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Estimation of genetic parameters for weight traits and Kleiber Index in a Brahman cattle population

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ABSTRACT: Interest in improving feed efficiency of cattle has been increasing. The residual feed intake (RFI), the most commonly used measurement of feed efficiency, is expensive and can only be used in a small number of animals. The Kleiber Index has also been proposed to measure RFI. In this study, we estimated genetic parameters for the Kleiber Index average daily weight gain and adjusted weights to obtain a more comprehensive understanding of potential responses to selection and support the development of breeding strategies. Genetic analyses were conducted on animal records from a data file with 36,505 animals recorded by ABCZ (Brazilian Association of Zebu Breeders). Restricted maximum likelihood estimates of genetic parameters were computed with Wombat software. Heritabilities ranged from 0.24 to 0.22 for adjusted weights, from 0.12 to 0.26 for Kleiber Indexes and from 0.15 to 0.22 for average daily gains. Correlations between traits ranged from -0.06 to 0.99. Results indicated that Kleiber Indexes at different ages do not constitute a viable solution for the selection of bulls and cows for Brazilian Brahman populations in terms of feeding efficiency.
Keywords: genetic correlation, average daily gain, heritability, standard age weight

Introduction

Most genetic breeding programs for beef cattle emphasize the selection for production development considering traits such as weight at several ages, daily weight gain (ADG), as well as carcass and reproduction data. However, recent results on cattle efficiency have shown the need to reduce inputs, mainly feeding, in order to increase efficiency and maximize profitability of the whole production system.

Feed provision accounts for most costs in the entire animal production system, including beef cattle (Archer et al., 1999), and increasing feed efficiency of animals is a strategy to reduce by selecting and using genetically superior reproducers for this trait. The use of more efficient animals may also play an important role in decreasing the environmental impact, since it reduces grazing areas needed for livestock as well as production of residues, such as manure and methane, when the diet is properly manipulated (Basarab et al., 2003).

Among the proposals to evaluate the feed efficiency of animals, feed intake and residual feed intake (RFI) have been used as indicators in beef cattle mostly because they are not directly correlated to the gain rate and live weight (Koch et al., 1963). However, when investigating energy metabolism, Kleiber (1936) described another feed efficiency Index, called the Kleiber Index (KI), which does not need individual measurement of intake and is used to identify animals with improved growth efficiency regarding their body size. A disadvantage of most feed efficiency indexes is that they require measuring feed intake individually, except for KI, which increases costs to identify superior animals for these traits (Robinson and Oddy, 2004).

KI high values is an indicator of lower maintenance demands, that is, body growth is greater without increasing the net energy for maintenance (Archer et al., 1999).

For beef cattle, especially Brahman, KI and possible biological consequences of the selection for this trait are still scarce. Therefore, this study aimed to estimate genetic parameters for average daily weight gain, the Kleiber Index, and weight traits for a broader understanding of potential responses to selection for those traits.

Materials and Methods

Approval of Animal Care and Use Committee was not necessary for this study because the data were obtained from an existing database. The data set was provided by Brazilian Association of Zebu Breeders (Uberaba, Minas Gerais, Brazil) and included Brahman animals that were born between 1996 and 2012 from states of São Paulo, Minas Gerais, Rio de Janeiro, Espírito Santo, Distrito Federal, Mato Grosso, Mato Grosso do Sul, and Goiás.

Data description

This study was carried out using animal records from a live weight database of 36,505 Brahman cattle raised on pasture. In addition, 47,781 animals were in pedigree file.

We analyzed animal weight adjusted to 205 days (W 205), weight adjusted to 365 days (W365), weight adjusted to 550 days (W550), Kleiber Index at 205 days (KI205), Kleiber Index at 365 days (KI365), Kleiber Index at 550 days (KI550), weight gain from birth to 205 days of age (WGB-205), weight gain from 205 to 365 days of age (WG205-365), weight gain from 365 to 550 days of age (WG365-550).

Age intervals were pre-established to include weight assessment in the analyses. Table 1 shows the considered age intervals according to the studied trait. Moreover, weights adjusted to standard ages were obtained according to the formula:

$$WA = [(BWf - BWi)/DS]C + BWi$$

where, WA is the body weight at the standard age (kg), BWf is the final body weight (kg), BWi is the initial body weight (kg), Ds is the number of days between weights and C is the standard age in days (205, 365, or 550 days). Only files from animals that had initial and final weight measurements taken at both ages were used for the computation of these weight gains adjusted.

Kleiber Index was calculated by dividing the average daily weight gain (ADG) by live metabolic weight ($LW^{0.75}$) (Arthur et al., 2001a; Kleiber, 1936).

