Genetics of fighting ability in cattle using data from the traditional battle contest of the Valdostana breed

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ABSTRACT: The tendency to fight is a well-known behavior in Valdostana cattle, and noncruel traditional contests are organized yearly by farmers to identify the most dominant cow. Cow battles consist of elimination matches that have important economic implications for both tourism and farmers. The aims of this study are 1) to validate a scoring system to express fighting ability, and 2) to carry out a genetic analysis for this trait using different data sets and models. A data set accounting for 16,509 fighting records of 5,981 cows relevant to contests over 6 yr was retained after editing (data set 1). Data on placements were used to compute a placement score accounting for wins, tournament size, and difficulty, and differentiating the 20 preliminary battles each year from the final match. A second data set was created using only the individual best yearly placement scores, that is, deleting repeats with a smaller placement score for the same animal within each year (data set 2; n = 10,367 records, corresponding to a single datum per year per cow). Compared with the placement or position of each cow, the placement score proved to be less skewed (−1.45 for placement position and 1.25 for placement score, respectively) and exhibited better coefficients for the probability of a normal distribution. An animal model REML method analysis (accounting for 13,456 animals in the pedigree) was carried out, with consideration given to different combinations of fixed and random nongenetic factors other than the random animal and permanent environmental effects. Results indicated that random factors other than additive genetic and permanent environment effects did not improve the model fit; therefore, it was not useful to take them into account. Heritability estimates obtained with the model showing the best fit were 0.078 (data set 1) and 0.098 (data set 2). Results of this study indicate that selection for fighting ability in Valdostana cattle using data on battle performance is possible.

Key words: battle contest, cattle, fighting ability, genetics, Valdostana breed

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INTRODUCTION

In all social species, the access to resources is regulated through dominance relationships involving repeated dyadic agonistic interactions generating a within-group hierarchy of social dominance (Drews, 1993). Rigid relationships are typical of confined ungulates living in groups, such as bison, zebus, and cattle (Reinhardt et al., 1986). In cattle herds, firm hierarchies are always established, and the regrouping at pasture or the remixing of unfamiliar animals produces aggression aimed at defining a new social order (Phillips, 1993; Boe and Færevik, 2003). Dominance shows a heritable component, but few studies in cattle have shed light on this (Dickson et al., 1970; Wieckert, 1971). Fighting ability has been investigated in breeds used for bullfighting and selected for aggressiveness (González Caicedo et al., 1994; Silva et al., 2006). Genetic analyses have also been carried out for Hérens and Valdostana cattle by using data from traditional cow battle contests (Plusquellec and Bouissou, 2001; Mantovani et al., 2007). These competitions between cows represent both an attraction for tourists and a source of income for farmers because of the increased economic value of the most competitive cows and their offspring. Although selection for fighting ability has not yet been formally carried out, farmers pay a great deal of attention to...
this trait, in addition to selecting for the dual-purpose attitude (i.e., milk and meat production). As part of a project aimed at identifying the possible implementation of selection for fighting ability in the Valdostana breed (Mantovani et al., 2007), this study aims to 1) validate a scoring system as a suitable dependent variable to analyze fighting ability, and 2) investigate different combinations of fixed and random effects in different data sets to identify the model with the best fit. As an outcome, variance components and rank correlations among EBV are analyzed and discussed.

MATERIALS AND METHODS

Data used in the study were obtained following the guidelines given by the association of farmers responsible for the battle organization. These guidelines are formulated in respect of Italian legislation on animal care.

