Association of Residual Feed Intake to Metrics of Tanganyika Shorthorn Zebu Cattle in Maswa and Misungwi Districts, Tanzania

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Abstract

Increasing competition for feed resources and greenhouse gases pollution have been compelling beef production systems to operate at higher feed utilization. These challenges imply the need to breed cattle for Residual Feed Intake (RFI) to lower feeding costs and enteric methane production per output. To explore relevant indicator traits of RFI, this study investigated the association of RFI to Tanganyika Shorthorn Zebu (TSZ) cattle metrics from the Misungwi and Maswa Districts of Tanzania, where Tarime and Sukuma ecotypes are common. A correlation study involving the fattening of twenty-eight TSZ bulls was conducted at Tanzania Livestock Research Institute -Mabuki. From the animals' body weight and feeding data, regression of daily feed intake on average daily gain and metabolic body weight was analyzed to estimate the animals' RFI. Subsequently, the correlation of RFI to metrics of belly, horn, hip, dewlap and body length was investigated. Residual Feed Intake and Belly Length (BeL) were highly positively correlated, while RFI and Dewlap Depth (DD) were moderately positively correlated. The results indicated prospects for using BeL and DD as indicator traits for RFI. Extensive studies are recommended to analyze the correlation of RFI to hump depth, ear length, muzzle circumference and kidney fat.

Keywords: Belly, Dewlap, Feed efficiency, Metrics, Tanganyika Shorthorn Zebu.

Introduction

Livestock production is among the major economic activities in Tanzania, and Tanganyika Shorthorn Zebu (TSZ) cattle constitute the backbone of the country's livestock industry (Muzzo and Provenza 2018). Tanganyika Shorthorn Zebu cattle breed has potential for beef and its within breed diversity shows enormous potential for productivity improvement through selection (Ministry of Livestock and Fisheries 2017). Over 80% of the cattle are under the agro-pastoral system which is currently facing a critical constraint of depletion of grazing resources and escalating prices of feeds (Olago et al. 2006, Muzzo and Provenza 2018). Low productivity of TSZ cattle in the agro-pastoral system has also been aggravating the problem of greenhouse gases pollution from enteric methane emissions (Weisbjerg et al. 2018). These indicate the need to breed TSZ cattle for RFI improvement so as to enhance their feed utilization (Ribeiro et al. 2012).

Residual feed intake measures an animal's ability to use less feed than expected from its

body size and gain rate (Arthur et al. 2001). Therefore, improving RFI enhances productivity by lowering feeding costs and enteric methane emission per output (Bishop 1992, Weisbjerg et al. 2018). The trait is moderately heritable, and its selection has extra advantages of reducing enteric methane pollution and improving calf weight per cow intake (Negesse et al. 2017, Weisbjerg et al. 2018). As a breeding goal trait for beef cattle, RFI has recently been gaining more popularity than the rate of gain due to the independence of its selection on body weight, which makes it more responsive in improving profitability (Arthur et al. 2001). As such, selection for RFI exploits the additive genetic variation in energy expenditure for body maintenance and heat production of animals (Basarab et al. 2003).

The majority of the research that was done to characterize RFI in beef cattle was conducted in industrialized countries, which are home to heavy beef production. *Bos taurus* cattle were used in the studies that evaluated RFI (Archer et al. 1997, Arthur and Herd 2008, Berry and Crowley 2013). As a result of being subjected to selection based on looks over an extended period, these have lost a significant portion of their phenotypic variations (Kluyts et al. 2003, FAO 2011). Consequently, findings from past studies linked RFI with metabolic and body composition variables, which are difficult to measure with low technologies commonly found in developing countries (Negesse et al. 2017). The RFI of many indigenous breeds in sub-Saharan Africa remains uncharacterized, and relevant indicators for RFI are lacking (Steyn et al. 2014).

Metrics such as Body Length (BL), Horn Length (HoL), Hip Circumference (HC) and Belly Length (BeL) have a reflection on metabolic body size, whose maintenance accounts for a big part of dietary energy expenditure in cattle (Basarab et al. 2003). Dewlap Depth (DD) represents size of localized adipose tissues linked to animal thermoregulation which constitutes another major dietary energy expenditure pathway for cattle (Ferreira et al. 2021). Therefore, RFI might be correlated to BL, HoL, HC, BeL and DD as they reflect on dietary energy expenditure for maintenance and thermoregulation. However, the association of these metrics with RFI remains less explored, and their reliability as indicator traits for RFI is not known. Todate, no study has documented the evaluation of RFI in TSZ cattle or other Small East African Zebu cattle breeds.

