultrasound, and bovinometric traits may be genetically improved in Colombia. However, the high estimates of variances due to b_0 represented not only genetic differences among individual animals, but may also have included maternal effects, and pre-weaning environmental differences (management, nutrition, climate) among farms supplying buffaloes for the NM and DP performance tests. These differences among animals due to genetic differences among herds, maternal effects, and preweaning environmental differences among herds are usually referred to as residual effects due to herd of origin, which could potentially be minimized by using an adaptation period (Schenkel *et al*., 2004; Nephawe *et al*., 2006).

Thus, an aspect to consider during performance tests is the exclusion of the effect of herd of origin that remains during the test (Schenkel *et al*., 2004; Nephawe *et al.,* 2006). Studies have shown significant effect of herd of origin on performance of bulls in the test after the adaptation period (Tong *et al*., 1986; Amal and Crow 1987; Liu and Makarechian, 1993; Schenkel *et al*., 2002, 2004), and the existence of a negative correlation between weight gain before and after weaning, indicating the presence of compensatory gain during the test (Tong, 1982; De Rose *et al*., 1988; Tong *et al*., 1986).

Altough it is undeniable that the herd of origin can have an effect on performance tests results, it is important to note that this effect has two components: environmental and genetic. The environmental effect can be minimized or eliminated by a suitable adaptation period, but the genetic component due to genetic differences among herds will remain. Animals from farms with high selection pressure for growth traits are expected to have a higher weight at the same age than animals from farms that do not have a breeding program, and these differences may remain throughout the test. This is a relevant issue because the effect of herd of origin may remain until the end of the test. The problem is how to separate these two components. The DP buffaloes entered the tests at a similar age (first test: maximum difference was 77 d; second test: maximum difference was 115 d). However, their initial weight ranged between 170 and 322 kg (first test) and between 210 and 465 kg (second test), and this difference persisted until the end of the test, although the coefficient of variation decreased from 19% to 13%. Similarly, NM buffaloes entered their performance tests with a maximum age difference of 73 and 68 d, for first and second test, respectively, but their initial weight difference was 91 kg (first test: ranging from 215 to 306 kg) and it increased to 168 kg (ranging from 298 to 412 kg) at the end of this test. The difference in the second test for the NM animals was 80 kg (ranging from 254 to 334 kg) and it increased to 99 kg.

These results indicate that although the effect of herd of origin was important during the test, NM animals under performance tests expressed their own ability to grow under the environmental conditions provided by the test. This did not happen in the performance test for the DP animals, likely because the diet supplied to buffaloes in the first test prevented them from expressing their individual growth potential. According to Pereira (1999), the lower the animal weight variations are at the beginning of the performance test, the lower the effects of the previous environment and the greater the possibility of test success. Three aspects were considered here with the aim of reducing the weight variation at the beginning of the performance tests: 1) Low variation in initial age (maximum difference 73 d and 68 d of the two test for NM, and 77 d of the first test for DP). This age difference was smaller than the range used in other performance test stations (except for the second test of DP animals: 115 d); e.g., 90 d in the

Central Station in Ontario, Canada (Schenkel *et al.*, 2004), the Sertãozinho Experimental Station for Animal Husbandry in Sao Paulo, Brazil (Razook *et al.*,1997), and the Brazilian Association of Zebu Breeders (ABCZ, 2003), but greater than the age difference of 60 d for Zebu cattle performance tests in Colombia (ASOCEBÚ, 2007); 2) Pre-selection of participating animals based on their performance in contemporary groups in the herd of origin. Weaning weight was taken into account for the tests of NM animals. Milk yield of the mother and weaning weight were considered for the tests of DP animals; and 3) Tests were conducted independently for animals from NM and DP production systems. In spite of these measures, there was high variation among weights in the NM and DP performance tests in this study. As indicated above, pre-weaning herd environmental conditions, maternal environmental effects, and genetic differences among herds may have contributed to these differences.

Lastly, linear regression variances were small for all traits, suggesting that although selection of animals within these performance tests is possible, expected changes in the buffalo population will be small. Larger samples of buffaloes in performance tests and better accounting for preweaning environmental conditions and genetic differences among herds will improve chances of identifying the best buffaloes in performance tests in Colombia. Although the evaluated animal sample is too small to be able to successfully identify the best buffaloes in Colombia, performance tests can be a good alternative to begin a breeding program for this species in the country. These tests plus the evaluation of all animals in all farms in Colombia using an in-farm genetic evaluation program would allow the accurate assessment of genetic variability and provide buffalo producers with accurate genetic evaluations across all Colombian environments.

In conclusion, the regression mixed models of first and second order were adequate to describe buffalo growth in terms of weight, ultrasound, and bovinometric traits. The NM animals showed an adequate growth rate during the test, while growth of DP buffaloes was limited by the supply of low quality forage. To obtain higher growth rates during performance tests, good quality diets and completely mixed and homogenized rations must be supplied to ensure consistent nutritional value throughout the test, independent of the weather conditions. It was not possible to entirely separate genetic and environmental components. Environmental and genetic differences among farms (herd of origin effect) may have influenced the high variability among individuals for the intercept. Slope variances were low for all traits. The random parameters of intercept and growth rate showed a negative correlation, indicating that animals with higher initial weights had lower growth rates during the performance test.

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