



# Genetic correlations between visual slaughter conformation scores and growth and reproductive traits in Canchim cattle

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Genet. Mol. Res. 15 (2): gmr.15027555

Received August 31, 2015

Accepted February 4, 2016

Published May 20, 2016

DOI <http://dx.doi.org/10.4238/gmr.15027555>

**ABSTRACT.** We obtained heritability and (co)variance component estimates for slaughter conformation scores at 420 days of age ( $SCS_{420}$ ), age at calving (first, AFC; second, ASC), calving occurrence until 38 months of age ( $CP_{38}$ ), weight at 420 days of age ( $W_{420}$ ), and scrotal circumference at 420 days ( $SC_{420}$ ) in Canchim (5/8 Charolais + 3/8 Zebu) cattle. A total of 23,168 records of Canchim animals, including 12,493 females and 10,675 males, were analyzed.  $SCS_{420}$  indicated carcass structure, muscle development, and subcutaneous fat deposition. The slaughter conformation score of each animal was relative to the whole contemporary group; 1 corresponded to the lowest expression

of the trait and 6 to the highest. Heritabilities, and genetic and residual correlation estimates between  $SCS_{420}$  and reproductive and weight traits, were estimated by multitrait analyses using an animal model with Bayesian inference, employing a linear model for AFC, ASC, SC420, and W420 and a threshold model for CP38 and SCS420. Heritability estimates for  $SCS_{420}$ , AFC, ASC,  $CP_{38}$ ,  $W_{420}$ , and  $SC_{420}$  were 0.11, 0.15, 0.15, 0.15, 0.30, and 0.30, respectively. Genetic correlation estimates between  $SCS_{420}$  and the other traits were 0.08 (AFC), 0.58 (ASC), 0.08 ( $CP_{38}$ ), 0.43 ( $W_{420}$ ), and 0.17 ( $SC_{420}$ ). Visual slaughter conformation scores respond to individual selection and can be used as selection criteria in Canchim cattle. Selection to improve sexual precocity would not be effective in improving carcass conformation and composition, and selection for animals with high breeding values for yearling weight may improve slaughter conformation at the yearling stage.

**Key words:** Bayesian inference; Beef cattle; Conformation score; Heritability; Threshold model

## INTRODUCTION

Brazilian beef exports have increased significantly in the last few years, and the demand for value-added beef products has also increased. Therefore, carcass and meat traits have been gaining importance in determining the price of beef and access to new markets. Despite its relevance, genetic improvement for carcass and meat traits has not been implemented, mainly because of the difficulty of measuring these traits in live animals.

In order to assess the composition of carcasses and days to slaughter, many breeding programs have adopted visual score systems to evaluate conformation, precocity, and musculature traits (Cardoso et al., 2001). Conformation slaughter scores indicate the amount of meat produced by an animal, and allows the evaluation of the growth or gain obtained. Visual scores have been included in beef cattle breeding programs with the goal of improving carcass and meat traits. Despite their importance, few studies have estimated the genetic variability of visual scores, and their genetic associations with other traits of interest.

Growth traits, such as weight and weight gain at specific ages, are commonly applied as selection criteria in most beef cattle breeding programs, because they are easy to measure, are highly accurate, and are strongly correlated with carcass weight (Razook et al., 2001). Although reproductive traits are the main determinants of the biological and economic efficiency of beef cattle production systems, they are rarely included in selection indices of zebu breeds due to their low heritabilities and the difficulty involved in measuring them (Bittencourt et al., 2002; Formigoni et al., 2005; Jorge Junior et al., 2006, 2007). In the 1990's, some traits related to reproductive efficiency and sexual precocity were incorporated into genetic evaluation programs of beef cattle in Brazil (Alencar, 2002).

