Genetic associations of sexual precocity with growth traits and visual scores of conformation, finishing, and muscling in Nelore cattle

L. Shiotsuki,* J. A. V. Silva II,† H. Tonhati,* and L. G. Albuquerque*2,3

*Faculdade de Ciências Agrárias e Veterinárias, São Paulo State University (UNESP), 14884-000, Jabaoticabal, São Paulo, Brazil; and †Pesquisador Alta Genetics Brazil, 38045-000, Uberaba, Minas Gerais, Brazil

ABSTRACT: The objective of this study was to determine the possible use of heifer pregnancy at 16 mo as a selection criterion and its possible genetic associations with hip height, yearling weight, and visual scores of conformation, finishing, and muscling. The data set contained records of 56,458 Nelore yearlings for the traits described above. Covariance components were estimated by bivariate animal models assuming a linear model for hip height, yearling weight and conformation, and finishing and muscling scores, and a nonlinear (threshold) model for heifer pregnancy. Variance components were estimated using Bayesian inference. Flat distributions were used for all (co)variance components and genetic correlations. The first 5,000 rounds were considered as the burn-in period and discarded. The heritability estimate of heifer pregnancy indicates that the trait can be used as a selection criterion. Long-term selection for heifer pregnancy will result in a reduction of animal height. However, selection for increasing yearling weight should be possible in this population of Nelore cattle without having major effects on fertility. Selection for increasing visual scores of conformation, finishing, and muscling will result in small or no response in heifer pregnancy at 16 mo.

Key words: Bayesian inference, heifer pregnancy, hip height, visual score

INTRODUCTION

The current trend in beef cattle farming is to search for precocious animals that meet market requirements in terms of meat quantity and quality and that are in equilibrium with the production system. In tropical countries, one of the tools available to adapt genotypes to the production systems is the implementation of breeding programs that classify animals according to empirical indexes comprising reproductive traits, growth traits, type, and conformation.

Although expected progeny differences for reproductive traits have been published in some summaries, these traits are not included in selection indexes (Albuquerque et al., 2006). Heifer pregnancy is a trait that has been suggested as a selection criterion for female sexual precocity. The definition of this trait is simple (i.e., it consists of observation of a heifer that conceived and calved after being exposed to a bull during the breeding season).

With respect to growth traits, yearling weight and hip height are measures used to evaluate the size of the animal. However, selection for increasing animal size might result in difficulties on most Brazilian cattle farms in terms of meeting nutritional requirements because the farms are based on extensive rearing systems with low nutritional value pasture. Visual scores are also commonly included as a selection criterion in an attempt to make inferences about carcass composition in terms of meat quantity including muscling, size, and finishing.

Data regarding genetic correlations between heifer pregnancy and hip height, yearling weight, and visual scores are scarce in the literature. Therefore, the objective of the present study was to determine the possible application of heifer pregnancy at 16 mo of age (Pr16) as a selection criterion and to estimate possible genetic associations between this trait and hip height, yearling weight, and visual scores of conformation, finishing, and muscling to provide data necessary for the development of economic selection indexes including these traits.

1The authors acknowledge the financial support from Fundação de Apoio à Pesquisa do Estado de São Paulo (FAPESP, 2005/53385-0) and Agropecuária Jacarezinho Ltda. for providing the data.
2Corresponding author: lgalb@feav.unesp.br
3Current address: Via de acesso Paulo Donato Castellane s/n. Departamento de Zootecnia, Prédio 2. CEP: 14884-900, Jabaoticabal, São Paulo, Brazil.

Received May 12, 2008.
Accepted December 17, 2008.
MATERIALS AND METHODS

Animal Care and Use Committee approval was not obtained for this study because the data were obtained from an existing database (Agropecuária Jacarezinho Ltda.).

