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Genetic variation and parameters for growth and feed efficiency traits in Boran beef cattle in Kenya

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Abstract
A major drawback of improving feed efficiency in beef cattle enterprises is to identify measures of feed efficiency which do not require feed intake information on an individual animal basis. Kleiber Index, (KI) and relative growth rate (RGR) are alternative measures which do not need individual measurement of intake and can be used select for improved feed and growth efficiency in relation to their body size. The aim of this study was to estimate genetic parameters for measures of feed efficiency and growth traits for the Boran beef cattle in Kenya. A total of 1348, 2209, 2183 and 2184 weight records were available for birth, weaning, yearling and 550-day weight records, respectively, were available for animals born between 1973 and 2019. The traits derived were growth rates (ADG), adjusted weights (WA), KI and RGR at weaning (205 days), yearling (365 days) and 550 days. Genetic parameters were estimated using a maternal genetic effects model. Direct heritability estimates for direct heritability estimates for ADG ranged from 0.12±0.04 for ADG205-365 to 0.27±0.02 for ADGB-205. Estimates for WA were in range of 0.05±0.05 at to 0.10±0.05 at 550 days. Estimates for KI were 0.13±0.05 at 205 to 0.29±0.05 at 550 days. For RGR estimate direct heritability at 205 was 0.21±0.05, 0.19±0.04 at 365 and 0.33±0.05 at 550 days. The direct-maternal genetic correlations for WA, ADG, KI and RGR at 205 days were -0.30±0.05, -0.30±0.04, 0.90±0.05 and -0.72±0.04, respectively. Alongside growth traits, Kleiber Index and residual growth rate had substantial heritability estimates, implying potential for improvement through selection.

Keywords: Climate change, greenhouse gases, kleiber index, relative growth rate

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) [14]. A strategy that is increasingly being adopted to reduce feed cost is to improve feed efficiency through selection (Matos *et al.*, 2019) [17]. 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) (Lovendahll *et al.*, 2018) [16]. 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.*, 2021) [18].

Feed efficiency is usually measured using feed conversion ratio (FCR) which is defined as the ratio of feed intake to weight gain (Robinson & Oddy 2004) [22] or 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 & Crowley, 2013) [4]. Both RFI and FCR require feed intake information which is difficult to measure in most livestock production systems (Talebi, 2012) [24]. 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 & Crowley 2013; Matos *et al.*, 2019; Mehrban *et al.*, 2021) [21, 4, 17, 18]. Kleiber index is defined as the ratio of rate of gain to metabolic body weight, while RGR obtained as the logarithm of rate of daily gain multiplied by 100 (Matos *et al.*, 2019; Mehrban *et al.*, 2021) [17, 18]. As such the two traits can easily be derived from data that is

routinely recorded in most beef cattle production enterprises.
In the wake of climate change selection of improved feed efficiency can be used as mitigating strategy to reduce methane gas (CH_4) production hence play an important role in decreasing the environmental impact by means of minimizing the area needed for grazing and production of residues, such as manure and methane (Matos *et al.*, 2019) [17]. 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 & Kyriazakis 2016) [15]. Efforts are now being directed towards developing animal husbandry approaches that lower enteric CH_4 emissions (Beauchemin *et al.*, 2010) [3]. Feed efficiency traits can help to complement the efforts to reduce the negative impacts of animal production on the environment by reducing carrying capacity while achieving the same or higher productivity per unit of land (Gidenne *et al.*, 2017) [8]. 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 (Lovendahll *et al.*, 2018) [16]. Therefore, this study aimed to estimate 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