Contemporary groups were composed of farm and breeder, sex, birth season, and birth year. Contemporary groups containing less than three animals were not included in the analysis.

Data consistency and formation of contemporary groups were performed by using R software (R Development Core Team, version 3.4.2). Data consistency was performed by means of maximum and minimum values, as well as the mean values.

Statistical Models

A bivariate analysis was used to estimate components of covariance in the linear-animal model of the method of restricted maximum likelihood (REML) with Wombat software (Meyer, 2007) [convergence criterion: 10^{-9}]. The mathematical description of the models used was represented as follows:

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

where: $\boldsymbol{y}$ was the vector of observations; β was the vector of the fixed effect; $\boldsymbol{a}$ was the vector of random effects that represent additive genetic direct effects; $\boldsymbol{m}$ was the vector of random maternal genetic effects; $\boldsymbol{pe}$ was the vector of random maternal permanent environmental effects; and $\boldsymbol{e}$ was the vector of random residual effects. $\boldsymbol{X}$, $\boldsymbol{Z}$, $\boldsymbol{M}$ and $\boldsymbol{W}$ were incidence matrices relating β, $\boldsymbol{a}$, $\boldsymbol{m}$, and $\boldsymbol{pe}$ to $\boldsymbol{y}$.

In the fixed effects, contemporary group was included for all traits. Maternal genetic and permanent environmental effects were only included in the model for W205, KI205, and WGB-205. Therefore, incidence matrices $\boldsymbol{M}$ and $\boldsymbol{W}$, and vectors $\boldsymbol{m}$ and $\boldsymbol{pe}$ were excluded from models for W365, W550, KI365, KI550, WG205-365, and WG365-550.

Assumptions for the general model were: E(y) = Xβ; E(a) = 0, E(m) = 0; E(pe) = 0; and E(e) = 0. Variances were: var(a) = $A\sigma^2_a$; var(m) = $A\sigma^2_m$; cov(a,m) = $A\sigma_{am}$; var(pe) = $I_{nv}\sigma^2_{pe}$; and var(e) = $I_{nb}\sigma^2_e$.
where: A is the matrix of additive genetic relationship; I_{nv} and I_{nb} were identity matrices of number of mothers (nv) and number of total observations (nb); σ^2_a is direct additive genetic variance, σ^2_m is maternal additive genetic variance; σ_{am} covariance between direct and maternal effects; σ^2_{pe} is variance of maternal permanent environment, and σ^2_e is residual variance.

Results and Discussion

The descriptive statistics for all traits are presented in Table 2. Estimates of variance components, direct and maternal heritabilities, as well as maternal repeatability, are shown in Table 3. Estimated genetics correlations are shown in Table 4.

Negative values were observed for WG205-365 and KI365 (Table 2). The reduction of average daily gain observed for weaning may be explained by stress that weaning caused to calves, leading to weight loss and greater susceptibility to diseases and parasites (Mercadante et al., 2004). In Brazil, calves are weaned during the dry season, when there is usually lack of pasture and susceptibility to diseases and weight loss.

High values of Kleiber Index at weaning (KI205) and low values in adult life are indicators of lower maintenance demands, that is, greater body growth of the animals studied at weaning without increasing energy requirements for maintenance. According to Bullock et al. (1993), the greater the gain rate, the higher the con-

Table 1 – Age range considered for weight standardization of Brahman cattle.

Ages*	Age range (days)
W205	155 to 255
W365	315 to 415
W550	500 to 600

*W205: weight adjusted to 205 days; W365: weight adjusted to 365 days; W550: weight adjusted to 550 days.

Table 2 – Descriptive statistics for weight adjusted to 205 days (W205), weight adjusted to 365 days (W365), weight adjusted to 550 days (W550), weight gain from birth to 205 days of age (WGB-205), weight gain from 205 to 365 days of age (WG205-365), weight gain from 365 to 550 days of age (WG365-550); Kleiber Index at 205 days(KI205), Kleiber Index at 365 days (KI365) and Kleiber Index at 550 days (KI550) of Brahman cattle.

Traits	Animals (n)	GC (n)	Min	Max	Average	SD	CV%
W205 (kg)	22865	1659	129.14	347.39	198.03	27.46	13.87
W365 (kg)	11930	1344	208.07	459.73	273.79	38.84	14.19
W550 (kg)	14398	1252	243.1	578.32	342.2	54.67	15.98
WGB-205 (kg)	22866	1659	0.44	1.54	0.8	0.13	16.25
WG205-365 (kg)	10198	1206	-0.35	1.44	0.42	0.22	52.38
WG365-550 (kg)	7989	1025	0.2	1.42	0.51	0.21	41.18
KI205	22866	1659	1.13	1.91	1.51	0.97	64.24
KI365	10198	1206	-0.56	1.57	0.61	0.27	44.26
KI550	7989	1025	0.21	1.28	0.6	0.19	31.67

GC = groups of contemporaries; SD = standard deviation; CV = coefficient of variation.

