Genetic parameters of age at first calving, weight gain, and visual scores in Nelore heifers

Luís Afonso Marques Claus[1], Celso Koetz Júnior[2*], Vanerlei Mozaquatro Roso[3], Marcelo Henrique Favaro Borges[2], Júlio Otávio Jardim Barcellos[4], Edson Luis de Azambuja Ribeiro[5]

[1] Universidade Estadual de Londrina, Programa de Pós-graduação em Ciência Animal, Londrina, PR, Brazil.
[2] Universidade Norte do Paraná, Arapongas, PR, Brazil.
[3] GenSys Consultores Associados S/S, Porto Alegre, RS, Brazil.
[4] Universidade Federal do Rio Grande do Sul, Faculdade de Agronomia, Departamento de Zootecnia, RS, Brazil.
[5] Universidade Estadual de Londrina, Departamento de Zootecnia, Londrina, PR, Brazil.

ABSTRACT - This study aimed at estimating the heritability of age at first calving and of performance traits included in the selection index and the genetic correlations between age at first calving and these performance traits. Data were extracted from the Conexão Delta G database and only data from herds in which heifers were bred younger than 24 months of age were used, resulting in a file with 331,310 evaluated animals. The following traits were included in the analyses: age at first calving, birth to weaning gain, post-weaning weight gain, visual scores of conformation, precocity, and muscling evaluated at weaning and in yearling heifers. Covariance components were obtained by bi-character analyses between traits. An alternative age at first calving was also taken into account, in which all heifers were used, including those that were mated and did not calve. Covariance components and estimates of the effects included in the model were obtained using the software program DMU. Heritability estimates were 0.11 and 0.13 for age at first calving and alternative age at first calving, 0.38 for birth to weaning gain, and 0.13 for post-weaning weight gain. Visual score estimates ranged between 0.16 and 0.18 at weaning and 0.19 and 0.29 in yearlings. Genetic correlation estimates of the traits were low, but in the desirable direction. Selection for birth to weaning gain and visual scores does not have a negative effect on age at first calving or alternative age at first calving.

Key Words: beef cattle, breeding, heritability

Introduction

Age at first calving (AFC) in cattle determines reproduction precocity of heifers, that is, how early they are able to conceive, gestate, and calve. Although this trait is easy to collect when calving date is known, AFC expression depends on the breeding season when the heifer was born and when it was mated. In tropical regions, late age at first calving is one of the main negative factors that influence beef production. Reducing age at first calving increases profitability (Nunez-Domingues et al., 1991). Although estimates of heritability for reproductive traits are low (Dias et al., 2004; Azevêdo et al., 2006), age at first calving of Nelore heifers is highly variable, ranging from

47 (Biffani et al., 2000) to 35 months (Dias et al., 2004), suggesting that it can be reduced.

To improve carcass characteristics in Nellore cattle, the use of visual scores has been used (Forni et al., 2007; Koury Filho et al., 2009, 2010). The use of these visual scores has the advantage of being performed on live animals and at early ages.

Selection for unique characteristics may be accompanied by correlated responses in other characteristics. However, these correlated answers are not always in the desired direction. This can be seen when the selection for weight gains and carcass characteristics can result in larger-sized animals. Consequently, the size of the females may also increase, resulting in higher nutritional requirements, which in turn may negatively affect the reproductive performance of females kept on pasture. To try to solve these problems, the use of selection indices are fundamental (Hazel et al., 1994).

Whenever using selection indexes, it is essential to evaluate whether the results of the selection are in accordance with what was predicted, as well as to make the necessary adjustments. In this way, it is very important to monitor the genetic changes that may have occurred. Therefore, the objectives of the present study were to estimate the heritability of age at first calving and

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production traits included in the Conexão Delta G selection index and to estimate the genetic correlations between age at first calving and these production traits.

Material and Methods

Data of Nelore cattle were extracted from the database of Conexão Delta G. Only data from commercial herds that breed their heifers younger than 24 months of age were included, resulting in a file with 331,310 animals born between 1984 and 2008 in herds of eight different states of Brazil. The pedigree file contained 387,877 animals.