Production environment

Records of growth from body weight records of animals born between 1973 and 2019 from the National Beef Research Centre of The Kenya Agricultural and Livestock Research Organisation, Kenya, Ol Pajeta and Mugwooni ranches. These ranches maintain improved Boran cattle stud herds which are registered with the Kenya Stud Book and are members of the Kenya Boran cattle Breeders Society (KBCBS). The three branches are located in agro-ecological zone (AEZ) IV, which is classified as arid and semi-arid land (ASAL). The National Beef Research Station receives an average annual rainfall of 800 mm. Ol Pejeta ranch covers 90,000 acres (360km^2), it lies between Mt. Kenya and the Aberdare Mountains (0°7.288'N, 36°42.384'E and 0°8.634'N, 37°0.605'E) (0°1.831'S, 36°46.578'E and 0°5.7025'S 37°2.492'E), at an average altitude of 1810m, mean annual rainfall of 739mm, mean maximum and minimum temperatures of 28°C and 12°C respectively (Kavwele *et al.*, 2017) [13]. Mogwooni Ranch, lies between longitude 360 4' West and 370 27' East and between latitude 00 17' South and 00 45' North. The annual rainfall ranged from 600 to 900mm. The vegetation is predominantly Savannah with scattered acacia and shrubs (Njiru *et al.*, 2001) [20].The rainfall pattern for the three ranches is bimodal, with the long rains falling in March to June and the short rains occurring in September to October with dry seasons in between. The hottest and the driest month in all the herds are January and February (Wasike *et al.*, 2006) [25].

Performance and pedigree records

A total of 1348, 2209, 2183 and 2184 weight records were available for birth, weaning, yearling and 550-day weight records, respectively, were available. Birth weight records were recorded at the National Beef Research Station herd only. Pedigree data consisted 3306 animals born between 1974 and 2018 with a maximum pedigree depth of 8 generations. The pedigree of each individual was be traced as far back as possible from the records. Performance records of each individual included birth weight (BW) and weaning weight (WWT) as well as the animal's sex, birth number (parity), age of dam at calving and dates of birth and weaning. An animal was retained for further analyses if it had both birth and weaning weights and the respective dates of weighting.

Derivation of growth and feed efficiency traits

The age intervals were pre-established to obtain adjusted body weights at 205 days (WA205), 365 days (WA365) and 550 days (WA550) as follows (Matos *et al.*, 2019) [17] as:

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

Where BW_f and BW_i are the final body weight and initial body weight, respectively; DS is the interval between weights while C is the standard age in days corresponding to 205, 365, or 550 days.

Relative growth rate at 205 days (RGR205), 365 days (RGR365) and 550 days (RGR550) were calculated as (Mehrban *et al.*, 2020) [18]:

$$RGR = \left(\frac{logBW_f - logBW_i}{age_{max} - age_{min}}\right) \times 100$$

Where age $_{min}$ and age $_{max}$ are the minimum and maximum recorded ages for each animal.

Kleiber Index (KI) at 205 days (KI205), 365 days (KI365) and 550 days (KI550) were calculated as (Arthur *et al.*, 2001a) [1]:

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

Where ADG is the rate of growth for the pre-established ages and MBW is $LW^{0.75}$ (for Live weight (LW) at weaning, yearling and 550 days).
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

A Univariate animal model analyses for each model was fitted to estimate genetic and phenotypic variances and heritability estimates for all the traits. The following general model was used:

$$\mathbf{y = X\beta + Za + Mmg + Wpe + e}$$

Where y is a vector of observations; β is a vector of fixed effects (sex, year-season of birth or weaning); 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)=Xβ; E(a)=0; E(mg)=0; E(pe)=0; and E(e)=0.

The variances were var(a)=$\mathbf{A}\sigma_a^2$; var(mg)=$\mathbf{A}\sigma_{mg}^2$ var (pe) $\mathbf{I}_d\sigma_{pe}^2$; var(e) = $\mathbf{I}_{nb}\sigma_e^2$ and cov(a, mg)= $\mathbf{A}\sigma_{a,mg}$, 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^2_a is the direct additive genetic variance; σ^2_{mg} is the maternal genetic variance; $\sigma_{a,mg}$ is the covariance between direct and maternal genetic effects; σ^2_{pe} is the variance of maternal permanent environment; and σ^2_e is the residual variance. Variance components and genetic parameter estimates were estimated using the BLUPF90 family of programmes (Misztal *et al.*, 2002) [19].

