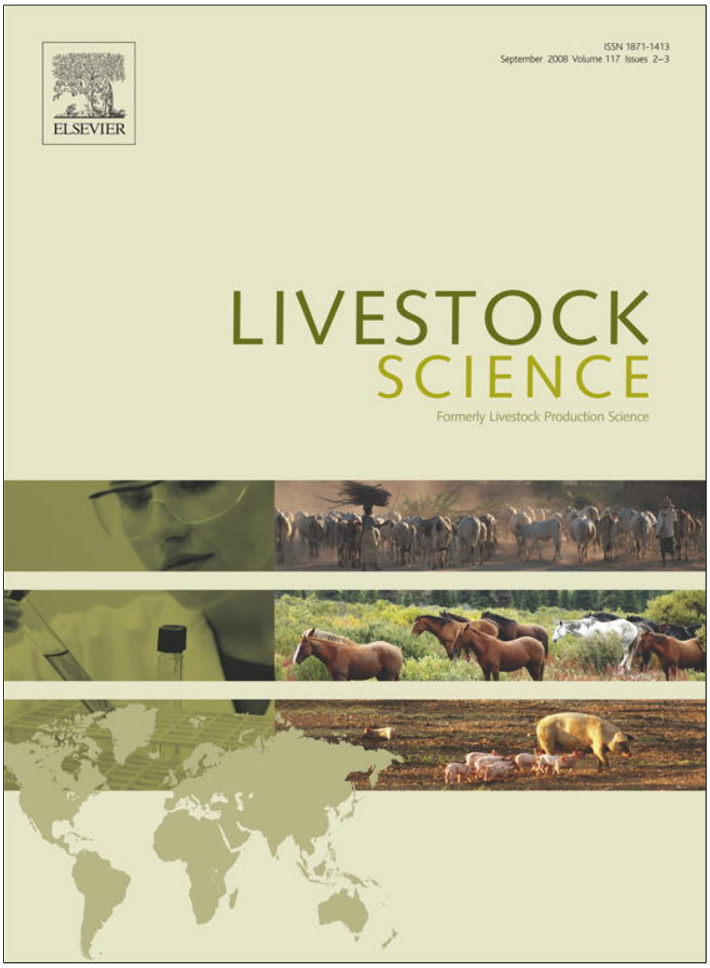
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# Genetic associations between accumulated productivity, and reproductive and growth traits in Nelore cattle

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**Abstract**

The total meat yield in a beef cattle production cycle is economically very important and depends on the number of calves born per year or birth season, being directly related to reproductive potential. Accumulated Productivity (ACP) is an index that expresses a cow's capacity to give birth regularly at a young age and to wean animals of greater body weight. Using data from cattle participating in the "Program for Genetic Improvement of the Nelore Breed" (PMGRN — Nelore Brasil), bi-trait analyses were performed using the Restricted Maximum Likelihood method based on an ACP animal model and the following traits: age at first calving (AFC), female body weight adjusted for 365 (BW365) and 450 (BW450) days of age, and male scrotal circumference adjusted for 365 (SC365), 450 (SC450), 550 (SC550) and 730 (SC730) days of age. Median estimated ACP heritability was 0.19 and the genetic correlations with AFC, BW365, BW450, SC365, SC450, SC550 and SC730 were 0.33, 0.70, 0.65, 0.08, 0.07, 0.12 and 0.16, respectively. ACP increased and AFC decreased over time, revealing that the selection criteria genetically improved these traits. Selection based on ACP appears to favor the heaviest females at 365 and 450 days of age who showed better reproductive performance as regards AFC. Scrotal circumference was not genetically associated with ACP.


*Keywords:* Beef cattle; Genetic correlation; Reproductive efficiency; Heritability

## 1. Introduction

In beef cattle production, the total amount of meat produced per year directly influences the profitability of the production system. To improve productive performance, beef cattle improvement programs have used growth traits like weight and average daily weight gain as selection criteria. However, selecting for these traits can have unfavorable effects on other traits of economic importance such as dam size, early fat deposition and reproductive traits.