General

Records from Nelore yearlings born between 1984 and 2004, belonging to Agropecuária Jacarezinho Ltda., located at the municipality of Valparaíso, São Paulo, Brazil, were used. The main objectives of Agropecuária Jacarezinho Ltda. are the sale of young breeding stock and animals for slaughter; for this purpose, the company relies on a herd consisting of 10,000 dams weaning about 8,000 calves per year.

In the genetic breeding program developed on the property, reproductive, growth, and finishing traits are used as selection criteria. The animals are weighed at birth, weaning (around 205 d of age), and yearling (around 550 d of age) ages. Both at weaning and as yearlings the animals are evaluated visually and receive a score ranging from 1 to 5 for conformation, finishing, muscling, and navel. In addition, scrotal circumference is measured at yearling ages. The animals are selected based on empirical indexes consisting of the traits that are evaluated during the 2 periods (i.e., weaning and yearling).

Bulls and cows are maintained on high-quality pastures, with mineral salt being available ad libitum. The breeding season for cows starts around the second half of November and lasts approximately 70 d. Heifers aged 16 to 18 mo are submitted to an anticipated breeding season between February and April, which lasts approximately 60 d. All heifers are exposed to reproduction, irrespective of BW and BCS. The mating systems used are AI, controlled breeding, and multiple sire mating groups with a bull:cow ratio of 1:30. The periods of birth of the calves are concentrated between August and October and between November and January, and the calves are kept on pasture with their mothers until 7 mo of age. Pregnancy of the heifers is evaluated by rectal palpation approximately 60 d after the end of the anticipated breeding season. Heifers that do not conceive during this period are again exposed to bulls at 2 yr of age. The following criteria are used to exclude females from the herd: failure to become pregnant in any breeding season, except heifers that failed to conceive at 16 to 18 mo, which have a second chance in the next breeding season, when they are 2-yr-olds; low progeny performance; and a small percentage for health reasons.

Traits

The trait Pr16 was obtained for all females that possessed a record of yearling weight. According to the management of the farm, all females that remained until yearling ages were mated. Thus, Pr16 was defined based on the conception and calving of the heifer as long as the yearling entered the breeding season at about 16 mo of age. The Pr16 is a binary trait (i.e., 1 (success) was attributed to heifers that calved at less than 31 mo and 0 (failure) to heifers that failed).

The traits evaluated in both sexes (i.e., yearling weight and hip height) were obtained at mean ages of 521 and 490 d, respectively (Table 1). This difference in age can be explained by the fact that hip height only started to be measured after 2003, whereas records of yearling weight were available since 1986. Hip height was measured with a height measuring stick in the midplane between the hipbones from a point between the last lumbar vertebra and the first sacral vertebra, immediately before the sacral bone, to the floor, and is expressed in centimeters.

The following definitions of the visual scores of conformation, finishing, and muscling were used: conformation evaluates the quantity of meat in the carcass. The

Table 1. Data structure for heifer pregnancy at 16 mo (Pr16), hip height (HH), yearling weight (YW), and conformation (C), finishing (F), and muscling (M) scores as yearlings in Nelore cattle

<table>
<thead>
<tr>
<th>Item</th>
<th>Pr16</th>
<th>HH</th>
<th>YW</th>
<th>C</th>
<th>F</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>n1</td>
<td>30,407</td>
<td>7,226</td>
<td>46,901</td>
<td>46,919</td>
<td>46,917</td>
<td>46,909</td>
</tr>
<tr>
<td>Mean</td>
<td>12.902</td>
<td>133.423</td>
<td>283.804</td>
<td>3.10 ± 0.805</td>
<td>3.22 ± 0.885</td>
<td>2.94 ± 0.893</td>
</tr>
<tr>
<td>GC, n</td>
<td>15</td>
<td>188</td>
<td>1,717</td>
<td>1,565</td>
<td>1,565</td>
<td>1,565</td>
</tr>
<tr>
<td>Sires, n</td>
<td>371</td>
<td>371</td>
<td>371</td>
<td>332</td>
<td>332</td>
<td>332</td>
</tr>
<tr>
<td>Dams, n</td>
<td>25,996</td>
<td>25,996</td>
<td>25,996</td>
<td>24,648</td>
<td>24,648</td>
<td>24,648</td>
</tr>
<tr>
<td>ASU 8</td>
<td>25,661</td>
<td>25,661</td>
<td>25,661</td>
<td>25,618</td>
<td>25,618</td>
<td>25,618</td>
</tr>
<tr>
<td>A2</td>
<td>68,543</td>
<td>68,543</td>
<td>68,543</td>
<td>65,288</td>
<td>65,288</td>
<td>65,288</td>
</tr>
</tbody>
</table>