Selection based on visual slaughter conformation scores has the potential to improve overall performance in Nellore cattle, as indicated by favorable correlations with weight at different ages (Faria et al., 2009; Koury Filho et al., 2010), carcass traits measured by ultrasound (Gordo et al., 2012), and reproductive and sexual precocity traits (Boligon et al., 2012). Although visual slaughter conformation scores are used as selection criteria in

Canchim breeding programs, their genetic associations with growth and reproductive traits are poorly understood. Therefore, the aim of this study was to obtain heritability and (co) variance component estimates in Canchim cattle for slaughter conformation scores, body weight and scrotal circumference at 420 days of age, age at first and second calving, and calving occurrence until 38 months of age.

## MATERIAL AND METHODS

The data records belonged to the Canchim Breeding Program of the Brazilian Canchim Breeders Association (ABCCAN), in collaboration with Embrapa-Genepplus. The Canchim breed (5/8 Charolais + 3/8 Zebu) is a synthetic Brazilian breed adapted to tropical conditions. Its main features are that it is precocious in weight gain, sexual maturity, and finishing (ABCCAN; <http://www.abccan.com.br/canchim/index.php/a-raca.html>).

Records of the following traits were used: visual slaughter conformation score at 420 days of age ( $SCS_{420}$ ), age at first calving (AFC), age at second calving (ASC), calving occurrence until 38 months of age ( $CP_{38}$ ), body weight at 420 days of age ( $W_{420}$ ), and scrotal circumference at 420 days of age ( $SC_{420}$ ). The animals were raised exclusively on pasture, with mineral supplementation throughout the year. A total 23,168 records of Canchim animals, including 12,493 females and 10,675 males, were analyzed (Tables 1 and 2). The following restrictions were applied in the dataset: only data from pasture-fed animals with yearling weight records (420 days of age); only data from animals whose measurements were within the mean  $\pm$  3 standard deviations in each contemporary group (CG); CGs containing at least four observations; and CGs with offspring of at least two sires. Data from males and females born between 1999 and 2006, and between 1978 and 2008, were used for  $SCS_{420}$  and  $W_{420}$  respectively, and data from males born between 1992 and 2007 were used for  $SC_{420}$ . For reproductive traits, records of females born between 1978 and 2004 (AFC and  $CP_{38}$ ) and 1978 and 2003 (ASC) were included.

**Table 1.** Number of animals, sires, dams, and contemporary groups (CGs) for slaughter conformation at 420 days of age ( $SCS_{420}$ ), age at first calving (AFC), age at second calving (ASC), calving occurrence until 38 months ( $CP_{38}$ ), live weight ( $W_{420}$ ), and scrotal circumference at 420 days of age ( $SC_{420}$ ).

Trait	Animals	Sires	Dams	CGs
$SCS_{420}$	2,841	258	2,207	242
AFC	5,001	680	4,193	460
ASC	3,013	527	2,680	330
$CP_{38}$	8,469	725	6,448	432
$W_{420}$	23,168	1,107	13,487	1,624
$SC_{420}$	5,772	693	6,141	533

**Table 2.** Descriptive statistics for slaughter conformation at 420 days of age ( $SCS_{420}$ ), age at first calving (AFC), age at second calving (ASC), calving occurrence until 38 months ( $CP_{38}$ ), body weight at 420 days of age ( $W_{420}$ ), and scrotal circumference at 420 days of age ( $SC_{420}$ ).

Trait	Minimum	Means $\pm$ SD	Maximum	CV (%)
$SCS_{420}$	1	4.31 $\pm$ 0.97	6	22.56
AFC (days)	662	1117 $\pm$ 165	1594	14.75
ASC (days)	1037	1647 $\pm$ 223	2266	13.48
$CP_{38}$	1	1.39 $\pm$ 0.49	2	35.02
$W_{420}$ (kg)	120	260.00 $\pm$ 52	438	20.14
$SC_{420}$ (cm)	12.00	24.85 $\pm$ 3.82	39.50	15.4

SD = standard deviation; CV = coefficient of variation.

