Ciência Rural, Santa Maria, v.51:5, e20200488, 2021
http://doi.org/10.1590/0103-8478cr20200488
ISSNe 1678-4596
ANIMAL PRODUCTION

Carcass traits, commercial cuts, tissue composition, intake, digestibility, and performance of Sindhi bulls subjected to feed restriction

Jaqueline da Silva Trajano[1] Severino Gonzaga Neto[2] Ariosvaldo Nunes Medeiros[2] Gabriela Brito Cambuí[2] Juliana Silva de Oliveira[2] Daniele Farias dos Santos[2] Flávio Soares dos Santos[2] Tairon Pannunzio Dias-Silva[3*] Leilson Rocha Bezerra[4]

[1]Universidade Federal da Bahia (UFBA), Salvador, BA, Brasil.
[2]Universidade Federal da Paraíba (UFPB), Areia, PB, Brasil.
[3]Universidade Federal do Piauí (UFPI), 64960-000, Bom Jesus, PI, Brasil. E-mail: tairon.mvet@gmail.com. *Corresponding author.
[4]Universidade Federal de Campina Grande (UFCG), Patos, PB, Brasil.

ABSTRACT: *This study showed the effect of feed restriction on performance, nitrogen balance (NB), microbial protein synthesis, carcass traits and meat cut of the thirty-two Sindhi non-castrated males (296 ± 21.3 kg initial BW and 21 ± 1.5 months old). All bulls were distributed in a completely randomized design with four treatments (feed restriction levels) (0, 15, 30, and 45% in total dry matter –DM) and the data were subjected to analysis of variance and regression. Nutrient intake, NB, final BW, total gain, feeding efficiency, carcass gain, hot and cold carcass weight, subcutaneous fat thickness, commercial cuts and fat tissue decreased linearly (P<0.05) by feed restriction level. A linear increased on digestibility of DM, NDF_{ap}, total carbohydrates and on the proportion of muscle tissue, as well as quadratic increase on non-fibrous carbohydrates and bone tissue percentage with the restriction level imposed on bulls (P<0.05). The feed restriction did not affect (P>0.05) the digestibility of crude protein, synthesis and microbial efficiency, deposition efficiency, longissimus dorsi area and muscle + fat/bone ratio. The feed restriction reduced intake and consequently performance, carcass traits and meat cuts of Sindhi bulls; however, it promoted a reduction in the N excretion, which can be important if conducted a subsequent compensatory weight gain.*
Key words: *carcass yield, efficiency, microbial protein, nitrogen, zebu.*

Características da carcaça cortes comerciais, composição tecidual, consumo, digestibilidade e desempenho de touros Sindi submetidos à restrição alimentar

RESUMO: *Este estudo mostrou o efeito da restrição alimentar no desempenho, balanço de nitrogênio, síntese microbiana de proteínas, característica da carcaça e corte de carne de 32 machos Sindi não castrados (296 ± 21,3 kg de peso corporal inicial e 21 ± 1,5 meses de idade). Todos os touros foram distribuídos em delineamento inteiramente casualizado, com quatro tratamentos (níveis de restrição alimentar) (0, 15, 30 e 45% no total de matéria seca - MS) e os dados foram submetidos à análise de variância e regressão. Consumo de nutrientes, balanço de nitrogênio, peso corporal final, ganho total, eficiência alimentar, ganho de carcaça, peso de carcaça quente e fria, espessura subcutânea de gordura, cortes comerciais e tecido adiposo diminuíram linearmente (P<0,05) com o nível de restrição alimentar. Houve aumento linear na digestibilidade do DM, FDNap, carboidratos totais e quantidade de tecido muscular, além de aumento quadrático de carboidratos não fibrosos e porcentagem de tecido ósseo com o nível de restrição imposto aos touros (P<0,05). A restrição alimentar não afetou (P>0,05) a digestibilidade da proteína bruta, balanço de N, síntese e eficiência microbiana, eficiência de deposição, área do longissimus dorsi e relação músculo + gordura / osso. A restrição alimentar reduziu a ingestão e, consequentemente, o desempenho, as características da carcaça e os cortes de carne de touros Sindi, porém promoveu redução na excreção de N, o que pode ser importante se for realizado um subsequente ganho compensatório.*
Palavras-chave: *eficiência, nitrogênio, proteína microbiana, rendimento de carcaça, zebu.*

INTRODUCTION

Restricted feeding is a technique used to feedlot and finishing cattle. It includes any method of feed management in which intake is restricted relative to actual scheduled ingestion or *ad libitum* ingestion. As there is an occurrence of compensatory gain after a period of feed restriction, this technique can be adopted to improve feed efficiency (GONZAGA NETO et al., 2011; BEZERRA et al., 2013). Owing to this certainty, some producers exploit this technique because when the feed is scarce or expensive, as in drought, a temporary feed restriction can be practiced without producing harmful biological effects in the

Received 05.26.20 Approved 10.30.20 Returned by the author 12.28.20
CR-2020-0488.R3

animals; additionally, it offers economic advantages when the feed is plentiful and cheap (LOERCH, 1990; FEIJÓ et al., 2011).

However, the application of feed restriction is limited by concerns related to large scale *vs.* small-scale use and to the potential adverse effects of the restriction on daily weight gain and carcass quality grade. Dry matter intake (DMI) is an important factor in ruminant nutrition. It may be influenced by several inherent dietary factors, weather conditions, and factors related to the animal (the physiological stage, gestation, age, and weight), which have a direct impact on feed efficiency and animal weight gain (LOERCH & FLUHARTY 1998; GONZAGA NETO et al., 2011). Thus, restrictions in feed intake may prevent the nutritional requirements from being met (AZEVÊDO et al., 2010); consequently, preventing animal weight gain and reducing the farmer's income.

In addition, possible improvements in the feed efficiency of animals are subjected to moderate restrictions, such as reducing the size of the liver, protein and energy losses, maintaining the DMI, and digestibility increase (MURPHY & LOERCH 1994). Thus, we hypothesized that feed restriction can be applied in Sindhi bulls reducing N urine losses and increase protein synthesis by microorganisms, reducing production system costs without affecting performance, carcass traits and meat cuts. Thus, this research evaluated the performance, nitrogen balance, microbial protein synthesis and quantitative characteristics of the carcass of Sindhi bulls under different levels of feed restriction.