The beef produced on a farm depends on the number of calves born per year or birth season, and is thus directly related to reproductive potential. Cows that do not give birth to heavy calves with a short interval

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between calving are not useful in the cattle production system. Thus, owing to difficulty in establishing an indicator trait that simultaneously represents productive and reproductive traits, indexes consisting of several traits are often employed in genetic evaluation.

Accumulated Productivity (ACP) is an index that evaluates female productivity, considering calf body weight at weaning and number of offspring produced. The ACP depends directly on age at first calving, on the interval between calvings, and on the time the cow remains in the herd. ACP expresses the cow's ability to give birth regularly, to begin early, and to wean heavier calves (Lôbo et al., 2000). Since this index incorporates many traits important in the selection of females and expresses genetic variability, Schwengber et al. (2001) have suggested the inclusion of ACP in beef cattle improvement programs.

The present investigation aims to provide tools for the selection of Nelore breed females participating in PMGRN — Nelore Brasil, employing both phenotypic variation and the genetic associations between ACP and reproductive and growth traits. Genetic trends were also estimated for ACP and age at first calving (AFC) to evaluate genetic evolution of these traits.

## 2. Materials and methods

### 2.1. Animals and data

Data were collected from Nelore breed animals, born between 1976 and 2002, belonging to 22 farms located in the state of São Paulo, Brazil, participating in the PMGRN — Nelore Brasil program, coordinated by the National Association of Breeders and Researchers ("Associação Nacional de Criadores e Pesquisadores" — ANCP).

Animals were raised in a pasture regime without supplemental feeding. Calves were weaned at six to eight months of age. Reproductive management consisted of a breeding season lasting from 60 to 120 days using artificial insemination or controlled natural breeding. Body weights and male scrotal circumferences were measured every three months up to at least 18 months of age.

An index, termed 'total genetic merit', developed by PMGRN — Nelore Brasil was employed to select genetically superior males and females (Lôbo et al., 2000). This index includes breeding value estimates for the following weighted traits: maternal ability (0.20), pre-weaning gain (0.20), post-weaning gain (0.20), yearling gain (0.20), and scrotal circumference at 365 (0.10) and 450 days of age (0.10).

The traits evaluated in the cows were: accumulated productivity (ACP), age at first calving (AFC), and body weight adjusted for 365 (BW365) or 450 (BW450) days of age. Traits evaluated in males were scrotal circumference corrected for 365 (SC365), 450 (SC450), 550 (SC550) or 730 (SC730) days of age.

The ACP index was calculated using the following expression (Lôbo et al., 2000):

$$\mathrm{ACP} = \frac{W_{210} \times n_{\mathrm{c}} \times 365}{\mathrm{ADC_n} - 550}.$$

Where ACP is accumulated productivity, $W_{210}$ average body weight of weaned calves corrected for 210 days of age, $n_{\mathrm{c}}$ the total number of calves produced, and $\mathrm{ADC_n}$ dam's age at last calving. The constants 365 and 550 enable expression of fertility on an annual basis, given that an AFC of around 30 months is the goal of PMGRN — Nelore Brasil.

### 2.2. Data editing and contemporary groups

Data were limited to offspring whose parents and birth dates were known. In the data set used for the bi-trait analyses of ACP and AFC, traits BW365 and BW450 were considered only in animals providing measurements for both traits. Animals born up to 1988 were placed in the same birth year class, and those born in 1989 were placed with those born in 1990, owing to the few data available.

Exclusion criteria were: parents with less than two offspring in each variable, contemporary group (CG) showing less than four observations per trait, and animals that died during husbandry.

The definition of CG was the same for all traits and comprised animals belonging to the same farm born in the same year and birth season. Two birth seasons were defined: calves born from October to March (rainy season), and calves born from April to September (dry season).

