ABSTRACT: The aim of the present study was to estimate genetic parameters for flight speed and its association with growth traits in Nellore beef cattle. The flight speed (FS) of 7,402 yearling animals was measured, using a device composed of a pair of photoelectric cells. Time interval data (s) were converted to speed (m/s) and faster animals were regarded as more reactive. The growth traits analyzed were weaning weight (WW), ADG from weaning to yearling age, and yearling scrotal circumference (SC). The (co)variance components were estimated using REML in a multitrait analysis applying an animal model. The model included random direct additive genetic and residual effects, fixed effects of contemporary groups, age of dam (classes), and age of animal as covariable. For WW, the model also included maternal genetic and permanent environmental random effects. The direct heritability estimate for FS was 0.26 ± 0.05 and direct heritability estimates for WW, SC, and ADG were 0.30 ± 0.01, 0.48 ± 0.02, and 0.19 ± 0.01, respectively. Estimates of the genetic correlation between FS and the growth traits were -0.12 ± 0.07 (WW), –0.13 ± 0.08 (ADG), and –0.11 ± 0.07 (SC). Although the values were low, these correlations showed that animals with better temperaments (slower FS) tended to present better performance. It is possible to infer that long-term selection for weight and scrotal circumference can promote a positive genetic response in the temperament of animals. Nevertheless, to obtain faster genetic progress in temperament, it would be necessary to perform direct selection for such trait. Flight speed is an easily measured indicator of temperament and can be included as a selection criterion in breeding programs for Nellore cattle.

Key words: average daily gain, genetic correlation, heritability, scrotal circumference, temperament

INTRODUCTION

Brazilian beef cattle production is characterized by the use of extensive systems and a predominance of Zebu breeds, mostly Nellore and its crosses. The ability of Zebu breeds to adapt to the climatic conditions that prevail in the tropical zone, as well as their moderate growth capacity and resistance to ectoparasite infestations, favors their use in extensive production systems under tropical conditions (Cundiff, 2005).

Several studies comparing Zebu and European breeds have shown that Zebu breeds and their crosses demonstrate greater reactivity, defined by a behavioral predisposition to respond to handling by humans (Fordyce et al., 1988; Burrow, 1997). The management of highly reactive animals is more difficult and brings a series of inconveniences, such as an increased stress response in animals (Curley et al., 2006) and risk of accidents (Grandin, 1999), resulting in a poor reputation for these breeds due to their temperament (Fordyce et al., 1988). In this context, it is possible to reduce cattle reactivity, either through the learning process resulting...
from improved handling skills, which tends to decrease reactivity in future managements (Becker and Lobato, 1997), or through the selection of less reactive animals for reproduction (Jensen et al., 2008; D’Eath et al., 2010).

Several measures have been used to assess temperament in cattle. One of these measures is flight speed (FS), which determines the speed at which an animal exits the squeeze chute and proceeds toward an open space, usually one of the pen areas of the corral (Burrow et al., 1988). The advantages of this measure include its objectivity and ease of use, and it is performed automatically, using a relatively simple and inexpensive electronic device (Curley et al., 2006; Müller and von Keyserlingk, 2006). Moreover, there is some evidence that FS has enough genetic variability to respond to individual selection (Burrow, 2001; Nkrumah et al., 2007). For instance, Burrow and Corbet (2000) estimated a value of 0.35 for the heritability of FS in a sample of 591 purebred and crossbred Brahman animals.

Although the importance of improving temperament in cattle is generally recognized, and there is evidence that temperament responds to selection, most Zebu breeding programs focus on growth traits and temperament is not used as a criterion for selection (Yokoo et al., 2007). Body weight at different ages and BW gain are included as selection criteria in almost all beef cattle breeding programs, because these traits have enough genetic variability to respond to selection and are associated with other traits of economic interest (El er et al., 1995; Albuquerque and Meyer, 2001). Scrotal circumference is also used as a selection criterion in breeding programs, because it is associated with growth traits and indicators of female sexual precocity, with moderate to high heritability estimates (Yokoo et al., 2007, Boligon et al., 2010). In some cases, temperament is assessed in beef cattle breeding programs; however, generally, this trait is not included in the selection indexes. Rather, it is used as an independent selection criterion, resulting in the culling of animals that present the worst temperament scores. To date, few studies (Burrow, 2001; Prayaga et al., 2009) have been conducted to estimate the genetic basis of FS and correlation between FS and traits normally used as selection criteria in Zebu breeds.