Visual evaluation of the conformation score was performed by trained technicians, according to the methodology described by Silva (2000). The effect of technician was nested within CG, because the same technician evaluated the entire CG; therefore, it was not necessary to consider this effect in the model. To assess the visual slaughter conformation scores, which describe carcass structure, muscle development, and subcutaneous fat deposition, an overall inspection of the CG to be evaluated was first performed. Then, an evaluation of the average profile for slaughter conformation, which served as a baseline, was conducted. Next, scores ranging from 1 to 6 were attributed, with 6 corresponding to the highest expression of the trait and 1 to the lowest. For CP<sub>38</sub>, a score of 2 (success) was attributed to females that had calved for the first time until 1159 days of age, and a score of 1 (failure) to those that had not calved, or had calved for the first time after this age.

To determine the significance of fixed effects to be included in the CGs, prior analyses were performed using specific procedures of the SAS program (SAS Institute, 2004) for each trait. CP<sub>38</sub> was analyzed with a non-linear model using the PROC GENMOD procedure, assuming a binomial distribution and applying a probit link function. SCS<sub>420</sub>, AFC, ASC, W<sub>420</sub>, and SC<sub>420</sub> were subjected to variance analyses in a linear model, assuming a normal distribution, using the PROC MIXED procedure. For all of the traits, the model included the fixed effects of year, season, farm of birth, sex (except for AFC, ASC, CP<sub>38</sub>, and SC<sub>420</sub>), and the animal's age at evaluation for SCS<sub>420</sub>, SC<sub>420</sub>, and W<sub>420</sub>. Next, the CGs were formed by combining year, season, and farm of birth. The following birth seasons were defined for this purpose: 1) animals born between January and March; 2) animals born between April and June; 3) animals born between July and September; and 4) animals born between October and December. For SCS<sub>420</sub> and W<sub>420</sub>, the effect of sex was also included in the CG. For SCS<sub>420</sub>, SC<sub>420</sub>, and W<sub>420</sub>, the age of the animal at the evaluation was included in the model as a covariate (linear and quadratic effects).

The number of farms and CGs differed for AFC and CP<sub>38</sub> (Table 1), because some of the CGs for CP<sub>38</sub> did not exhibit any phenotypic variability for this trait and were excluded from the analyses.

The (co)variance component and genetic parameter estimates between SCS<sub>420</sub> and the reproductive and growth traits were estimated by multitrait analyses using an animal model, in the THRGIBBS1F90 program (Misztal et al., 2002), which allowed the use of a linear model for AFC, ASC, SC<sub>420</sub>, and W<sub>420</sub> and a threshold model for CP<sub>38</sub> and SCS<sub>420</sub>. The model adopted could be described as follows:

$$y = Xb + Za + e \quad (\text{Equation 1})$$

where  $y$  is the vector of dependent variables,  $b$  is the vector of systematic effects,  $a$  is the vector of direct additive genetic effects,  $e$  is the vector of random residual errors associated with the observations, and  $X$  and  $Z$  are the respective incidence matrices for each effect. The presumptions of the distributions of  $y$ ,  $a$ , and  $e$  could be described as:

$$y \sim \text{MVN}(Xb + Za, I\sigma_e^2) \quad (\text{Equation 2})$$

$$p(a | \sigma_a^2) \sim \text{MVN}(0, A \otimes G) \quad (\text{Equation 3})$$

$$p(e | \sigma_a^2) \sim \text{MVN}(0, I \otimes R) \quad (\text{Equation 4})$$

where  $A$  is the numerator matrix of Wright's coefficient of relationship between animals,  $I$  is the identity matrix whose order is equal to the dimension of  $y$ ,  $G$  and  $R$  are direct additive genetic and residual (co)variance matrices, respectively, and  $s_a^2$  and  $s_e^2$  are direct additive genetic and residual variances, respectively. The relationship matrix contained 39,720 animals.

A total 800,000 samples were generated in the Gibbs analyses with a burn-in 100,000 cycle period and a 100 cycle sampling interval, corresponding to 7000 samples for subsequent analysis. The following procedures of the R 2.9.0 program (R Development Core Team, 2009) were used to determine the convergence of the estimates: 1) Geweke's convergence diagnostic (Geweke, 1992), in which initial values of the Markov chain are compared with final values in order to identify convergence failures; 2) Heidelberger and Welch diagnostic (Heidelberger and Welch, 1983), which tests the null hypothesis of stationarity of the sample generated. If there were signs of non-stationarity, the test was repeated after elimination of the 10% initial iterations; 3) Visual inspection, in which convergence of the chains was evaluated by analyses of tendency and areas of density in the distribution of the chain. All of these procedures were conducted in the BOA package (Smith, 2005).