### 2.3. Adjustment of body weight and scrotal circumference for age

Female body weights were adjusted for 365 and 450 days of age, and scrotal circumferences were adjusted for 365, 450, 550 and 730 days of age, using a modified, non-linear Logistics function that best adjusted growth, considering the non-linear curves examined: Brody (Brody, 1945), Richards (Richards, 1959), Von Bertalanffy (Von Bertalanffy, 1957), Logistics (Nelder, 1961), Gompertz (Laird, 1965) and a modified Logistics (Quirino et al., 1999). On analyzing body growth of males in this same database, Frizzas (2006) also found that the non-linear modified logistics function best described testicular growth per unit time.

The non-linear modified logistics function is described by:

$$Y = \frac{A}{(1 + Be^{-kt})} + \varepsilon.$$

Where $Y$ is body weight in kg, or scrotal circumference in cm, adjusted for age "$t$", $A$ the asymptotic value of "$Y$" when "$t$" tends towards infinity and is interpreted as the body weight or testicular size of the adult animal, $B$ an integration constant related to the initial weight or measurement, $e$ natural logarithm, $k$ maturation rate, $t$ animal's age in days and ε random error associated with each weight or measurement.

Female body weight adjusted to 210 days (BW210) used as a covariable for ACP and AFC was derived from the product of observed body weight and a linear correction factor, *i.e.*, the ratio between the expected body weight at 210 days and the expected body weight at each age. The expected body weights at each age were obtained from a quadratic regression of body weight on age. Thus, the body weight considered was that closest to body weight at 210 days, within an interval of 150 to 305 days of age.

This adjustment was adopted to increase the number of animals in the analyses. A body weight close to 210 days is sufficient to adjust a linear correction; at least three measurements of body weight taken during each dam's life are necessary. After correction, a least squares analysis was performed to validate the efficiency of the BW210 adjustment. The effect of age was not significant for BW210, indicating that the correction was effective.

Male body weights, adjusted for 365 (MBW365), 450 (MBW450), 550 (MBW550) and 730 (MBW730) days of age, and respectively used as covariates for SC365, SC450, SC550 and SC730 were obtained from the non-linear logistics function used by Nelder (1961) and described by Frizzas (2006) as the curve that best described male body growth in this database.

This logistic function is described by:

$$Y = A\left(1 + e^{-k \cdot t}\right)^{-m} + \varepsilon.$$

Where $Y$ is body weight in kg adjusted for age "$t$", $A$ the asymptotic value of "$Y$" when "$t$" tends towards infinity interpreted as the body weight of an adult animal, $e$ natural logarithm, $k$ maturation rate, $t$ animal's age in days, $m$ a constant that defines the shape of the curve, and ε random error associated with each measurement.

### 2.4. Statistical analyses

A least squares analysis, employing the GLM procedure available in the SAS software package (SAS 9.1, SAS Institute, Cary, NC, USA) helped define the environmental effects considered in the mixed model.

The age of the dam at calving did not significantly affect ACP but did affect AFC. However, this effect was not included in the AFC model owing to the few data available for dam age. The coefficient of determination also was unaffected when the dam's age at calving was considered as a covariate in the AFC model.

Maternal genetic and permanent environmental effects were not considered in these models. The data set structure excluded the maternal permanent environment effect from the analyses, owing to the fact that most dams had only one offspring.

Residual normality was verified for each variable and observations exhibiting a standardized residual 3.5-fold above or below the standard deviation were excluded. The final data set is described in Table 1. The total number of animals in the numerator relationship matrix, including base animals, was 42,734.