MATERIALS AND METHODS

The experiment was conducted in the cattle sector at the Federal University of Viçosa, Viçosa, Minas Gerais, Brazil. The experimental period lasted 89 days, of which 14 days were used for the adaptation of the animals to the diets, management, installations, and facilities, and data were collected in the remaining 75 days. Thirty-two non-castrated Sindhi bulls (initial body weight: 296 ± 21.3 kg (mean ± SD), age: 21 ± 1.5 months old) were included in the study. At the beginning of the experiment, the animals were weighed, identified by ear tags, dewormed, and then allocated to individual stalls, with an area of 33.8 m^2 per animal and a coated concrete floor covered with asbestos tiles. Each stall was equipped with a Bay covered feeder (2.5 m) and concrete trough. Bulls were distributed to four treatment groups and eight bulls per group in a completely randomized design. Treatments were defined according to the level of restriction of DMI, being 0, 15, 30, and 45%. The DMI was regulated every three days for animals with 0% feed restriction, and then the restriction levels were applied in the other treatments.

The diet was devised according to the Nutrient requirements of beef cattle in Brazil (BR-CORTE) (VALADARES FILHO et al. 2010) for an average daily gain (ADG) of 1.0 kg. The Sindhi bulls were fed with a total mixed ration (TMR), with roughage:concentrate ratio of 400:600 (g/kg DM). Corn silage was used as roughage source and the concentrate was made from soybean meal, corn meal, wheat bran, commercial mineral and urea mixture, and ammonium sulfate. The diet was supplied twice per day (at 6:30 and 14:30 h) in a completely mixed form and water provided *ad libitum*. Leftovers were recorded daily and DMI was regulated to ensure 100 g/kg of leftovers only for treatment *ad libitum* (0% restriction).

Corn silage, ingredients of the concentrate, and feed leftovers were pre-dried at 55 °C for 72 h, then ground using a Willey mill (Tecnal, Piracicaba City, São Paulo State, Brazil) with a 1-mm sieve, and stored in air-tight plastic-labeled containers with lids (ASS®, Ribeirão Preto, São Paulo, Brazil). These materials were subjected to further laboratory analysis to determine their chemical composition according to Association of Official Analytical Chemists (AOAC, 2012), dry matter (DM) (method 967.03), ash (method 942.05), crude protein (CP) (method 981.10), and ether extract (method 920.29). To quantify the neutral detergent fiber (NDF) contents, the methodology of VAN SOEST et al. (1991) was used, with the modifications proposed in the Ankon device manual (Ankon Technology Corporation, Macedon, New York, USA). The NDF was corrected for ash and protein content (NDF_{ap}). The NDF residue was incinerated in an oven at 600 °C for 4 h, and the correction for protein content was applied by subtracting the neutral detergent insoluble nitrogen content. The percentage of total carbohydrates (TC) was assessed using the equation provided by SNIFFEN et al. (1992): TC (g/kg DM) = 100 − (ash + CP + ether extract (EE)), and the non-fibrous carbohydrates (NFC) was determined according to the method described by HALL et al. (1999):
NFC (g/kg DM) = 100 – [ash – EE – NDF – (CP – CPu + U)], where: U = urea in the diet; CPu = CP from urea.

The percentages and composition of the ingredients used in the experimental diet formulation are shown in table 1.

Table 1- Chemical composition and percentage of ingredients of the experimental diet.

	----------Proportion of Ingredients (g/kg DM)----------					
Chemical composition (g/kg DM)	Corn silage	Corn meal	Soybean meal	Wheat meal	Urea[1]	Mineral[2] Mixture
	400	360	60	150	10	20
Dry matter[3]	266	881	880	868	1000	900
Ash	56.3	11.2	61.2	50.7	-	-
Crude protein	66.2	92.3	535	190	2.80	-
Ether extract	33.7	47.7	19.7	36.9	-	-
Neutral detergent fiber$_{ap}$[4]	574	103	117	441	-	-
Total carbohydrates	843	848	383	721	-	-
Non-fibrous carbohydrates	269	745	266	280	-	-
iNeutral detergent fiber[5]	238	24.2	21.1	151	-	-
Total Digestible Nutrients[6]	646	797	805	647	-	-

[1]Mixture of urea and ammonium sulfate (9:1). [2]Guaranteed levels (per kg, in active elements): calcium (max.) - 220.00 g and calcium (min.) - 209.00 g; phosphorus – 163 g; sulfur – 12 g; magnesium - 12.5 g; copper – 3,500 mg; cobalt - 310 mg; iron – 1,960 mg; iodine - 280 mg; manganese – 3,640 mg; selenium - 32 mg; zinc – 9,000 mg; and fluorine (max.) – 1,630 mg; [3](g/kg as fed); [4]Corrected for ash and protein; [5]According to Casali et al. (2008); [6]Estimated according to NRC (2000).

Dry matter intake and nutrients were calculated based on the difference between the offered quantities and the amounts reported in the feed refusals. During the experiment, samples of feces (stool) (10% of the total) and urine from all thirty-two bulls were collected. The samples were collected for three consecutive days (58th, 59th, and 60th) at three time points (7:00 to 8:00 h, 12:00 to 13:00 h, and 16:00 to 17:00 h).

The stools of each bull were collected (10% of the total) from the pen floor immediately after defecation for further laboratory analysis, after discarding the portion that was in contact with the floor. After collection, the stools were identified, weighed, and pre-dried in a forced ventilation oven at 55 °C for approximately 72 h, then weighed again, and passed through a 1-mm sieve to determine the chemical composition and passed through a 2-mm sieve to determine the excretion of fecal DM (DM_{fecal}).

