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Estimation of genetic parameters for reproductive traits evaluated by ultrasonography in Senepol heifers

Estimativa de parâmetros genéticos para características reprodutivas avaliadas por ultrassonografia em novilhas Senepol

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Highlights

AFC presented moderate heritability, while RTS exhibited low heritability.
Selection for RTS will not induce genetic changes in AFC.
This study found favorable genetic correlations between weight and RTS.

Abstract

Studies on reproductive tract score (RTS) and antral follicle count (AFC) in Senepol cattle are limited. These traits are essential as they are linked to the reproductive ability and reproductive performance of animals. Understanding the heritability and genetic correlation of these traits is crucial for guiding selection programs and selecting animals with greater reproductive efficiency and higher production potential. Therefore, this study aimed to estimate the genetic parameters of weight, RTS, and AFC in Senepol cattle using transrectal ultrasonography. Reproductive data were collected from 850 female Senepol cattle aged 10-16 months. At the time of evaluation, the following were measured: RTS traits (scores from 1 to 5), AFC (0 to 100), and female weight (kg). The components of (co)variance estimates and genetic parameters were estimated by univariate and bivariate analyses using the bull model. Heritability estimates were moderate for AFC (0.52) and weight (0.46), and low for RTS (0.12). The genetic correlation between RTS and AFC was almost zero (-0.05). The estimated genetic correlation between weight and AFC was -0.41, while the correlation between weight and RTS was 0.48. Selective breeding

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of AFC and RTS can enhance the reproductive efficiency of the herd and result in animals with earlier pubertal age and increased fertility.
Key words: Beef cattle. Follicular population count. Genetic correlation. Heritability. Reproductive tract score.

Resumo

Estudos sobre o escore do trato reprodutivo (ETR) e a população folicular em bovinos da raça Senepol são limitados. Essas características são essenciais, pois estão ligadas à capacidade reprodutiva e ao desempenho reprodutivo dos animais. Compreender a herdabilidade e a correlação genética dessas características é crucial para orientar os programas de seleção, permitindo a escolha de animais com maior eficiência reprodutiva e potencial de produção. Portanto, este estudo teve como objetivo estimar os parâmetros genéticos para características de peso, ETR e CFA usando ultrassonografia transretal em bovinos da raça Senepol. Dados reprodutivos foram coletados de 850 fêmeas Senepol com idades entre 10 e 16 meses. As características de ETR (pontuações de 1 a 5), CFA (0 a 100) e o peso das fêmeas (em kg) no momento da avaliação foram analisados. Componentes de variância e covariância, juntamente com herdabilidade genética e correlações, foram estimados por meio de análises univariadas e bivariadas usando o modelo de touro. As estimativas de herdabilidade foram moderadas para CFA (0,52) e peso (0,46) e baixas para ETR (0,12). A correlação genética entre ETR e CFA foi próximo de zero (-0,05). A correlação genética estimada entre peso e contagem de folículos foi de -0,41, enquanto a correlação entre peso e RTS foi de 0,48. A seleção genética para CFA e ETR pode aprimorar a eficiência reprodutiva do rebanho, resultando em animais com idades puberais mais precoces e maior fertilidade.
Palavras-chave: Bovinos de corte. Contagem de população folicular. Correlação genética. Herdabilidade. Escore do trato reprodutivo.

Introduction

In the reproductive efficiency of beef cattle significantly influences the production cycle and economic yield of the industry (Damiran et al., 2018). Enhancing reproductive traits through selective breeding can augment the performance of beef cattle by promoting sexual precocity and fertility (Brunes et al., 2018). Senepol cattle, an adapted taurine breed derived from the crossbreeding of N'Dama (African taurine) and Red Poll (British taurine) breeds, are renowned for their superior meat production, parasite resistance, heat tolerance, and notably, exceptional reproductive performance, as acknowledged by the Associação Brasileira dos Criadores de Bovinos Senepol (ABCB, 2023).