Results

The least square means for growth and feed efficiency traits are shown in Table 1. Average daily gain was highest from birth to weaning (0.51±0.11 kg/day) and slowed down until 0.36±0.17kg/day) at 550 days of age. Kleiber index and relative growth rate were highest at

Table 1: Number of records (N), least square means (LS Means) ± standard deviation (SD) and coefficient of variation (CV, %) for growth and feed efficiency traits in improved Boran cattle in Kenya

Traits	N	LS Mean ± SD	CV, %
W205, kg	1348	129.92±23.54	18.12
ADGB-205, kg/day	1348	0.51±0.11	22.41
KI205, kg/kg$^{0.75}$	1348	1.24±0.15	12.55
RGR205, kg/day	1348	0.32±0.05	15.80
WA365, kg	2182	248.59±39.02	15.70
ADG205-365, kg/day	2183	0.39±0.19	49.61
KI365, kg/kg$^{0.75}$	2144	0.04±0.03	71.3
RGR365	2169	0.05±0.03	67.6
WA550, kg	2150	319.19±47.84	15.0
ADG365-550, kg/day	2174	0.36±0.17	47.42
KI550, kg/kg$^{0.75}$	2150	0.49±0.19	38.24
RGR550	2109	0.07±0.04	49.3

W205=weaning weight adjusted to 205 days; ADGB-205=pre-weaning average daily gain; KI205=Kleiber index at 205 days of age; RGR205=relative growth rate at 205 days; WA365=weight at 1 year adjusted to 365 days; ADG205-365=average daily gain from weaning to yearling; KI365=Kleiber index at 365 days; RGR365=relative growth rate at 365 days; WA550=adjusted weight at 550 days; ADG365-550=average daily gain from yearling to 550 days; KI550=Kleiber index at 550 days; RGR550=relative growth rate at 550 days

205 days (1.24±0.15kg/kg$^{0.75}$ and 0.32±0.05, respectively) and lowest at 365 days (0.04±0.03 kg/kg$^{0.75}$ and 0.05±0.03, respectively). The means for WA205, WA365 and WA550 were 129.92±23.54 kg, 248.59±39.02 kg and 319.19±47.84 kg, respectively (Table 1). The coefficient of variation was highest for ADG (22.41%) and low for KI205 (12.55%) and BW (11.67%).

Variance components, estimates of direct and maternal (where applicable) heritability and common environmental effects and direct-maternal genetic correlation for growth and feed efficiency traits are shown in Table 2. Direct heritability estimates were higher for ADGB-205 (0.27±0.02) compared to ADG205-305 (0.12±0.04) and ADG365-5550 (0.18±0.05) (Table 2). Direct heritability for adjusted weight was higher for WA550 (0.10±0.05) than for either WA205 (0.05±0.05) or WA365 (0.05±0.03). Estimates for KI increased with age from 0.13±0.05at 205 days to 0.29±0.05 at 550 days. For RGR direct heritability at 205 was 0.21±0.05 which decreased to 0.19±0.04 at 365 days before increasing to 0.33±0.05 at 550 days. Maternal permanent environment effects were higher for KI205 and WA205 relative to direct maternal genetic effects (Table 2). 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 ADGB-205 (0.29±0.02 and 0.27±0.02), WA205 (0.05±0.02 and 0.04±0.02), KI205 (0.10±0.02 and 0.13±0.02) and RGR205 (0.21±0.02 and 0.23±0.04) (Table 2) indicate that the two effects are equally important in determining the performance of an animal at weaning. Direct heritability of 0.27±0.02 for ADGB-205 was below the estimates reported previously for various beef cattle populations of 0.34 to 0.38 (Crowley *et al.*, 2010; Goyache *et al.*, 2003; Arthur *et al.*, 2001b) [7, 12, 2]. However, WA205 had a lower estimate (0.05±0.05) compared to 0.24±0.02 for Brahman cattle (Matos *et al.*, 2019) [17]. For ADGB-205, the heritability of 0.27±0.02 found in the current study was similar to estimate of 0.21±0.02 (Matos *et al.*, 2019) [17] but lower than those reported by Mehrban *et al.* (2021) [18], Crowley *et al.* (2010) [7], Hoque *et al.* (2005) [11] and Takeda *et al.* (2018) [23] which were in the range of 0.33 to 0.54. Average daily gains from 205 days to 365 days and from 365 days to 550 days had direct heritability estimates similar to those reported by Matos *et al.* (2019) [17].