Description of the Subject

The Batailles de Reines are yearly traditional contests that have taken place since 1958 in the Valle d’Aosta region (i.e., northwest Italian Alps), in which cows participate in bloodless elimination matches aimed at identifying the most competitive animal (Mantovani et al., 2007). Contests revive the natural behavior to fight that cows exhibit at the beginning of the summer grazing season, when unfamiliar cows meet after regrouping. The fights are carried out in grass arenas, where pairs of cows are left to fight under the supervision of their owners and a judge. Participants are divided into 3 BW categories that battle at the same time but without interactions between BW categories. The escalated fight (Parker, 1974; Clutton-Brock and Albon, 1979) can end quickly if a cow immediately recognizes the superiority of its rival, but it may last more than 1 h, with cows pushing each other until the loser gives way. When a cow recognizes the hierarchical supremacy of the adversary, it is eliminated from the competition, whereas the winner advances in the tournament. Yearly tournaments consist of 20 preliminary battles that begin on the last Sunday of March and a final match that takes place at the end of the summer pasture season (i.e., in about the middle of October). The final match is held every year in a special arena in Aosta, Italy, and the title is disputed for each of 3 BW categories by all animals classified in the elimination tournaments (winner and up to the fourth place) plus the winner from the previous year. The winners of each category gain the title of “queen of the year.” Both the elimination and final battle boards are established within each category and across the tournaments by drawing animal numbers (i.e., without seedings). Only cows belonging to the autochthonous Aosta Chestnut and Aosta Pie Black breeds from farms located within the regional territory are allowed to compete in the tournaments. These breeds have a strict genetic relationship (Del Bo et al., 2001), and they are considered 2 varieties of the same breed managed within the same herdbook. To fight, cows need both ongoing or documented milk production records before fighting and to be diagnosed as pregnant. Last, cows not classified for the final match are allowed to compete in further preliminary tournaments within the same year. It is important to note that the Batailles de Reines tournament does not involve the same ethical problems that can arise from traditional dog, cock, or bullfights because it is a bloodless, noncruel competition.

Data Collection and Editing

Raw data regarding the results of fights carried out in 6 successive years (2001 to 2006) of the traditional Batailles de Reines contest were collected from the Valle d’Aosta farmer association, which is responsible for organizing the battles and collecting fight data. The original data consisted of the results of 19,665 fighting matches performed by 7,379 cows in 3 BW categories, and accounted for both the preliminary and final tournaments held in each year. The yearly data sets were organized in pairs for participants, reporting the winner and the loser of each match. These original data were edited and rearranged to report, for each cow, the corresponding year-battle for each BW category, the individual BW at the time of the fight, and the final position reached on the battle board. Individual records from each cow were completed with information about the herds, the cow age at the time of the battle (in years), and information on genealogy. The yearly data sets were joined, and data were discarded if they were incomplete or if they belonged to a herd-year class with only 1 cow in the competition. After editing, 16,509 fighting results belonging to 5,891 cows were retained for further analysis (data set 1). This data set could contain several fight results for the same cow within a particular year. Another data set (data set 2) was created from the previous one, keeping only the best yearly performances of each cow within a year (10,367 fighting records) and discarding other performances that led to poorer results. In spite of the nonrandom choice of records, data set 2 aimed to reflect the tendency of breeders to bring animals to more than 1 tournament when they were not satisfied with the placement of an individual cow (mainly because of the absence of seeds). Descriptive statistics concerning the 2 data sets are reported in Table 1. Because there were no changes in the actual number of individual cows included in both data sets, a single relationship matrix was set up containing all available pedigree information. As a result, a total of 13,456 animals were retained in the pedigree file for subsequent analysis. When the maximum number of generations traced for each individual was taken into account, a mean number of 2.3 generations per cow was considered. Moreover, individuals in the pedigree
referred to 858 sires drawn from AI and natural insemination programs, for an average half-sib family size of 6.1 daughters per sire.