Reproductive traits in females, such as age at first calving, probability of precocious calving, and stayability, have been measured (Brunes et al., 2018; Damiran et al., 2018). Antral follicle count (AFC) is another reproductive trait that has been linked to the reproductive performance and fertility of females (Morotti et al., 2015, 2017). AFC and RTS indicate reproductive efficiency. The use of transrectal ultrasonography to measure AFC is recognized as a valuable tool for identifying females with a higher likelihood of reproductive success (Garcia et al., 2020). Ultrasonography can also be employed to assess the RTS, a measure of the genital tract's maturation level in bovine heifers. These two traits are indicative of reproductive efficiency, sexual precocity, and pregnancy rate. They are beneficial for the selection and culling of heifers as well as for determining the nutritional program for females before the onset of the breeding season (Gottschall et al., 2018).

Research conducted by Berry et al. (2014) has demonstrated that heritability estimates for most conventional fertility measures are of low magnitude. However, studies involving beef cattle have identified the AFC trait as having medium to high heritability, with estimates ranging from 0.31 in dairy cows (Walsh et al., 2014) to between 0.30 and 0.49 in Nelore cows (Grigoletto et al., 2020; Oliveira et al., 2017). The RTS trait exhibited moderate heritability (0.32) in the research by Andersen et al. (1991), whereas Carthy et al. (2015) reported a low heritability estimate (0.02) in dairy cows. Although reproductive traits have moderate heritability, they are still important economic and productive indicators for breeding herds.

No research reports have been found estimating the genetic parameters for RTS and AFC in Senepol cattle. These traits have been widely employed as selection criteria for breeders of this breed. Therefore, this study aimed to estimate the genetic parameters for reproductive traits assessed through ultrasonography in Senepol females.

Material and Methods

This study was approved by the Animal Ethics and Experimentation Committee (CEUA) of the Federal University of Uberlândia (Protocol no. 019/20). Reproductive data from 850 Senepol females, aged between 10 and 16 months, were evaluated over the period from 2012 to 2017. These animals were reared under an intensive regime in the Southeast and Midwest regions of Brazil. The RTS with scores ranging from 1 to 5) were assessed based on the method proposed by Andersen et al. (1991). Additionally, the AFC and the weight of the females (in kg) at the time of evaluation were also recorded.

Reproductive traits were measured through ultrasonographic evaluation of the ovaries and uterus, using a Mindray DP 2200 VET ultrasound equipment, performed by a single technician from RS Consultoria through transrectal palpation. Andersen et al. (1991) proposed an RTS classification that predicts the performance of heifers designated for breeding. Heifers with an infantile reproductive system, lacking uterine tone, poorly functional ovaries, and without follicular dominance, were assigned a score of 1. A score of 2 was given to heifers with partially developed ovaries and uterus, and small follicles. Heifers nearing the cycling stage, with ovarian follicles approximately 10 mm in diameter, were assigned a score of 3. Females already considered cyclic, but without a palpable corpus luteum, were given a score of 4. Lastly, heifers with a corpus luteum and follicles larger than 10 mm were assigned a score of 5.

The animals evaluated were part of a contemporary group (CG), all the same breed, born in the same year and season, of the same sex, and subjected to identical feeding and management conditions. The birth season was categorized into four classes: animals born from August to October, November to January, February to April, and May to July. Any contemporary group with fewer than four females and phenotypic records displaying measures of 3.5 standard deviations above or below the mean of the contemporary group were excluded. For RTS, AFC, and weight, 60, 63, and 33 contemporary animal groups were established, respectively.