The following traits were included in the analyses: age at first calving, birth to weaning weight gain, post-weaning weight gain, visuals scores of conformation at weaning and at 18 months, precocity at weaning and at 18 months, muscling at weaning and at 18 months, and final index.

An alternative age at first calving (AFCg) was also evaluated, in which all heifers, including those that were mated and did not calve, were taken into account. The AFCg of non-calving heifers was computed as if heifers calved 60 days after the last heifer of the same management group had calved (Bormann and Wilson, 2010).

Animals were individually scored for conformation, precocity, and muscling relative to their management group in a scale of 1 to 5, as described by Severo (1994).

The production traits were pre-adjusted for age, dam age, and Julian birth date using correction factors generated by Conexão Delta G.

Age at first calving and AFCg contemporary groups were formed by farm, year of birth, calving season, and management group. Contemporary groups of production traits were formed by farm, year and season of birth, sex, management group, and Julian date of the evaluation.

Animals were evaluated and ranked according to an index, called final index. Percentage weightings applied on the standardized expected progeny differences of the traits included in the final index were: birth to weaning weight gain (kg), 25%; conformation at weaning (1-5 score), 4%; precocity at weaning (1-5 score), 8%; muscling at weaning (1-5 score), 8%; post-weaning weight gain (kg), 25%; conformation at 18 months (1-5 score), 4%; precocity at 18 months (1-5 score), 8%; muscling at 18 months (1-5 score), 8%; and scrotal circumference (cm), 10%.

Traits were analyzed using a bi-character animal model (Schaeffer, 2011), in which reproductive traits (AFC or AFCg) were analyzed together with production traits (weight gains, visual scores, and final index).

The general model used, in matrix notation, is described as follows:

$$Y = X\beta + Za + Wm + Sp + e,$$

in which Y = vector of phenotypic records; X = incidence matrix relating each observation to each fixed effect; β = vector of fixed effects (contemporary groups); Z = incidence matrix of direct additive genetic effects; a = vector of direct additive genetic effects; W = incidence matrix of maternal additive genetic effects; m = vector of maternal additive genetic effects; S = incidence matrix of permanent environmental effects; p = vector of permanent environmental effects; e = vector of random residuals. Assuming $E[Y] = X\beta$ and $E[a] = E[m] = E[p] = E[e] = 0$.

Maternal additive genetic effects and maternal permanent environmental effects were included only in the traits evaluated at weaning. In the final index analyses, only direct additive genetic effects were considered.

Covariance components were estimated by the method of restricted maximum likelihood. The DMU program (Madsen et al., 2006) was employed to obtain covariance components and the solutions of the effects included in the statistical model.

Direct (σ_a^2) and maternal (σ_m^2) additive genetic variance estimates were expressed as ratios of the phenotypic variance (σ_t^2), as: $\sigma_t^2 = \sigma_a^2 + \sigma_m^2 + \sigma_{am} + \sigma_p^2 + \sigma_e^2$.

Direct and maternal heritabilities were calculated as: $h_a^2 = \sigma_a^2/\sigma_t^2$ and $h_m^2 = \sigma_m^2/\sigma_t^2$, respectively.

The genetic correlations between direct additive effects of the pairs of traits analyzed together (r_{a12}) were calculated as $r_{a12} = \sigma_{a12}/(\sigma_{a1} \sigma_{a2})$, in which σ_{a12} = genetic co-variance between direct additive effects of the pair of traits evaluated together, σ_{a1} = direct additive genetic standard deviation of the first trait, and σ_{a2} = direct additive genetic standard deviation of the second trait.

Results

Age at first calving and AFCg calculated means were 33.36 and 33.39 months, respectively (Table 1). The heritability estimates of the direct effect of the reproductive traits AFC and AFCg were both 0.11 at weaning (Table 2) and were higher at age of 18 months (0.13) (Table 3). When the second character was the final index, heritability for AFC and AFCg was 0.12 (Table 4).

Although the estimated heritability for AFC and AFCg was of low magnitude, the analysis of data of the bulls included in the selection program with more than 100 daughters evaluated (Figure 1) showed high variability in the percentage of daughters with AFC lower than 28 months

of age, suggesting that AFC may be reduced by genetic selection if the best bulls for this trait are used.

