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Genetic evaluation of milking buffaloes (*Bubalus bubalis*): bull ranking

[*Avaliação genética de búfalas leiteiras (*Bubalus bubalis*): classificação de touros*]

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ABSTRACT

The objective of this study was to evaluate genetic aspects related to production and reproductive efficiency of Murrah and Mediterranean buffaloes and their crosses. A ranking of bulls from Embrapa Eastern Amazonia was also composed to guide assisted mating. Birth records of 2,322 Murrah, Mediterranean, and crossbred buffaloes from the Embrapa Eastern Amazon herd, from 1953 to 2013, as well as information on production and reproductive traits were used. Genetic analyzes were performed in the WOMBAT software using the animal model with two-trait analysis. While heritability (h^2) for total milk production (TMP) and fat milk percentage (F) were generally high, for reproductive traits h^2 tended to be low. Genetic correlations for TMP with the other traits were low and negative, except for TMP with calving interval (CI) and service period (SP) in the Mediterranean breed and with age at first calving (AFC) and SP in crossbred, which were positive and high. Bull 1001 had high predicted transmitting ability (PTA) for TMP, so it should transmit a greater volume of milk to his offspring, although it had a lower PTA for F. There was sufficient variability within the herd to work with genetic management for both production and reproductive efficiency.

Keywords: genetic management, heritability, correlation, reproductive efficiency

RESUMO

O objetivo deste estudo foi avaliar os aspectos genéticos relacionados à produção e à eficiência reprodutiva de búfalas das raças Murrah, Mediterrâneo e suas cruzas. Uma classificação de touros da Embrapa Amazônia Oriental também foi composta para orientar os cruzamentos assistidos. Foram utilizados 2.322 registros de nascimento de búfalas das raças Murrah, Mediterrâneo e cruzadas do rebanho da Embrapa Amazônia Oriental, de 1953 a 2013, bem como características produtivas e reprodutivas. As análises genéticas foram realizadas pelo software *Wombat, utilizando-se o modelo animal com análise de duas características. Enquanto a herdabilidade (h^2) para a produção total de leite (PTL) e para a porcentagem de gordura (G) foi alta, para as características reprodutivas a h^2 tendeu a ser baixa. As correlações genéticas da PTL com as demais características foram baixas e negativas, exceto para a PTL com intervalo entre partos (IP) e período de serviço (PS) na raça Mediterrâneo e com idade ao primeiro parto (IPP) e PS nas cruzadas, que foram positivas e altas. O touro 1001 apresentou alta capacidade de transmissão predita (CTP) para a PTL, então deve transmitir um maior volume de leite para seus descendentes, embora com um menor conteúdo transmissível de CTP para G. Portanto, existe variabilidade suficiente dentro do rebanho para trabalhar com o manejo genético para a produção e a eficiência reprodutiva.*

Palavras-chave: correlação, eficiência reprodutiva, herdabilidade, manejo genético

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INTRODUCTION

Although the buffaloes are mainly bred for meat production in Brazil, dairy production has shown excellent results, with this activity being considered an alternative to improve economic results on-farm. Buffalo milk showed 40% higher industrial yield in the preparation of dairy products than the cow milk (Lourenço Jr. and Garcia, 2008).

According to IBGE (Censo…, 2006), Brazil had 48,864 buffaloes in milk, producing 45,955 million liters annually (4.22% of the dairy herd of 1,157 million animals). The states of Pará (13,901), São Paulo (10,088), Amazonas (5,272) and Minas Gerais (5,20) had the largest number of dairy cows, corresponding to 70.6% of the total. The Pará herd showed higher milk production, 11,264 million liters, followed by São Paulo (10,296), Minas Gerais (7,406) and Amazonas (4,722). The sum of the output of the four states corresponded to 73.3% of the total.

Breeding programs were essential for identifying individuals with superior genotypes to improve the production potential of these herds, leaving a larger number of offspring and promoting the improvement of the species (Araújo *et al*., 2008). For effective selection of the traits of interest, it is necessary to estimate genetic parameters in the population under selection. The correct estimation of the genetic parameters is important in breeding programs because it allows for the prediction of the genetic value to identify genetically superior animals (Paula *et al*., 2008).

