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Temperament and performance of Nellore bulls classified for residual feed intake in a feedlot system

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Abstract: This study aimed to evaluate the performance in feedlot and temperament of Nellore bulls classified by residual feed intake. The residual feed intake was calculated as the difference between the observed and predicted dry matter intake. Bulls classified as low residual feed intake had lower dry matter intake (kg day–1) and dry matter intake (g kg–1 d–1) of body weight, and were more efficient in feed conversion ratio than those classified as medium and high. The average daily gain didn't differ among residual feed intake classes and was 1.69 kg day–1, 1.82 kg day–1 and 1.71 kg day–1 for bulls classified as low, medium, or high, respectively. The residual feed intake was positively associated with dry matter intake, feed conversion ratio and subcutaneous fat thickness. The subcutaneous fat thickness was lower in bulls classified as low residual feed intake than in those with medium and high. No differences were observed in flight speed and reactivity score among residual feed intake classes. Overall, we concluded that bulls classified as low residual feed intake consumed less dry matter than high, with no differences in average daily gain, temperamentand had better feed efficiency, albeit their subcutaneous fat thickness was lower.

Key words: body morphometric, feed efficiency, loin-eye area, subcutaneous fat, temperament.

INTRODUCTION

The improvement of feed efficiency in the beef cattle production system is economically important because of the high cost of feed. Feed conversion ratio is one of the variables used to measure feed efficiency in beef cattle. However, this measurement is related to body size and growth rate, and thus, selection may result in heavier animals (Herd & Bishop 2000) and, consequently, increased maintenance requirements.

Selection based on residual feed intake (RFI; Koch et al. 1963) has been recently used as a measure of feed efficiency as it is not related to body weight (BW; Herd & Bishop 2000). Residual feed intake is defined as the difference between the observed and predicted dry matter intake (DMI).

Some studies on European cattle breeds have demonstrated that more efficient animals tend to have less fat in the carcass (Archer et al. 1999, Herd et al. 2004), whereas no relationship between RFI and the main carcass characteristics (loin-eye area, LEA; subcutaneous fat thickness, SFT and rump fat thickness, RFT), has been reported in Brazilian zebu cattle (Castilhos et al. 2010, Ribeiro et al. 2012). Other characteristics can explain variations in feed efficiency among animals. Temperament may also have an influence on these variations by altering the feed intake and weight gain.

The selection of cattle classified as low RFI is expected to be associated with improved feed efficiency because it identifies animals consuming less feed than predicted, based on the animal's performance and growth. The present study aimed to evaluate the growth performance, subcutaneous fat thickness, rump fat thickness, loin-eye area, temperament, and body morphometric measurements of Nellore bulls classified by RFI.

MATERIALS AND METHODS

All procedures were approved by the Ethics Committee (CEUA; protocol no. 202/11). The study was conducted in Goiânia - GO, Brazil (16° 36' 17" S; 49° 15' 40" W, and 790 m).

One hundred twenty Nellore bulls with an initial mean age of 19 ± 1 mo and initial BW of 397 ± 35 kg were used in a feedlot trial over a period of 84 days of data collection and 14 days of adaptation. The bulls used were born in 2009 and were selected in 25 farms that participate in the genetic breeding program "Nelore Qualitas" (Goiânia, Goiás, Brazil), are certified by the Brazilian Ministry of Agriculture and Food Supply (MAPA), and are authorized to issue the Special Certificate of Identification and Production of bulls and dams. The animals were selected by the program technicians evaluated over eight thousand contemporary animals in which only 1050 were certified, and only the top one hundred and twenty were used for the test of feed efficiency. The performance indices utilized for the selection were weaning BW, BW gain post-weaning, scrotal circumference at 15 mo of age, muscularity, and morphometric measurements. Bulls selected for the feed efficiency test remained on pasture from birth to the beginning of the experimental period.

Bulls were housed in collective pens and were fed an adaptation diet with a roughage:concentrate ratio of 60:40, which transitioned to a higher concentrate diet (23:77) after the 14 days adaptation period. After adaptation, bulls were transferred to individual pens without cover (2.5 m width × 10 m length) and provided *ad libitum* access to feed and water. Diet was formulated to meet the nutritional requirements of bulls in the finishing phase (Table I), according to the National Research Council (NRC 2000) recommendations to allow maximum ADG.