Therefore, the aim of the present study was to estimate genetic parameters for FS (as an indicator of temperament) in Nellore cattle and study the genetic associations between FS and weaning weight (WW), postweaning ADG, and scrotal circumference (SC). The intended goal was to explore the possibility of using FS as a selection criterion in breeding programs for Nellore cattle.

MATERIAL AND METHODS

This study was approved by the Comittee of Ethical Use of Animals from the Faculty of Agricultural and Veterinarian Sciences, São Paulo State University, Jaboticabal-SP, Brazil, Certified n.007808/11.

The study was conducted on herds of Nellore cattle from the Agropecuária Jacarezinho Ltda. on farms located in the counties of Valparaíso, in southeast Brazil, and Cotegipe, in northeast Brazil. The growth traits analyzed were WW, ADG, and SC of animals born between 1990 and 2010.

Both farms followed the same procedures for the formation of management groups. Calves were weighed immediately after birth and assigned to management groups, which were kept in pastures and received only a mixture of minerals as dietary supplementation. Weaning occurred at ~210 d of age, when they were weighed and subjected to the first evaluation. Animals were assigned visual scores for conformation, precocity, muscling, and navel (considers the size and positioning of navel and sheath). When the animals reached 550 d of age, they were subjected to a second evaluation, recording their BW, visual scores, and testicular measurements (in males).

A certain number of animals were selected to be discarded at weaning and at 550 d (50% of males and 10% of females in each age). The decision was based on a selection index that included these criteria: i) number of days required to gain 160 kg of BW from birth to weaning; ii) number of days required to gain 240 kg of BW postweaning; iii) visual scores of conformation, precocity, and muscling in both age groups; and iv) SC at 550 d, adjusted for age and BW.

The traits used in the present study were: i) WW, to minimize the influence of selection and culling on genetic parameter estimates; ii) ADG, calculated based on WW and yearling weight; iii) SC, measured at 550 d of age; and iv) temperament, assessed using the FS test. The average age of the animals (± SD) in assessments for WW, ADG, SC, and FS were: 188.04 ± 25.17, 506.75 ± 35.57, 510.52 ± 39.97, and 494.59 ± 39.48 d, respectively.

The FS was assessed during handling for weight determination at yearling age, in males and females born in 2008 and 2009, as described by Burrow et al., (1988). Measurements were performed with an electronic device composed of 2 pairs of photoelectric cells, a chronometer, and a small processor programmed to record the time taken by each animal to cover a known distance, which ranged from 1.6 to 2.0 m (depending on facilities). Time data (s) were converted to speed (m/s); faster animals were considered to have less desirable temperaments. Contemporary groups were formed for each trait, using these criteria: i) for WW, farm and year of birth; management groups at birth and weaning; and calf sex; ii) for ADG, farm, year, and season of birth; management groups at birth and weaning; farm, year, and management group at yearling age; and calf sex; iii) for SC, farm and year of birth; management groups...
at birth, weaning, and yearling age; iv) for FS, farm of birth; management group at weaning and yearling age; paddock; date of yearling assessment; and calf sex.

Contemporary groups (CG) with <5 animals and CG presenting coefficients of variation >67% were excluded from the analysis. For each trait, records out of range (within CG) given by the mean of CG + 3 SD were also excluded.