Indigestible neutral detergent fiber (iNDF) was used as an internal indicator for the determination of DM_{fecal} in the samples after they were incubated for 240 h, according to the recommendation by CASALI et al. (2008). After incubation, the samples were analyzed for NDF content as previously described. Estimation of fecal production (FP) was performed using the following formula:

DM_{fecal} (kg/day) = (iNDF intake/iNDF in stools) × 100

The clear digestibility of the nutrients was calculated based on the quantity ingested and excreted in the DM_{fecal}. The fecal excretion was estimated using iNDF as an internal indicator. To calculate the digestibility coefficient (DC) of the nutrients, we used the following equation [15]:

DC (%) = [(ingested nutrient – nutrient excreted)/ingested nutrient] × 100

Spot urine samples (10-L aliquots) were diluted with 40 mL of 0.036 N H_2SO_4. The pH of the samples was adjusted to less than 3.0 to prevent bacterial destruction of urine purine bases and uric acid precipitation. The samples were stored at −20 °C until analysis for measuring creatinine, urea, allantoin, and uric acid content (CHEN & GOMES, 1992).

Urea and creatinine (modified with picrate and acidifier [Kit LABTEST[1], São Paulo, Brazil], respectively) in the urine were analyzed using the diacetyl methods, using a light absorption spectrophotometer. Allantoin and uric acid were analyzed using the colorimetric method proposed by FUJIHARA et al. (1987).

The daily urine volume was estimated from the mean daily creatinine excretion, which was obtained in mg/kg body weight (BW)/d, and the creatinine concentration (mg/L) of the urine spot sample was determined using the following equation (CHIZZOTTI et al., 2006):

$CE=32.27-0.01093 \times BW$

where CE is the concentration of creatinine excreted daily (mg/kg of BW) and BW is the body weight (kg).

This volume was used to calculate the estimated daily urea, allantoin, and uric acid excretion of each animal.

The nitrogen balance was calculated as the difference between the total nitrogen intake and the total nitrogen excreted in the stools and urine. The estimated daily excretion of N-urea in the urine was calculated by multiplying the urea urinary concentration by the estimated urinary volume and a factor of 0.466 (corresponding to the N content of urea).

The total number of excreted purine derivatives was determined by calculating the sum of allantoin and uric acid urinary excretions. From these data, the content of absorbed microbial purines was calculated (X, mmol/d) according to the following equation (VERBIC et al., 1990):

$Y = 0.85X + 0.385BW^{0.75}$

where 0.85 is the recovery of purines absorbed as purine derivatives in the urine, and $0.385BW^{0.75}$ represents the endogenous contribution of purine excretion.

The intestinal flow of microbial nitrogen (N) compounds (Y, gN/d) was calculated as a function of absorbed purines (X, mmol/d), according to the following equation:

$Y = (70X) / (0.83 \times 0.134 \times 1000)$

where 70 is the purine nitrogen content (mg N/mmol), 0.83 represents the digestibility of microbial purines and 0.134 represents the N-purine: the total N in bacteria (VALADARES et al., 1999).

The animals were weighed every 25 days, throughout the experiment, after a 16-h solid-food fast to monitor the weight gain. ADG was computed as the difference between final BW and initial BW of each animal divided by the total days of the experiment. The feed conversion ratio (kg/kg) was obtained by dividing ADG by DMI. At the end of the experimental period (after 89 days), after 16 h of fasting, all bulls were slaughtered to determine carcass characteristics, and the slaughter procedure was conducted according to the instructions of RIISPOA (BRASIL, 1997).

The empty body weight (EBW) of each animal was obtained based on the sum of the constituent parts of the body, carcass weight, and blood. Guts were weighted after emptied and the value obtained was added to those from the organs and other parts of the body to compose the body's final empty weight and, then was used to determine the ratio between the empty body weight gain (EBWG) and body weight gain (BWG) (EBWG/BWG ratio). The carcass gain (CG), feed efficiency as a function of CG (efficiency of carcass deposition) was determined. Using a chainsaw, the carcass of each bull was divided into two halves, which were identified and individually weighed to determine half-carcass weight, hot carcass weight (HCW), and hot carcass yield (HCY). Then, the carcasses were cooled in cold storage at 4 °C for 24 h. Subsequently, the half-carcasses were weighed to determine the cold carcass weight (CCW) and cold carcass yield (CCY). After cooling, the subcutaneous fat thickness (SFT) was measured in the *longissimus dorsi* area (LDA) of the *longissimus dorsi* muscle between the 12th and 13th ribs on the right half-carcass.

Commercial cuts as chuck, shoulder clod, topside and rump steak, were made in the middle of the right half carcass. After weighing the cuts, the yield of the cuts was estimated, and then the cuts were dissected to obtain the tissue composition and separation of muscle, fat, and bone.

The experimental design was completely randomized, with four treatments and eight replicates per treatment. The following statistical model was used, $Yij = \mu + si + eij$, where Yij = observed value, μ = overall mean, si = effect of feed restriction level, and eij = effect of the experimental error in the plots. The data were subjected to analysis of variance and regression, considering the model of the effect of the covariate initial body weight (BW) when the effect was effect. Statistical analyses were performed using the MIXED procedure function of the statistical program SAS (SAS 9.1® Institute, Cary, NC, 2003), using 0.05 as the critical level of significance.

RESULTS

The DMI, CP, EE, NDF corrected for ash and protein, TC, NFC, and total digestible nutrients decreased linearly (P<0.01) according to the level of feed restriction imposed on Sindhi bulls (Table 2), characterizing the aim of the study (the feed restriction).

A linear increase (P<0.01) on the digestibility of DM, NDFap and TC was verified. However, NFC showed a quadratic reduction (P<0.01) on digestibility with the level of feed restriction imposed on Sindhi bulls. The feed restriction did not affect the digestibility of CP (P=0.68) and EE (P=0.70).

The N intake and fecal (P<0.01) and urinary (P=0.027) nitrogen excretion showed a linear decrease with feed restriction. However, the nitrogen balance (NB) (P=0.21) and N retained (P=0.43) were not affected by the levels of feed restriction (Table 3).

The concentrations of blood urea nitrogen (BUN; P=0.02), urinary urea excretion (UUE, g/day and mg/kg BW; P<0.05) presented a linear decrease with increasing feed restriction. A higher N loss in

Table 2 - Intake and digestibility of nutrients in Sindhi bulls submitted to feed restriction.