The descriptive statistics of posterior distributions for each parameter were obtained from effective samples. The highest posterior density (HPD) region or confidence interval provided the interval that included 95% of the samples, and is a measure of reliability. The HPD can be applied to non-symmetric distributions (Hyndman and Fan, 1996).

## RESULTS AND DISCUSSION

Convergence of the parameter estimates was confirmed by Geweke's (1992) and Heidelberger and Welch (1983) convergence diagnostics, and also by inspection of the trace plots. The burn-in period was sufficient to reach convergence for all of the parameter estimates.

The heritability estimated for  $SCS_{420}$  suggests that, when applied carefully by skilled examiners, this trait can be used for direct selection in beef cattle (Table 3). Higher heritability estimates were reported by Barichello et al. (2010) in Canchim cattle for the same trait, which was assessed at weaning, and varied from 0.17 to 0.27. Heritability estimates for other visual score assessments in Nellore and Angus herds obtained at the weaning and yearling stages have ranged from 0.19 to 0.38 (Cardoso et al., 2004; Boligon and Albuquerque, 2010; Faria et al., 2009, 2010; Koury Filho et al., 2010; Boligon et al., 2012; Wenceslau et al., 2012). These differences in heritability estimates could be caused by differences in the definition of visual assessment scores, the model applied to estimate the (co)variance components, as well as to differences in genetic and environmental variability between the populations or herds studied.

The heritability estimates for AFC and ASC (Table 3) were similar to those reported by Baldi et al. (2008) for Canchim cattle (0.10 and 0.08, respectively). For the same breed, Gaviolli et al. (2012) reported similar heritability estimates to those estimated in the present study for AFC ( $0.14 \pm 0.04$ ) and ASC ( $0.16 \pm 0.06$ ). Buzanskas et al. (2010), using Bayesian inference, obtained a lower heritability estimate for AFC ( $0.04 \pm 0.01$ ). The low heritability estimates obtained for AFC and ASC in the present study could have been a consequence of the criteria normally adopted by farmers for first breeding the heifers, such as weight or age, and the records used in the present study were of heifers exposed late to first breeding. If heifers are not challenged at an early age, it becomes difficult to detect additive genetic variation for sexual precocity. Pereira et al. (2002) exposed heifers to bulls for the first time at 14 and 26 months, and obtained heritability estimates for AFC of 0.18 and 0.02, respectively. In general,

these results indicate a poor response to direct selection for low AFC and ASC values in Canchim herds. Therefore, AFC and ASC are significantly affected by environmental factors; consequently, responses to direct selection are expected to be of a low magnitude, and the accurate prediction of genetic merit requires the evaluation of numerous progenies.

**Table 3.** Posterior means and highest posterior density (HPD) region for heritability ( $h^2$ ) and additive genetic ( $\sigma_a^2$ ) and residual ( $\sigma_e^2$ ) variance estimates for slaughter conformation score at 420 days of age ( $SCS_{420}$ ), age at first calving (AFC), age at second calving (ASC), calving occurrence until 38 months ( $CP_{38}$ ), live weight ( $W_{420}$ ), and scrotal circumference at 420 days ( $SC_{420}$ ) obtained by multitrait analysis.