The variability is also observed when AFC is standardized to expected progeny differences and bulls with more than 100 daughters were analyzed (Figure 2). In this particular case, the difference between best and worst bulls is close to 20 days and the use of best bulls could generate heifers with AFC 10 days earlier than average bull's daughter. The heritability estimate obtained for birth

to weaning weight gain was 0.18 and 0.19 for post-weaning weight gain.

Heritability estimates for the evaluated visual score traits ranged between low and intermediate, with the lowest value obtained at weaning for muscling (0.16) and the highest for precocity (0.18). The lowest heritability estimate obtained in yearlings was for weight gain (0.19) and the highest for precocity (0.29).

Direct heritability estimates found for the visual score traits at weaning were 0.17, 0.18, and 0.16, respectively for conformation, precocity, and muscling. Maternal heritability estimates found for the visual score traits at weaning were 0.07, 0.06, and 0.07, respectively for conformation, precocity, and muscling.

Table 1 - Number of observations, means, standard deviations, and minimal and maximal values of weight gain, weaning and yearling visual scores, age at first calving (AFC and AFCg), and final index

Trait	Number of observations	Mean	SD	Minimum	Maximum
WG[1] (kg)	331.310	152.66	26.35	38.47	333.64
WC[1] (score)	278.068	3.40	1.11	0.30	7.18
WP[1] (score)	278.074	3.50	1.13	0.29	7.10
WM[1] (score)	278.072	3.31	1.15	0.25	6.95
YG[2] (kg)	169.361	105.15	34.66	31.32	368.82
YC[2] (score)	184.769	3.60	1.08	0.13	8.15
YP[2] (score)	184.764	3.56	1.10	0.50	7.81
YM[2] (score)	184.726	3.34	1.12	0.17	8.19
AFC (days)	42.813	1001.09	129.97	600.00	1598.00
AFCg (days)	53.240	1001.89	132.11	600.00	1599.00
Final index (points)	113.323	7.3734	5.11	0.19	33.35

[1] WG - weight gain; WC - conformation; WP - precocity; and WM - muscling at weaning.
[2] YG - weight gain; YC - conformation, YP - precocity; and YM - muscling at eighteen months of age.
AFC - age at first calving; AFCg - alternative age at first calving, including heifers that did not calve; SD - standard deviation.
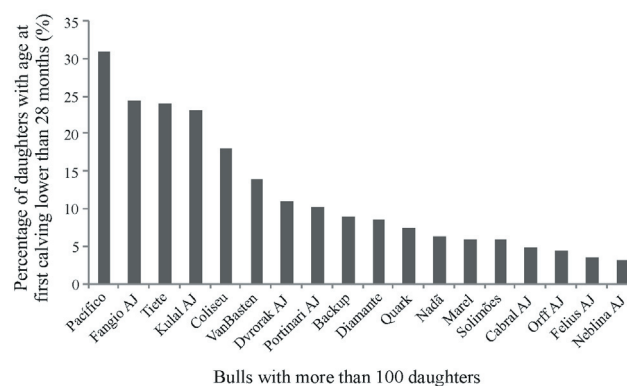

Figure 1 - Bulls with more than 100 daughters and percentage of daughters with age at first calving lower than 28 months.

Table 2 - Covariance component estimates and genetic parameters obtained with the bi-character analyses of the traits age at first calving (AFC) and age at first calving with the inclusion of heifers that did not calve (AFCg) with weight gain (WG), conformation (WC), precocity (WP), and muscling (WM) at weaning