1n = number of animals with data.  
2Measurement in percentage (%).  
3Measurement in centimeters.  
4Measurement in kilograms.  
5Measurement in scale from 1 to 5.  
6Minimum and maximum age.  
7GC = number of contemporary groups.  
8ASU = number of animals with unknown sire; A2 = number of animals in the relationship matrix.
scores are attributed to imagining the slaughter of the animal at the time when the evaluation is performed. This trait is influenced by size (especially length) and by the degree of muscularity. Finishing evaluates the capacity of the animal to reach a minimal degree of carcass finishing in the absence of increased BW. Deeper ribs, a larger rib cage, a full silhouette, fuller twist, and the onset of subcutaneous fat deposition, mainly at the base of the tail, indicate earlier finishing. Tall and thin, extremely lean animals, with a shallow rib cage and the silhouette of a gazelle are considered to be late. Muscling evaluates the development of muscle mass as a whole, observed at sites such as the forearm, shoulder, loin, hip, and, especially, hindquarters.

The scores for conformation, finishing, and muscling were attributed individually to each animal. At the time of weighing at 18 mo of age, the whole lot (contemporary group) was observed, and the average animal for each trait was identified and used for comparison. Therefore, the scores are relative to the contemporary group. After weighing, the animals were released into a division of the corral and evaluated individually by 3 trained observers who assigned scores ranging from 1 to 5, where 5 represents maximum expression of the trait. The final score of each animal for the conformation, finishing, and muscling traits was obtained by consensus among the 3 examiners.

Data Set

Contemporary groups with less than 4 animals were deleted. For the analysis of hip height and yearling weight, animals whose measures were greater or less than the mean of their contemporary group, plus or minus 3.5 SD, were removed. For all animals, at least the mother was known. For Pr16, in the present data set no case of a contemporary group without variability was observed.

A summary of data structure is presented in Table 1. Numbers of animals in common for 2 traits were 2,218 for Pr16 and hip height; 23,860 for Pr16 and yearling weight; 23,836 for Pr16 and conformation; 23,834 for Pr16 and finishing; and 23,828 for Pr16 and muscling. A total of 23,827 yearlings had measurements of Pr16, as well as conformation, finishing, and muscling scores.

In view of the large number of animals with unknown parents, a data set including animals for whom only the father or mother was known was constructed to determine whether there were consistent differences in the parameter estimates. However, no difference in the estimates was observed between the complete data set and that including also animals in which only the dam was known.

Statistics

Two-trait analyses were applied to estimation of (co)variance components using a linear animal model for hip height, yearling weight and conformation, and finishing and muscling scores, and a nonlinear (threshold) model for heifer pregnancy. The MTGS software (multiple trait Gibbs sampling in animal models), developed by Van Tassell et al. (1998), was used for the estimation of variance components by Bayesian inference. The model used can be described as follows:

$$ y = X\beta + Z_a + e, $$

where $y$ = vector of observations; $\beta$ = vector of fixed effects; $a$ = random additive genetic effect of the animal; $X$ and $Z$ = known incidence matrices; $e$ = vector of residual effects.