Table 1
Number of animals, sires, dams and contemporary groups (CG) considered in bi-trait analyses of accumulated productivity (ACP) based on age of first calving (AFC), female body weight adjusted for 365 (BW365) and 450 (BW450) days of age, and scrotal circumference adjusted for 365 (SC365), 450 (SC450), 550 (SC550) and 730 (SC730) days of age

| Trait | Number of animals | Sires | Dams | CG |
|---|---|---|---|---|
| ACP and AFC [a] | 1661 | 184 | 184 | 133 |
| ACP and BW365 [a] | 1685 | 191 | 1379 | 124 |
| ACP and BW450 [a] | 1677 | 191 | 1373 | 123 |
| ACP [b] | 1739 | 189 | 1438 | 134 |
| SC365 | 2525 | 199 | 1951 | 110 |
| SC450 | 2538 | 199 | 1962 | 110 |
| SC550 | 2540 | 199 | 1963 | 110 |
| SC730 | 2536 | 199 | 1961 | 110 |

[a] Same structure for both traits.
[b] ACP data used in bi-trait analyses with scrotal circumference at different ages.

Animal models were defined for the following traits:

- For ACP, in bi-trait analyses using BW365 or BW450, only the CG class was considered as a fixed effect;
- For ACP, in bi-trait analyses using AFC, SC365, SC450, SC550 or SC730, the CG class was considered a fixed effect and the BW210 effect a linear covariate.
- For AFC, the CG class fixed effects and the BW210 effect as a second degree linear covariate were considered;
- For BW365 and BW450, only the CG class was considered as a fixed effect;
- For SC365, SC450, SC550 and SC730, the CG class was considered a fixed effect, and MBW365, MBW450, MBW550 and MBW730 were considered linear covariates, respectively.

Estimation of genetic parameters and breeding values was performed using the Restricted Maximum Likelihood Method (REML) for bi-trait animal models and computed using MTDFREML (Boldman et al., 1995). Initial values were taken from least squares analyses, ACP single-trait REML analysis, and from the literature (Lôbo, 1998; Gutiérrez et al., 2002; Forni and Albuquerque, 2005). Environmental covariances between ACP and SC365, SC450, SC550 and SC730 were defined as zero. After reaching the convergence stipulated at $10^{-9}$, the analyses were resumed until confirmation of a global maximum (not a local maximum estimate). The models adopted represented in matrix notation were:

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} + \begin{bmatrix} Z_1 & 0 \\ 0 & Z_2 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \end{bmatrix}.$$

Where $y_1$ is the observations vector of variable 1 (ACP), $y_2$ the observations vector of variable 2 (AFC, BW365, BW450, SC365, SC450, SC550, SC730), $b_1$ the fixed effect vector for variable 1, $b_2$ the fixed effect vector for variable 2, $u_1$ the vector of random effect of breeding value for variable 1, $u_2$ the vector of random effect of breeding value for variable 2, $X_1(X_2)$ the incidence matrix that associates the elements of $b_1(b_2)$ with $y_1(y_2)$, and $Z_1(Z_2)$ is the incidence matrix that associates the elements of $u_1(u_2)$ with $y_1(y_2)$.

The following assumptions were made for the models: $E(y_i)=X_i b_i$ for = 1, 2 and

$$\mathrm{Var}\begin{bmatrix} u_1 \\ u_2 \\ e_1 \\ e_2 \end{bmatrix} = \begin{bmatrix} A\sigma^2_{a1} & A\sigma_{a1a2} & 0 & 0 \\ A\sigma_{a1a2} & A\sigma^2_{a2} & 0 & 0 \\ 0 & 0 & I\sigma^2_{e1} & \\ 0 & 0 & & I\sigma^2_{e2} \end{bmatrix}.$$

Where $A$ is the additive numerator relationship matrix and $I$ is the identity matrix, $\sigma^2_{a1}$ and $\sigma^2_{a2}$ are the additive genetic variances for traits 1 and 2, respectively, $\sigma_{a1a2}$ is the additive genetic co-variance between traits 1 and 2, and $\sigma^2_{e1}$ and $\sigma^2_{e2}$ are the residual variances for traits 1 and 2, respectively.