Covariance	AFC				AFCg			
	WG-AFC	WC-AFC	WP-AFC	WM-AFC	WG-AFCg	WC-AFCg	WP-AFCg	WM-AFCg
σ^2_{a1}	68.57±2.82	0.18±0.008	0.21±0.009	0.20±0.009	68.45±2.81	0.18±0.008	0.21±0.009	0.20±0.009
σ^2_{m1}	32.28±1.91	0.07±0.005	0.07±0.006	0.08±0.006	32.18±1.90	0.07±0.005	0.07±0.006	0.08±0.006
σ^2_{p1}	66.09±1.52	0.14±0.004	0.15±0.004	0.17±0.004	66.05±1.52	0.14±0.004	0.15±0.004	0.17±0.004
σ^2_{e1}	197.15±1.94	0.61±0.005	0.68±0.006	0.70±0.006	197.27±1.93	0.61±0.005	0.68±0.006	0.70±0.006
σ_{am1}	15.39±1.47	0.01±0.004	0.01±0.005	0.01±0.005	15.52±1.47	0.01±0.004	0.01±0.005	0.01±0.005
σ^2_{a2}	146.07±19.24	146.83±19.77	148.51±19.89	147.21±19.85	173.42±20.25	180.92±21.36	184.71±21.47	184.23±21.48
σ^2_{e2}	1134.77±19.35	1128.18±19.84	1126.84±19.92	1127.97±19.91	1351±20.31	1358.28±21.28	1355.99±21.34	1356.42±21.35
σ_{a12}	14.75±5.97	0.94±0.334	−0.51±0.36	−0.24±0.35	10.76±5.98	0.70±0.34	−0.94±0.36	0.24±0.22
h^2_{a1}	0.18	0.17	0.18	0.16	0.18	0.17	0.18	0.16
h^2_{m1}	0.08	0.07	0.06	0.07	0.08	0.07	0.06	0.07
h^2_{a2}	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
r_{a12}	0.14±0.06	0.18±0.06	−0.09±0.06	−0.04±0.06	0.09±0.05	0.12±0.05	−0.14±0.05	−0.10±0.05

σ^2_{a1} - variance of the direct effect of the first trait; σ^2_{m1} - variance of the maternal effect of the first trait; σ^2_{p1} - variance of the maternal permanent environmental effect on the first trait; σ^2_{e1} - residual variance of the first trait; σ_{am1} - covariance between direct and maternal effects of the first trait; σ^2_{a2} - variance of the direct effect of the second trait (AFC); σ^2_{e2} - residual variance of the second trait (AFC); σ_{a12} - covariance between the direct effect of the first trait and the direct effect of the second trait; h^2_{a1} - heritability of the direct effect of the first trait (weight gain, conformation, precocity, or muscling); h^2_{m1} - heritability of the maternal effect of the first trait (weight gain, conformation, precocity, or muscling); h^2_{a2} - heritability of the direct effect of the second trait (AFC or AFCg); r_{a12} - genetic correlation between both traits.

Direct heritability estimates of the visual scores at 18 months were 0.27, 0.29, and 0.27 for conformation, precocity, and muscling scores, respectively.

The analyses demonstrate, in general, weak and negative correlations between production traits and AFC, ranging from almost zero (–0.01 for post-weaning gain - AFC) to low (–0.13±0.03 for precocity at 18 months - AFC), except for the correlations between weight gain and conformation at weaning (0.14 and 0.18, respectively), which were positive.

The estimated direct heritability for the final index was almost 1 (0.98) and genetic correlations between final index and AFC or AFCg were –0.08 and –0.09, respectively (Table 4).

Discussion

Means for AFC and AFCg were close to the value observed by Dias et al. (2004) of 34.44 months. Higher values were reported in Nelore heifers (Azevêdo et al., 2006). The lower AFC values obtained in the present study relative to those reported in literature resulted from the strong genetic selection imposed on the studied herds for this trait, as well as to the management practice of sexually challenging the heifers between 13 and 16 months of age. It is known that AFC expression is also limited by breeding season, considering both the season when the heifer was born and its first breeding season. Heifers born late in the breeding season are younger and

Table 3 - Covariance component estimates and genetic parameters obtained with the bi-character analyses of the traits age at first calving (AFC) and age at first calving with the inclusion of heifers that did not calve (AFCg) with weight gain (YG), conformation (YC), precocity (YP), and muscling (YM) at eighteen months of age