Table 3 – Estimates of additive (σ_a^2) and maternal (σ_m^2) genetic variances, variance of the maternal permanent environment (σ_{pe}^2), residual variance(σ_e^2), direct heritability (h_a^2), maternal heritability (h_m^2), and maternal repeatability (r_m^2) of bivariate analyses for weight adjusted to 205 days (W205), weight adjusted to 365 days (W365), weight adjusted to 550 days (W550), weight gain from birth to 205 days of age (WGB-205), weight gain from 205 to 365 days of age (WG205-365), weight gain from 365 to 550 days of age (WG365-550); Kleiber Index at 205 days (KI205), Kleiber Index at 365 days (KI365) and Kleiber Index at 550 days (KI550) of Brahman cattle.

Traits	σ_a^2	σ_m^2	σ_{pe}^2	σ_e^2	h_a^2	h_m^2	r_m^2
W205	137.58	24.93	48.45	356.92	0.24 ± 0.02	0.04 ± 0.01	0.07 ± 0.01
W365	200.7			721.84	0.22 ± 0.02		
W550	366.11			1173.32	0.24 ± 0.02		
WGB-205	$2.72*10^{-03}$	$6.15*10^{-04}$	$1.23*10^{-03}$	$8.52*10^{-03}$	0.21 ± 0.02	0.05 ± 0.01	0.09 ± 0.01
WG205-365	$6.49*10^{-03}$			$23.51*10^{-03}$	0.22 ± 0.03		
WG365-550	$3.37*10^{-03}$			$21.46*10^{-03}$	0.15 ± 0.03		
KI205	$1.34*10^{-03}$	$3.12*10^{-04}$	$6.05*10^{-04}$	$4.72*10^{-03}$	0.19 ± 0.02	0.04 ± 0.01	0.09 ± 0.01
KI365	$1.29*10^{-02}$			$3.67*10^{-02}$	0.26 ± 0.03		
KI550	$2.76*10^{-02}$			$0.2*10^{-01}$	0.12 ± 0.03		

Table 4 – Estimates of genetic correlations for weight adjusted to 205 days (W205), weight adjusted to 365 days (W365), weight adjusted to 550 days (W550), weight gain from birth to 205 days of age (WGB-205), weight gain from 205 to 365 days of age (WG205-365), weight gain from 365 to 550 days of age (WG365-550); Kleiber Index at 205 days (KI205), Kleiber Index at 365 days (KI365) and Kleiber Index at 550 days (KI550) of Brahman cattle.

	W205	W365	W550	WGB-205	WG205-365	WG365-550	KI205	KI365	KI550
W205	-	0.75 ± 0.05	0.86 ± 0.03	0.99 ± 0.00	-0.42 ± 0.08	0.70 ± 0.9	0.99 ± 0.01	-0.66 ± 0.05	0.57 ± 0.11
W365		-	0.92 ± 0.03	0.75 ± 0.05	0.54 ± 0.07	0.73 ± 0.11	0.76 ± 0.05	0.36 ± 0.08	0.44 ± 0.15
W550			-	0.85 ± 0.03	0.33 ± 0.09	0.85 ± 0.06	0.84 ± 0.03	0.11 ± 0.9	0.63 ± 0.10
WGB-205				-	-0.42 ± 0.08	0.69 ± 0.09	0.98 ± 0.00	-0.66 ± 0.05	0.58 ± 0.11
WG205-365					-	0.21 ± 0.14	0.43 ± 0.08	0.98 ± 0.00	0.04 ± 0.15
WG365-550						-	-0.67 ± 0.09	0.02 ± 0.13	0.96 ± 0.01
KI205							-	-0.66 ± 0.06	0.55 ± 0.11
KI365								-	-0.09 ± 0.14
KI550									-

version efficiency due to low maintenance demands that are relatively constant. Animals decrease demand of metabolizable energy for maintenance during the growth period, ensuring greater energy availability for weight gain (Hoog, 1991).

Estimates of direct heritability ranged from 0.12 to 0.24, and these ranges were sufficient to indicate additive genetic variability, therefore, all traits may be explored in the selection process.