Diet was offered daily at 13h00 as a total mixed ration (TMR) and prepared using a 3-m^3 tractor-pulled mixer/delivery unit (Siltomac 203, São Carlos, SP, Brazil). The diet of each animal was weighed on a digital scale and manually provided in the trough. The weight of feed offered and orts were recorded daily. Samples of diet and orts were collected weekly for analysis. Subsamples were stored at -20°C for chemical analyses, and the remainder was dried at 105°C for 24 h for the determination of DM. Diet samples were composited for each 28 days dietary period, whereas ort samples were composited first for each bull and then for each 28-d dietary period. Bulk samples were dried in a forced-air oven at 55°C for 72 h and ground using a Wiley mill to pass through a 1-mm screen. Samples were analyzed for the concentrations of DM, ash, crude protein, and ether extract using the methods of the Association of Official Analytical Chemists (AOAC 1990). Neutral detergent fiber and ADF were calculated as described by Van Soest et al. (1991) using heat-stable alpha-amylase (Sigma-Aldrich, St. Louis, MO, USA).

Average daily gain (ADG), DMI, and RFI were measured for 84 days following a 14 days acclimation period. Bulls were weighed

Table I. Composition and nutrient content of experimental diet.

Item	Diet
Ingredient composition	g kg^{-1} as fed
Corn silage without cobs	180
Sugarcane bagasse	50
Soybean hulls	243
Sorghum grain (ground)	468
Soybean meal	35
Urea	8
Mineral supplement[1]	16
DM content and chemical composition	**g/kg DM**
DM (g/kg as feed)	618
Crude protein	147
Neutral detergent fiber	360
Acid detergent fiber	240
Ash	45
Metabolizable energy (Mcal/kg DM)[2]	2.6

DM, dry matter; [1]Composition of the mineral mix g/kg: 40 g sodium, 15 g phosphorus, 845 mg virginiamycin, 250 g calcium, 15 g magnesium, 40 g sulfur, 110,000 IU vitamin A, 500 IU vitamin E, 1,900 mg zinc, 10,000 mg copper, 25 mg cobalt, 50 mg iodine, 150 mg fluorine, and 1,250 mg monensin sodium. [2]Estimated according to the National Research Council (NRC 2000).

at the beginning (15 days) and end (98 days) of the experimental period after 16 h of feed withdrawal. The ADG was calculated as the difference between the final and initial BW divided by days on feed. Total daily DMI was computed as DM of diet (silage and concentrate) offered daily minus DM of refused daily for each animal. The feed conversion ratio (FCR) of each animal was computed as the ratio of average daily DMI to ADG.

Ultrasonography images were taken using an Aloka SSD 500-V instrument (Corometrics Medical Systems, Wallingford, CT, USA) with a 17.2-cm linear transducer (3.5 MHz frequency) in the lumbar region, located between the 12^{th} and 13^{th} ribs and in the rump area. Images were interpreted for measuring SFT, RFT, and LEA using AUSKey4W (Cornell University, Ithaca, NY, USA). Only one image per bull at the end of the test feed efficiency was used for each measured characteristic.

At d 15 and d 98, body morphometric measurements were obtained to calculate any changes throughout the 84-d period. Four morphometric traits, including chest circumference (across the posterior to the scapula passing through the sternum and through the spinal processes of the thoracic vertebrae); scrotal circumference (measured in the scrotal area of the largest diameter); rump width (distance between the tuber coxae); and body depth (distance from the thoracic vertebrae to the sternum) were measured as described by Rezende et al. (2011). The morphometric measurement were obtained at the initial and final of the test, was also calculated and the gain of each characteristic during the period by subtracting the final by initial.