Variables	-------Levels of feed restriction (%)-------				SEM[1]	----------*P*-value[2]---------	
	0	15	30	45		L	Q
----------Nutrient intake (kg/day)----------							
Dry matter	7.65	6.82	5.77	4.38	0.50	<0.01	0.12
Dry matter (%BW)	2.25	1.99	1.69	1.28	0.13	<0.01	0.09
Crud protein	1.14	1.00	0.84	0.64	0.07	<0.01	0.18
Ether extract	0.29	0.25	0.22	0.16	0.13	<0.01	0.23
Neutral detergent $fiber_{ap}$	2.60	2.32	1.96	1.49	0.15	<0.01	0.54
Total carbohydrates	5.92	5.28	4.47	3.39	0.46	<0.01	0.62
Non-fibrous carbohydrates	3.32	2.96	2.50	1.90	0.19	<0.01	0.11
Total digestible nutrients	4.78	4.25	3.63	2.85	0.31	<0.01	0.26
----------Coefficient of digestibility (g/kg) ----------							
Dry matter	585	586	597	614	21.9	<0.01	0.30
Crude protein	604	614	607	612	26.6	0.68	0.80
Ether extract	684	701	672	683	51.5	0.70	0.87
Neutral detergent $fiber_{ap}$	334	354	398	415	44.7	<0.01	0.91
Total carbohydrates	615	611	627	652	23.8	<0.01	0.09
Non-fibrous carbohydrates	871	860	854	900	30.6	0.10	<0.01

[1]Standard error of mean; L-Linear; Q-Quadratic; [2]Significance at 0.05.

the form of urea was observed when the level of feed restriction was increased.

The feed restriction did not influence the values of N microbial synthesis (P=0.14), CP microbial synthesis (P=0.14), CP microbial efficiency (P=0.54) or CP microbial efficiency (P=0.56) in Sindhi bulls.

Quadratic effects were observed in the final BW (P=0.04), total weight gain (P=0.04), ADG (P=0.03), EBW gain (P=0.02), and feeding efficiency (P=0.02). However, the deposition efficiency was not influenced (P=0.78) by the feed restriction. The EBWG/BWG ratio (P=0.02) and the carcass weight gain (P<0.01) showed a linear decrease with increasing restriction in Sindhi bulls (Table 4).

The carcass quantitative characteristics were influenced by dietary restriction, with a linear reduction in the HCW (P<0.01), CCW (P<0.01), and subcutaneous fat thickness (P<0.01). However, the HCY (P=0.81), CCY (P=0.88), and *longissimus dorsi* area (P=0.42) were not influenced by the applied levels of dietary restriction in Sindhi bulls.

The restriction in DMI decreased the half-carcass weight (P<0.01) and commercial cuts of the carcass (expressed in kg) as chuck (P<0.01), short rib (P<0.01), rump (P<0.01), and front (P<0.01). The weights of the pallet (P<0.01), cushion (P=0.03), and rear (P=0.04) showed a quadratic effect, with more weight in the palette (34.2 kg at 12.76% feed restriction), cushion (55.7 kg at 15.2% feed restriction), and rear (133 kg at 4.31% feed restriction). However, the front (P=0.93) and rear (P=0.93) cutting in Sindhi bulls, expressed as percentages, were not affected by the dietary restriction. The tissue carcass composition was affected by the feed constraint, showing a linear increase in the muscle (P<0.01), fat percentage (P<0.01), and muscle/bone ratio (P<0.01), while the bone percentage (P=0.04) showed a quadratic decrease with minimal perceptual observed differences at 16.9% of the applied restriction. There was no influence of the feed restriction on the muscle + fat/bone ratio of Sindhi bulls (P=0.69).

DISCUSSION

As expected, the intake of DM and nutrients decreased linearly with increasing levels of feed restriction. A decrease in DMI of 73.8 g was observed for every 1.00% of applied feed restriction. However, there was an increase in DM digestibility because of

Table 3 - Nitrogen balance, blood and urinary urea nitrogen, synthesis and efficiency of microbial protein excretion in Sindhi bulls submitted to feed restriction.

Nitrogen (N) balance	------Levels of feed restriction (%)------				SEM[1]	---------*P*-value[2]-------	
	0	15	30	45		L	Q
N intake (g/day)	183	161	135	102	11.4	< 0.01	0.19
N fecal (g/day)	72.0	62.1	53.2	39.6	5.91	< 0.01	0.38
N urinary (g/day)	55. 9	54.9	51.3	22.5	28.3	0.03	0.18
N balance (g)	55.6	43.6	30.6	39.7	27.9	0.21	0.31
Blood urea nitrogen (BUN, mg/dL)	14.5	16.4	13.1	12.4	2.50	0.02	0.16
Urinary urea nitrogen (UUN, g/day)	19.2	18.9	16.6	7.56	10.2	0.03	0.24
UUN (mg/kg BW)	184	185	163	77.6	100	0.04	0.24
N microbial synthesis (g N/day)	64.7	79.7	65.4	33.8	30.2	0.14	0.19
CP microbial synthesis (g N/day)	404	498	409	211	188	0.14	0.19
N microbial efficiency (kg CMODR)	24.4	32.8	29.3	19.8	12.8	0.54	0.26
CP Microbial efficiency (g/kg TDN)	89.4	121	108	73.1	46.9	0.56	0.26

[1]Standard error of mean; [2]Significance at 0.05; L-Linear; Q-Quadratic.

the high dietary nutrient assimilation when the animals were subjected to nutrient limitation (BEZERRA et al., 2013; HORNICK et al., 1998; ZHANG et al., 2013). This could be attributed to the fact that animals subjected to feed restriction tend to be more efficient in using the nutrients (BEZERRA et al., 2013; HORNICK et al., 1998). The dilution of maintenance requirements is another important factor that alters the efficiency of usage of metabolizable energy and its conversion into weight. In growing animals, the nutrients consumed are directed to primarily meet the requirements of body maintenance and secondarily used for body development (NRC, 2000).