Heritability range for estimated KI in this study points to a potential to reduce beef production costs by incrementing the feed efficiency in genetic breeding programs. Heritability estimates ranged from 0.28 (Koch et al., 1963) to 0.49 (Arthur et al., 2001b) for beef cattle from European breeds related to traits such as feed efficiency regarding body weight gain and consumed feed. The authors highlight that although economic analyses indicate benefits of selection for feeding efficiency, the initial cost to identify animals that are higher for feed efficiency is a barrier for quick adoption of technology.

Correlations with Kleiber Index and different ages (Table 4) showed that this trait must be analyzed as a different trait in each life period of the individuals. The animals with the best additive genetic values for Kleiber Index (feeding efficiency) until weaning (KI205) may not be the best for weight gain before weaning (WG205-365 and WG365-550). KI550 is the closest measurement that feed efficiency may reach in adult animals. Therefore, according to the results, animal selection for KI205 may produce animals that are more efficient in adult life (KI550). This is particularly useful for dams, because cows spend more time in production systems than bulls do. In addition, it is not important to have animals with large frame size, rather, it is useful to have animals that are more feed efficient However, for bulls, which remain for a short time in the herd, a heavy weight at slaughter is desirable. Nevertheless, the heavier the animals are at 550 days, the greater the tendency for higher weights when adults. Therefore, if we use these sires to produce cows, they will also tend to have higher weight. Thus, selection by lines may be the best solution for breeding programs, as bulls and cows are usually submitted to the same selection process. Two lines might be used, the production line of bulls for slaughtering and a line of cows for reproduction.

The genetic correlations between KI205 and WGB-205, KI365 and WG205-365, and KI550 and WG365-550 were similar. Therefore, selection for KI or weight gain has the same effect, that is, it selects the same animals and the same alleles. Likewise, selection for greater KI205 and KI550 must have a correlated response to increase W205 and W550, respectively. A correlated response must also occur for W365 when the direct selection is KI365, however, the response may not display a wide range since the genetic correlation between those traits was 0.36.

In general, the results for genetic correlations between the traits mentioned above indicate that selection based on the choice of animals with high weight gains rather than age leads to choosing animals that are more efficient in terms of energy use.

Positive and high genetic correlations between KI550 and WG365-550 (0.96), and between KI550 and W550 (0.63) are not desirable for cows, because selection for greater KI550 produces cows with higher genetic values for W550 and, consequently, with high genetic values for adult weight. Thus, for heifers or cows, selection for KI365 could be the most feasible option, because this trait is highly correlated with WG205-365 (0.98), however, it is not strongly associated to W365 (0.36). It is possible to find dams with high feed efficiency and good weight gain without increasing W365 and W550. Moreover, KI365 and KI550 are not correlated.

As mentioned before, it is important not to select heifers for weaning traits, once KI205, WGB-205, and W205 are highly correlated, similar to W205 and W550. Thus, any selection at weaning favors individuals to reach high W205 and high W550. Moreover, there is a negative genetic correlation between W205 and KI365 (-0.66).

Therefore, selection of dams could work well for feed efficiency (Kleiber Index), if they were selected after one year of age. Thus, progress is possible by applying a selection index for dams that considers high values for the Kleiber Index at all ages and moderate values for W550.

It is desirable to obtain females with high values of the Kleiber Index and good weight gains at all ages, but with moderate values of W550. However, gains in these traits may be very small because of: negative correlations between KI205 and KI365; high positive correlations between KI205 and W205. Also, the correlation between W205 and KI550 make the appearing of animals with high feed efficiency and moderate weight at 550 days of age (closer to adult age).

The use of the Kleiber Index as a more economically viable alternative for the measurements of feeding efficiency, such as residual feed intake, may not be feasible for dams with greater energy efficiency and smaller frame size. For bulls, the KI can be correlated with weight gains. Selection based on weight gains will obtain animals that are more energetically efficient with greater frame size at 550 days of age.

Conclusion

Kleiber Indexes at different ages do not constitute a viable solution for the selection of bulls and cows for the Brazilian herds of Brahman cattle due to unfavorable correlations between the KI and weights, which tend to increase frame size and energy maintenance, compromising the use of the animals in the production system.

Authors' Contributions

Conceptualization: Manuel, M.; Fonseca, R.; Cavani, L.; Millen, D.D.; Andrighetto, C.; Lupatini, G.C. Data acquisition: Manuel, M.; Fonseca, R. Data analysis: Manuel, M.; Fonseca, R. Design of Methodology: Fonseca, R.; Cavani, L.; Millen, D.D.; Andrighetto, C.; Lupatini, G.C. Writing and editing: Manuel, M.; Cavani, L.; Millen, D.D.; Fonseca, R.

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