For feed efficiency traits, the heritability estimates for KI205 and RGR205 of 0.13±0.02 and 0.21±0.02, respectively, were lower than estimates of 0.28 (Mehrban *et al.*, 2021) [18], 0.40 (Arthur *et al.*, 2001a) [1], 0.43 (Crowley *et al.*, 2010) [7], 0.53 (Grion *et al.* 2014; Ceacero *et al.*, 2016) [9, 6]. The direct heritability estimate for KI365 (0.26) was similar that of Brahman cattle of 0.26 while KI550 had higher value (0.29 vs 0.12) (Matos *et al.*, 2019) [17]. These reported differences 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 (Mehrban *et al.*, 2021) [18]. In general, the estimates of direct heritability for growth and feed efficiency traits which ranged from 0.05 to 0.33, and maternal heritability (0.04 to 0.29) indicate sufficient additive genetic variability, therefore improvement of all the studied traits may be explored in the selection process.

The heritability estimates for RGR and KI provide a basis for reduction of the amount of feed needed for a given body weight through selection, thereby improving feed efficiency and reducing the cost of producing a unit of beef (Lovendahll *et al.*, 2018) [16]. Animals with high values of Kleiber Index at weaning and lower values at subsequent ages are expected to have lower maintenance requirements, leading to higher growth rate without increasing maintenance requirements (Hoog, 1991; Bullock *et al.*, 1993) [10, 5]. 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 & Kyriazakis 2016; Lovendahll *et al.*, 2018) [3, 15, 16]. This attempt at complementing the efforts to reduce the negative impacts of animal production on the environment (Gidenne *et al.*, 2017) [8] would be achieved without incurring extra recording costs since these traits utilise already existing routine records (Mehrban *et al.*, 2021) [18].

Table 2: Variance components for direct (σ_a^2) and maternal σ_{mg}^2) genetic, permanent environment due to dam (σ_{pe}^2) and direct genetic (h_a^2) and maternal heritability (h_{mg}^2), Maternal permanent environment effect (c^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	$r_{g_{a,mg}}^2$
WA205, kg	26.18	19.12	57.66	-0.19	378.96	0.05±0.05	0.04±0.03	0.12±0.06	-0.30
ADGB-205, kg/day	0.64	0.67	0.11	-0.13	0.91	0.27±0.05	0.29±0.03	0.05±0.05	-0.30
KI205, kg/kg$^{0.75}$	0.12	0.13	0.36	0.10	0.37	0.13±0.05	0.10±0.04	0.38±0.06	0.90
RGR205, kg	0.38	0.41	0.12	-0.21	0.87	0.21±0.04	0.23±0.04	0.07±0.05	-0.72
WA365	35.02				687.73	0.05±0.03			
ADG205-365	1.57x10^{-2}				1.21x10^{-2}	0.12±0.04			
KI365	1.57x10^{-4}				5.56x10^{-4}	0.26±0.08			
RGR365	5.7x10^{-5}				2.39x10^{-4}	0.19±0.04			
WA550	59.91				565.39	0.10±0.05			
ADG365-550	1.17x10^{-3}				5.31x10^{-3}	0.18±0.05			
KI550	2.46x10^{-3}				5.88x10^{-3}	0.29±0.05			
RGR550	1.14x10^{-4}				2.3x10^{-4}	0.33±0.05			

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

Conclusion

Kleiber Index and residual growth rate had substantial heritability estimates, implying potential for improvement through selection alongside growth traits. The high direct genetic heritability estimates for the two traits were found at yearling and 550 days of age. This study has for the first time 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 an 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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