The (co)variance components were estimated by REML, using WOMBAT software (Meyer, 2006). Multitrait analyses were performed applying an animal model. The direct additive genetic and residual effects were included in the model as random effects. Fixed effects were: CG, age of dam at calving (in classes ranging from 2 to 14 yr), and age of animal at time of measurement (linear effect for FS and quadratic effect for WW, ADG, and SC). The model for WW also included the maternal genetic and permanent environmental random effects. The general model used was as follows: \( y = Xb + Z_1a + Z_2m + Z_3c + e \); where \( y \) = vector of the observed traits; \( b \) = vector of fixed effects; \( a \) = vector of direct additive genetic effects; \( m \) = vector of maternal additive genetic effects; \( c \) = vector of maternal permanent environmental effects; and \( e \) = vector of residual effects. The \( X, Z_1, Z_2, \) and \( Z_3 \) are incidence matrices associating \( b, a, m \) and \( c \) to \( y \). In this study, it was assumed that \( E[y] = Xb \); \( \text{Var}(a) = A \otimes (\otimes \text{Kronecker product}) S_a \); \( \text{Var}(m) = A \otimes S_m \); \( \text{Var}(c) = I \otimes S_c \); and \( \text{Var}(e) = I \otimes S_e \), where \( S_a \) is the additive genetic covariance matrix; \( S_m \), the maternal genetic covariance matrix; \( S_c \), the maternal permanent environmental covariance matrix; \( S_e \), the residual covariance matrix; \( A \), the additive genetic numerator relationship matrix; \( I \), the identity matrix; and \( \otimes \), the direct product of the matrices. The vectors \( a, m, c, \) and \( e \) were assumed to be uncorrelated.

The pedigree file included 706 sires, 38,285 dams, 492 maternal grandsires, and 19,236 maternal grandmothers; the relationship matrix included 124,730 animals.

**RESULTS AND DISCUSSION**

The average FS obtained in the present study (Table 1) was within the ranges reported in the literature for Zebu breeds and their crosses. In Nellore cattle, the mean FS ranges from 0.68 to 1.68 m/s (Paranhos da Costa et al., 2002; Maffei et al., 2006; Barbosa Silveira et al., 2008a). In crossbred animals, FS ranges from 0.99 to 2.08 m/s for Charolais x Nellore crosses (Barbosa Silveira et al., 2008b) and from 0.46 to 0.96 m/s for Angus x Nellore crosses (Barbosa Silveira et al., 2006). Similar results were obtained for Brahman animals and their crosses, whose flight speeds range from 0.59 to 2.83 m/s (Burrow, 2001; Kadel et al., 2006; Petherick et al., 2009).

The heritability estimate for FS was moderate (Table 2). The only heritability estimate found in the literature for this trait in Nellore cattle was greater (0.35) than that obtained in the present study; however, these results are not widely comparable because the authors used a database that included 4 breeds of cattle (*Bos indicus*: Nellore, Gir, and Guzerat, and *Bos taurus*: Caracu, a breed adapted to the tropics) and applied a sire model with breed as a fixed effect (Paranhos da Costa et al., 2009). Conversely, the heritability estimated in the present study was greater than that found by Prayaga et al. (2009) for Brahman cattle (0.17 ± 0.07), though less than that obtained by the same authors for a synthetic breed adapted to the tropics (“Tropical Composite,” which is composed of ~50% *Bos indicus*, or African Sanga, and 50% *Bos taurus* of British and European breeds not adapted to the tropics; 0.31 ± 0.09).

The FS heritability estimate was less than that obtained in the studies conducted in Australia, both with *Bos indicus* (Brahman) cattle and their crosses with *Bos taurus* (Belmont Red, Angus, Hereford, Shorthorn, Charolais, and Limousin), which ranged from 0.35 (Burrow and Corbet, 2000) to 0.40 (Burrow, 2001). Additionally, in Australia, Kadel et al. (2006), working with crossbred animals (Brahman, Belmont Red and Santa Gertrudis), obtained heritability estimates of 0.30 ± 0.02 and 0.34 ± 0.03 at 246 and 564 d of age, respectively. A similar result (0.49 ± 0.18) was found for a synthetic cattle breed of European origin (Angus, Charolais, Hereford, and Simmental; Nkrumah et al., 2007). However, our heritability estimate for FS was similar to or greater than some estimates obtained for European breeds, with values of 0.11 ± 0.08 for Limousin, 0.15 ± 0.06 for Angus, and 0.33 ± 0.10 for Hereford (Hoppe et al., 2010).

**Table 1. Descriptive statistics for WW\(^1\), ADG, SC\(^1\), and FS\(^1\) in Nellore cattle**

<table>
<thead>
<tr>
<th>Trait</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>CV, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>WW, kg</td>
<td>108,386</td>
<td>172.29</td>
<td>26.47</td>
<td>15.35</td>
</tr>
<tr>
<td>ADG, kg/d</td>
<td>76,432</td>
<td>0.30</td>
<td>0.09</td>
<td>30.00</td>
</tr>
<tr>
<td>SC, cm</td>
<td>30,515</td>
<td>26.54</td>
<td>3.12</td>
<td>11.70</td>
</tr>
<tr>
<td>FS, m/s</td>
<td>7,402</td>
<td>2.26</td>
<td>1.00</td>
<td>47.19</td>
</tr>
</tbody>
</table>

\(^1\)WW = weaning weight; SC = scrotal circumference; FS = flight speed.

