Genetic and phenotypic parameters for feed and water efficiency in Senepol cattle

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Summary

The sustainability of beef production in the world demands the identification and selection of efficient animals that can produce more products with fewer inputs. Feed accounts for around 50-70% of variable costs of beef cattle systems, depending on the level of intensification adopted. Water has been traditionally considered an inexpensive, readily available, and renewable natural resource. However, growing concerns about the availability of drinkable water have increasingly pushed pressure on livestock production, especially cattle. Thus, genetic and phenotypic parameters were estimated for feed and water efficiency in Senepol cattle in order to evaluate their use as selection criteria. Records on 587 Senepol heifers, involved in performance tests, were used. Traits studied included residual feed intake (RFI), residual water intake (RWI), average daily feed intake (ADFI), average daily water intake (ADWI) and average daily gain (ADG). Individual daily feed and water intake records were collected over a 70-day period, using electronic feed and water bunks developed by Intergado Ltd. The ADG was calculated dividing the total weight gained during the test by its duration. A linear regression model of ADFI on metabolic weight (mean weight$^{0.75}$) and ADG was fitted, within each test edition. RFI was calculated as ADFI minus that predicted using the regression equation. The same was performed for calculating RWI by using ADWI instead of ADFI in the linear regression model. Genetic (co)variances were estimated using two-trait animal models and software AIREMLF90. Direct heritability estimates for RFI, RWI, ADFI, ADWI and ADG were 0.12 ± 0.10, 0.39 ± 0.12, 0.23 ± 0.11, 0.47 ± 0.12 and 0.15 ± 0.09 (averaged across all analyses), respectively. RFI was genetically (r_g = 0.50 ± 0.65) and phenotypically (r_p = 0.37 ± 0.04) correlated with RWI. Both RFI and RWI presented phenotypic correlations near to zero with ADG (r_p = -0.11 ± 0.05 and -0.09 ± 0.05, respectively). Genetically, RFI was not correlated (r_g = 0.06 ± 1.12) with ADG, whereas RWI was (r_g = 0.45 ± 0.79). The correlations between the pairs RFI-ADFI and RWI-ADWI were all positive (r_g = 0.68 ± 0.91, r_p = 0.78 ± 0.02; and r_g = 0.90 ± 0.11, r_p = 0.84 ± 0.01, respectively). ADFI was positive correlated with ADWI (r_g = 0.75 ± 0.41, r_p = 0.57 ± 0.03), and both traits presented similar correlations with ADG (r_g = 0.61 ± 0.77, r_p = 0.28 ± 0.04; and r_g = 0.70 ± 0.69, r_p = 0.29 ± 0.04, respectively).

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Genetic improvement for feed and water efficiency in Senepol cattle can be achieved through selection. Genetic progress for water efficiency is expected to be superior to the one for feed efficiency. Feed intake and efficiency can be genetically improved by selecting animals for water intake and efficiency.

Keywords: beef, correlation, heritability, residual feed intake, residual water intake, selection.

Introduction

Increasing food production for the growing human population of a constraining land base will require greater efficiency of production (Berry and Crowley, 2013). With limited resources available for production, there is a need to identify and select for efficient animals that can produce more product with fewer inputs (Ahlberg *et al*., 2017).

Feed accounts for around 50-70% of variable costs of beef cattle systems, depending on the level of intensification adopted. Hence, feed efficiency, undoubtedly, has a major role to play in increasing production efficiency (Berry and Crowley, 2013).

Water has been traditionally considered an inexpensive, readily available, and renewable natural resource (Brew *et al*., 2011). However, with the increasing demand for animal products in the coming decades, balancing animal productivity with water use will require a concerted effort among producers, scientists, agroindustries, and consumers to reduce the risks associated with animal water demand and scarcity (Palhares *et al*., 2017). According to Nardone *et al*. (2010), the efficiency of water utilization will be the primary mission necessary to achieve sustainability of animal agriculture.

The Senepol breed was developed from the beginning of the twentieth century on the Virgin Island of Saint Croix as a tropically adapted taurine breed. Since the arrival of the first animals in Brazil in 2000, the population has increased its census considerably. Considering only taurine breeds with semen produced in Brazil in 2014, the Senepol breed was surpassed only by the Angus breed (ASBIA, 2015).

Thus, genetic and phenotypic parameters were estimated for feed and water efficiency in Senepol cattle in order to evaluate their use as selection criteria.

Material and methods

Records from 587 Senepol heifers (*Bos taurus taurus*), progenies of 61 sires and 264 dams, were used. The pedigree contained 1,965 animals. The data were obtained from a compilation of eight commercial performance tests performed on Grama Farm, Pirajuí, São Paulo, Brazil (21º 59' S; 49º 27' W), between 2014 and 2016. The animals started the tests with an average weight of 397 ± 52 kg and age of 520 ± 59 days.

Animals were housed in collective pens, where individual daily feed and water intake records were collected over, approximately, a 70-day period, using Intergado® System (Intergado® Ltd, Contagem, Minas Gerais, Brazil). For more information about Intergado® System, see Chizzotti *et al.* (2015) and Oliveira Jr *et al.* (2017). Prior to the tests, the animals were allowed to adapt to the diet and facilities for a minimum period of 14 days. The animals had ad libitum access to diet and water. The feed composition of the diet offered was modified over the tests, but was equivalent in energy and protein content, with 2.64 Mcal of metabolizable energy and 14% of crude protein in dry matter basis (DM).