Heritability is usually low for reproductive traits, and high variation observed in the literature for these estimates was mainly attributed to non-genetic effects, indicating that more accurate models should be developed and proposed for obtaining more reliable estimates of the genetic parameters (Pires *et al.,* 2000). Buffalo farmers require proven bulls to meet the demand for genetic improvement, this being important to increase sustainable productivity, as well as improving the quality of the products.

Considering the importance in the productive and economic processes and the lack of information on the reproductive performance of buffaloes, the objective of this study was to evaluate genetic aspects related to production and reproductive efficiency of Murrah and Mediterranean buffaloes and their crosses, as well as to compose the ranking of bulls from Embrapa Eastern Amazonia to guide assisted mating.

MATERIAL AND METHODS

Birth records of 2,322 Mediterranean breed (483), Murrah breed (932) and crossbred herd (907) from Embrapa Eastern Amazonia, born between 1953 and 2013, as well as information on productive and reproductive traits were used in this study. The herd was kept in an experimental station of Embrapa Eastern Amazonia, located in the metropolitan area of the Belém city in Pará State, at 01º 27' 21'' S and 48º 30' 16'' W, with an altitude of 10m. The animals were raised in a semi-intensive, *in situ* conservation system. This location has a rainy tropical climate, with a short dry season, according to the Koppen classification. The annual mean temperature was 27.2°C, ranging from 21.8 to 32.4°C. The relative humidity showed an annual mean of 88% and the mean annual rainfall was around 2,537mm. The total annual insolation was 2,300 hours. The soils of the region belong to the moist yellow latosols. The main diet of the animals consisted of *Brachiaria* and *Panicum* pasture.

Total milk production (TMP), fat milk percentage (F), age at first calving (AFC), calving interval (CI), lactation length (LL) and service period (SP) traits were used for estimation of the genetic parameters such as heritability and correlations, as well as predicted transmitting ability (PTA) to compose the ranking of bulls in the Buffalo Breeding Program of Embrapa Eastern Amazônia. A two-trait animal model analysis was carried out, including animals having two or more progeny and more than two animals per contemporary group.

For milk production, fat milk percentage and calving interval the mixed linear model used was: $Y = X\beta + Za + Wp + \varepsilon$, where: Y is the vector of observations; β, a, p and ε are vectors of fixed effects, additive genetic value, maternal permanent environmental effect and error, respectively. Fixed effects included contemporary group, as well as linear and quadratic effects of calving age as a covariate. For age at first calving and service period the model was the same as described above with the exclusion of permanent maternal environmental effect. Assumptions about the distribution of the vectors y, a, p and e were as follows:

$$\begin{bmatrix} y \\ a \\ p \\ e \end{bmatrix} \sim \left\{ \begin{bmatrix} X\beta \\ 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} Z'GZ + W'PW + R & Z'G & W'P & R \\ GZ' & G & 0 & 0 \\ PW' & 0 & P & 0 \\ R & 0 & 0 & R \end{bmatrix} \right\},$$

where: $G = A \otimes G_0$; $P = I \otimes P_0$ and $R = I \otimes R_0$, with A being the relationship matrix between individuals of order equal to the number of individuals; G_0, P_0 and R_0 are direct additive genetic, maternal additive, permanent and temporary environment (co)variance matrices, respectively.

The covariance between two characteristics were considered null between permanent and temporary environment effects. Genetic analysis was performed using WOMBAT software (Meyer, 2007). After estimation of the genetic values of the bulls, they were ranked based on predicted transmitting ability (PTA).

RESULTS AND DISCUSSION

The genetic analysis were performed using the data described in Table 1. Little difference was seen between the genetic groups for production traits such as cow and calf weights, age at first calving (AFC) or total milk production (TMP). Nevertheless, the Murrah breed showed a shorter lactation length and the Mediterranean breed higher fat milk percentage (F).

Genetic parameters (Table 2) showed differences in heritability, particularly for fat milk percentage (F) and between genetic groups. While heritability for total milk production (TMP) and fat milk percentage (F) were generally high, for reproductive traits heritability tended to be low. Within breed correlations between traits and total milk production also varied widely.