Covariance	AFC				AFCg			
	YG-AFC	YC-AFC	YP-AFC	YM-AFC	YG-AFCg	YC-AFCg	YP-AFCg	YM-AFCg
σ^2_{a1}	69.23±2.27	0.25±0.005	0.29±0.006	0.27±0.006	69.27±2.27	0.25±0.005	0.29±0.006	0.27±0.006
σ^2_{e1}	293.01±2.10	0.65±0.004	0.72±0.005	0.75±0.005	293.05±2.10	0.65±0.004	0.72±0.005	0.75±0.005
σ^2_{a2}	166.26±21.06	164.82±20.87	165.57±20.81	166.16±20.84	206.58±23.02	203.45±22.37	201.16±22.22	202.92±22.28
σ^2_{e2}	1102.29±21.06	1114.19±20.61	1113.86±20.55	1113.35±20.57	1290.99±22.48	1331.18±21.92	1333.42±21.82	1331.91±21.85
σ_{a12}	−1.79±5.17	−0.28±0.26	−0.94±0.27	−0.70±0.27	−5.02±0.53	−0.36±0.26	−1.21±0.28	−1.03±0.28
h^2_{a1}	0.19	0.27	0.29	0.27	0.19	0.27	0.29	0.27
h^2_{a2}	0.13	0.12	0.12	0.12	0.13	0.13	0.13	0.13
r_{a12}	−0.01±0.04	−0.04±0.04	−0.13±0.03	−0.10±0.04	−0.04±0.04	−0.05±0.03	−0.15±0.03	−0.13±0.03

σ^2_{a1} - variance of the direct effect of the first trait; σ^2_{e1} - variance of the maternal effect of the first trait; σ^2_{a2} - variance of the direct effect on the second trait (AFC); σ^2_{e2} - residual variance of the second trait (AFC); σ_{a12} - covariance between the direct effect of the first trait and the direct effect of the second trait; h^2_{a1} - heritability of the direct effect of the first trait (weight gain, conformation, precocity, or muscling) ; h^2_{a2} - heritability of the direct effect of the second trait (AFC or AFCg); r_{a12} - genetic correlation between both traits.
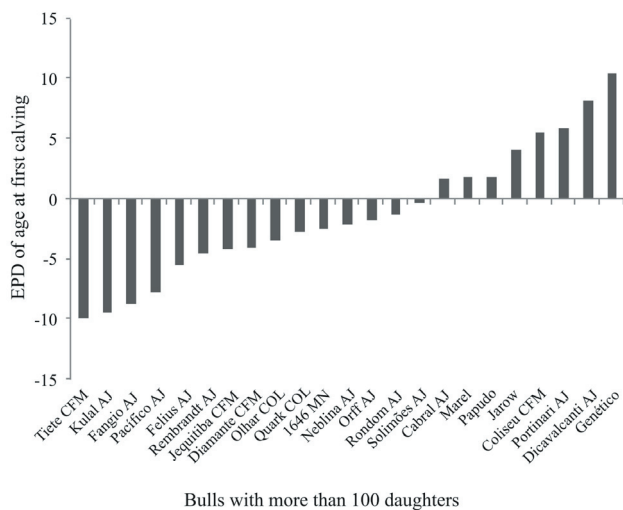

Figure 2 - Expected progeny differences (EPD) of age at first calving (in days) for bulls with more than 100 daughters.

Table 4 - Covariance component estimates and genetic parameters obtained with the bi-character analyses of the traits age at first calving (AFC) and age at first calving with the inclusion of heifers that did not calve (AFCg) with final index

Covariance	Final index-AFC	Final index-AFCg
σ^2_{a1}	22.47±0.15	22.47±0.15
σ^2_{e1}	0.32±0.06	0.32±0.06
σ^2_{a2}	169.00±21.23	193.14±22.12
σ^2_{e2}	1112.71±20.92	1332.25±21.82
h^2_{a1}	0.98	0.98
h^2_{a2}	0.12	0.12
r_{a12}	−0.08±0.02	−0.09±0.02

σ^2_{a1} - variance of the direct effect of final index; σ^2_{e1} - variance of the residual effect of final index; σ^2_{a2} - variance of the direct effect on the second trait (AFC or AFCg); σ^2_{e2} - residual variance of the second trait (AFC or AFCg); h^2_{a1} - heritability of the direct effect of final index; h^2_{a2} - heritability of the direct effect of the second trait (AFC or AFCg); r_{a12} - genetic correlation between both traits.

may calve earlier than those born early in the same season (Bormann and Wilson, 2010).

The low values for AFC and AFCg heritabilities are consistent with those reported in literature for Nelore, ranging between 0.09±0.03 (Dias et al., 2004) and 0.21±0.05 (Azevêdo et al., 2006). The similar values obtained for AFC and AFCg heritability estimates may be explained by the high heifer pregnancy rate in the studied herds, which number of non-pregnant females represented 19.58%. This probably happened because farmers do not report all heifers exposed to breeding, but only those that got pregnant and calved.