Temperaments were determined on d 15 and 98 by a reactivity score and flight speed. Reactivity scoring is a subjective measurement of behavioural response, which was made by two observers standing next to the chute behind the head of the animal, in order not to influence its behaviour. As a bull entered the chute, the evaluators focused on its limbs and body movements. Evaluation criteria were based on a scale of 1 to 5 described by Voisinet et al. (1997), where 1 = calm, no movement; 2 = restless movement, shifting; 3 = frequent movements with writhing; 4 = continuous and vigorous movement with shaking; and 5 = violent movements with continuous struggling. Flight speed m/s is velocity in which each animal exits the squeeze chute, as determined by the speed each animal passes through 2 light-emitting diodes optical sensors (Polaris wireless timer, FarmTek Inc., Wylie, TX), placed at a distance of 1.7 m apart, were recorded. Flight speed was calculated dividing the distance (1.7 m) by the time needed to traverse that distance (Burrow et al. 1988).

The RFI was calculated as the difference between the observed and predicted average individual DMI as described by Koch et al. (1963). The regression equation for the predicted DMI was a follows: DMI = –3.1232 + 2.01439 × ADG + 0.08862 × $BW^{0.75}$ with R^2 = 0.7052, where $BW^{0.75}$ is the mean metabolic BW (kg) of bulls. Subcutaneous fat thickness between the 12^{th} and 13^{th} ribs, RFT, and LEA were tested in the intake-prediction model, but had no significant contribution to determination coefficient (R^2), therefore, were removed. After the RFI were calculated, the animals were classified as low efficient (animals with high RFI; > 0.5 standard deviation [s.d] of mean), moderately efficient (animals with medium RFI; ± 0.5 s.d of mean), and highly efficient (animals with low RFI; < 0.5 s.d of mean), similar to descriptions in previous studies (Basarab et al. 2003, Richardson & Herd 2004). The number of animals classified as low RFI was 34 (28.3%), 44 bulls medium RFI (36.7%), and 42 high RFI (35%).

Bulls were divided based on their RFI performance and the mathematical model used was described by the following: Yij = μ + ti + eij, Y = μ + ti + eij, where Yij is the observed value, μ is the overall mean, ti is the effect of RFI, and eij is the experimental error. Individual animals served as the experimental unit. The data of DMI, DMI, %BW, ADG, BW, FCR, SFT, RFT, LEA, CC, SC, RW, BD, after being grouped by the RFI, were subjected to analysis of variance using the "easyanova" package in R program (Arnhold 2013; R Development Core Team, Vienna, Austria). Analysis of variance was performed in conjunction with Tukey's test for identifying differences among RFI classes (animals with low RFI, medium RFI, and high RFI) at $P \leq 0.05$. Temperament scores were analyzed using the Kruskal–Wallis test at $P \leq 0.05$ using the "easyanova" package in R program. Pearson's correlation coefficients were calculated between RFI and FCR and the main performance variables, LEA, RFT, SFT and DMI at $P \leq 0.05$ using the "epr" package in R program (Arnhold 2013; R Development Core Team, Vienna, Austria).

RESULTS

The mean RFI was 0.00 ± 0.61 kg day^{-1} DM, ranging from –1.90 kg day^{-1} DM to 1.66 kg day^{-1} DM (Table II). Age, initial BW, final BW, $BW^{0.75}$ and ADG did not differ among RFI classes ($P > 0.05$). The DMI, kg day^{-1} and DMI (g kg^{-1} d^{-1}) of body weight was significantly lower ($P < 0.05$) in bulls classified as low RFI than in those classified as medium and high RFI. The FCR was 12% lower in bulls classified as low RFI than in those classified as high RFI ($P < 0.05$).

No differences were observed in LEA among RFI classes ($P > 0.05$). The subcutaneous fat thickness was lower ($P < 0.05$) in bulls classified as low RFI than in bulls with medium and high

Table II. **Growth performance, loin-eye area (LEA), subcutaneous fat thickness (SFT), and rump fat thickness (RFT) of Nellore bulls classified according to residual feed intake (RFI).**