Parameter		Mean	SD	HPD	
				Lower limit	Upper limit
$W_{420}$	$\sigma_a^2$	382.6	34.7	316.2	443.7
	$\sigma_e^2$	891.5	26.5	842.20	941.8
	$h^2$	0.30	0.02	0.26	0.35
AFC	$\sigma_a^2$	3753	4543	770.2	6282
	$\sigma_e^2$	19,621	1201	17,560	21,590
	$h^2$	0.15	0.07	0.04	0.26
ASC	$\sigma_a^2$	6232	2723	2,106	10,760
	$\sigma_e^2$	33,931	1906	30,080	37,230
	$h^2$	0.15	0.06	0.06	0.26
$CP_{38}$	$\sigma_a^2$	0.30	3.40	0.03	0.32
	$\sigma_e^2$	1.00	0.02	0.97	1.03
	$h^2$	0.15	0.07	0.04	0.25
$SCS_{420}$	$\sigma_a^2$	0.008	0.014	0.003	0.012
	$\sigma_e^2$	1.78	50.8	0.05	0.09
	$h^2$	0.11	0.03	0.05	0.17
$SC_{420}$	$\sigma_a^2$	3.02	1.47	2.06	4.06
	$\sigma_e^2$	7.00	4.25	5.63	8.02
	$h^2$	0.30	0.07	0.20	0.41

SD = standard deviation.

The heritability estimate for  $CP_{38}$  was low ( $0.06 \pm 0.02$ ), indicating that the response to selection for this trait should be low. Silva et al. (2005) reported a heritability of 0.12 for pregnancy probability at 24 months of age in Nellore females. Higher heritability estimates for pregnancy probability at 16 months of age were estimated by Silva et al. (2005) (0.52) and Boligon and Albuquerque (2011) (0.45). The high genetic variability for pregnancy probability observed at 16 months of age may be due to the better identification of genetic differences between females. At a young age, only sexually precocious heifers exhibited physiological characteristics that allowed conception during the breeding season. Sexual precocity is an important trait for beef cattle production systems, but is generally not considered in selection indices.

$W_{420}$  and  $SC_{420}$  heritability estimates were moderate, and similar to those obtained by Buzanskas et al. (2010), also working with Canchim cattle, who estimated heritability coefficients for live weight and scrotal circumference at the yearling stage of  $0.24 \pm 0.04$  and  $0.24 \pm 0.06$ , respectively. Yearling weight is important, because it is the last weight assessed by most breeders before selling the animals for breeding, or for slaughter. There is evidence that scrotal circumference is negatively and favorably correlated with AFC (Pereira et al., 2002; Dias et al., 2003; Boligon et al., 2007), and positively correlated with the probability of early conception in young heifers (Eler et al., 2006). In Brazil, most of the beef cattle breeding programs use growth traits as selection criteria, such as yearling weight and scrotal circumference. The results obtained in this study suggest that these traits should respond to selection. The genetic correlation estimates of  $SCS_{420}$  with AFC and  $CP_{38}$  were low, and

with ASC were moderate (Table 3). Selection to increase the slaughter conformation score at the yearling stage should not affect AFC or calving occurrence until 38 months of age. However, selection for a high slaughter conformation score in yearlings would increase the ASC. Females with high slaughter conformation scores as yearlings would probably be heavy cows during the second breeding season; consequently, these animals would have higher energy requirements for maintenance. This would lead to a greater nutritional imbalance in heavy cows when forage supplies are scarce, and consequently the beginning of reproduction activity after first calving is delayed in these animals. Boligon and Albuquerque (2010) studied Nellore cattle, and estimated low genetic correlations between AFC and yearling scores of conformation ( $-0.26 \pm 0.01$ ), precocity ( $-0.29 \pm 0.02$ ), and muscling ( $-0.23 \pm 0.02$ ). Recently, Boligon et al. (2012) obtained low and favorable genetic correlations between days to first calving and yearling scores of conformation, precocity, and muscling, which ranged from  $-0.11 \pm 0.09$  to  $-0.19 \pm 0.09$ . Therefore, the selection of animals with a good body composition as evaluated by visual slaughter conformation scores in yearlings would not affect female sexual precocity.

The genetic correlation estimates between  $SCS_{420}$  and  $W_{420}$  and  $SC_{420}$  (Table 4) were moderate and low, respectively. Barichello et al. (2010) also reported moderate (0.61) and low (0.17) genetic correlation estimates between slaughter conformation scores and live weight and scrotal circumference at weaning, respectively, in Canchim animals. Recently, Wenceslau et al. (2012), working with Nellore cattle, obtained positive and moderate to high genetic correlation estimates that ranged from 0.61 to 0.81 between growth traits (weight at weaning and yearling) and slaughter conformation scores at weaning and yearling. The results obtained in the present study suggest that selection to increase yearling weight would improve carcass conformation and composition. However, selection to increase scrotal circumference should not influence the slaughter conformation score at the yearling stage.