Scoring the Position in Each Battle

Because the rank on the battle board has a skewed distribution (Mantovani et al., 2007), a position scoring system was developed to obtain an almost normal distribution, to be used in the subsequent analysis. Thus, a dominance index was computed based on the results of dyadic interactions of participants in the tournaments. However, unlike the previous placement score (PS; Mantovani et al., 2007), the present one was formulated by combining the suggestions for scoring a place value, as reported by Langlois (1984) and modified from Dorofejew and Dorofejewa (1976), with a relative place number, as reported by Bruns (1981) and attributed to H. Shertler (unpublished data). Both these methods, previously analyzed by Mantovani et al. (2007), were derived from a scoring system for placement of horses in jumping and dressage competitions. In the present study, the PS accounted for the number of wins obtained by each cow in a specific tournament, correcting for the number of participants in the competition (from 16 to 153) and assigning a different value to the final match as compared with the preliminary battles. The PS can be summarized by the following formula:

$$PS_{ijkl} = 20 + ty_i + 2w_j + dk,$$  

where $PS_{ijkl}$ represents the score of cow $l$ in a given tournament, depending on the type of tournament, $ty_i$ (with $ty = 0$ for $i$ elimination tournaments and $ty = 7$ for $i$ final tournament in Aosta); on the number of wins ($w_j$) obtained by each animal in the given tournament category (with $j = 0, \ldots, 8$); and on a tournament difficulty coefficient ($dk$) related to the number of participants in the tournament category linked to the size of the battle board [5 classes, with $k = −2 (>128$ participants), $−1 (65$ to $128$ participants), $0 (33$ to $64$ participants), $1 (17$ to $32$ participants), and $2 (<17$ participants), respectively]. An arbitrary constant value of 20 was added to the final PS to avoid negative values. Table 2 shows all possible values of PS in preliminary tournaments by applying Eq. [1].

Models and Analyses

The UNIVARIATE procedure (SAS Inst. Inc., Cary, NC) was applied to data set 1 for a preliminary comparison of the distribution of PS and the simple individual placement (POS). A subsequent ANOVA on non-

<table>
<thead>
<tr>
<th>Item</th>
<th>Data set 1</th>
<th>Data set 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of records</td>
<td>16,509</td>
<td>10,367</td>
</tr>
<tr>
<td>No. of herd-year classes</td>
<td>2,337</td>
<td>2,182</td>
</tr>
<tr>
<td>No. of participants within year-battle × category</td>
<td>$44.7 \pm 22.9$</td>
<td>$28.1 \pm 14.1$</td>
</tr>
<tr>
<td>No. of participants within herd-year</td>
<td>$7.1 \pm 7.0$</td>
<td>$4.8 \pm 3.7$</td>
</tr>
<tr>
<td>No. of fights/cow</td>
<td>$2.8 \pm 2.4$</td>
<td>$1.8 \pm 1.0$</td>
</tr>
<tr>
<td>Age of participant, yr</td>
<td>$6.1 \pm 1.7$</td>
<td>$6.0 \pm 1.7$</td>
</tr>
<tr>
<td>BW of participant, kg</td>
<td>$548 \pm 61$</td>
<td>$544 \pm 60$</td>
</tr>
<tr>
<td>BW category, kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (heavy)</td>
<td>$633 \pm 43$</td>
<td>$629 \pm 42$</td>
</tr>
<tr>
<td>2 (medium)</td>
<td>$545 \pm 20$</td>
<td>$543 \pm 19$</td>
</tr>
<tr>
<td>3 (light)</td>
<td>$495 \pm 22$</td>
<td>$492 \pm 22$</td>
</tr>
</tbody>
</table>

Table 2. Possible placement score values, with the number of wins achieved by individuals in parentheses$^1$