For the TSZ breed in particular, past studies on metrics focused on the analysis of their association with body size, growth rate and tolerance to adverse environmental conditions (Chasama 2013). There is a need to identify metrics with linear association with RFI to facilitate indirect selection for RFI. This study employed correlation analysis to explore potential metrics for use as indicator traits of RFI for TSZ cattle. The study focused on the Lake Zone area in Tanzania, where the issue of inadequate feed resources is most severe. The descript ecotypes of TSZ cattle in the zone are Sukuma and Tarime cattle, and Maswa and Misungwi Districts are among locations where both ecotypes are found and have low introgression. To gain insight into the variability of RFI of TSZ cattle, the study included comparisons based on ecotype and location by incorporating them as fixed effects in the analysis of variance of RFI and accompanying variables under the investigation.

Materials and Methods
Study sites

Tanganyika Shorthorn Zebu cattle for use in the study were collected from Lake Zone Misungwi and Maswa Districts. In each district, four villages were sampled purposively to get sites suggesting the lowest introgression of TSZ cattle from other breeds. The Lake Zone was the primary area of investigation since it is most affected by the problem of insufficient feed resources. Misungwi District is found in Mwanza Region and is located between latitude 2.35°S and 3.15°S and between longitude 33.15°E and 33.083°E (Misungwi District Council 2022). The total area for Misungwi District is 2,553 km², of which 2,378 km² are inland,

and 175 km^2 are in water (Misungwi District Council 2022). Agriculture and livestock keeping are the major economic activities employing more than 80% of the population (Misungwi District Council 2022). The altitude for Misungwi is 1,188 m above sea level. Annual rainfall ranges 700–1000 mm, and temperature averages 27.5 °C. The district has 188,319 cattle, of which 188, 215 are of TSZ breed, and 104 are dairy crossbreds (Misungwi District Council 2022).

Maswa District, on the other hand, is found in Simiyu Region and lies between latitude 2.75°S and 3.25°S and longitude 33°E and 34.02°E (Maswa District Council 2022). The total area size of Maswa District is 3,398 km^2, of which 2,475 km^2 is used for agriculture and livestock keeping, which are the significant economic activities employing around 92% of the population (Maswa District Council 2022). The altitude for Maswa lies between 1,200 m and 1,300 m above sea level, whereas annual rainfall averages 750 mm and temperature averages 26 °C. The district has 389,834 cattle, of which 389,203 are of TSZ breed, and 631 are dairy crossbreds (Maswa District Council 2022).

Study design

The study design was of correlation type and based on the methodology of Basarab et al. (2003). It used a total of 28 TSZ cattle which were obtained from the 8 study villages of Misungwi and Maswa Districts. From Misungwi, there were nine Tarime cattle and five Sukuma cattle, whereas, from Maswa, there were three Tarime cattle and 11 Sukuma cattle. Tarime cattle, on the one hand, is an ecotype of TSZ cattle which evolved in the Mara Region in the Lake Zone of Tanzania, and their mature weight usually is less than 300 kg (Chenyambuga et al. 2008). On the other hand, Sukuma cattle is an ecotype of TSZ cattle which evolved in Sukumaland and are a bit heavier than Tarime cattle as, at maturity, they usually attain body weight above 300 kg (Mpiri 1994). Consideration was made to select male cattle to avoid including pregnant animals, which complicates measurements. Dentition

was used to estimate age and ensure that only matured cattle were selected.

The 28 selected TSZ cattle were taken to the Bushini farm of Tanzania Livestock Research Institute (TALIRI)–Mabuki in early December 2022. The first week after their arrival, they were allowed to graze under quarantine conditions to control communicable diseases. Health management strategies for the animals entailed dipping weekly (before the data collection period), applying pour-on acaricides at intervals of two weeks (during the data collection period), and drenching with albendazole at two monthly intervals. All the cattle were identified using ear tags. Individual fattening pens were also labelled according to identification numbers in ear tags. From the second week, animals were confined in pens matching their numbers. The confined animals were fed in two phases, starting with a three-week acclimatization phase. Subsequently, the animals entered a data collection phase of 70 days, during which measurements were taken as the animals continued to feed the fattening diet and drink water *ad-libitum* in individual pens. The fattening diet was formulated using locally available and widely researched feed ingredients to meet dietary recommendations for growing cattle under feedlot conditions. It was composed of rice polishing (32%), sunflower seed meal (12.5%), maize bran (5%), common salt (0.5%) and *Hyparrhenia rufa* hay (50%).