Genetic trends were calculated from a linear regression of mean predicted breeding values (PBV) based on birth year. A $t$-statistic was used to test the hypothesis that the regression coefficient for each equation is equal to zero. The 24,433 male and female animals whose PBV was estimated from ACP with AFC REML bi-trait analyses were used in the linear regressions.

## 3. Results and discussion

The ACP values varied from 66 to 255 kg with means of 149±26, 146±26 and 147±26 kg calves/dam/year in the data set for bi-trait analyses of AFC, female body weight and scrotal circumference, respectively. Mean values and standard deviations, and minimum and maximum values for AFC, BW365, BW450, SC365, SC450, SC550 and SC730 are provided in Table 2.

Schwengber et al. (2001), Azevêdo et al. (2005) and Faria et al. (2007) noted smaller mean ACP in the Nelore breed (130.0±35.0, 96.7±46.7 and 134 kg weaning calves/dam/year, respectively) compared to those found here. Since these authors used data from herds in different regions of Brazil, the smaller means may result from the different genetic and environmental factors in each area. Baldi Rey (2006) found a mean of 79.0± 29.0 kg weaned calves per year in a herd for the Canchim breed.

Real fertility (RF) is an index that measures kg weaned calves per dam per effective year, *i.e.*, calf weight at weaning every year is adjusted by the ratio between 365 days and the interval between calving during the period examined. Silveira et al. (2004) estimated a mean RF similar to that found here (148.1 kg weaned calves/dam).

Our AFC mean agrees with those reported by Pelicioni et al. (1999), Garnero et al. (2001) and Pereira et al. (2002) that varied from 36.0 to 37.0±3.2 months, also in Nelore cattle. Silveira et al. (2004), Mercadante et al. (2000) and Bertazzo et al. (2004), studying Nelore cattle in the state of São Paulo, Brazil reported means of 41.7, 38.3±3.5 and 38.7±4.5 months, respectively, and for another zebu breed, Lôbo (1998) calculated a mean of 59±16.4 months for the same trait. Smaller means are recorded European cattle (Frazier et al., 1999; Pelicioni et al., 1999) and in Nelore herds where dams had been prematurely exposed to sires (Pereira et al., 2002; Dias et al., 2004; Silva et al., 2005).

Table 2
Means, standard deviation (SD), and minimum (Min) and maximum (Max) values for age at first calving (AFC, months) female body weights (BW, kg) adjusted for 365 (BW365) and 450 (BW450) days of age, and scrotal circumference (SC, cm) adjusted for 365 (SC365), 450 (SC450), 550 (SC550) and 730 (SC730) days of age

| Trait | Mean±SD | Min | Max |
|---|---|---|---|
| AFC | 36.0±4.0 | 27.0 | 49.0 |
| BW365 | 224.0±27.0 | 118.0 | 341.0 |
| BW450 | 260.0±31.0 | 141.0 | 383.0 |
| SC365 | 19.7±2.3 | 10.7 | 27.2 |
| SC450 | 23.2±2.7 | 13.1 | 31.6 |
| SC550 | 26.5±3.0 | 16.6 | 35.8 |
| SC730 | 30.7±3.7 | 17.2 | 42.3 |

The variation recorded in the literature reflects the diversity of genetic material in different regions of Brazil. Further, the breeding management practices adopted by cattle producers to define whether animals should begin reproduction by body weight or age, influence variation in this trait. Earlier maturing animals do not have the opportunity to express their genetic potential because they are crossed only during the controlled breeding season. Animals that had not yet given birth for the first time or were discarded were not included in our analyses.

The means for BW365 were similar to those reported by Marcondes et al. (2002) and Bertazzo et al. (2004) in Nelore cattle, and by Ferraz Filho et al. (2002) in the Tabapuã breed. Of the articles consulted, only Siqueira et al. (2003) examined standardized body weight near 450 days of age, observing an average of 250.0±44.0 kg for standardized body weight at 455 days of age.