<table>
<thead>
<tr>
<th>No. of participants$^2$</th>
<th>1st</th>
<th>2nd</th>
<th>3rd to 4th</th>
<th>5th to 8th</th>
<th>9th to 16th</th>
<th>17th to 32nd</th>
<th>33rd to 64th</th>
<th>65th to 128th</th>
<th>&gt;129th</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 16</td>
<td>30 (4)</td>
<td>28 (3)</td>
<td>26 (2)</td>
<td>24 (1)</td>
<td>22 (0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 to 32</td>
<td>31 (5)</td>
<td>29 (4)</td>
<td>27 (3)</td>
<td>25 (2)</td>
<td>23 (1)</td>
<td>21 (0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33 to 64</td>
<td>32 (6)</td>
<td>30 (5)</td>
<td>28 (4)</td>
<td>26 (3)</td>
<td>24 (2)</td>
<td>22 (1)</td>
<td>20 (0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>65 to 128</td>
<td>33 (7)</td>
<td>31 (6)</td>
<td>29 (5)</td>
<td>27 (4)</td>
<td>25 (3)</td>
<td>23 (2)</td>
<td>21 (1)</td>
<td>19 (0)</td>
<td></td>
</tr>
<tr>
<td>&gt;128</td>
<td>34 (8)</td>
<td>32 (7)</td>
<td>30 (6)</td>
<td>28 (5)</td>
<td>26 (4)</td>
<td>24 (3)</td>
<td>22 (2)</td>
<td>20 (1)</td>
<td>18 (0)</td>
</tr>
</tbody>
</table>

$^1$All scores from the final battle in Aosta received 7 points in addition to the depicted values.

$^2$Number of participants = number of contestants on a given battle board within a BW category.
The genetic effects treated as fixed effects were performed on each data set using the GLM procedure of SAS, aimed at identifying the magnitude of each possible source of variation. With the exception of the breed variety (Chestnut or Black Pied), all nongenetic effects taken into account in the ANOVA produced a significant effect on the PS ($P < 0.001$; data not presented), with a final $R^2$ of 0.45 (data set 1) and 0.50 (data set 2), respectively. Therefore, the nongenetic factors included in the genetic analysis were the effect of the year-battle $\times$ BW category ($YB\times C$, 123 different year-battles $\times$ 3 categories, for a total of 369 levels), the herd-year effect ($HY$, with 2,337 different levels in data set 1 and 2,182 in data set 2), the effect of the age class of participants (7 classes: $\leq 3, 4, 5, 6, 7, 8$ and $\geq 9$ yr of age at the time of fighting), and the individual BW as a covariate within each BW category (3 levels). Preliminary ANOVA indicated that all these factors could be retained in the final animal model analysis because no variance overlap among them could be detected.

The subsequent analysis, aimed at estimating variance components, was carried out with a single-trait animal model (expectation maximization-REML method) using the appropriate program from the BLUPF90 family (Misztal, 2008). In the genetic analysis, a comparison of data set 1 with data set 2 was also carried out, with consideration given to different combinations of fixed and random nongenetic factors other than the random animal and permanent environmental effects. Model 1 considered $YB\times C$ and the $HY$ as fixed effects, whereas models 2 to 4 considered different combinations of $YB\times C$, $HY$, or both as random effects. Therefore, the most complete matrix notation of the models can be expressed as

$$\mathbf{y} = \mathbf{X}\beta + \mathbf{W}_1\mathbf{q}_1 + \mathbf{W}_2\mathbf{q}_2 + \mathbf{W}_3\mathbf{p} + \mathbf{Z}\mathbf{u} + \mathbf{e},$$

where $\mathbf{y}$ is an $N \times 1$ vector of observations, $\beta$ is the vector of systematic fixed effects of order $p$, $\mathbf{q}_1$ is the vector of $YB\times C$ when considered as a random effect (models 2 and 4), $\mathbf{q}_2$ is the vector of $HY$ of order $z$ when considered as a random effect (models 3 and 4), $\mathbf{p}$ is the vector of permanent environmental effects of order $q$, $\mathbf{u}$ is the vector of animal effects with order $m$, and $\mathbf{e}$ is the vector of residual effects. Furthermore, $\mathbf{X}$, $\mathbf{W}_1$, $\mathbf{W}_2$, $\mathbf{W}_3$, and $\mathbf{Z}$ are the corresponding incidence matrices with the appropriate dimensions.

