

Research Application Summary

Genetic variation and parameters of feed efficiency traits in Boran cattle in Kenya

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Abstract

The aim of this study was to evaluate the effect of fixed factors on measures of feed efficiency and estimate genetic parameters for feed efficiency for the Boran cattle in Kenya. A total of 1348 records of birth weight and weaning weight were used to derive pre weaning measures of feed efficiency. The traits derived were pre-weaning daily gain (ADG), weaning weight adjusted to 205 days (WA205), Kleiber Index at 205 days (KI205), and relative growth rate (RGR). The fixed effects model included effects of sex, parity, year-season of birth or weaning and dam weight at weaning. A maternal genetic effects model was fitted to estimate the genetic parameters for the traits. All fixed effects except parity and dam age at weaning significantly influenced the studied traits. Direct heritability estimates for WA205, kg, ADG, kg/day, KI205, kg/kg0.75, RGR were 0.05 ± 0.02 , 0.27 ± 0.02 , 0.13 ± 0.02 and 0.21 ± 0.02 while the maternal heritability estimates were 0.04 ± 0.02 , 0.29 ± 0.02 , 0.10 ± 0.02 and 0.23 ± 0.02 , respectively. The genetic correlations between direct and maternal genetic effects for the traits were -0.18 ± 0.05 , -0.30 ± 0.04 , 0.9 ± 0.05 and -0.72 ± 0.04 , respectively. This study has provided genetic parameters for measures of feed efficiency for the improved Boran cattle in Kenya. The parameters can be used to incorporate the traits in the selection programmes with the aim of reducing the cost of feed leading to improved profitability as well as reduction in methane (CH₄) gas emission.

Key words: Boran Cattle, climate change, greenhouse gases, kleiber index, relative growth rate

Résumé

Le but de cette étude était d'évaluer l'effet de facteurs fixes sur les mesures de l'efficacité alimentaire et d'estimer les paramètres génétiques de l'efficacité alimentaire des bovins Boran au Kenya. Un total de 1348 enregistrements de poids à la naissance et de poids au sevrage ont été utilisés pour dériver des mesures pré-sevrage de l'efficacité alimentaire. Les caractères dérivés étaient le gain quotidien avant sevrage (GTS), le poids au sevrage ajusté à 205 jours (PA205), l'indice de Kleiber à 205 jours (KI205) et le taux de croissance relatif (TCR). Le modèle à effets fixes incluait les effets du sexe, de la parité, de l'année-saison de naissance ou de sevrage et du poids de la mère au sevrage. Un modèle d'effets génétiques maternels a été adapté pour estimer les paramètres génétiques des traits. Tous les effets fixes, à l'exception de la parité et de l'âge au sevrage, ont influencé significativement les caractères étudiés. Les estimations de l'héritabilité directe pour PA205, kg, GTS, kg/jour, KI205, kg/kg0,75, TCR étaient de $0,05 \pm 0,02$, $0,27 \pm 0,02$, $0,13 \pm 0,02$ et $0,21 \pm 0,02$ tandis que les estimations de l'héritabilité maternelle étaient de $0,04 \pm 0,02$, $0,29 \pm 0,02$, $0,10 \pm 0,02$ et $0,23 \pm 0,02$, respectivement. Les corrélations génétiques entre les effets génétiques directs et maternels pour les traits étaient de $-0,18 \pm 0,05$, $-0,30 \pm 0,04$, $0,9 \pm 0,05$ et $-0,72 \pm 0,04$, respectivement. Cette étude a fourni des paramètres génétiques pour les mesures

de l'efficacité alimentaire des bovins Boran améliorés au Kenya. Les paramètres peuvent être utilisés pour incorporer les traits dans les programmes de sélection dans le but de réduire le coût de l'alimentation conduisant à une meilleure rentabilité ainsi qu'à une réduction des émissions de gaz méthane (CH₄).

Mots clés : Bovin Boran, changement climatique, gaz à effet de serre, indice de Kleiber, taux de croissance relatif

Introduction

Feed provision in beef cattle enterprises is a major economic factor influencing the profitability of beef enterprises since feeds account for up to three-quarters of total direct costs (Kenny *et al.*, 2018). A strategy that is increasingly being adopted to reduce feed cost is to improve feed efficiency through selection (Manuel *et al.*, 2019). Generally, feed efficiency is defined as the ratio between product (product) and feed intake (costs) in the form of mass or energy value of product per kilogram of dry matter intake (DMI) (Lovendahl *et al.*, 2018). Feed efficiency related traits have been shown to have low to medium heritability, meaning that animals that can efficiently make use of feed resources for reducing feeding costs and improving feed efficiency can easily be identified (Mehrban *et al.*, 2020).