Item	RFI			P-value
	Low	Medium	High	
Age (days)	617	606	609	0.266
Mean RFI (kg)	$-0.76^{c} \pm 0.06$	$0.01^{b} \pm 0.02$	$0.62^{a} \pm 0.05$	< 0.001
Initial BW (kg)	397 ± 6.7	402 ± 4.7	391 ± 6.3	0.412
Final BW (kg)	537 ± 8.2	553 ± 5.7	533 ± 8.2	0.102
$BW^{0.75}$ (kg)	100 ± 1.1	102 ± 0.8	100 ± 1.1	0.185
DMI (kg day^{-1})	$8.43^{b} \pm 0.17$	$9.58^{a} \pm 0.11$	$9.77^{a} \pm 0.19$	< 0.001
DMI g kg^{-1} d^{-1} of BW	$18.0^{c} \pm 0.2$	$20.1^{b} \pm 0.1$	$21.1^{a} \pm 0.2$	< 0.001
ADG (kg day^{-1})	1.69 ± 0.06	1.82 ± 0.03	1.71 ± 0.04	0.102
FCR (kg DMI / kg ADG)	$5.09^{b} \pm 0.12$	$5.43^{b} \pm 0.06$	$5.70^{a} \pm 0.09$	< 0.001
LEA (cm^2)	77.3 ± 1.37	81.5 ± 1.29	79.5 ± 1.32	0.083
SFT[1] (mm)	$5.7^{b} \pm 0.27$	$7.4^{a} \pm 0.36$	$6.9^{a} \pm 0.36$	0.005
RFT (mm)	$6.6^{b} \pm 0.33$	$7.9^{a} \pm 0.35$	$7.3^{ab} \pm 0.35$	0.035

RFI Low, < 0.5 standard deviation of mean; RFI Medium; ± 0.5 standard deviation of mean and RFI High > 0.5 standard deviation of mean. BW, body weight; $BW^{0.75}$, average metabolic BW; DMI, dry matter intake; ADG, average daily gain, FCR, feed conversion ratio. Means in the same row with different letters differ significantly (P<0.05). [1]Measured between the 12th and 13th ribs. The data are expressed as mean ± SEM.

RFI. Rump fat thickness was lower (P < 0.05) in bulls classified as low RFI than in bulls with medium RFI, but similar in bulls classified as high RFI.

No relationship was observed between RFI and ADG, $BW^{0.75}$, initial BW, and final BW (P > 0.05). It would be expected that no relationship existed for RFI and BW and ADG because they were used in the regression model for the calculation of RFI (Table III), and between the RFI with LEA and RFT (P > 0.05). Positive correlations were observed between RFI and DMI (r = 0.54; P < 0.001), FCR (r = 0.53; P < 0.001), and SFT (r = 0.23; P < 0.05). Therefore, bulls classified as low RFI had the lowest DMI (P < 0.05) and the lowest FCR (P < 0.05). The FCR showed a negative correlation with ADG (r = –0.68; P < 0.001).

Initial RW, final RW, gain RW, initial CC, final CC, final BD, initial SC, final SC and gain SC did not differ among RFI classes (P > 0.05). Significant differences were detected among RFI classes (P < 0.05) for gain in CC, initial BD, and gain in BD (Table IV). Gain of chest circumference and gain BD was higher in bulls classified as high RFI than in bulls classified as low RFI. The initial body depth was higher in bulls classified as low RFI than in bulls with higher RFI.

No significant differences (P> 0.05) were observed in flight speed m/s among RFI classes with mean of 2.18 m/s (Low), 2.21 m/s (Medium) and 2.25 m/s (High) represented in Table V. No significant differences (P> 0.05) were observed in reactivity score among RFI classes with mean of 1.92 (Low), 2.00 (Medium) and 2.02 (High).

Table III. Correlation coefficients of growth performance, loin-eye area (LEA), subcutaneous fat thickness (SFT), and rump fat thickness (RFT) with residual feed intake (RFI) and feed conversion rate (FCR) of Nellore bulls.

Item	RFI	FCR
Initial BW (kg)	−0.008	0.392***
Final BW (kg)	0.006	−0.028
$BW^{0.75}$ (kg)	0.000	0.160
DMI (kg day^{-1})	0.542***	0.019
ADG (kg day^{-1})	−0.000	−0.679***
FCR (kg DMI / kg ADG)	0.527***	-
LEA (cm^2)	0.080	−0.056
SFT[1] (mm)	0.233*	0.087
RFT (mm)	0.151	0.012

RFI Low, < 0.5 standard deviation of mean; RFI Medium; ± 0.5 standard deviation of mean and RFI High > 0.5 standard deviation of mean. BW, body weight; $BW^{0.75}$, average metabolic BW; DMI, dry matter intake; ADG, average daily gain. *P < 0.05; **P < 0.01; and ***P < 0.001. [1]Measured between the 12^{th} and 13^{th} ribs.