In the model with the greater number of random factors, the assumptions about the structure of (co)variance were as follows:

$$\text{Var} \begin{bmatrix} \mathbf{y} \\ \mathbf{p} \\ \mathbf{h} \\ \mathbf{e} \end{bmatrix} = \begin{bmatrix} \mathbf{A}\sigma^2_a & 0 & 0 & 0 \\ 0 & \mathbf{I}\sigma^2_p & 0 & 0 \\ 0 & 0 & \mathbf{I}\sigma^2_h & 0 \\ 0 & 0 & 0 & \mathbf{I}\sigma^2_e \end{bmatrix},$$

where $\sigma^2_a$ is the additive genetic variance, $\sigma^2_p$ is the permanent environmental variance, $\sigma^2_h$ is the $YB\times C$ variance (in models 2 and 4), $\sigma^2_y$ is the HY variance (in models 3 and 4), $\sigma^2_e$ is the random residual variance, $\mathbf{A}$ is the numerator relationship matrix, and $\mathbf{I}$ are identity matrices.

For all data sets and models investigated, the heritability ($h^2$) and repeatability ($r$) of fighting ability were estimated as follows:

$$h^2 = \frac{\sigma^2_a}{\sigma^2_t},$$

and

$$r = \frac{\sigma^2_a + \sigma^2_p}{\sigma^2_t},$$

where $\sigma^2_t$ is the total phenotypic variance, given by the sum of all estimated variance components.

Because of software limitations, the SE for heritability estimates were approximated by using the following formula (Falconer, 1989):

$$\text{SE}_{h^2} = 4\sqrt{\frac{2(1-t)^2[1+(k-1)t]^2}{k(k-1)(s-1)}},$$

where $t$ is the intraclass correlation approximated by $(h^2/4)$ for paternal half-sib estimates, $k$ is the average number of offspring per sire, and $s$ is the number of sires obtained from the pedigree file.

A comparison between Akaike information criterion values (Akaike, 1974) was used to evaluate how well the models fit in all scenarios (models and data sets) as discussed in Ødegard et al. (2003). Rank correlations between EBV in both data sets while using only the model that showed the best fit (model 1) were also obtained separately for animals with fighting records ($n = 5,891$) and for their sires ($n = 858$) by using the CORR procedure of SAS.

**RESULTS**

The distribution of the POS and PS obtained by applying the above-mentioned formula to the complete data set containing 16,509 records retained for analysis is presented in Figure 1. The PS was closer to the normal distribution than the POS, as indicated by smaller Kolmogorov-Smirnov and Anderson-Darling values (data not shown). Both distributions proved to be skewed, but PS showed a smaller absolute skewness coefficient compared with POS (1.25 vs. $-1.45$ for PS.
and POS, respectively) while still indicating that PS was closer to a normal distribution than POS, as shown in Figure 1. Indeed, the distribution of POS was almost totally asymmetric (Figure 1). This is because each subsequent position after the winner and the animals classified as second (which had the same frequency) presented almost double the frequency compared with the next position because of the structure of the battle board used for fighting.

Table 3 reports REML estimates obtained with different models and data sets. The data set containing only one yearly individual performance (data set 2) and the model that accounted for both YB×C and HY as fixed factors (model 1) gave the best fit, as revealed by the smaller Akaike information criterion value (Table 3). Heritability estimates ranged from 0.068 (model 2, data set 1) to 0.148 (model 3, data set 2). In all cases, the data set including only the best yearly performance of a cow (data set 2) produced greater heritability estimates. In the analysis that produced the best fit (i.e., model 1, data set 2), $h^2$ was 0.098. The SE of heritability estimates proved to be 0.043 on average, with a reduced range of variation among data sets and models (from 0.042 to 0.044; data not shown). The repeatability was on average 0.24 and ranged from 0.21, in the model including both YB×C and HY as random factors, to 0.28, when only HY was considered random. The ratio between the permanent component and the total variance was on average 0.138 (data sets 1 and 2), revealing a slightly greater magnitude of the permanent component than the additive genetic component. The rank correlation among breeding values estimated in the 2 data sets for model 1 was 0.915. This correlation, when limited to the 858 sires, reached a similar value of 0.924.