In the wake of climate change selection of improved feed efficiency can be used as mitigating strategy to reduce methane gas (CH₄) production. This would play an important role in decreasing the environmental impact of climate change by minimizing the area needed for grazing and production of residues, such as manure and methane (Manuel *et al.*, 2019). Reduction of the amount of feed needed for a given body weight by improving feed efficiency minimizes the emissions arising from both feed and manure management (Leinonen and Kyriazakis, 2016). Efforts are now being directed towards developing animal husbandry approaches that lower enteric CH₄ emissions (Beauchemin *et al.*, 2010). Feed efficiency traits can help to complement the efforts to reduce the negative impacts of animal production on the environment (Gidenne *et al.*, 2017). Therefore it is possible and practical to improve profitability and reduce environmental impacts by selecting for higher feed efficiency and lower methane (CH₄) emission traits in livestock farms (Lovendahl *et al.*, 2018).

Feed efficiency is usually measured using feed conversion ratio (FCR) which is defined as the ratio of feed intake to weight gain (Robinson and Oddy, 2004). Residual feed intake (RFI) which is the difference between actual and predicted intake based on its body weight and growth rate over a time period is another measure of feed efficiency (Berry and Crowley, 2013). Both RFI and FCR require feed intake information which is difficult to measure in several livestock production systems (Talebi, 2012). Kleiber Index (KI) and relative growth rate (RGR) are measures of feed efficiency which do not need individual measurement of intake and can be used to identify and select animals with improved growth efficiency in relation to their body size (Pitchford, 2004; Berry and Crowley, 2013; Manuel *et al.*, 2019; Mehrban *et al.*, 2020). Keiber index is derived as the ratio of rate of gain to metabolic body weight, while RGR is obtained as the logarithm of rate of daily gain multiplied by 100 (Manuel *et al.*, 2019; Mehrban *et al.*, 2020). As such the two traits can easily be derived from data that is routinely recorded in most beef cattle production enterprises. Therefore, this study estimated genetic parameters for feed efficiency trait such as relative growth rate RGR, the Kleiber Index, average daily weight gain for a broader understanding of potential responses to selection for these traits.

Material and Methods

Performance records, data and traits. Records of growth from birth to weaning of animals born between 1973 and 2019 were obtained from the National Beef Research Centre of The Kenya Agricultural and Livestock Research organisation, Kenya, situated in the outskirts of Nakuru City, 150 km North West of Nairobi. The ranch maintains an improved Boran cattle stud herd which are registered with the Kenya Stud Book and are members of the Kenya Boran Cattle Breeders Society (KBCBS). The climatic conditions and general management of animals is described in details by Wasike *et al.* (2006). The pedigree of each individual was traced as far back as possible from the records. Growth performance records of each individual included birth weight (BW) and weaning weight (WWT). An animal was retained for further analyses if it had both birth and weaning weights and the respective dates of weighting.

Derivation of feed efficiency traits. Feed efficiency traits were derived for the age interval from birth to weaning. The age interval was pre-established to obtain adjusted body weights at 205 (WA205). The weight adjusted to 205 days was obtained according to Manuel *et al.* (2019) as:

$$WA205 = \left[\frac{(BW_f - BW_i)}{DS} \right] C + BW_i$$

where BW_f and BW_i are the final body weight and initial body weight, respectively. In this context BW_f represents weaning weight while BW_i is the birth weight; DS is the interval between birth and weaning while C is the standard age in days, i.e., 205 days. Contemporary groups were year-season of birth or weaning, sex and parity. Each contemporary group was required to have at least three animals. Relative growth rate (RGR) and mid - test age was calculated following Mehrban *et al.* (2020) as:

$$RGR = \left(\frac{\log FBW - \log IBW}{age_{max} - age_{min}} \right) \times 100$$

where FBW and IBW are final body weight and initial body weight, respectively; age_{min} and age_{max} are the minimum and maximum recorded ages for each animal. Kleiber Index (KI) at 205 days (KI205) was calculated according to Arthur *et al.* (2001) as:

$$KI = \frac{ADG}{MBW}$$

where ADG was calculated as (W205- birth weight BW)/ Age (days) and MBW is the metabolic body weight calculate as WWT^{0.75}.