The DM digestibility improved with increasing restriction, which can be explained by the lower passage rate mechanism adopted for animals with lower feed intake (ZHANG et al., 2013). When subjected to feed restriction, animals use the available nutrients more efficiently, as demonstrated by increased usage of nutrients in the digestive tract (BEZERRA et al., 2013). There was an improvement in the digestibility of NDF and NDFap with increasing dietary restrictions. As the NDF intake decreased, the time needed to digest the fiber reduced, thereby enabling an increase digestibility of 0.17 g/100 g ingested for every 1% applied restriction.

Increasing the restriction level produced an increase in the digestibility of NFC, probably because the best synchronization between degradation and the rate of passage was provided by lower DM intake, leading to increased digestibility. Diets with higher concentrate percentage are more digestible, increasing the digestibility of NFC (MURPHY & LOERCH, 1994). The use of dietary restriction can have other advantages, including increased diet digestibility with decreased intake and improved feed efficiency (GALYEAN, 1999).

The increase in dietary restriction promoted a linear decrease in crude protein intake; and consequently, N intake, which was reflected in the lower N urinary and fecal excretion. However, the N balance was not affected by restriction levels, indicating that there was nitrogen retention in the animal and that the N intake in the restricted diets met the animal feed requirements. These results were similar to those obtained by Gonzaga Neto et al. (2011), in which it was observed that protein retention allowed animals to gain weight when the energy requirements were balanced. In this context, the feed restriction can be a tool to mitigate N pollution, especially when bulls are subjected to a high protein diet or under *ad libitum* intake. Thus, depending on the feed restriction level, this practice can improve feed efficiency, with a concomitant reduction in the amount of waste and nutrients excreted.

The excretion of urinary urea (g/day and mg kg/BW) showed a similar pattern as BUN. Greater the presence of urea nitrogen in the blood stream, higher was the volume of urine excreted by the kidneys, which caused greater N urinary losses due to

Table 4 - Performance, carcass traits, commercial cuts and tissue composition of the half-carcasses of Sindhi bulls submitted to feed restriction.

Variables	------Levels of feed restriction (%)------				SEM[1]	----------*P*-value[2]----------	
	0	15	30	45		L	Q
----------Growth performance----------							
Initial body weight (kg)	299	294	297	294	22.6	-	-
Final body weight (kg)	378	373	357	330	14.3	<0.01	0.04
Total gain (kg)	82.3	76.1	60.7	33.8	14.3	<0.01	0.04
Average daily gain (kg)	1.17	1.10	0.87	0.49	0.19	<0.01	0.03
Empty body weight gain (kg)	1.35	1.32	1.01	0.71	0.16	<0.01	0.02
EBWG/BWG ratio[c]	1.12	1.24	1.16	1.45	0.23	0.02	0.29
Feeding efficiency (kg/kg)	0.15	0.16	0.15	0.11	0.03	<0.01	0.02
Carcass gain (kg)	0.90	0.91	0.67	0.54	0.12	<0.01	0.11
Deposition Efficiency	0.12	0.13	0.11	0.12	0.02	0.78	0.45
----------Carcass traits----------							
Hot carcass weight (kg)	215	215	200	190	11.5	<0.01	0.25
Cold carcass weight (kg)	211	210	196	186	11.3	<0.01	0.24
Hot carcass yield (%)	56.9	57.8	56.1	57.6	1.26	0.81	0.43
Cold carcass yield (%)	55.6	56.5	54.8	56.3	1.31	0.88	0.52
SFT (mm[d])	3.40	2.90	2.50	1.90	1.06	<0.01	0.84
Longissimus dorsi area (cm²)	59.4	59.3	58.1	57.6	4.93	0.42	0.91
----------Commercial cuts----------							
½ Carcass (kg)	105	105	98.1	93.3	4.46	<0.01	0.13
Pallet (kg)	33.5	34.4	33.0	30.5	1.90	<0.01	0.01
Chuck (kg)	45.0	42.0	38.9	38.8	2.98	<0.01	0.20
Short rib (kg)	41.9	42.0	38.0	35.2	2.41	<0.01	0.09
Short rib (%)	19.8	19.9	19.3	18.8	0.86	<0.01	0.34
Cushion (kg)	55.0	56.5	53.2	50.2	2.90	<0.01	0.03
Rump (kg)	35.3	35.8	33.0	31.9	1.71	<0.01	0.20
Front (kg)	78.6	76.6	71.9	69.3	3.98	<0.01	0.80
Front (%)	37.2	36.3	36.6	37.1	1.15	0.93	0.09
Rear (kg)	132	134	124	117	6.09	<0.01	0.04
Rear (%)	62.7	63.6	63.3	62.8	1.15	0.93	0.09
----------Tissue composition----------							
Muscle (%)	64.7	69.0	68.6	70.7	3.07	<0.01	0.31
Fat (%)	15.9	14.3	13.9	12.6	1.86	<0.01	0.83
Bone (%)	18.2	16.6	17.4	18.2	1.65	0.79	0.04
Muscle/bone ratio	4.16	4.85	4.98	5.79	0.82	<0.01	0.83
Muscle + fat/bone ratio	4.45	5.03	4.81	4.64	0.57	0.69	0.07

[a]Standard error of mean; [b]Significance at 0.05; [c]Empty body weight gain/body weight gain; [d]Subcutaneous fat thickness; L-Linear; Q-Quadratic.

a reduction in the use of recycled N in the urea cycle. The BUN concentration can be used to verify the protein nutritional status of animals (VALADARES et al., 1999).

The maintenance of NB may have indicated a stability of rumen microbiota, even with feed restriction, probably because the N balance remained positive between treatments. This observation

indicated that N intake requirements were met. The crude protein levels led to reduced intake, which resulted in a smaller amount of nitrogen degradation in the rumen. There was no concomitant microbial N synthesis, probably because these animals were more efficient in reusing nitrogen derived from recycling. GONZAGA NETO et al. (2011) observed the influence of feed restriction on microbial N synthesis in Guzerá heifers, and synthesis was reduced with a decreased availability of peptides and amino acids for microbial growth.