The Statistical Analysis System Program [SAS] (2004) was utilized for data file structuring and graph creation. The SAS software's GLM and RE procedures were employed to verify environmental effects. Genetic parameter estimates for reproductive traits were derived using single-trait analysis (heritability) and bi-trait analysis (genetic correlations) using a bull model. This was achieved by employing the Derivative Free Restricted Maximum Likelihood methodology via the Multiple Traits Derivative Free Restricted Maximum Likelihood (MTDFREML) application, as developed by Boldman et al. (1995). The comprehensive model can be depicted using matrix notation as follows:

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

where, Y is the vector of observations (evaluated traits), β is the vector of fixed effects (environmental effects), u is the vector of random effects (genetic values obtained for each animal), *e* corresponds to the vector of residual random effects, and X and Z are the incidence matrices that relate the observations to the fixed effects and the direct additive genetic random effect, respectively. The genealogy file included the data of 216 sires of the Senepol breed. The kinship matrix was constructed up to the generation of founder animals.

The fixed effects of contemporary groups were considered for both AFC and RTS traits, with the age of the animal at the time of measurement serving as a covariate (linear effect). For weight, only the contemporary animal groups were considered as a fixed effect.

Results and Discussion

Descriptive statistics for the analyzed traits are presented in Table 1. The coefficient of variation values revealed low variability for most traits, except for AFC, which exhibited higher variability. Phenotypic variability was also observed for weight and RTS, facilitating the identification and formation of distinct groups based on these traits. This implies that weight and RTS traits could potentially be subjected to selection, a finding corroborated by Fonseca et al. (2013), who reported a similar outcome with a coefficient of variation of 28.15% for RTS in Angus females. RTS exceeding 3, as observed in this study, are deemed satisfactory. This is corroborated by Gottschall et al. (2018), who noted that RTS values surpassing 3 yield a pregnancy rate exceeding 50%. Conversely, RTS values of 1 are typically associated with prepubertal Angus, Devon, and crossbred heifers aged 14 to 27 months. This is attributed to the fact that heifers with an RTS of 1 display poor uterine tone, minimal ovarian activity, and lack follicular dominance. In contrast, females boasting RTS values over 3 are nearing their cycling phase and possess ovarian follicles with a diameter larger than 10 mm, as documented by Andersen et al. (1991).

Table 1
Descriptive statistics for estimating antral follicle count (AFC), reproductive tract score (RTS), weight (WEIGHT), and age of Senepol females.

Trait	N	Mean	SD	CV (%)	Min	Max
Age (days)	850	404	36.76	9.10	303	479
Weight (kg)	338	298	49.30	16.51	155	503
AFC (0 a 100)	850	32.65	17.16	52.58	5	100
RTS (score)	807	3.51	0.81	23.01	1	5

SD: standard deviation; CV: coefficient of variation.

The coefficient of variation for AFC was notably high at 52%, a result of the broad range of this characteristic, which fluctuated from 0 to 100. Both heifers with minimum scores (5, near zero) and those with maximum scores (100) were observed. This contrasts with the findings of Walsh et al. (2014), who reported a lower coefficient of variation of 9% when assessing Holstein animals aged between 12 and 13 months. The discrepancy in AFC results from those reported in the literature may be due to the differences in the range of body weights of the females evaluated, as there was no control over minimum or maximum weight during the ultrasound evaluation. Furthermore, the age variation of the females in this study, which spanned from 303 to 479 days old (10 to 16 months old), may also account for the discrepancy of the findings with those from the study by Walsh et al. (2014).

The AFC values obtained from this study surpass those reported by Cushman et al. (2014) (21.4) and Grigoletto et al. (2020) (12.49) in their respective evaluations of Angus and Nellore heifers. It is crucial to underscore that numerous intrinsic factors tied to animal physiology, such as breed differences between Bos taurus and Bos indicus (Alward et al., 2023), the phase of the estrous cycle (Ireland et al., 2008), age (Burns et al., 2005), body condition (Moraes et al., 2019), nutritional status (Cushman et al., 2014), and individual genetic variability, can influence these results.

Heritability, genetic correlations, and phenotypic correlations are shown in Table 2. The heritability estimates for RTS (0.12) was low, suggesting that it is a trait with high environmental influence on its expression. Nutrition and weight are two of the main factors affecting the development of the reproductive tract in heifers until puberty (D'Occhio et al., 2019). This low heritability suggests that genetic progress may be slow due to reduced response to direct selection. However, this trait should be used to assess reproductive tract development in females, particularly when making management decisions during the breeding season.