The Proc GLM of SAS (SAS, 2002) was used to test the effect of systematic fixed factors on the traits. The factors included year-season of birth or weaning, sex, parity and dam weight at birth or weaning.

Estimation of genetic parameters for feed efficiency traits. A univariate animal model analyses for each model was fitted using BLUPF90 package (Aguilar *et al.*, 2018) to estimate genetic and phenotypic variances and heritability estimates for all the traits. The following general model was used:

$$y = X\beta + Za + Mmg + Wpe + e$$

where y is a vector of observations; β is a vector of fixed effects; a , mg , and pe are vectors of random direct genetic, maternal genetic and permanent maternal environmental effects, respectively; e is a vector of random residual effects. X , Z , M and W are incidence matrices relating β , a , m , and pe , respectively, to y .

The assumptions for the models where applicable were:

$$E(y)=X\beta; E(a)=0; E(mg)=0; E(pe)=0; \text{ and } E(e)=0.$$

The variances were $\text{var}(a)=A\sigma_a^2$; $\text{var}(mg)=A\sigma_{mg}^2$ $\text{var}(pe) I_d \sigma_{pe}^2$; $\text{var}(e) = I_{nb} \sigma_e^2$ and

$$\text{cov}(a, mg)=A\sigma_{a, mg};$$

where A is the additive genetic relationship matrix; I_d and I_n are identity matrices of number of dams (d) and total number of observations (n); σ_a^2 is the direct additive genetic variance; σ_{mg}^2 is the maternal genetic variance; $\sigma_{a, mg}^2$ is the covariance between direct and maternal genetic effects; σ_{pe}^2 is the variance of maternal permanent environment; and σ_e^2 is the residual variance.

Results and Discussion

The least square means for growth and feed efficiency traits are shown in Table 1. Weaning weight adjusted to 205 days (W205) had a least square mean of 129.92 ± 23.54 kg, while the least square means for ADG, KI205 and RGR were 0.51 ± 0.11 , kg/day, 1.24 ± 0.15 kg/kg 0.75 and 0.32 ± 0.05 , respectively (Table 1). The coefficient of variation was highest for ADG (22.41%) and low for KI205 (12.55%) and BW (11.67%).

Table 1. Number of records, least square means (LSMeans)±standard deviation (SD) and coefficient of variation (CV%) for growth and feed efficiency trait in improved Boran cattle in Kenya

Traits	N	LSMean±SD	CV, %
W205, kg	1348	129.92±23.54	18.12
ADG, kg/day	1348	0.51±0.11	22.41
KI205, kg/kg0.75	1348	1.24±0.15	12.55
RGR, kg/day	1348	0.32±0.05	15.80

W205=weaning weight adjusted to 205 days; ADG=pre-weaning average daily gain; KI205=Kleiber index at 205 days of age; RGR=relative growth rate

The factors fitted to test the significant of fixed effects fairly described the data, with the coefficient of determination ranging from 0.72 to 0.78 (Table 2). Year-season of birth (YSB), year-season weaning (YSW), and sex had a significant effect ($P < 0.05$) on all the studied traits (Table 2). Parity, weight of dam at birth and weaning did not have any effect on the studied traits ($P > 0.05$)

Table 2. Coefficient of determination (R^2) sums of squares (SS) and level of significance of fixed factors on growth and feed efficiency trait in improved Boran cattle in Kenya

Traits	R^2	Parity	Dam weight weaning	Year-season of birth	Year-season of weaning	Sex
W205, kg	0.77	ns	ns	***	***	***
ADG, kg/day	0.78	ns	ns	*	**	***
KI205, kg/kg ^{0.75}	0.78	ns	ns	**	*	***
RGR	0.72	ns	ns	***	***	ns

W205=weaning weight adjusted to 205 days; ADG=pre-weaning average daily gain; KI205=Kleiber index at 205 days of age; RGR=relative growth rate; an effect with *, **, or *** is significant at $P < 0.05$, 0.01 or 0.001, respectively; ns=not significant

The significant effects in Table 2 were fitted in a univariate animal model to estimate variance and covariance components for growth and feed efficiency traits shown in Table 3. Relative to direct genetic effects, maternal genetic effects were higher for feed efficiency traits compared to growth traits (Table 3). Genetic heritability estimates were higher for ADG (0.27 ± 0.02) and RGR (0.21 ± 0.02) and lowest for WA205 (0.05 ± 0.02). Maternal permanent environment effects were highest for KI205 and WA205 relative to direct maternal genetic effects. This implies that feed efficiency traits were more influenced by the environment provided by the dam from birth until weaning. The more or less similar maternal and direct genetic heritability estimates for ADG (0.29 ± 0.02 and 0.27 ± 0.02), W205 (0.05 ± 0.02 and 0.04 ± 0.02), KI205 (0.10 ± 0.02 and 0.13 ± 0.02) and RGR (0.21 ± 0.02) (Table 3) indicate that the two effects are equally important in determining the performance of an animal.