Values found for direct heritability for visual score traits were consistent with those obtained by Forni et al. (2007), who obtained heritability estimates of 0.12, 0.15, and 0.12 for conformation, precocity, and muscling at weaning, respectively in Nelore cattle. Koury Filho et al. (2010), in herds with predominantly Nelore genes in their genetic composition, found heritability estimates of visual scores of 0.13, 0.25, and 0.23 for conformation, precocity, and muscling, respectively, at weaning.

The highest heritability values found at 18 months of age show that maternal environmental effects and maternal genetic effects were in some way important in the estimation of heritability at weaning. Koury Filho et al. (2010) observed that the inclusion of the maternal environmental effect is important in the evaluation of traits up to weaning, even though the maternal genetic effect is considered. These authors also found higher heritability estimates for data at 18 months than at weaning.

Forni et al. (2007) obtained lower maternal heritability estimates than those found in this study for visual scores at weaning (0.04 for conformation, 0.03 for precocity, and 0.05 for muscling) in Nelore cattle. Values for direct heritability estimates for conformation, precocity, and muscling were similar to those obtained by several researchers (Cardoso et al., 2004; Koury Filho et al., 2009).

The results for the genetic correlations were consistent with literature, in which the genetic association between growth and reproductive traits are usually reported as close to zero or slightly negative (Mercadante et al., 2000; Pereira et al., 2001). The genetic correlations between weight gain from birth to weaning and conformation at weaning with AFC (0.14 and 0.18, respectively) indicate that the higher the weight gain at this stage, and the better the conformation, the greater the age at first calving. On the other hand, AFC correlations with precocity and muscling at weaning were small, showing that they are almost genetically independent. The negative signs in these two correlations indicate that the greater the muscling, and the greater the

precocity, the lower the age at the first parturition. These results suggest that these traits, which are subjective and related to finishing, should be used with caution when the intention is to correlate them with sexual precocity.

The positive associations between AFC and weight gain from birth to weaning and between AFC and conformation at weaning may also be explained by the fact that weight gain is genetically determined and associated to mature size. Selection for weaning and yearling weights of replacement heifers result in cows with bigger mature sizes (Klosterman, 1972), which may negatively affect female fertility (Luna-Nevarez et al., 2010).

However, Mercadante et al. (2003), in a study with Nelore cattle, concluded that the selection for body weight results in significant body weight responses in yearlings and older cattle, but the trait days to calving is not affected. Our results partially agree with theirs, once the correlation close to zero between AFC and weight gain at 18 months of age (–0.01 and –0.04, respectively for AFC and AFCg) indicates they are genetically independent from each other.

At eighteen months of age, the correlations between precocity and muscling with AFC and AFCg remained low and negative, despite a small numerical increase. On the other hand, the correlation with conformation decreased, being close to zero and negative.

The inclusion of heifers that did not calve in the analysis of the data of 18 months increased correlation values up to 5%. Supporting the idea that heifers that did not conceive after the breeding season would have worse genetic merit for this trait and removing them from the analysis may exclude relevant information on genetic differences among herds (Meyer et al., 1990).

The genetic correlations between AFC and final index (Table 4) were low (–0.08 and –0.09, respectively for AFC and AFCg). Despite this low genetic correlation, it is favorable, as the increase in the final index tends to be coupled with a reduction in AFC. The negative correlation is probably due to the traits precocity and muscling, which are part of final index and are negatively correlated with it. The heritability estimates close to 1.00 found in the present study for final index are due to the fact that this index is based on standardized expected progeny differences, which contain the sum of the additive genetic effects after the non-genetic effects that influence the phenotype to be removed.

Conclusions

The heritability estimates obtained in the present study show that it is possible to achieve genetic gains by selection

of all the analyzed traits. However, higher response to selection is expected when selection is practiced at eighteen months of age than at weaning. Apparently, selection for traits related to carcass characteristics and production, such as visual scores and selection index including these traits, do not affect, or minimally affect, the age at first calving and vice versa.

Acknowledgments

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