Genetic parameters for productive and reproductive traits showed high variability, but consistent with bibliographic references for the traits studied. Heritability (h^2) for total milk production (TMP) was 0.55, 0.48 and 0.39 for Murrah breed, Mediterranean breed and crossbreds, respectively. These values can be considered high, indicating that this trait was influenced by genetic factors and therefore should respond well to selection. In the literature values ranging from 0.14 to 0.29 were observed (Tonhati *et al*., 2004; Ghaffar *et al*., 2007; Malhado *et al*., 2009; Rodrigues *et al*., 2010; Bezerra Jr. *et al*., 2014; Sesana *et al*., 2014), being of medium magnitude. In other studies, Campos *et al*. (2007) found a heritability of 0.26 for cumulative production on 305 days of lactation using dairy buffaloes in 13 farms in São Paulo State. Araújo *et al*. (2008) studying buffalo herds of Murrah in different regions of Brazil, obtained a mean h^2 of 0.39 for milk production according to the class standard deviation (high: 0.33, low: 0.41), and the authors verified the existence of heterogeneity of variance for milk production between herds and the source of this heterogeneity was due to environmental factors. The higher heritability found here might be a reflection of the analysis being carried out within breed and herd, giving rise to more stable environmental conditions, thereby increasing heritability. The high heritability for productive traits indicated the possibility of a high response to mass selection, i.e., the selection of animals by their phenotypic value or apparent merit.

Fat milk percentage normally shows high heritability, as observed in this study for Murrah breed (0.75). However, the values of 0.38 and 0.36 found for Mediterranean breed and crossbreds, respectively, can be explained due to the action of other factors such as management differences as well as variability due to month/year of lactation as described by Aspilcueta-Borquis *et al*. (2007) who found heritability estimates ranging from 0.08 to 0.23 depending on the month of lactation. Heritability estimates of 0.24 and 0.28 were found by Tonhati *et al.* (2000a) and Campos *et al.* (2007), respectively in buffalo herds of various breeds and crosses in the São Paulo State. As these authors obtained data from several herds/breeds, a lower genetic variation is expected. According to Cassiano *et al.* (2004), major management differences can dilute the genetic influences of a herd, but can improve production rates due to improvement in management conditions.

Table 1. Descriptive analysis for production and reproductive traits of the Embrapa Eastern Amazonia buffaloes from 1957 to 2013

Traits	N	Mean	SD	CV (%)	Min	Max
All animals						
Calving number	1,825	3.48	2.31	66	1	13
Cow weight at calving (kg)	2,093	546.19	76.05	14	331.00	812.00
Calf birth weight (kg)	1,568	35.68	2.98	8	30.00	40.00
Lactation length (days)	842	272.46	67.22	25	68.00	819.00
Total milk production (kg)	1,148	1,745.55	495.64	28	621.50	4.682.80
Fat milk percentage (%)	830	7.07	0.86	12	3.46	10.30
Age at first calving (months)	594	40.53	7.44	18	21.37	60.11
Calving interval (months)	576	13.19	0.80	6	12.00	14.80
Service period (days)	576	91.12	24.18	27	55.00	140.00
Murrah breed						
Calving number	888	3.29	2.23	68	1	12
Cow weight at calving (kg)	1,143	558.59	76.11	14	336.00	782.00
Calf birth weight (kg)	888	35.96	2.98	8	30.00	40.00
Lactation length (days)	255	258.21	56.37	22	104.00	406.00
Total milk production (kg)	432	1,775.31	490.72	28	668.80	3,341.10
Fat milk percentage (%)	253	6.76	0.83	12	3.46	8.75
Age at first calving (months)	363	40.81	7.58	19	25.16	60.11
Calving interval(months)	318	13.17	0.83	6	12.00	14.80
Service period (days)	318	90.40	25.26	28	55.00	140.00
Mediterranean breed						
Calving number	469	3.63	2.23	6	1	10
Cow weight at calving (kg)	494	547.73	78.60	14	331.00	812.00
Calf birth weight (kg)	355	35.68	2.85	8	30.00	40.00
Lactation length (days)	227	290.32	72.66	25	117.00	819.00
Total milk production (kg)	333	1,714.67	466.47	27	709.10	3,087.23
Fat milk percentage (%)	218	7.50	0.80	11	5.60	9.50
Age at first calving (months)	129	39.97	7.85	20	21.37	60.01
Calving interval(months)	108	13.31	0.79	6	12.00	14.76
Service period (days)	108	94.71	23.92	25	55.00	139.00
Crossbred						
Calving number	468	3.68	2.48	67	1	13
Cow weight at calving (kg)	456	513.45	62.39	12	358.00	744.00
Calf birth weight (kg)	325	34.89	2.99	9	30.00	40.00
Lactation length (days)	360	271.28	68.31	25	68.00	548.00
Total milk production (kg)	383	1,738.83	524.33	30	621.50	4,682.80
Fat milk percentage (%)	359	7.03	0.82	12	5.00	10.30
Age at first calving (months)	102	40.21	6.37	16	23.15	60.11
Calving interval(months)	150	13.16	0.72	0.05	12.04	14.76
Service period (days)	150	90.06	22	24	56.00	139.00