**Table 2. Estimates of variance components and heritability (± SE) for FS\(^1\), WW\(^1\), ADG, and SC\(^1\)**

<table>
<thead>
<tr>
<th>Trait</th>
<th>( \sigma_{a1}^2 )</th>
<th>( \sigma_{a2}^2 )</th>
<th>( \sigma_{a3}^2 )</th>
<th>( \sigma_{d1}^2 )</th>
<th>( h^2 )</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS</td>
<td>0.22</td>
<td>-</td>
<td>-</td>
<td>0.72</td>
<td>0.26 ± 0.05</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>WW</td>
<td>85.53</td>
<td>28.74</td>
<td>44.65</td>
<td>0.44</td>
<td>0.30 ± 0.01</td>
<td>0.10</td>
<td>0.16</td>
</tr>
<tr>
<td>ADG</td>
<td>0.01</td>
<td>-</td>
<td>-</td>
<td>0.81</td>
<td>0.19 ± 0.01</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SC</td>
<td>3.09</td>
<td>-</td>
<td>-</td>
<td>0.52</td>
<td>0.48 ± 0.02</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

\(^1\)FS = flight speed; WW = weaning weight; SC = scrotal circumference; \( \sigma_{a1}^2 \) = additive genetic variance; \( \sigma_{a2}^2 \) = maternal genetic variance; \( \sigma_{a3}^2 \) = maternal environmental variance; \( \sigma_{d1}^2 \) = residual variance; \( h \) = heritability; c = fraction of phenotypic variance due to maternal genetics; d = fraction of phenotypic variance due to maternal environment.
The model applied can affect the estimation of variance components for FS; however, the genetic variability estimated in the present study using a multitrait animal model was close to those found by Prayaga and Henshall (2005), using different single-trait models. These authors compared different statistical models, from simple (e.g., considering only the animal as a random effect) to more complete models (e.g., including direct and maternal genetic effects and permanent environmental effect of the animal). They obtained heritability estimates for FS ranging from 0.19 ± 0.03 to 0.58 ± 0.02 for a crossbred of Bos taurus (Hereford, Simmental, Shorthorn, Charolais) with Bos indicus (Brahman; Prayaga and Henshall, 2005).

Despite the differences in heritability estimates found in the literature for different breeds and with different statistical methods, it is possible to infer that the reaction of the animals when leaving a condition of physical restraint presents sufficient genetic variability to respond to selection. The results of the present study corroborate prior findings on the additive genetic variability of FS.

The heritability estimates for growth traits obtained in the present study are within the range found in the literature for Nellore cattle. Furthermore, the heritability estimates for WW and ADG were similar to those found by Dias et al. (2003), Boligon et al. (2007), and Yokoo et al. (2007) for SC, and by Eler et al. (1995) and Albuquerque and Meyer (2001).

The genetic correlation estimates between FS and growth traits were negative and low (Table 3). Scrotal circumference is used as a selection criterion in breeding programs, because it is positively associated with sexual precocity in heifers (Toelle and Robison, 1985; Forni and Albuquerque, 2005; Eler et al., 2006), semen production, semen quality (Sarreiro et al., 2002), and growth traits (Silva et al., 2006). The results of the present study show that selection for larger SC will not lead to a correlated response in FS, even in the long term. Our result is similar to that described by Barrozo et al. (2012) for the genetic correlation of SC with a temperament visual score (–0.07) in Nellore cattle. The estimated correlation between FS and SC obtained in the present study is less than that reported by Burrow (2001) for purebred and crossbred Brahman cattle when SC was measured at yearling age (–0.22); however, it was similar to the estimate of Burrow (2001) when SC was obtained at weaning (–0.13).

Our results, with the support of the literature, suggest that low genetic association exists between SC and FS. Consequently, the selection for one of these traits will not result in a correlated response in the other.