The studied traits included average daily gain (ADG – kg d^{-1}), average daily feed intake (ADFI – kg DM d^{-1}), average daily water intake (ADWI – L d^{-1}), residual feed intake (RFI – kg DM d^{-1}) and residual water intake (RWI – L d^{-1}). The ADG was calculated dividing the total weight gained during the test by its duration. A linear regression model of ADFI on mid-test metabolic body weight (mid-test body $weight^{0.75}$) and ADG was fitted (Koch *et al.*, 1963), within each test edition. RFI was calculated as ADFI minus that predicted using the regression equation. The same was performed for calculating RWI by using ADWI instead of ADFI in the linear regression model.

The contemporary groups were defined as test edition and farm of origin of the heifer. Records outside the interval of ± 3.0 standard deviations from the mean of the contemporary group were eliminated. Only animals with valid records for all five traits studied were kept. Animals from contemporary groups with less than five individuals were also discarded. Table 1 shows the data structure and descriptive statistics of the traits.

The (co)variance components were estimated by the restricted maximum likelihood method under a two-trait animal model using the AIREMLF90 program (Misztal *et al.*, 2002). The model included random direct additive genetic effects, the fixed effects of contemporary group and age of animal nested in the respective contemporary group as a covariate (linear effect). Direct heritability estimates for each trait were obtained by averaging across all two-trait analyses.

Results and discussion

The direct heritability estimates for the studied traits ranged from 0.12 to 0.47 (Table 2). These results, which are pioneers for Senepol cattle, indicate that selection can be used for increasing feed and water efficiency. However, genetics gains for ADWI and RWI are expected to be quite superior to those for ADFI and RFI due to the significant differences in heritabilities. Berry and Crowley (2013) performed a meta-analysis of genetic parameters for feed efficiency in beef cattle and reported higher values than the ones found in the present study (pooled heritabilities of 0.40 ± 0.01 for ADFI and 0.33 ± 0.01 for RFI). No study was found in the literature with genetic parameters for water intake and efficiency in cattle.

RFI was genetically and phenotypically correlated with RWI (Table 2). These results indicate that selection for animals with better feed efficiency could also lead to genetic progress for water efficiency. Despite water is often thought of as an irrelevant factor in beef cattle production, increasing water efficiency could be strategic, especially, in a long-term context. According to Nardone *et al.* (2010), all effects of global warming on water availability could force the livestock sector to establish a new priority in producing animal products that need less water. Both RFI and RWI presented phenotypic correlations (r_p) near to zero with ADG (Table 2). Genetically (r_g), RFI was

Table 1. Description of the final data set of studied traits.

Trait[1]	Mean ± SD	Number of animals with records	Number of contemporary groups
ADG (kg d^{-1})	0.87 ± 0.21	587	51
ADFI (kg d^{-1})	7.49 ± 1.16	587	51
ADWI (L d^{-1})	24.68 ± 3.99	587	51
RFI (kg d^{-1})	0.00 ± 0.79	587	51
RWI (L d^{-1})	0.00 ± 2.96	587	51

[1]ADG, average daily gain; ADFI, average daily feed intake in dry matter basis; ADWI, average daily water intake; RFI, residual feed intake in dry matter basis; RWI, residual water intake.

Table 2. Heritability (diagonal), phenotypic correlation (below the diagonal) and genetic correlation (above the diagonal) estimates for the studied traits.

Traits[1]	ADG	ADFI	ADWI	RFI	RWI
ADG	**0.15 ± 0.09**[2]	0.61 ± 0.77	0.70 ± 0.69	0.06 ± 1.12	0.45 ± 0.79
ADFI	0.28 ± 0.04	**0.23 ± 0.11**	0.75 ± 0.41	0.68 ± 0.91	0.57 ± 0.40
ADWI	0.29 ± 0.04	0.57 ± 0.03	**0.47 ± 0.12**	0.39 ± 0.90	0.90 ± 0.11
RFI	-0.11 ± 0.05	0.78 ± 0.02	0.30 ± 0.04	**0.12 ± 0.10**	0.50 ± 0.65
RWI	-0.09 ± 0.05	0.29 ± 0.02	0.84 ± 0.01	0.37 ± 0.04	**0.39 ± 0.12**

[1] ADG, average daily gain; ADFI, average daily feed intake; ADWI, average daily water intake; RFI, residual feed intake; RWI, residual water intake.
[2] standard error.

not correlated with ADG, whereas RWI was (Table 2). Berry and Crowley (2013) reported similar estimates (pooled) for r_p and r_g between RFI and ADG. For r_p, these authors found a range of -0.06 to +0.04; while for r_g, a range of -0.15 to +0.53. Guimarães *et al*. (2017) also estimated r_p close to zero between RFI and ADG for Senepol cattle. Kennedy *et al*. (1993) pointed out that although RFI is phenotypically independent of the component traits, except ADFI, it is not genetically independent. As RWI is calculated similarly to RFI, the same could be said for this trait.

The r_p and r_g between the pairs RFI-ADFI and RWI-ADWI were all positive (Table 2). Berry and Crowley (2013) and Guimarães *et al*. (2017) found results of similar magnitude and sign of the ones estimated in the present study. ADFI was highly positive correlated with ADWI (Table 2), both genetically and phenotypically. It suggests that ADWI could be used to estimate ADFI in cattle what would be useful since measuring the former is easier and cheaper than the latter. This would be especially advantageable in grazing systems where evaluating ADFI in large scale is not yet a feasible alternative. ADG presented similar correlations with both intake traits (Table 2), corroborating the findings of Berry and Crowley (2013).

Conclusions

Genetic improvement for feed and water efficiency in Senepol cattle can be achieved through selection. Genetic progress for water efficiency is expected to be superior to the one for feed efficiency. Feed intake and efficiency can be genetically improved by selecting animals for water intake and efficiency.

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