It was assumed that direct genetic and residual effects were not correlated. For traits assuming a continuous distribution (i.e., hip height, yearling weight and conformation, and finishing and muscling scores), the following assumptions were made:

$$ y \sim N(X\beta + Z_a, I \sigma^2_a), $$

$$ a \sim N(0, A \otimes G), $$

$$ e \sim N(0, I \sigma^2_e), $$

where $\sigma^2_a$ = direct additive genetic variance; $A$ = matrix of relationship coefficients between animals; $\sigma^2_e$ = residual variance; $I$ = identity matrix; $G$ = genetic (co)variance matrix.

Heifer pregnancy is a categorical or threshold trait. Thus, in this case a threshold model was used, assuming that the underlying distribution ($U$) is given by

$$ U \sim N(X\beta + Z_a, I \sigma^2_e). $$

The initial distributions for genetic and residual effects followed normal multivariate distributions:

$$ p(a | \sigma^2_a) \sim N(0, A \sigma^2_a); $$

$$ p(e | \sigma^2_e) \sim N(0, I \sigma^2_e). $$

Because $\sigma^2_e$ cannot be estimated (Gianola and Foulley, 1983), an arbitrary value of 1.0 was attributed to this parameter. Uniform priori distributions were defined for fixed effects ($b' = EF'$) and for $\sigma^2_a$.

According to Gianola and Foulley (1983) and Harville and Mee (1984), after definition of the parameters of the model, the connection between the 2 scales (categorical and continuous) can be established in such a way that the probability of an observation falling in the first category is proportional to

$$ P(y_r = 0 | t, \theta) = P(U_r < t | t, \theta) = \phi((t - w_r \theta) / \sigma_e), $$

where $y_r$ = vector of observations; $\theta$ = vector of fixed effects; $a$ = random additive genetic effect of the animal; $X$ and $Z$ = known incidence matrices; $e$ = vector of residual effects.
where $y_r$ = response variable for the rth observation, assuming a value of 0 or 1 if the observation belongs to the first or second category, respectively; $t$ = threshold; because it cannot be estimated, an arbitrary value is fixed; $U_r$ = value of the underlying variable for the mentioned observation; $\phi(\cdot)$ = cumulative distribution function of a standard normal variable; $w_r$ = incidence column vector that relates $\theta$ to the rth observation; $\theta = (b', \ a')$ is the vector of location parameters of order $s$ with $b$ (defined in terms of frequency, such as fixed effects) and $a$ (such as random effect).

The model for Pr16 included systematic effects of contemporary group (farm + year of birth), the linear effect of age at entry in the breeding season as a covariate, and animal and residual effects.

For hip height, yearling weight and conformation, and finishing and muscling scores, the effects of contemporary group (farm + year and month of birth + sex + management group at weaning and yearling ages), the linear covariate of age at the time of measurement, and animal and residual effects were considered.

For bivariate analysis between Pr16, hip height, and yearling weight, 2 independent chains of 600,000 rounds were computed. For bivariate analysis between Pr16 and conformation, finishing, and muscling scores, 2 independent chains of 400,000 rounds were computed. In both cases, the first 5,000 rounds were discarded (burn-in period) for analysis of a posterior distributions of heritabilities, and flat distributions were used for all (co)variance components and genetic correlations. A heritability of 0.20 and a genetic correlation of 0.30 were assumed as initial values for the traits, and the convergence criterion between traits was $10^{-12}$.

Estimates of a posterior distributions were analyzed regarding their convergence using the Gibbanal software (Van Kaam, 1998). This program uses the test of Raftery and Lewis (1992), which is based on a low serial correlation between rounds to indicate convergence of the chain.

RESULTS AND DISCUSSION

The percentage of heifers pregnant at 16 mo of age (Table 1) is within the range reported in different studies evaluating Nelore females younger than 18 mo, with pregnancy rates ranging from 10 to 18% (Eler et al., 2002, 2004; Silva et al., 2003, 2005). In contrast, a greater rate of 32% has been reported by De Lucia et al., 2002, 2004; Silva et al., 2003, 2005). In the present study, conformation, finishing, and muscling score means were close to 3 (Table 1), values also observed by other investigators (Jorge Júnior et al., 2001; Lopes et al., 2005). This is expected because the scores were calculated in relation to the average of the contemporary group in which the animal was evaluated.