Table 2
Estimates of heritability (diagonal), genetic correlation (above the diagonal), and phenotypic correlation (below the diagonal) for antral follicle count (AFC), reproductive tract score (RTS), and weight (weight) of Senepol heifers

Traits	RTS	AFC	WEIGHT
RTS	0.12	-0.05	0.48
AFC	0.04	0.52	-0.41
WEIGHT	0.32	0.06	0.46

Carthy et al. (2015) reported a low heritability estimate of 0.02 for RTS in female Bos taurus of the Holstein, Jersey, Montbéliarde, and Red Norwegian breeds. Conversely, Andersen et al. (1991) reported a moderate heritability estimate of 0.32 in beef heifers. The significant influence of non-additive genetic effects on RTS suggests that the expression of this trait is largely contingent on environmental factors and the management practices implemented on the farms. These practices include the age and weight of the animals at the onset of the reproductive season, as well as their nutritional management.

Andersen et al. (1991) posited that the RTS is a valuable selection tool due to its correlation with age at puberty, synchronization response, and pregnancy rate. Furthermore, RTS has been employed to evaluate puberty in heifers and acts as a method for identifying animals with reproductive potential. It is also used for selecting females for culling and replacement, and for formulating nutritional plans for cows in the pre-breeding season. Thus, despite the low genetic variability observed in this study, the selection for RTS as a criterion in genetic and reproductive improvement programs is significant. This is due to its link with the sexual precocity of heifers and their capacity to enter the breeding season.

The heritability estimate for AFC (0.52) was moderate to high, suggesting that additive genetic effects largely influenced the expression of this trait, and genetic gains for this trait were expected in response to selection. The high heritability observed in this study can also be attributed to the use of AFC to classify breeding females for productive and reproductive purposes in the Senepol breed. In this breed, follicle population size was used as a selection criterion for fertility. Snelling et al. (2012) conducted a study involving 452 Bos taurus crossbred females and reported a high heritability estimate (0.73) for AFC. Similarly, Grigoletto et al. (2020) and Oliveira et al. (2017) reported moderate to high heritability estimates for AFC in Nelore heifers, with values of 0.30 and 0.49, respectively, at a mean age of 16 months. In the context of dairy cattle, Walsh et al. (2014) discovered an average heritability of 0.25 for AFC in Holstein-Friesian heifers aged 14 months.

Increased AFC in cows has been associated with increased ovarian follicle accumulation, enhanced oocyte quality (Ireland et al., 2007), improved pregnancy rates (Martinez et al., 2016), and higher anti-Müllerian hormone (AMH) concentrations (Ireland et al., 2011; Sakaguchi et al., 2019). Moreover, research has indicated that an increase in follicular production can positively influence the quantitative aspects of superovulation and large-scale in vitro production of embryos (Ireland et al., 2008; Alward et al., 2023).

The heritability estimate for weight in the present study was high (0.46). This value exceeds that of Baldi et al. (2010), Boldt et al. (2018), and Rezende et al. (2022), who found estimates ranging from 0.22, 0.29 and 0.32 in the Canchim, Red Angus, and Charolais breeds, respectively. Conversely, a heritability estimate similar to our findings was reported by Novo et al. (2021), who recorded a value of 0.48 in Senepol heifers aged between 10 to 16 months. Given the heritability coefficients identified in this study, we propose that genetic progress in weight gain can be achieved through an effective response to direct selection, ultimately leading to the production of heavier animals.

The genetic correlation between RTS and AFC was close to zero (-0.05) (Table 2), signifying a minimal genetic link between these traits. This weak genetic connection can be ascribed to the variability in follicle quantities in sexually mature females, as determined by RTS, contingent on the phase of the estrous cycle. A diminished total follicular population is typically observed in the presence of a dominant follicle (Ireland et al., 2008). Consequently, selection predicated on RTS is unlikely to instigate genetic alterations in AFC. This implies that both traits can be independently utilized in direct selection to achieve genetic gain for both traits.