Table 3. Variance components, direct genetic (h_a^2) and maternal heritability (h_{mg}^2), covariance ($\sigma_{a,mg}$) and correlation ($r_{g_{a,mg}}^2$) between direct genetic and maternal genetic effects for growth and feed efficiency trait in improved Boran cattle in Kenya

Traits	σ_a^2	σ_{mg}^2	σ_{pe}^2	$\sigma_{a,mg}$	σ_e^2	h_a^2	h_{mg}^2	c^2	$r_{g_{a,mg}}^2$
W205, kg	26.18	19.12	57.66	-0.19	378.96	0.05	0.04	0.12	-0.18
ADG, kg/day	0.64	0.67	0.112	-0.13	0.91	0.27	0.29	0.05	-0.30
KI205, kg/kg ^{0.75}	0.12	0.13	0.36	0.10	0.37	0.13	0.10	0.38	0.90
RGR, kg/0.38	0.41	0.12	-0.21	0.87	0.21	0.23	0.07	-0.72	

W205=weaning weight adjusted to 205 days; ADG=pre-weaning average daily gain; KI205=Kleiber index at 205 days of age; RGR=relative growth rate; Standard errors for the parameter estimates were 0.02 while those for genetic correlations ranged from 0.04 to 0.05

Estimates of direct heritability ranged from 0.05 to 0.27, maternal heritability ranged from 0.04 to 0.29 and these ranges were sufficient to indicate additive genetic variability, therefore, all traits may be explored in the selection process. Heritability of 0.27 ± 0.02 for ADG was below the ranges reported previously (0.34 to 0.38; by Arthur *et al.* (2001), Goyache *et al.* (2003) and Crowley *et al.* (2010). The direct heritability of KI205 was 0.13 ± 0.02 which was within the same range of that of 0.19 ± 0.02 reported by Manuel *et al.* (2019). The estimate of heritability for WA205 of

0.05±0.02 was lower than estimates reported by Manuel *et al.* (2019). The value of heritability of 0.27±0.02 found in the current study was similar to previous estimates of 0.21±0.02 (Manuel *et al.*, 2019) but lower than those reported by Hoque *et al.* (2005), Crowley *et al.* (2010), Takeda *et al.* (2018) and Merhban *et al.* (2020) which were in the range of 0.33 to 0.54. for feed efficiency traits. The heritability estimates for KI205 and RGR of 0.13±0.02 and 0.21±0.02, respectively, were lower than estimates of 0.28 (Merhban *et al.*, 2020), 0.40 (Arthur *et al.*, 2001), 0.43 (Crowley *et al.*, 2010), 0.53 (Groin *et al.*, 2014 and Ceacero *et al.*, 2016). The differences found could be as a result of the differences in the number of animals considered, breed, the completeness of the pedigree, precision of recording, environmental variation, and statistical models used for analyses (Merhban *et al.*, 2020).

The heritability estimates for RGR and KI205 provide a basis for reduction of the amount of feed needed for a given body weight, thereby improving feed efficiency and reducing the cost of producing a unit of beef (Lovendahl *et al.*, 2018). This has the added and desirable advantage of minimising greenhouse gas emissions from both feed and manure management, apart from reducing the cost of producing a unit of beef (Beauchemin *et al.*, 2010; Leinonen and Kyriazakis, 2016; Lovendahl *et al.*, 2018). This attempt at complementing the efforts to reduce the negative impacts of animal production on the environment (Gidenne *et al.*, 2017) would be achieved without incurring extra recording costs since these traits utilise already existing routine records (Merhban *et al.*, 2020).

Conclusions

This study has provided genetic parameters for measures of feed efficiency for the improved Boran cattle in Kenya. The parameters can be used to incorporate the traits in the selection programmes with the aim of reducing the cost of feed leading to improved profitability and sustainability of beef cattle enterprises and also as a mitigation strategy to climate change.

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