**Table 4.** Posterior means and highest posterior density (HPD) region for estimates of genetic ( $s_{a1,2}$ ) and residual ( $s_{r1,2}$ ) covariance and genetic ( $r_a$ ) and residual ( $r_r$ ) correlation between slaughter conformation score at 420 days of age ( $SCS_{420}$ ) and age at first calving (AFC), age at second calving (ASC), calving occurrence until 38 months ( $CP_{38}$ ), live weight ( $W_{420}$ ), and scrotal circumference at 420 days of age ( $SC_{420}$ ) obtained by multitrait analysis.

Parameter		Mean	SD	HPD	
				Lower limit	Upper limit
$W_{420}$ - $SCS_{420}$	$\sigma_a$	0.72	0.33	0.16	1.23
	$\sigma_r$	2.95	5.34	2.28	4.03
	$r_a$	0.43	0.15	0.14	0.70
	$r_r$	0.41	0.042	0.34	0.48
$AFC$ - $SCS_{420}$	$\sigma_a$	0.57	6.13	-2.23	3.06
	$\sigma_r$	2.95	5.34	2.28	4.03
	$r_a$	0.08	0.25	-0.38	0.57
	$r_r$	-0.22	0.08	-0.38	-0.08
$ASC$ - $SCS_{420}$	$\sigma_a$	4.15	4.29	1.17	7.37
	$\sigma_r$	-14.46	16.52	-22.50	-5.99
	$r_a$	0.58	0.16	0.31	0.87
	$r_r$	-0.31	0.083	-0.48	-0.16
$CP_{38}$ - $SCS_{420}$	$\sigma_a$	-0.002	0.18	-0.02	0.03
	$\sigma_r$	0.06	0.32	0.014	0.10
	$r_a$	0.08	0.31	-0.50	0.71
	$r_r$	0.21	0.08	0.07	0.36
$SCS_{420}$ - $SC_{420}$	$\sigma_a$	0.023	0.033	-0.02	0.07
	$\sigma_r$	-0.009	6.98	0.14	0.31
	$r_a$	0.17	0.17	-0.16	0.48
	$r_r$	0.34	0.08	0.22	0.45

SD = standard deviation.

The residual correlation estimates between  $SCS_{420}$  and female reproductive traits and  $SC_{420}$  (Table 4) were low, indicating that these traits are not influenced by the same environmental conditions or the same non-additive genetic effects. However, the residual correlation estimate of  $SCS_{420}$  with  $W_{420}$  was moderate.

The use of the visual slaughter conformation score as a selection criterion would improve yearling weight, carcass conformation, precocity, and muscling in Canchim cattle. However, breeders should exercise caution, because selection for high visual slaughter conformation scores would negatively affect the ASC. After first calving, cows with a large frame have large nutritional requirements; therefore, under drought conditions, these animals might have a longer service period. Regardless of the sexual precocity indicator used, indirect selection for visual slaughter conformation scores using sexual precocity indicator traits would promote low genetic gain. Although the visual scoring system allows a rapid collection of a large number of records, it is essential that examiners are trained and that the method adopted is simple and easily understood. In Brazil, several beef cattle breeding programs have recognized the importance of carcass and meat traits, and these breeding programs have assessed body composition and conformation indicator traits for genetic evaluation.

## CONCLUSIONS

Visual slaughter conformation scores respond to individual selection and can be used as selection criteria in Canchim cattle. Selection to improve sexual precocity would not be effective in improving carcass conformation and composition, because the findings of this study indicate that these traits have a weak genetic association. Selection currently practiced in the herds studied, which favors animals with high breeding values for yearling weight, would improve slaughter conformation at the yearling stage.

## Conflicts of interest

The authors declare no conflict of interest.

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