Moderate and favorable genetic correlations between RTS and weight (0.48) were observed in this study. The findings suggest that it is feasible to predict which heifers will reach puberty at a younger age, either at weaning or at one year of age, and display increased sexual precocity. This is because heavier heifers tend to possess a more developed reproductive tract. These findings align with expectations, given that RTS can act as an indicator of age at puberty, and the development of the reproductive tract is influenced by various factors, including weight and average daily gain (Andersen et al., 1988). Consequently, selecting for accelerated growth during the rearing phase could result in genetic gains in sexual precocity among Senepol cattle.

A moderate, negative genetic correlation (-0.41) was observed between AFC and weight, suggesting that certain genes influencing weight gain in heifers during their growth phase might also contribute to a decrease in AFC. Consequently, within a contemporary group, larger-sized or larger-framed Senepol females may exhibit lower AFC estimates, potentially indicating delayed sexual fertility. A moderate phenotypic correlation (Table 2) was also noted between RTS and weight (0.32). RTS can serve as a phenotypic selection method for heifers without negatively impacting productive traits (Andersen et al., 1988).

Table 3 presents the descriptive statistics of the (EPDs) for RTS, AFC, and weight. The variations in values and standard deviations indicate significant genetic variability between individuals of the Senepol breed. Understanding EPD predictions can facilitate selection and mating decisions aimed at genetically improving herds for these traits. It is important to recognize that without EPD information, the likelihood of using sires with inferior genetic scores increases, potentially leading to reduced performance in the reproductive traits of Senepol cattle.

Table 3
Descriptive statistics of expected progeny differences (EPDs) for antral follicle count (AFC), reproductive tract score (RTS), and weight (Weight) of Senepol bulls

Traits	N	Mean	SD	Min	Max
EPDAFC (unit)	216	0.08	3.07	-8.72	+13.81
EPDRTS (score)	216	0.00	0.04	-0.14	+0.16
EPDWeight (kg)	216	-0.16	4.15	-15.82	+12.80

The distributions of EPDs pertaining to RTS, AFC, and weight traits in Senepol bulls were examined (Figure 1). The EPD distributions displayed a pattern akin to a normal distribution, suggesting precision and dependability in the prediction of EPDs utilizing the bull model. The animal model is frequently employed to estimate (co)variance components. However, in certain databases and for specific traits, convergence to the genetic covariance regression factor might not be attained due to the existence of numerous fixed effects or variability among the effects (Silva et al., 2003).