N: number of observations, SD: standard deviation, CV: coefficient of variation, MIN: minimum, MAX: maximum.

Table 2. Genetic parameters for production and reproductive traits of the eastern Amazonia buffaloes during 1957 to 2013

Traits	Murrah breed		Mediterranean breed		Crossbred	
	h^2	*r*	h^2	*r*	h^2	*r*
TMP	0.55		0.48		0.39	
F	0.75	0.06	0.38	-0.27	0.36	-0.63
AFC	0.0016	-0.94	0.0002	-0.82	0.0015	0.50
CI	0.31	0.10	0.0019	0.56	0.0058	0.23
SP	0.0269	0.08	0.0072	0.62	0.0251	0.63

TMP: total milk production, F: fat milk percentage, AFC: age at first calving, CI: calving interval, SP: service period, h^2: heritability, *r*: genetic correlation with TMP.

For reproductive traits, the heritability for age at first calving (AFC) was 0.0016, 0.0002 and 0.0015 for Murrah breed, Mediterranean breed and crossbred, respectively. According to Tonhati *et al.* (2000b), the fertility traits had heritability values very low or close to zero, suffering influence of environmental and management effects. Seno *et al.* (2010) found AFC heritability of 0.07 for Murrah bufalloes. Cassiano *et al.* (2004) found means of 0.24 and 0.12 for Murrah and Mediterranean buffaloes, respectively in the Brazilian Amazon. High values (h^2= 0.41) were found by Malhado *et al.* (2009) studying 628 female crossbred buffaloes in farms in São Paulo and Pará States. Vercesi Filho *et al.* (2007) estimated h^2 of 0.48 and Lôbo *et al*. (2000) found a mean h^2 of 0.31 in 94 papers reviewed in the tropical environment, confirming the existence of considerable genetic variation for this trait. Many aspects can influence these values, such as the high variability within and across herds, making phenotypic and environmental variances larger. Mistakes in the parental identification can also lead to error in calculation of genetic variability estimates.

A high calving interval (CI) heritability value was found for Murrah breed (0.31), while in the Mediterranean breed and crossbred the values were low, 0.0019 and 0.0058, respectively. For service period (SP), the heritability values were low, ranging from 0.0269 for Murrah breed, 0.0072 for the Mediterranean breed and 0.0251 for crosses. Estimates of low heritability were normal for reproductive traits such as calving interval and service period, which depend on environmental influences and proper management for breeding success. Similar results were described by Cassiano *et al.* (2004) for CI and SP heritability, with values of 0.26 and 0.25 for Murrah breed and 0.00 and 0.04 for Mediterranean breed, respectively. Malhado *et al.* (2009) also found a h^2 of 0.03 in crossbred buffaloes in São Paulo and Pará States. Variations in the magnitude estimates of heritability were expected due to environmental and management differences and genetic variation, as well as different methodologies used in parameter estimation. Despite these variations, in general, there was sufficient additive genetic variance to justify the selection of genetically superior animals (Bezerra Junior *et al*., 2014).