Data collection

The 70 days data collection phase was divided into five two weeks long periods. Body Weight (BW) was taken using a digital weighing scale at the beginning and at completion of every period, for the five periods. Metric measurements were taken using tape measure at the beginning of day one, and at the end of day 70 of the data collection phase, and their averages were taken as the values for the measurements. The metrics selected were Belly Length (BeL), Dewlap Depth (DD), Horn Length (HoL), Hip Circumference (HC) and Body Length (BL). Belly length was taken as the

distance between the flanks and the girth. Dewlap depth was taken as the maximum depth of the dewlap from the neck. Horn length was measured as the outer length of the horn between its base and its tip. Hip circumference measures the circumference of the body around the flanks. Body length was measured as the distance between the anterior base of the hump and the tail head. These body metrics were selected because they can suggest the variation of dietary energy expenditure in cattle as they are related to the size or tissue composition of the animal body.

Data analysis

Feeding and body weight data of the animals were used to calculate periodical averages for actual Dry Feed Intake (DFI), Average Daily Gain (ADG) and Metabolic Body Weight (MBW). Actual DFI for a period was calculated as the average of the differences between daily offers and residues for all 14 days in aparticular period. Average Daily Gain for a period was calculated as the quotient of weight gain (difference between final and initial body weight for a period) and 14, which is the number of days in a period. Metabolic Body Weight (MBW) for a period was calculated according to Equation 1:

$$MBW = \left[\frac{(FLW + ILW)}{2}\right]^{0.75} \dots\dots\dots(1)$$

Where: FLW = Final live weight and ILW = Initial live weight.

Then individual animals' scores for DFI, ADG and MBW were calculated by summing the five periodical values for DFI, ADG and MBW, which belong to one animal and dividing by five. The 70 generated periodic data for DFI, ADG and MBW were used to run regression analysis which generated Equation 2 for estimating expected DFI as described by Leao et al. (2021).

$$DFI = 4.732 + 0.049\ MBW$$
$$- 0.367\ ADG \dots(2)$$

Using Equation 2, therefore, the expected DFI estimates of all the 28 animals were obtained. RFI was then calculated as the deviation of actual DFI from expected DFI estimated from Equation 2.

Data of all animals for all the eight variables under the study (RFI, DFI, ADG,

BeL, HoL, DD, HC and BL) were firstly tested for normality using Shapiro–Wilk procedure using SPSS and the probability significance levels (p) ranged between 0.06 and 0.74, which implied normal distributions in all the variables. Then, using SAS General Linear Model with the MANOVA option, comparisons of means for RFI, DFI, ADG, BeL, HoL, DD, HC and BL were analyzed for the 28 animals, with district and ecotype being used as fixed effects. The Pearson Correlation test of PROC CORR was used to analyze the association between RFI and the metrics regarding correlation coefficients.

Results
Characteristics of study animals

This study used two ecotypes of TSZ cattle, namely Tarime and Sukuma cattle. Both ecotypes are found in both of the districts under the survey. However, Tarime cattle dominated in the group sampled from Misungwi (Misungwi group), while Sukuma cattle dominated in the group sampled from Maswa (Maswa group). All the cattle were entire bulls. Based on dentition assessment, the ages of selected cattle were estimated to be four years and above, implying they were all mature. The cattle's initial live weights, as measured just before being taken to the fattening facility, ranged from 228.87 kg to 314.32 kg.

Diet composition

Based on inclusion levels of the feed ingredients used to compound the diet (rice polishing, maize bran, sunflower seed meal, common salt and *Hyparrhenia rufa* hay at 32%, 5%, 12.5%, 0.5% and 50%, respectively), and assuming composition of these ingredients reported by Mgheni et al. (2013), the diet was qualified to have metabolizable energy density of 8.74 Mega Joules per kilogram (Table 1). The protein content expressed as crude protein in the diet was 11.64%. Minerals considered critical for beef cattle nutrition are calcium and phosphorus, which for this diet were at the levels of 0.51% and 0.52%, respectively.