The reduction in intake caused a linear decrease in the final BW, total weight gain, and ADG. Sindhi bulls that were restricted to 45% of DMI showed an ADG of 490 g/day. The diet was devised for a ADG of 1000 g/day, according to recommendations (VALADARES Filho et al., 2010) which was achieved in the treatments *ad libitum* and 15% of the feed restriction. When the restriction was 30 and 45%, the ADG was significantly reduced. For each 1% applied restriction, the animals showed a decrease of 21.6 g in the BW% of DMI. In fact, it was observed that reduction in intake by nearly 50% of DM (%BW) in the treatment *ad libitum* group resulted in no weight loss, with the average daily weight ranging from 1.17 to 0.500 kg among the bulls with restriction levels. The devised diet was efficient for the group fed at will, to obtain the expected gain, but the animals receiving the 15% restriction had 1100 g/day of gain, probably showing a greater capacity for the diet of the tight supply nutrients (HORNICK et al., 1998). The animals that received 85% of their nutritional requirements consumed approximately 0.83 kg less and had an ADG of 1.10 kg/day. The maximum gain in EBW was 1410 g at 6.83% feed restriction. Applying the feed restriction to this level promoted an increase in EBW's gain; however, after that point, the gain was reduced with increased feed restriction. The gain in EBW is a direct reflection of the gastrointestinal tract contents, verifying that with an increase in feed restriction, there was a reduction in the weight of the gastrointestinal tract, providing greater EBW gains with the application of the restriction (HORNICK et al., 1998; ZHANG et al., 2013).

The reduction of nutrient availability could be attributed to the lower body development at the end of the experiment. The muscle and fat deposition in the carcass can be influenced by dietary restriction. In particular, the adipose tissue may be affected by nutrient limitation, reducing its deposition in the carcass (BERG & BUTTERFIELD, 1968). This behavior is justified because protein deposition is less energy efficient but is more efficient in terms of deposited tissue weight, once approximately three units of water for each protein unity gain were deposited in combination (BEZERRA et al., 2013). We observed that the deposition of muscle weight in the middle is approximately four times more efficient than the deposition of adipose tissue (Blanco et al., 2015).

The limitation of nutrients may reduce carcass weight in addition to delaying the carcass finish because the reduced amount of feed intake reduces the deposition of fat in the carcass over muscle deposition, which may be considered as one of the disadvantages of the use of feed restriction (BEZERRA et al., 2013). However, the application of feed restriction in animals distributed in batches must respect certain criteria, such as the trough area, size of stall, group hierarchy, and animal type, to enable the animals to consume a certain amount so that no weight loss occurs. The TG achieved its maximum value at 82.2 kg and 0.70% feed restriction, and then decreased with an increase in the applied restriction, reflecting the decrease in DMI. The results reported in this study suggested that Sindhi bulls have a good ability to gain weight even with limited DMI and nutrients.

The application of restriction provided possible improvements in feeding efficiency in the animals subjected to restriction. The carcass gain decreased with increasing restriction. However, it was observed that the level with 0 to 15% restriction presented a similar carcass gain. This behavior can be explained by the improved feed efficiency level at the 15% restraint, with the final BW close to that of the animals fed *ad libitum*. In addition, the levels of feed restriction did not influence the deposition efficiency. This reinforces the claim that animals receiving a more reduced form of nutrients than their nutritional requirements, develop greater efficiency to adapt to nutrient limitation, which was evident by depositing muscle in the carcasses of animals subjected to even 45% feed restriction. The greater efficiency of weight gain in animals subjected to 15 and 30% restriction (moderate levels), when compared to that fed *ad libitum*, can be observed in the weight gain decreases of 7.67% and 25%, respectively. Even with this reduction in weight gain, no weight loss was observed among the animals, despite the reduction in feed by 45%. GONZAGA NETO et al. (2011) reported that dual release Zebu has a different nutrient-partitioning system because they prioritize muscle deposition even with nutrient limitation. The Sindhi cattle subjected to a 20% restriction in DMI reached the end of the experiment with weight gain similar to the group fed at ease, with their needs met for the estimated weight gain of 700 g/day. In Sindhi bulls,

even under feed restriction (15%), the performance results, carcass characteristics, and tissue deposition were similar to the bulls of the *ad libitum* intake. Thus, further studies should evaluate the nutritional requirements of Sindhi bulls. This fact could indicate that BR-Corte may be overestimated for Sindhi bulls. Of note, the Sindhi breed has smaller frame size than the breeds used in BR-Corte, and smaller breeds have lower requirements than bigger breeds.

The feed restriction up to 45% does not change the hot and cold carcass yield, suggesting that the animals do not mobilize muscle tissue, which reinforces the non-effect of feed restriction on income by reducing the gastrointestinal tract with increasing restriction, producing a more balanced casting production (ZHANG et al., 2013). In this study, the degree of carcass finish, assessed by SFT, decreased linearly. This result can be explained by the likely reduction in energy intake imposed by the nutritional deficiency to which the animals were submitted, with the aim of improving energy availability in the diet by providing a physiological response with greater deposition of fat in the carcass (MOREIRA et al., 2015). In addition, increased SFT usually accompanies an increase in the slaughter weight of the animal (EIRAS et al., 2014). In this study, it was observed that the carcass weight decreased with increasing restriction, with the decrease in dry matter intake, thus promoting a reduction in SFT (HOMEM JUNIOR et al., 2015).

Notably the greater weight of the largest cutting added to the value of the carcass, especially for cuts coming from the rear, which are considered cuts of greater commercial value. As for the performance of the rear cuts, there was a higher yield, demonstrating that animals of this breed have good muscle deposition in the back, reinforcing the hypothesis that this may be a feature (greater rear development) intrinsic to Sindhi cattle, (BEZERRA et al., 2013). We observed that the levels of restriction applied were not sufficient to affect the yield of the rear cuts, an important characteristic because the largest value of the carcass is concentrated in this section.