Most of the literature reports adjust body weight for 550 days of age. Averages in the Nelore breed range from 275.0±7.0 kg to 319.6±38.8 kg (Garnero et al., 2001; Marcondes et al., 2002; Bertazzo et al., 2004; Silveira et al., 2004; Horimoto et al., 2007) for this trait. Such average variations reported in the literature are expected since the cattle production system is extensive and depends on natural pastures. Consequently, the different nutritional conditions and herd management practices in each region affect growth and weight gain.

When studying 54 Nelore herds partaking in the PMGRN — Nelore Brasil, Borjas et al. (2003) found similar averages for scrotal circumference adjusted for 365, 456 and 548 days of age. Averages similar to that for SC550 also have been described by Silveira et al. (2004), Eler et al. (2006) and Horimoto et al. (2007). Higher values for this trait have been reported in the Nelore breed by Pereira et al. (2000) and in crossed animals by Dal-Farra et al. (2000). No investigation has analyzed scrotal circumference measured at 730 days of age in beef cattle.

The heritability estimates, their respective standard errors and the estimated correlation coefficients in ACP bi-trait analyses with AFC, BW365, BW450, SC365, SC450, SC550 and SC730 are given in Table 3.

Our ACP heritability estimates for the Nelore breed are greater than those presented by Schwengber et al. (2001) and Azevêdo et al. (2005), *i.e.*, 0.15 and 0.11±0.06, respectively. Using a Bayesian inference, Faria et al. (2007) found a 95% confidence interval for ACP heritability estimates of from 0.19 to 0.31. Baldi Rey (2006) estimated a heritability of 0.14 for an index that also measures kg weaned calves per dam per year for the Canchim breed. Our ACP heritability estimates suggest that inclusion of this index in the selection objectives can improve the production of kg weaned calves per dam per year.

On average, the reproductive rates exhibit moderate to low heritability estimates, since they consider reproductive traits highly influenced by the environment. The magnitude of the heritability estimates for these rates reflects the fact that the heritability of the index tends to be defined by the trait with the least heritability considered in its expression and which considers reproductive traits.

The differences in proportion of additive variance obtained in the ACP analyses with AFC, BW365 and BW450, and with SC365, SC450, SC550 and SC730 reveal that the data sets display different phenotypic variations. Further, the ACP model used in the analyses with BW365 and BW450 did not consider BW210 as a covariate.

Table 3
Estimates of heritability coefficients ($h^2$), and of genetic ($r_G$), phenotypic ($r_P$) and environmental ($r_e$) correlations obtained in accumulated productivity (ACP) bi-trait analyses for age at first calving (AFC), female body weight corrected for 365 (BW365) and 450 (BW450) days of age, and scrotal circumference corrected for 365 (SC365), 450 (SC450), 550 (SC550) and 730 (SC730) days of age

| Trait 2 | Trait 1 (ACP) | | | | |
|---|---|---|---|---|---|
| | $h_1^2$ | $h_2^2$ | $r_P$ | $r_G$ | $r_e$ |
| AFC | 0.14 (0.06) | 0.07 (0.04) | −0.36 | −0.33 (0.04) | −0.71 (0.27) |
| BW365 | 0.25 (0.06) | 0.43 (0.07) | 0.192 | 0.70 (0.12) | −0.05 (0.08) |
| BW450 | 0.23 (0.06) | 0.46 (0.07) | 0.209 | 0.65 (0.13) | −0.01 (0.08) |
| SC365 | 0.19 (0.06) [a] | 0.48 (0.07) [a] | 0.023 | 0.08 | 0.00 |
| SC450 | 0.19 (0.06) [a] | 0.66 (0.07) [a] | 0.024 | 0.07 | 0.00 |
| SC550 | 0.19 (0.06) [a] | 0.65 (0.07) [a] | 0.042 | 0.12 | 0.00 |
| SC730 | 0.19 (0.06) [a] | 0.43 (0.07) [a] | 0.046 | 0.16 | 0.00 |

Values in parentheses are the standard error of the estimate.
[a] Standard error of estimate obtained from single-trait analysis.