Table 1: Ration formula and composition of diet used to fatten Tanganyika Shorthorn Zebu cattle in the present study

Ingredient/ diet	Inclusion level (%)	Ingredient/diet composition				
		DM (%)	ME MJ/kg DM)	CP (%)	Calcium (%)	Phosphorus (%)
Rice polishing	32	89.4	12.75	11.38	0.35	0.5
Sunflower seed meal	12.5	90.2	10.4	37	0.41	1.33
Maize bran	5	88.9	12.7	12	0.31	0.7
Common salt	0.5	98.9	0	0	0	0
Hyparrhenia rufa hay	50	94.00	5.44	5.6	0.67	0.31
Diet	100	91.82	8.74	11.67	0.51	0.52

ME = metabolizable energy, DM = dry matter, CP = crude protein, MJ = Mega Joule, kg = kilogram (Source: Mgheni et al. 2013).

Feedlot performance of Tanganyika Shorthorn Zebu cattle in the lake zone

The cattle's feedlot performance, expressed as RFI, DFI, and ADG, is as shown in Table 2. On average, a mature TSZ bull fed the diet gained 0.81 ± 0.03 kg of body weight per day. To perform at that level it had to consume 7.76 ± 0.12 kg of the diet, and in doing that, it finished on average 0.10 ± 0.08 kg less than was expected from its body weight and growth rate. Respective Least Square Means (LSM) for TSZ cattle groups from Misungwi and Maswa Districts were -0.17 ± 0.12 kg feed/day and -0.03 ± 0.11 kg feed/day for RFI, 7.68 ± 0.16 kg feed/day and 7.84 ± 0.16 kg feed/day for DFI, and 0.76 ± 0.04 kg body weight/day and 0.85 ± 0.04 kg body weight/day for ADG. Differences between means of RFI, DFI and ADG for TSZ cattle groups from Misungwi and Maswa Districts were non-significant (at $p = 0.40$ for RFI, $p = 0.49$ for DFI and $p = 0.12$ for ADG). Conversely, remarkable differences were observed between ecotypes in all the evaluated feedlot performance measures. The respective LSMs for Sukuma and Tarime ecotypes were 0.13 ± 0.08 kg feed/day and -0.04 ± 0.10 kg feed/day for RFI, 8.06 ± 0.12 kg feed/day and 7.36 ± 0.16 kg feed/day for DFI, and 0.89 ± 0.04 kg body weight/day and 0.72 ± 0.03 kg body weight/day for ADG. The difference was most significant for RFI ($p \leq 0.0001$), followed by DFI ($p = 0.001$) and ADG ($p = 0.01$). Therefore, Sukuma cattle consumed more feed and grew faster but at a lower feed efficiency than Tarime cattle.

Table 2: Least square means with standard errors for feedlot performance measures of Tanzania Shorthorn Zebu Cattle in Lake Zone

Factor	RFI (kilogram feed/day)		DFI (kilogram feed/day)		ADG (kilogram body weight/day)	
	LSM	SE	LSM	SE	LSM	SE
Overall	-0.10	0.08	7.76	0.12	0.81	0.03
District groups						
Maswa group	-0.03	0.11	7.84	0.16	0.85	0.04
Misungwi group	-0.17	0.12	7.68	0.16	0.76	0.04
Ecotype						
Sukuma	0.13	0.08	8.06	0.12	0.89	0.04
Tarime	-0.40	0.10	7.36	0.16	0.72	0.03

RFI = residual feed intake, DFI = daily feed intake, ADG = average daily gain, LSM = least square mean, SE = standard error (df = 27).