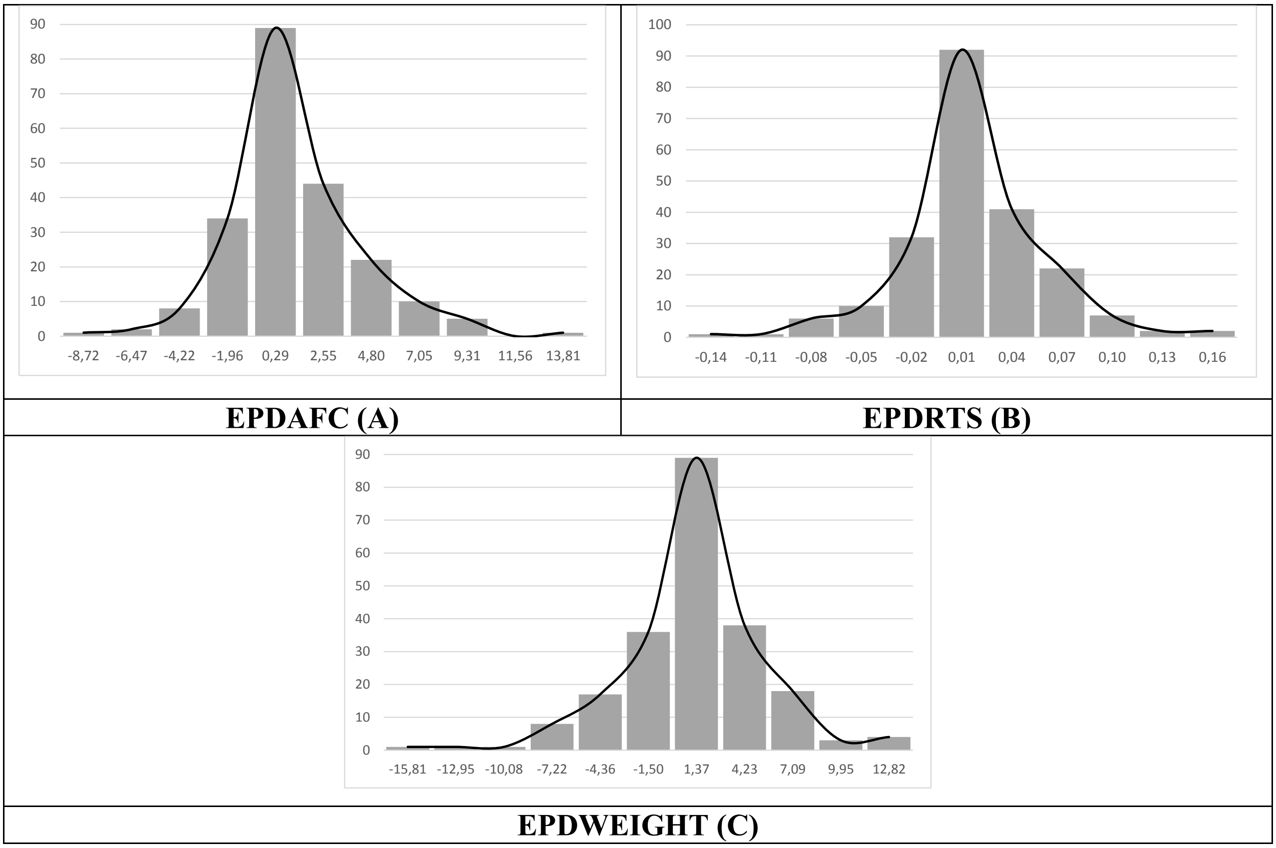

Figure 1. Distribution or frequency graph of expected progeny differences (EPDs) for the characteristics of antral follicle count (AFC, A), reproductive tract score (RTS, B), and weight (Weight, C) of Senepol bulls.

Conclusion

Selecting solely based on the RTS trait may lead to sluggish genetic progress due to its low heritability estimate. Conversely, the high heritability estimate for AFC indicates a faster response to selection, making it an important criterion in genetic improvement programs for Senepol females. Exclusive selection for RTS will not induce genetic alterations in AFC. Thus, to achieve genetic advancements in both traits, it is imperative to incorporate AFC and RTS simultaneously during the selection process.

Choosing females with increased body weight and development could lead to animals possessing a more mature reproductive tract and an earlier pubertal age, albeit with a reduced antral follicle count. Consequently, meticulous selection for RTS and AFC traits is vital for enhancing sexual precocity and fertility in Senepol heifers. Subsequent studies must concentrate on expanding the comprehension of the genetic and environmental factors that impact these traits, with the aim of further refining selection programs designed to improve these significant reproductive traits.

Author contributions

L. S. Pereira: Conceptualization, methodology, formal analysis, and writing - original draft. M. M.A. Gomes: Writing, reviewing, and editing. A. C. F. Faria: Writing, reviewing, and editing. R. R. Cunha: Data curation, writing, reviewing, and editing data. M.R.B.M. Nascimento: Writing, reviewing, and editing. R. M. Santos: Writing, reviewing, and editing. C. U. Faria: Conceptualization, methodology, formal analysis, and writing - original draft.

Conflicts of Interest

The authors declare no conflicts of interest.

Declaration of Funding statement

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Availability of Data

Due to ethical and privacy considerations, the data supporting this study cannot be publicly shared. However, it may be made available upon reasonable request to the corresponding author, if deemed appropriate.

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