It is desirable that the carcasses present income from the upper rear up to 48%, with 39% from the front, and up to 13% from the short rib (PRADO et al., 2015). These values were similar to those observed for returns from the front and rear. However, the performance of the cutting-edge needle in percentage was higher among the restriction levels than the recommended amount, probably because the animals were non-castrated, and this may have contributed to the greater weight of the cut. Another reason could be their age at the time of the experiment (PRADO et al., 2015). An increase in muscle percentage and decrease in fat percentage were observed with increasing intensity of the feed restriction. Tissues, especially the muscles, can be affected by not meeting the nutritional requirements of the animals (PRADO et al., 2015). However, we observed the contrary results in this study. The higher feed restriction increased muscle tissue percentage in the carcass compared to the animals fed *ad libitum*. According to CLÍMACO et al. (2011), determining the relationship of muscle + fat/bone is important in the evaluation of meat quality because this represents the ratio of the edible portion of the carcass to the amount of bone.

The fat decreased with increased feed restriction, and this may explain the higher proportion of muscle in the carcass with the application of the restriction. Probably, the animals subjected to restriction decreased fat deposition on the inside of the carcass cavity to become more efficient with the reduced nutrient intake because fat deposition demands more energy from the animal than muscle deposition (JONES et al., 1990; HORNICK et al., 1998). It was observed that at 16.9% applied restriction, the animals had an increased percentage of bone in the carcass. However, this did not affect the increase in the percentage of muscles in the carcass. This result is explained by the evident growth of animals.

CONCLUSION

The levels of feed restriction reduced feed intake; and consequently, impair performance, carcass traits and commercial cuts of Sindhi bulls. However, it promotes the reduction in N fecal and urinary excretion, which can be important if conducted a subsequent compensatory weight gain.

DECLARATION OF CONFLICTS OF INTERESTS

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analysis, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

REFERENCES

AOAC. **Official Methods of Analysis**. 19th ed. **Association of Official Analytical Chemists**, Gaithersburg, MD, USA, 2012.

AZEVÊDO, J.A.G. et al. **Prediction of dry matter intake for beef cattle feedlot. In: Nutrient requeriments of zebu cattle – BR CORTE** (Valadares Filho, S.C et al.), 1–12. Gráfica Suprema, Viçosa-MG, Brazil, 2010.

BERG, R.T.; BUTTERFIELD, R.M. Growth patterns of bovine muscle, fat and bone. **Journal of Animal Science,** v.27, p.611-619, 1968. Available from: <https://www.semanticscholar.org/paper/Growth-Patterns-of-Bovine-Muscle%2C-Fat-and-Bone-Berg-Butterfield/a7923cc9903b74505bba3bcc8ff755932ba8548c>. Accessed: May, 18, 2020. doi: 10.2527/jas1968.273611x.

BEZERRA, L.R. et al. Feed restriction followed by realimentation in prepubescent Zebu females. **Tropical Animal Health and Production**, v.45, p.1161-1169, 2013. Available from: <https://pubmed.ncbi.nlm.nih.gov/23269577/>. Accessed: May, 18, 2020. doi: 10.1007/s11250-012-0341-8.

BLANCO, M. et al. Modeling of intramuscular lipids in different muscles in bulls, steers, and cows. **Journal of Animal Science**, v.93, p.5073-5082, 2015. Available from: <http://www.https://pubmed.ncbi.nlm.nih.gov/26523599/>. Accessed: May, 18, 2020. doi:10.2527/jas.2015-9196.

BRASIL. Decreto n. 30, 691, alterado pelos Decretos n. 1,255 de 25-06-62, n. 1236 de 02-09-94, n. 1.812 de 08-02-96 e n. 2.244 de 04-06-97. **Aprova o regulamento da inspeção industrial e sanitária de produtos de origem animal** (RIISPOA). Lei: Diário Oficial da União de 5 de julho de 1997, seção I, Brasília, 1997.

CASALI, A.O. et al. Influence of incubation time and particles size on indigestible compounds contents in cattle feeds and feces obtained by in situ procedures. **Revista Brasileira de Zootecnia,** v.37, p.335-342, 2008. Available from: <https://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-35982008000200021>. Accessed: May, 18, 2020. doi:10.1590/S1516-35982008000200021.

CHEN, X.B.; GOMES, M.J. **Estimation of microbial protein supply to sheep and cattle based on urinary excretion of purine derivatives - an overview of technical details**. Bucksburnd: Rowett Research Institute/International Feed Research Unit, 21p, 1992.

CHIZZOTTI, M.L.;et al, Intake, digestibility and urinary excretion of urea and purine derivatives in heifers with different body. **Revista Brasileira de Zootecnia**, v.35, p.1813–1821, 2006. Available from: <https://www.scielo.br/scielo.php?pid=S1516-35982006000600032&script=sci_abstract> Accessed: Aug. 18, 2020. doi: 10.1590/S1516-35982006000600032.

CLÍMACO, S.M. et al. Performance and carcass traits of four genetic groups of beef cattle steers finished in feedlot. **Revista Brasileira de Zootecnia**, v,40, p.1562-1567, 2011. Available from: <https://www.scielo.br/scielo.php?pid=S1516-35982011000700023&script=sci_abstract&tlng=en>. Accessed: May, 18, 2020. doi: 10.1590/S1516-35982011000700023.

EIRAS, C.E. et al. Glycerine levels in the diets of crossbred bulls finished in feedlot: Carcass characteristics and meat quality. **Meat Science**, v.96, p.930-936, 2014. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0309174013005494>. Accessed: May, 18, 2020. doi: 10.1016/j.meatsci.2013.10.002

FEIJÓ, G.L.D. et al. Carcass evaluation of f1 angus-nellore steers on brachiaria decumbens pasture under different feeding regimes. **Revista Brasileira de Zootecnia**, v.30, p.1015-1020, 2011. Available from: <https://www.rbz.org.br/article/carcass-evaluation-of-f1-angus-nellore-steers-on-brachiaria-decumbens-pasture-under-different-feeding-regimes/>. Accessed: May, 18, 2020. doi: 10.1590/S1516-35982001000400015.

FUJIHARA, T. et al. The effect of protein infusion on urinary excretion of purine derivatives in ruminants nourished by intragastric nutrition. **Journal of Agricultural Science**, v.109, p.7-12, 1987. Available from: <https://www.cambridge.org/core/journals/journal-of-agricultural-science/article/effect-of-protein-infusion-on-urinary-excretion-of-purine-derivatives-in-ruminants-nourished-by-intragastric-nutrition/7CA3745F12D096B3DB0FA038D5BEF7D5>. Accessed: May, 18, 2020. doi: 10.1017/S0021859600080916.