Metrics of Tanganyika Shorthorn Zebu cattle in lake zone

Results for body metrics of Tanganyika Shorthorn Zebu under the study are presented in Table 3. Overall least square means estimated for BeL, DD, HoL, HC and BL, all being expressed in centimetres (cm) were 61.62 ± 1.2, 14.30 ± 0.3, 31.6 ± 1.4, 162.2 ± 0.9 and 90.6 ± 0.68, respectively. Respective Least Square Means (LSM) of body metrics for TSZ cattle groups from Misungwi and Maswa Districts were 60.1 ± 1.9 cm and 63.2 ± 1.6 cm for BeL, 14.18 ± 0.5 cm and 14.42 ± 0.4 cm for DD, 29.1 ± 2.1 cm and 34.1 ± 1.6 cm for HoL, 161.8 ± 0.6 cm and 162.5 ± 1.6 cm for HC, and 91.7 ± 0.6 cm and 89.4 ± 1.1 cm for BL. Comparisons of body metrics LSMs by district showed non-significant differences at probability levels of 0.22, 0.64, 0.07, 0.71 and 0.09 for BeL, DD, HoL, HC and BL, respectively. The least square means of body metrics for Sukuma and Tarime cattle ecotypes, respectively were 65.3 ± 1.5 cm and 56.8 ± 0.7 cm for BeL, 15.15 ± 0.4 cm and 13.17 ± 0.6 cm for DD, 33.6 ± 1.7 cm and 28.9 ± 2 cm for HoL, 161.5 ± 1.2 cm and 163.1 ± 1.3 cm for HC, and 90.3 ± 0.5 cm and 90.9 ± 0.7 cm for BL. In the comparison by ecotype, Sukuma cattle were found to have very highly significant bigger BeL ($p \leq 0.0001$) than Tarime cattle and significantly bigger DD ($p = 0.04$) than Tarime cattle. Differences between Sukuma and Tarime cattle concerning other metrics studied were non-significant ($p = 0.09$ for HoL, $p = 0.09$ for HC and $p = 0.67$ for BL). Therefore, in comparing the body metrics by ecotype BeL was the most variable and followed by DD.

Table 3: Least square means with standard errors for metrics of Tanganyika Shorthorn Zebu cattle in Lake Zone

Factor	BeL (cm)		DD (cm)		HoL (cm)		HC (cm)		BL (cm)	
	LSM	SE	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Overall	61.62	1.2	14.30	0.3	31.6	1.4	162.2	0.9	90.6	0.68
District group										
Maswa	63.2	1.6	14.42	0.4	34.1	1.6	162.5	1.6	89.4	1.1
Misungwi	60.1	1.9	14.18	0.5	29.1	2.1	161.8	0.6	91.7	0.6
Ecotype										
Sukuma	65.3	1.5	15.15	0.4	33.6	1.7	161.5	1.2	90.3	0.5
Tarime	56.8	0.7	13.17	0.6	28.9	2	163.1	1.3	90.9	0.7

BeL = belly length, DD = dewlap depth, HoL = horn length, HC = hip circumference, BL = body length, cm = centimeter, LSM = least square mean, SE = standard error (df = 27).

Association of residual feed intake to metrics of Tanganyika Shorthorn Zebu

Results on the association between RFI and metrics of TSZ cattle are presented in Table 4. Residual feed intake and BeL of TSZ cattle were found to be highly positively correlated ($r (26) = 0.67$, $p \leq 0.0001$). Residual feed intake and DD were observed to be moderately positively correlated ($r (26) = 0.39$, $p = 0.04$). Correlation of RFI with the rest of the metrics under the study (HoL, HC and BL) was also positive but low and non-significant ($r (26) = 0.34$, $p = 0.87$ for HoL, $r (26) = 0.19$, $p = 0.33$ for HC and $r (26) = 0.12$, $p = 0.53$ for BL). Therefore, among the metrics under the study, only BeL and DD showed a statistically significant linear association with RFI, and all vary in the same direction.

Table 4: Pearson's correlation coefficients between residual feed intake and metrics of Tanganyika Shorthorn Zebu cattle in Lake Zone

Metric	BeL	DD	Hol	HC	BL
Coefficient of correlation to RFI (r)	0.67	0.39	0.34	0.19	0.12
p	$\leq 0.000\ 1$	0.04	0.87	0.33	0.53

BeL = belly length, DD = dewlap depth, HoL = horn length, HC = hip circumference, BL = body length (df = 26).

Discussion

This study explored body metrics as indicator traits for RFI in TSZ cattle, and from the results, BeL was most recommended for use. The study involved fattening TSZ cattle to enable evaluation of their RFI, taking measurements of the body metrics and analyzing the correlation of RFI to the body metrics. In feeding the cattle,the roughage–concentrate balance of the diet allowed the minimum inclusion level of 30% recommended for diets of adult ruminants (Smith 2007). The effect of anti-nutritional factors of rice polishing and sunflower seed meal was considered to be within acceptable levels because their inclusion levels were also within recommended limits (McDonald et al. 2002). Energy and crude protein composition were above the minimum levels recommended by Smith (2007) for diets of growing cattle. Therefore, the diet used to fatten the cattle met standards for fattening growing cattle of small to medium-sized breeds like TSZ.