**DISCUSSION**

In comparison with our study, other research on social dominance has been based on registering the results of dyadic encounters between members within a social group, used for assigning competitive values to individuals (De Vries, 1998; Langbein and Puppe, 2004; Val-Laillet et al., 2008). Agonistic interactions occurring in a group of cows were generally recorded within a herd during a given period and were plotted to obtain an almost linear hierarchy (e.g., Beilharz and Zeeb, 1982; Reinhardt et al., 1986) and a consequent “aggressive order” (McGlone, 1986). Dominance relationships among individuals have also been investigated by forcing animals to engage in dyadic agonistic interactions in standardized environments. A “competitive order” has thus been obtained (Syme, 1974). The Batailles de Reines represents an ideal scenario for assessing dominance relationships through a competitive order because of its peculiar structure of dyadic agonistic interactions between large numbers of animals under the same conditions. However, interactions between all the members of a group cannot be investigated by using data from the battles because after a defeat, an animal is obliged to withdraw from the contest. Beginning from this point and by considering the importance of a symmetric distribution of fighting results, this study has attempted to identify a suitable scoring system.
for the fights. From this perspective, the PS was designed to take into account the number of wins each animal achieved within a tournament (i.e., more victories, greater score) corrected according to the number of participants in the tournament (with a large number of participants presenting a greater opportunity to win). Moreover, by assigning a different weight to preliminary tournaments as compared with the final match, a possible overlapping of scores was avoided.

In addition, the difficulty coefficient allowed a greater score to be assigned to matches disputed in small tournaments, where the probability of fighting against the final winner or another well-classified cow at the same competitive level was greater because of the reduced number of opponents. In general, the PS led to a fairly normal distribution, mitigating possible statistical analytical problems caused by the asymmetric distribution of simple placement on the battle board.

However, further steps in modeling the dyadic data of Batailles could be considered in the future, particularly those aimed at correcting the PS for the strength of the competitor or using a model better suited to analyze rank, such as the Thurstonian model (Gianola and Simianer, 2006). Alternatively, the competitor effect may be accounted for in the genetic model, as has been done in studies on genetic effects in social behavior (Moore et al., 1997; Bijma et al., 2007). Possible comparisons of PS with the literature are not easy because of the absence of population studies on fighting ability based on tournaments.

In a pilot study on social dominance in cattle, Schein and Fohrman (1955) observed that age and BW are important factors associated with fighting performance and dominance. Our results confirm that both age and BW can influence the PS, and consequently the fighting ability, of Valdostana cows. However, in our study, we also attempted to identify possible factors related to the specific contest of each fight (YB×C) and the behavioral background of individuals belonging to different herds that could be mirrored by the HY effect. The YB×C effect tells us exactly in which challenge an individual took part, allowing the performance of an individual cow to be adjusted based on the performance of the other participants in the same battle contest. Moreover, the HY effect is aimed at reflecting the within-herd social hierarchy and fighting background, which can change over the years because of variations in herd composition and which can influence the perception of an individual of its own fighting ability, and thus its fighting performance. In the present study, the data structure and the reduced size of half-sib families (6.1 daughters/sire) could have biased the genetic parameter estimates, although it is not easy to quantify the exact amount of such biases. Other possible biases could be due to the nonrandom choice of records in data set 2 (i.e., retaining only the best yearly performance of each cow). This could inflate the heritability estimates. However, the generally low heritability estimate in our study is in agreement with literature values obtained for other behavioral traits (Hohenboken, Table 3. Variance components, Akaike information criterion (AIC) estimates, heritability (h^2), and repeatability estimates (r) obtained with the different models and data sets used