Within breed, genetic correlations for total milk production (TMP) with the other traits were low and negative, except for TMP with CI (0.56) and SP (0.62) in the Mediterranean breed and with AFC (0.50) and SP (0.63) in crossbreds, which were positive and high. Low correlations hinder the simultaneous selection for these characteristics. Negative correlations (where an increase in one trait is correlated with a decrease in another) can be favorable, for example, where selection for increased milk production can lead to a decrease in service period as seen in Table 2 for Mediterranean breed and crossbreds.

Genetic correlations between TMP with F was 0.06, -0.27 and -0.63 for Murrah breed, Mediterranean breed and crossbred, respectively. Tonhati *et al.* (2000a) found a correlation between TMP and F of -0.18 in buffaloes in the São Paulo State. In general, an increase in milk production was accompanied by a decrease in fat, as water percentage tends to increase (Aspilcueta-Borquis *et al.*, 2010).

Genetic correlations of TMP with the reproductive traits varied highly, but for some important traits it was high and positive such as TMP with SP and CI for the Mediterranean breed and crossbreds, indicating that selection to increase the milk production can lead to a reduction in reproductive efficiency (i.e. increased service period and calving interval). This can be due to effects on several physiological and managerial processes (Carthy *et al*., 2016) such as resumed cyclicity at the time of examination, multiple ovulations, early ovulation, heat detection, ovarian cystic structures, embryo loss, and uterine score. Ramos *et al.* (2006) studying the production of milk and CI in Murrah buffaloes found favorable antagonism between milk production and CI, with a genetic correlation of -0.22. The same was shown by Malhado *et al.* (2009) who found a similar correlation value between TMP and CI in a crossbred buffalo herd. In the same study, the authors found a correlation with AFC of -0.02, indicating the little possibility of obtaining low indirect genetic gains in the AFC through selection for TMP.

Table 3 shows the ranking of bulls in the studied herd where animal identification was encoded in the sequence 1001 to 1023. Bull 1001 presented a predicted transmitting ability (PTA) for total milk production (TMP) of 280.19kg, with accuracy of 0.84. The poorest positive performance for TMP was bull 1013 with a PTA of 0.04kg, and accuracy of 0.58. Using TMP as a selection criterion, 13 bulls had a positive PTA, and the use of these may positively affect production in regional breeding herds resulting in positive genetic gains.

The PTA for fat milk percentage (F) was highest for bull 1006 of 0.469, with an accuracy of 0.860 followed by bull 1018 with PTA of 0.415, with an accuracy of 0.852. For the genetic correlation found in this study, bull 1001 had high predicted transmitting ability (PTA) for TMP, so it should transmit a greater volume of milk for their offspring, although with a lower transmittable content of F.