The mode, median, and mean obtained based on the number of rounds suggested by Gibbanal software (Van Kaam, 1998) were identical to those observed using the complete chain. The results of the Gibbanal software indicated that, to obtain a low serial correlation between rounds for muscling score posterior heritability estimates, a large interval between samples was necessary (8,977), a fact resulting in a small number of independent samples (44 rounds). This suggests the occurrence of problems in the convergence of the chain, impairing inferences about the parameter. Thus, single-trait analysis was performed for muscling score to verify the number of independent samples, according to Gibbanal software results, and to confirm the heritability estimate for this trait. The heritability estimates were the same as those obtained by 2-trait analysis, and the Gibbanal software results indicated a satisfactory number of independent samples (1,289). In the case of the residual correlation between Pr16 and yearling weight, the Gibbanal results indicated a small number of independent samples, suggesting the occurrence of problems in terms of serial correlation (i.e., the effective number of samples was small), a fact impairing inferences about the parameters.

The limits of the greater a posterior density intervals containing 90% of the observations were small, especially for heritability estimates (Table 2). The mean of posterior heritability estimates for Pr16 was high (Table 2) and is similar to those described in the literature for Zebu animals (Atencio, 2000; Eler et al., 2002; Silva and Albuquerque, 2004; Silva et al., 2005). Based on the results of Silva et al. (2005), Pr16 should respond efficiently to selection, with the possibility of genetic gains, and this trait is indicated for the selection of sires to increase female fertility. Because Pr16 is only measured in females, genetic evaluation of sires should be performed on the basis of the occurrence of
The genetic correlation between Pr16 and yearling weight was close to zero (Table 3). Based on this estimate of the genetic correlation, some increases in yearling weight should be possible in this population of Nelore cattle without having major effects on fertility. These results emphasize the recommendations of researchers studying sexual precocity regarding the importance of exposing all heifers to bulls at early ages, irrespective of their BW. The lack of similar studies did not permit comparison of the present results with literature data.

The genetic correlation estimates between Pr16 and visual scores of conformation, finishing, and muscling
were low and positive (Table 3). In agreement with the present study, Faria (2006) observed a favorable genetic correlation between morphological traits such as muscling, physical structure, and conformation and age at first calving in Nelore cattle. However, the magnitude of these correlations ranged from low (−0.17 for structure) to moderate (−0.35 for conformation). The author concluded that selection for animals with better body composition may lead to selection of more precocious animals. This fact was demonstrated phenotypically by Pita et al. (1998) and Semmelmann et al. (2001), who studied heifers mated at 18 mo of age and observed greater visual scores of conformation, finishing, and muscling for heifers that became pregnant compared with those that failed. Semmelmann et al. (2001) reported that selection indexes that include adequate weighting of visual scores permit the identification of traits associated with earlier finishing, such as fat deposition capacity, more developed muscle mass, and moderate size.

Positive and medium-low mean estimates of residual correlations were observed between Pr16 and hip height, yearling weight, and conformation, and finishing and muscling scores, indicating that environmental improvement will possibly act in the same direction on all traits. Similar results were reported by Silva et al. (2006).

The results show that Pr16 can be included in animal breeding programs to increase female fertility. Long-term selection for heifer pregnancy may result in reduction of the height of the animals. However, selection for increasing yearling weight in this population of Nelore cattle should not cause important genetic change in fertility. Selection for increasing visual scores of conformation, finishing, and muscling will result in small or no response for Pr16. When the objective is to increase visual scores and Pr16, both traits should be considered as selection criteria. Because references in the literature regarding the correlation estimates found in the present investigation are scarce, further studies using different data sets and other approaches are recommended.

### LITERATURE CITED


Faria, C. U. 2006. Análise Bayesiana de Características Morfológicas e suas Relações com o Desempenho Produtivo de Bovinos da