<table>
<thead>
<tr>
<th>Item</th>
<th>Variance component</th>
<th>AIC</th>
<th>h^2</th>
<th>r</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>σ_y^2</td>
<td>σ_h^2</td>
<td>σ_a^2</td>
<td>σ_p^2</td>
</tr>
<tr>
<td>Model 1</td>
<td>Data set 1</td>
<td>—</td>
<td>—</td>
<td>0.591</td>
</tr>
<tr>
<td>Model 1</td>
<td>Data set 2</td>
<td>—</td>
<td>—</td>
<td>0.752</td>
</tr>
<tr>
<td>Model 2</td>
<td>Data set 1</td>
<td>1.236</td>
<td>—</td>
<td>0.609</td>
</tr>
<tr>
<td>Model 2</td>
<td>Data set 2</td>
<td>1.917</td>
<td>—</td>
<td>0.796</td>
</tr>
<tr>
<td>Model 3</td>
<td>Data set 1</td>
<td>—</td>
<td>0.156</td>
<td>0.869</td>
</tr>
<tr>
<td>Model 3</td>
<td>Data set 2</td>
<td>—</td>
<td>0.228</td>
<td>1.190</td>
</tr>
<tr>
<td>Model 4</td>
<td>Data set 1</td>
<td>1.489</td>
<td>0.184</td>
<td>0.857</td>
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<tr>
<td>Model 4</td>
<td>Data set 2</td>
<td>1.995</td>
<td>0.244</td>
<td>1.210</td>
</tr>
</tbody>
</table>

1Variance components: σ_y^2 = year-battle × category (YB×C); σ_h^2 = herd-year (HY); σ_a^2 = additive genetic; σ_p^2 = permanent environmental; σ_e^2 = random residual.
2Model 1: YB×C and HY both treated as fixed effects.
3Data set with all performances for each cows, 16,509 records.
4Data set with the only year best performance for each cow, 10,367 records.
5Model 2: YB×C treated as a random effect and HY treated as a fixed effect.
6Model 3: YB×C treated as fixed effect and HY treated as a random effect.
7Model 4: YB×C and HY both treated as random effects.
in 1986; Mousseau and Roff, 1987), reflecting a strong behavioral plasticity that allows individuals to adapt to varying environments. Heritability estimates for social dominance ranged from 0.07 (Dickson et al., 1970) to 0.40 (Beilharz et al., 1966) in Holstein dairy cattle. Genetic evaluations carried out on agonistic performances of fighting bulls (i.e., Lidia cattle breed) revealed a heritability of 0.19 for fighting bulls in a Colombian herd (González Caicedo et al., 1994), and a heritability of approximately 0.30 for Spanish fighting bulls (Silva et al., 2006). A preliminary estimation of heritability for fighting ability was also obtained by analyzing traditional tournaments for Hérens cows in Switzerland (Plusquellec, 2001). The scoring method applied to evaluate fighting performance came from the ranking applied in horse competitions (Tavernier, 1991), and the heritability estimate was 0.045.

Behaviors typically include several different environmental factors (e.g., learning, social interactions) as well as the genetic component. In this study, the repeatability values obtained indicate that environmental effects were predominant with respect to additive components. This could be due to the kind of phenotype measured, which is modeled by previous experiences with other counterparts and is mainly recorded at an adult age.

The correlation between ranks of EBV derived from an analysis of the two different data sets showed only small changes in animal ranking, indicating substantial uniformity among data sets in spite of possible overestimates of heritability caused by the nonrandom choice of records in data set 2. Therefore, genetic indexes derived from this study may lead to possible application for selection. The knowledge of genetic components in behavioral traits could be important for developing strategies to modulate behavioral expression genetically, as has already been done for docility in Limousine cattle (Phocas et al., 2006). Future studies accounting for alternative scoring methods or different models as eventual genetic correlations between behavior and productive traits could be useful for better understanding fighting ability and its possible role in animal welfare and management.

This study indicates that genetic evaluation and selection for fighting behavior are possible, although the additive genetic component of the trait is small. However, this result is in agreement with the heritability estimates for other behavioral traits, especially those related to social dominance and fighting. The proposed PS obtained from the battle board seems a possible way to express phenotypic values useful for genetic evaluation and to address selection for fighting ability.

**LITERATURE CITED**