Table IV. Body morphometric measurements of Nellore bulls classified according to their residual feed intake (RFI).

Item	RFI			P-value
	Low	Medium	High	
Initial RW (cm)	43.2 ± 0.46	42.9 ± 0.35	42.3 ± 0.43	0.338
Final RW (cm)	49.3 ± 0.40	50.2 ± 0.36	49.1 ± 0.42	0.078
Gain RW (cm)	6.1 ± 0.36	7.3 ± 0.36	6.8 ± 0.36	0.110
Initial CC (cm)	175.0 ± 1.18	172.0 ± 0.73	171.0 ± 1.21	0.105
Final CC (cm)	190.6 ± 1.11	190.8 ± 0.90	190.2 ± 1.09	0.898
Gain CC (cm)	15.6^{b} ± 0.85	18.8^{ab} ± 0.75	19.2^{a} ± 0.81	0.048
Initial BD (cm)	62.4^{a} ± 0.41	61.3^{ab} ± 0.42	60.7^{b} ± 0.44	0.027
Final BD (cm)	66.5 ± 0.49	66.9 ± 0.29	66.7 ± 0.47	0.736
Gain BD (cm)	4.1^{b} ± 0.41	5.6^{a} ± 0.39	6.0^{a} ± 0.48	0.007
Initial SC (cm)	31.0 ± 0.47	31.5 ± 0.41	31.5 ± 0.51	0.774
Final SC (cm)	35.0 ± 0.43	36.0 ± 0.41	36.0 ± 0.43	0.526
Gain SC (cm)	4.0 ± 0.26	4.5 ± 0.20	4.5 ± 0.27	0.333

RFI Low, < 0.5 standard deviation of mean; RFI Medium; ± 0.5 standard deviation of mean and RFI High > 0.5 standard deviation of mean. RW, rump width; CC, chest circumference; BD, body depth; SC, scrotal circumference. Means in the same row with different letters differ significantly (P<0.05). The data are expressed as mean ± SEM.

Table V. Flight speed and reactivity score of Nellore bulls classified according to their residual feed intake (RFI).

RFI	Flight speed (m/s)			Minimum	Maximum
	Initial	Final	Average		
Low	2.40 ± 0.17	1.98 ± 0.11	2.17 ± 0.11	0.69	5.31
Medium	2.28 ± 0.10	2.14 ± 0.10	2.21 ± 0.09	0.64	4.32
High	2.41 ± 0.15	2.13 ± 0.09	2.22 ± 0.11	0.69	5.56
	Reactivity score				
Low	2.17 ± 0.17	1.85 ± 0.18	1.74 ± 0.15	1	5
Medium	2.22 ± 0.15	1.93 ± 0.15	1.84 ± 0.13	1	4
High	2.31 ± 0.15	1.83 ± 0.11	1.93 ± 0.09	1	4

RFI Low, < 0.5 standard deviation of mean; RFI Medium; ± 0.5 standard deviation of mean and RFI High > 0.5 standard deviation of mean. Flight speed, m/s (velocity in which each animal exits the squeeze chute) and reactivity score (subjective measurement of behavioral response). $P > 0.05$. The data are expressed as mean ± SEM.