The overall average values of DFI and ADG estimated for TSZ cattle in this study represent a typical feedlot performance comparable to those reported in other studies. Recently, Asimwe et al. (2015), for example, fattened TSZ cattle using diets meeting the requirements of growing cattle under feedlot conditions and reported a mean ADG of 0.92 kg body weight/day. According to DFI and ADG results of this study disaggregated by ecotype, Sukuma cattle consume more feed and grow faster than Tarime cattle. The variations in DFI and ADG between Tarime and Sukuma cattle were possibly due to differences in animal body weight between the TSZ ecotypes (McDonald et al. 2002).

The range of RFI for TSZ cattle observed in this study lies within those reported from other studies. Basarab et al. (2003), for example, worked with post-weaned *Taurine* cattle mixing Angus, Hereford, Limousin, Gelbvieh and Charolais breeds and observed their RFI range from -1.95 kg/day to +1.82 kg/day. The small range observed in this study is possibly due to the limitation of feed intake by the size of the animals because TSZ cattle are small in size, and their gut fill is small (Steyn et al. 2014). Assuming a maturity size of 320 kg body weight for TSZ cattle (Mpiri 1994) and a 2.5% daily intake level, the observed RFI range implies the possibility of lowering feeding costs and enteric methane production per output between the two RFI extremes by more than 20%. Considering that the cattle that constituted the study sample were from neighbouring districts, the potential for improving RFI is likely to be even larger than this because the breed has many ecotypes which are widely dispersed across the country (Msanga et al. 2012).

Disaggregation of the RFI results by ecotype indicated remarkable differences between the ecotypes, with the Tarime ecotype having lower RFI than the Sukuma ecotype. No studies have reported variations in digestive and absorptive efficiencies among TSZ cattle. Therefore, could not be considered as factors attributable to variations of RFI between the ecotypes (Elolimy et al. 2018). The observed variations in RFI between the TSZ ecotypes could likely be attributed, at least in part, to differences in maintenance energy expenditure due to differences in body size and composition of gain (Basarab et al. 2003).

Considering that BeL reflects the size of abdominal cavity organs, the high positive correlation between RFI and BeL observed in this study concurs with Basarab et al. (2003),

who showed RFI to correlate positively to the size of the stomach, intestines and liver. Being constantly functioning for vital processes, the gastrointestinal tract and visceral organs found in the abdominal cavity are more expensive to maintain than carcass components (Burrin et al. 1990). Therefore, animals with big BeL suggest having a significant energy expenditure for maintenance. This possibly contributed to the Sukuma cattle's high RFI, which had bigger BeL than Tarime cattle. Cooke et al. (2020) argued that cattle with high marbling scores tend to have significant RFI values because they deposit more fat relative to protein when they grow. As it reflects the amount of adipose tissue in the body, DD suggests having a positive correlation with the marbling score (Elis et al. 2016). Considering all these and based on the observed results for BeL and DD, Sukuma cattle would be expected to have higher RFI values than Tarime cattle, as has been observed.

Therefore, a linear association between RFI and metrics of TSZ cattle confirms the truth of the hypotheses in this study for BeL and DD and rejects for BL, HC and HoL. However, the current study recommends BeL as an indicator trait of RFI for use more than DD for two reasons. Firstly, it showed a stronger correlation with RFI, indicating a higher potential for making correlated responses to selection than DD. Secondly, it was found to be more variable between the ecotypes, thus indicating the potential for allowing a higher selection differential than DD.

Conclusions

The study has revealed the existence of a linear association between RFI, BeL, and DD. This indicates prospects for using metrics as indicator traits in breeding TSZ cattle for residual feed intake improvement. Extensive studies are recommended to analyze the correlation of RFI with other body indices, including hump depth, ear length, muzzle circumference and kidney fat.

Conflict of Interest
Authors declare that they do not have any conflict of interest.

Ethical Clearance
Ethical clearance for the research was obtained from Tanzania's Commission for Science and Technology (COSTECH) through permit No. 2021–517–NA–2021–140.

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