The estimates of genetic correlations of FS with WW and ADG were also low and negative. This result leads to the conclusion that selection for greater WW and ADG will have no effect on FS in the short and medium term. It should be noted that all genetic correlations of WW and ADG with FS were negative, indicating a favorable relationship between these traits, i.e., long-term selection for increasing WW and ADG will reduce FS.

Few studies have been conducted to assess the genetic correlation between temperament and performance traits in Nellore cattle (Figueiredo et al., 2009; Barrozo et al., 2012). Moreover, in these studies, FS was not used as an indicator of temperament; rather, they assessed temperament via visual scores. For instance, a study by Figueiredo et al. (2009) used flight distance score (ranging from 1 = worst temperament to 5 = best temperament) and obtained genetic correlation estimates of 0.04, 0.36, and 0.38 with BW at 120 d, weaning age, and yearling age, respectively, and 0.20 with ADG. The authors concluded that individuals with the best temperaments also presented greater performance for growth traits. Furthermore, Burrow (2001) found negative genetic correlation estimates between FS and WW (−0.03), 1 yr (−0.02), and yearling age (−0.05) for Brahman cattle and their crosses, although the estimates were close to 0. Genetic correlation estimates between FS and ADG for different genetic groups of European breeds (Angus, Charolais, Hereford, Limousin, and Simmental) were similar to or stronger than those observed in the present study (ranging from −0.04 for Angus to −0.41 for Limousin), and all correlations were negative, indicating a favorable genetic association between FS and performance traits (Hoppe et al., 2010). Stronger genetic correlations than those in the present study were reported by Nkrumah et al. (2007) for confined Bos taurus, with estimates of −0.25 and −0.57 for the correlation of FS with final BW and ADG, respectively.

The phenotypic correlation estimates between FS and performance traits (WW and ADG) were also negative and low. According to Burrow (2001), this low association is expected in an extensive production system, because short-term stressful situations resulting from management are less likely to interfere with long-term BW gain. Conversely, in intensive systems, due to the closer proximity between humans and animals, individual differences in temperament may affect performance (Burrow and Dillon, 1997; Voisin et al., 1997).

Despite the studies described above reporting an association between temperament and performance, their

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**Table 3. Estimates for genetic (above diagonal) and phenotypic (below diagonal) correlations (± SE) for FS, WW, ADG, and SC**

<table>
<thead>
<tr>
<th>Trait</th>
<th>FS</th>
<th>WW</th>
<th>ADG</th>
<th>SC</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS</td>
<td>–</td>
<td>–0.12 ± 0.07</td>
<td>–0.13 ± 0.08</td>
<td>–0.11 ± 0.07</td>
</tr>
<tr>
<td>WW</td>
<td>–0.07 ± 0.01</td>
<td>–</td>
<td>0.25 ± 0.03</td>
<td>0.22 ± 0.03</td>
</tr>
<tr>
<td>ADG</td>
<td>–0.06 ± 0.01</td>
<td>–0.06 ± 0.01</td>
<td>–</td>
<td>0.13 ± 0.03</td>
</tr>
<tr>
<td>SC</td>
<td>–0.07 ± 0.02</td>
<td>0.21 ± 0.01</td>
<td>0.21 ± 0.01</td>
<td>–</td>
</tr>
</tbody>
</table>

1FS = flight speed; WW = weaning weight; SC = scrotal circumference.
results do not provide concrete evidence regarding which mechanisms underlie the expression of temperament, nor do they explain the reason for the relationship of temperament with performance traits. Animals with worse temperaments are known to have greater concentrations of plasma cortisol (Curley et al., 2006), glucose, and lactate (Cafe et al., 2011). Furthermore, these animals require a longer time to return to baseline concentrations of glucose when subjected to handling in the corral (Cafe et al., 2011). However, further studies are needed to explain why this association can be observed only under certain conditions, whereas in others, (e.g., in the present study) there is no phenotypic evidence to suggest that temperament affects BW gain.

It can be concluded that the selection criteria currently used in breeding programs for beef cattle are not effective for improving the temperament of animals. Therefore, to obtain genetic improvement for this trait, the selection indexes for Nellore cattle should include temperament-based criteria. Flight speed is an appropriate measure for this purpose, because it presents sufficient genetic variability to respond to selection. Furthermore, FS is easy and inexpensive to measure, and it can be used to assess temperament objectively.

LITERATURE CITED