DISCUSSION

Results from this study indicate that RFI, not FC, was independent of BW and BW gain and is in agreement with those of previous studies (Koch et al. 1963, Zorzi et al. 2013). The DMI of animals classified as low RFI was 1.3 kg day^{-1} lower than that of animals classified as high RFI, indicating a difference of 13.7%. Similar results were reported in Nellore breed (14.58 and 11.7%; Santana et al. 2012 and Nascimento et al. 2015), and Simmental breed (decrease of 14%; Fitzsimons et al. 2014). The positive relationship between RFI and DMI is well established (Koch et al. 1963, Archer et al. 1998, Basarab et al. 2003, Santana et al. 2012, Fitzsimons et al. 2014), and indicates that animals classified as low RFI consume less feed, but have the same weight gain as those classified as medium and high RFI. The difference in DMI between individuals of the same breed has a moderate heritability of 0.18 – 0.35 (Koch et al. 1963, Archer et al. 1998, Herd & Bishop 2000, Arthur et al. 2001a). Variations in RFI can be explained partly by individual variation in energy requirements for maintenance, which can result in lower ADG and greater DMI in animals classified as high RFI (Ribeiro et al. 2012).

According to Johnson et al. (2003), the coefficient of variation of residual metabolizable energy intake required for maintenance ranges from 10% to 12% in beef cattle, indicating a considerable reduction in feed costs that can benefit the entire beef chain.

The positive correlation between RFI and FCR (Table III) indicated that the selection of animals with low RFI improves FCR (Arthur et al. 2001a, b, Nkrumah et al. 2007). Arthur & Herd (2008) also reported that RFI is positively correlated with the FCR (r = 0.45–0.85).

Feed conversion presented high negative correlation with ADG (r = -0.68). Thus, a possible selection for these parameters would result in the gradual elevation of the adult weight of the animals, since this index, unlike the RFI does not take into account body weight, or the final weight of the animal, which ultimately select larger animals (Herd & Bishop 2000). Such animals can have higher production costs, since most of metabolizable energy consumed is spend on maintenance.

Animals classified as high RFI had a greater SFT than those classified as low RFI, which can be explained because they reached the carcass finishing earlier. According to Richardson et al. (2001), less than 5% of the variation in RFI can be explained by the variation in body composition of the progeny. Additionally, the relationship between RFI and carcass characteristics is inconsistent. Basarab et al. (2003) suggested that RFI is related to the composition of weight gain; animals with negative RFI have leaner carcasses, with less fat cover, and a lower proportion of intramuscular fat than animals classified as high RFI. Thus, these factors may have a negative impact on carcass and meat quality; since fat plays an important role in the carcass finishing degree, the loss of liquids during the carcass chilling, and meat flavor. However, studies on Nellore bulls and Simmental bulls did not show any relationship between RFI and subcutaneous fat thickness, demonstrating that the selection of the most efficient animals in feed utilization does not have any undesirable effects on carcass composition (Castilhos et al. 2010, Fitzsimons et al. 2014).

These results showed that the initial body depth of animals with low RFI was greater than medium and high RFI indicating that RFI affects morphometric measurements of animals; the initial body depth of animals classified as low RFI was greater than medium and high RFI. However, the gain on the circumference of the chest and gain in body depth of animals classified as high RFI were relatively higher, which maintained uniformity of these measurements at the end of the trial. Previous studies did not identify any differences in morphometric measurements among the RFI classes of Simmental heifers, European-breed cattle, or Simmental-Holstein heifers (Basarab et al. 2003, Kelly et al. 2010, Lawrence et al. 2011).

To our knowledge, the relationship between temperament and RFI of Nellore bulls has not been evaluated previously. In the present study, RFI was not influenced by the temperament of animals. Black et al. (2013) working with heifers of different breed types, also reported no relationship between RFI and temperament traits. In the beginning of the experimental period, only 27% of animals had a reactivity score 1, whereas at the end of the experimental period, the percentage of these animals increased to 45%, suggesting that the daily management in the feedlot made the animals less susceptible to stress from human contact.

CONCLUSIONS

Bulls classified as low RFI consume less food than those classified as high RFI, with no influence in ADG and temperament. Bulls classified as low RFI have better feed efficiency, and deposit less subcutaneous fat than that bulls classified as high RFI.

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Author contributions

Tiago Guimarães performed the literature review, data collection, data analysis and wrote the paper. João Restle and Juliano Fernandes were the supervisors of this research. Kíria Karolline, Marcondes Dias helped in the design of methodology, data collection, data analysis. Leonardo Souza and Émerson Moraes are proprietary Nellore Qualitas Breeding Program that provided the animals for this study, and helped in the design of methodology, data collection, data analysis.