Table 3. Ranking of buffalo bulls from Embrapa Eastern Amazonia

Bull	Breed	NP	TMP (kg)			F (%)			AFC (months)			CI (months)			SP (days)		
			Rank	PTA	AC	Rank	PTA	AC	Rank	PTA	AC	Rank	PTA	AC	Rank	PTA	AC
1001	MU	18	1	280.19	0.84	24	-0.127	0.817	18	0.653	0.997	18	0.101	0.331	18	0.023	0.049
1002	MU	13	2	223.84	0.83	6	0.145	0.804	1	-3.226	0.997	3	-1.607	0.231	3	-0.226	0.091
1003	MU	1	3	161.09	0.58	5	0.208	0.450	17	0.652	0.831	17	0.090	0.060	17	0.010	0.100
1004	ME	5	4	123.1	0.65	23	-0.052	0.173	8	-0.604	0.997	8	-0.504	0.062	8	-0.049	0.100
1005	MU	8	5	112.15	0.79	11	0.016	0.051	11	-0.472	0.997	11	-0.202	0.401	11	0.000	0.100
1006	MU	28	6	70.18	0.88	1	0.469	0.860	2	-5.743	0.998	1	-2.052	0.384	1	-0.288	0.170
1007	ME	3	7	65.56	0.59	21	-0.028	0.159	5	-1.425	0.998	5	-1.364	0.589	5	-0.146	0.071
1008	MU	3	8	42.32	0.52	13	0.006	0.034	21	3.216	0.998	21	0.238	0.126	21	0.036	0.160
1009	MU	4	9	26.18	0.64	15	0.004	0.041	7	-0.623	0.830	7	-0.929	0.440	7	-0.107	0.078
1010	MU	1	10	25.91	0.54	16	0.004	0.035	15	-0.138	0.831	15	0.001	0.321	15	0.000	0.148
1011	ME	3	11	21.15	0.66	7	0.090	0.619	10	-0.524	0.831	10	-0.222	0.395	10	-0.010	0.100
1012	MU	11	12	0.98	0.78	17	0.000	0.051	22	3.531	0.997	22	1.236	0.134	22	0.188	0.057
1013	ME	6	13	0.04	0.58	18	0.000	0.154	6	-0.894	0.996	6	-1.225	0.464	6	-0.128	0.050
1014	ME	3	14	-11.01	0.51	14	0.005	0.136	4	-2.321	0.998	4	-1.602	0.433	4	-0.205	0.220
1015	MU	3	15	-29.11	0.65	4	0.219	0.657	20	2.409	0.998	20	0.191	0.361	20	0.030	0.040
1016	ME	10	16	-60.94	0.67	10	0.026	0.178	14	-0.165	0.830	14	-0.016	0.284	14	0.000	0.100
1017	ME	5	17	-66.28	0.54	12	0.007	0.319	19	0.997	0.831	19	0.118	0.049	19	0.024	0.067
1018	MU	18	18	-113.68	0.84	2	0.415	0.852	9	-0.552	0.830	9	-0.305	0.209	9	-0.041	0.100
1019	ME	11	19	-130.19	0.72	8	0.055	0.192	13	-0.184	0.998	13	-0.096	0.373	13	0.000	0.100
1020	ME	8	20	-143.28	0.71	9	0.046	0.619	3	-4.708	0.998	2	-1.790	0.204	2	-0.271	0.130
1021	MU	19	21	-157.12	0.83	19	-0.023	0.054	12	-0.376	0.831	12	-0.109	0.299	12	0.000	0.100
1022	MU	3	22	-173.63	0.65	20	-0.025	0.042	24	5.009	0.998	24	4.028	0.576	24	0.485	0.217

TMP: total milk production, F: fat milk percentage, AFC: age at first calving, CI: calving interval, SP: service period, MU: Murrah breed, ME: Mediterranean breed; NP: number of progeny, PTA: predicted transmitting ability, AC: accuracy.

For reproductive traits, negative gains are better because higher numbers mean longer periods, such as AFC which is expressed in months and there is a need to reduce age at first calving which is approximately 40 months or 3½ years, especially when animals are late maturing. Thus, the bull with the best performance for AFC, with a PTA equal to -3.226 months and accuracy of 0.997 was 1002, and the worst performance with positive PTA for AFC was bull 1022 with 5.009 months and an accuracy of 0.998.

For calving interval (CI), the best ranked bull was 1006 with PTA equal to -2.052 months and accuracy of 0.384, and bull 1022 showed the poorest performance with a PTA for CI of 4.028 months and 0.576 accuracy. For service period (SP) bull 1006 showed PTA equal to -0.288 days and an accuracy of 0.170 and bull 1022 had the lowest performance with positive CI of 0.485 months and an accuracy of 0.217.

Thirteen bulls had positive PTA for total milk production (TMP), 17 for fat milk percentage (F), 15 for age at first calving (AFC), 14 for calving interval (CI) and 12 for service period (SP). Higher accuracies were seen in bulls with a higher number of offspring, as expected.

CONCLUSIONS

Results from the present study show that the estimation of genetic parameters such as heritability and correlations can depend on the genetic group being evaluated, as well as the environment where animals are reared. Predicted Transmitting Ability is also specific trait for each animal. Therefore, the construction of breeding programs should consider these factors.

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