Silveira et al. (2004) estimated a heritability of 0.06 for RF, an index that also measures kg weaned calves per dam. Bertazzo et al. (2004) estimated heritabilities varying from 0.09 to 0.46 for different indexes consisting of productive (dam body weight and body weight of calves at weaning) and reproductive (number of calvings and intervals between calving) traits. The smallest heritability estimates were found when the sum of kg calves produced during a dam's lifetime was considered.

Mercadante et al. (2000) and Bertazzo et al. (2004) analyzing information on number of calvings, intervals between calving, and age at first calving, as an index evaluating reproductive efficiency (RE), estimated heritabilities of 0.16 and 0.0, respectively.

The heritability estimated here for AFC was greater compared to those found by Grossi (2006) studying the same database in bi-trait analysis of AFC using female body weights and scrotal circumference.

Although AFC is easy to observe and is measured early in life for females, this index is greatly influenced by the environment, as noted by Mercadante et al. (2000), Pereira et al. (2002) and Silveira et al. (2004). The heritabilities estimated by these authors were 0.09, 0.02 and 0.05, respectively, for this trait in Nelore cattle. The greatest heritability values, 0.36 and 0.27, were estimated by Bertazzo et al. (2004) and Gressler et al. (2005), respectively. Estimates of heritability for AFC vary from 0.08 to 0.22 in different breeds (Frazier et al., 1999; Martínez-Velázquez et al., 2003; Talhari et al., 2003).

Pereira et al. (2002) and Dias et al. (2004), studying herds in which Nelore heifers were exposed to a sire at younger ages (14 to 18 months) found greater heritability estimates for AFC (0.18 and 0.12, respectively) compared to those found here.

With regard to BW365, Mercadante et al. (2000) and Gunski et al. (2001) reported smaller heritability values in Nelore breed herds compared to our values. Marcondes et al. (2002) and Bittencourt et al. (2002) proposed different models to examine the variance components of BW365 and BW455, corrected by average daily gain and linear adjustment, respectively, noting that heritability estimates increase when the permanent environment and maternal effects on the model were not considered. In the analyses where these effects were not considered, heritability agreed with our present estimates. The heritability estimated here (0.46) for BW450 agrees with those from Siqueira et al. (2003) for standardized

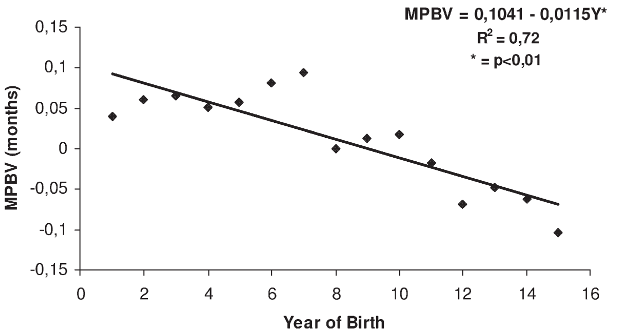


Fig. 1. Linear regression of mean breeding values (MPBV, in months), based on year of birth (Y), from 1988 to 2003, to age of first calving (AFC).

body weight at 455 days of age that varied from 0.44 to 0.53.

The estimated heritability values for BW365, BW450, SC365, SC450, SC550 and SC730 in the ACP bi-trait analyses agree with those from Grossi (2006) for bi-trait analyses of these body weights and scrotal circumferences using AFC. Eler et al. (2006) employing method R procedures reported similar estimates for SC450 and SC550 while Horimoto et al. (2007) found a higher estimate for SC550 (0.55±0.05). Thus, body weight and scrotal circumference traits corrected for age should respond to selection based on phenotype. However, selection for scrotal circumference may be more efficient when measured between 450 and 550 days of age.

The estimates of genetic and environmental correlations between AFC and ACP were −0.71±0.27 and −0.33±0.04, respectively. The negative, elevated genetic correlation indicates that younger cows can produce more kg weaned calves per year, a favorable correlation that may hold because cows with early AFC have a longer overall lifetime efficiency in the herd, improving their total productive contribution. No information correlating these two traits in Nelore breed cattle was found. However, Silveira et al. (2004) and Mercadante et al. (2000) estimated genetic correlations of −0.89 and −0.80 between AFC and RF, respectively.

Baldi Rey (2006) estimated genetic correlations in Canchim breed cattle that varied from −0.42 to −0.66 between AFC and indexes that considered both kg and number of weaned calves per cow up to 10 years old, and during the time in the herd.

Summarizing, the genetic correlation between AFC and reproductive indexes is high, decreasing when total kg calves produced is considered rather than kg produced per year. This derives from the fact that cows that did not become pregnant during one of the breeding seasons are not penalized when considering kg calves produced per year. This is not so when the unit considered is kg calves produced during the animal's lifetime.

The genetic correlations between ACP and BW365 and BW450 indicate that cows with larger body weights at these ages produce more kg weaned calves per year. However, maximum limits of body weight should be established, since very heavy dams can exhibit reduced fertility rates and produce larger calves. Very large and heavy calves are not economically advantageous because of a higher incidence of dystocia, and since they demand greater maternal ability.

The genetic association between ACP and scrotal circumference was low, regardless of the age at which circumference was measured (Table 3). The estimated genetic correlation was greater between ACP and scrotal circumference measured at 550 days of age, which suggests that ACP may be more related to animal size than to early growth.

Genetic trends in mean breeding values (MPBV) per birth year for AFC and ACP (Figs. 1 and 2) indicate a significant increase ($P<0.0001$) of 0.166 kg/year for ACP and a significant reduction ($P<0.0001$) of 0.01 months/year for AFC, revealing that the traits respond favorably and indirectly to selection used in the herds. The selection criteria adopted by the producers do not harm the productive and reproductive performance of the animals. Bastos et al. (1996) noted a linear increase of 0.067±0.034 months/year for AFC in a Pitangueiras breed herd. However, Roso and Schenkel (1999) reported an absence of genetic trend and −68 days/year for the same trait in Nelore cattle, for two different periods.

## 4. Conclusions

Inclusion of ACP in the selection criteria for herds is recommended, given the economical importance of the traits that constitute this index. However, genetic gain may be modest owing to the low estimated heritability

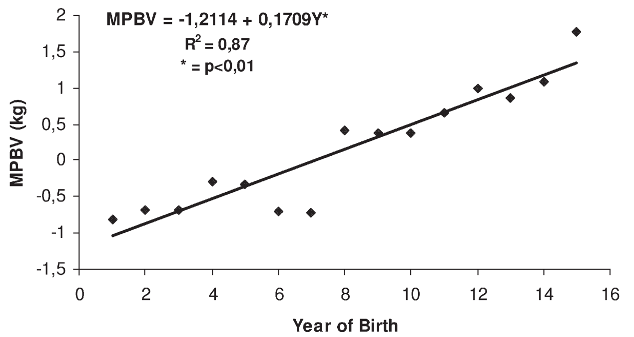


Fig. 2. Linear regression of mean breeding values (MPBV, in kg), based on year of birth (Y), from 1988 to 2003, for accumulated productivity (ACP).

value. ACP-based selection may favor heavier females at 365 and 450 days of age, better reproductive performance and lower AFC. Scrotal circumference was not genetically associated with the ACP index.

The selection criteria adopted in these herds favor AFC and ACP. Better phenotypic performances in these traits may also be achieved through changes in Nelore cattle management.

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