GALYEAN, M.L. Review: Restricted and programmed feeding of beef cattle definitions, application, and research results. **The Professional Animal Scientist**, v.15, p.1-6, 1999. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S1080744615317150>. Accessed: May, 18, 2020. doi: 10.15232/S1080-7446(15)31715-0.

GONZAGA NETO, S. et al. Feed restriction and compensatory Growth in Guzerá Females. **Asian-Australasian Journal of Animal Sciences**, v.24, p.791-799, 2011. Available from: <https://www.ajas.info/journal/view.php?number=22520>. Accessed: May. 18, 2020. doi: 10.5713/ajas.2011.10417.

HALL, M. B. et al. A method for partitioning neutral detergent soluble carbohydrates. **Journal of the Science of Food and Agriculture**, v.79, p.2079-2086, 1999. Available from: <https://onlinelibrary.wiley.com/doi/abs/10.1002/%28SICI%291097-0010%28199912%2979%3A15%3C2079%3A%3AAID-JSFA502%3E3.0.CO%3B2-Z>. Accessed: May, 18, 2020. DOI: https://doi.org/ 10.1002/(SICI)1097-0010(199912)79:15<2079::AID-JSFA502>3.0.CO;2-Z.

HOMEM JUNIOR, A.C. et al. Fatty acids and cholesterol of meat from lambs fed diets containing lipid sources and subjected to restriction and refeeding. **Ciência Rural**, v.**45**, p.1674-1680, 2015. Available from: <https://www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-84782015000901674>. Accessed: May, 18, 2020. doi: https:// 10.1590/0103-8478cr20140293.

HORNICK, J. L. et al. Different periods of feed restriction before compensatory growth in Belgian Blue bulls: I. animal performance, nitrogen balance, meat characteristics, and fat composition. **Journal of Animal Science**, v.76, p.249-259, 1998. Available from: <https://pubmed.ncbi.nlm.nih.gov/9464906/>. Accessed: May, 18, 2020. doi: 10.2527/1998.761249x.

JONES, S.J. et al. Myofibrillar protein turnover in feed-restricted and realimented beef cattle. **Journal of Animal Science**, v.68, p.2707-2715, 1990. Available from: <https://pubmed.ncbi.nlm.nih.gov/2211400/>. Accessed: May, 18, 2020. doi: https://10.2527/1990.6892707x.

LOERCH, S.C.; FLUHARTY, F.L. Effects of programming intake on performance and carcass characteristics of feedlot cattle. **Journal of Animal Science**., v.76, p.371-377, 1998. Available from: <https://pubmed.ncbi.nlm.nih.gov/9498341/>. Accessed: May, 18, 2020. doi: https:// 10.2527/1998.762371x.

LOERCH, S.C. Effects of feeding growing cattle high-concentrate diets at restricted intake on feedlot performance. **Journal of Animal Science**., v.68, p.3086-3095, 1990. Available from: <https://pubmed.ncbi.nlm.nih.gov/2254187/>. Accessed: May, 18, 2020. doi: https:// 10.2527/1990.68103086x.

MOREIRA, P.S.A. e al. Productive performance and carcass traits of Nellore × Aberdeen Angus and Nellore × Red Angus heifers under tropical conditions. **Revista Colombiana de Ciencias Pecuarias**, v.28, p.247-254, 2015. Available from: <http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S0120-06902015000300006>. Accessed: May, 18, 2020. doi: 10.17533/udea.rccp.v28n3a5.

MURPHY, T.A.; LOERCH, S.C. Effects of restricted feeding of growing steers on performance, carcass characteristics, and composition. **Journal of Animal Science**, v.72, p.2497-2507, 1994. Available from: <https://pubmed.ncbi.nlm.nih.gov/8002469/>. Accessed: May, 18, 2020. doi: 10.2527/1994.7292497x.

NRC. **Nutrient Requirements of Beef Cattle**.7th ed. Natl. Acad. Press, Washington, DC, USA. 2000.

PRADO, I.N. et al. Carcass composition and cuts of bulls and steers fed with three concentrate levels in the diets. *Asian Australas.* **Journal of Animal Science**, v.28, p.1309-1316, 2015. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4554872/>. Accessed: May, 18, 2020. doi: 10.5713/ajas.15.0021.

SAS. 2003. **Inst. SAS User's Guide: Basics**. Cary: SAS Inst. Inc.

SNIFFEN, C.J. et al. A net carbohydrate and protein system for evaluation of cattle diets. II Carbohydrate and protein availability. **Journal of Animal Science**, v.70, p.3562-3577, 1992. Available from: <https://pubmed.ncbi.nlm.nih.gov/1459918/>. Accessed: May, 18, 2020. doi: 10.2527/1992.70113551x.

VALADARES FILHO, S.C. et al. **BR CORTE - Nutrient requeriments of zebu cattle**. Viçosa: Gráfica Suprema, 142p, 2010.

VALADARES, R.F.D. et al. Effect of replacing alfalfa silage with high moisture corn on ruminal protein synthesis estimated from excretion of total purine derivatives. **Journal of Dairy Science**, v.82, p.2686-2696, 1999. Available from: <https://www.journalofdairyscience.org/article/S0022-0302(99)75525-6/abstract>. Accessed: May, 18, 2020. doi: 10.3168/jds.S0022-0302(99)75525-6.

VAN SOEST, P.J. et al. Methods for dietary fiber, neutral detergent fiber, and nonstarchpolyssacharides in relation to animal nutrition. **Journal of Dairy Science**, v.74, p.3583-3597, 1991. Available from: <https://pubmed.ncbi.nlm.nih.gov/1660498/>. Accessed: May, 18, 2020. doi: 10.3168/jds.S0022-0302(91)78551-2.

VERBIC, J. et al. Excretion of purine derivatives by ruminants. Effect of microbial nucleic acid infusion on purine derivative excretion by steers. **Journal of Agricultural Science**, v.114, p.243-248, 1990. Available from: <https://www.cambridge.org/core/journals/journal-of-agricultural-science/article/excretion-of-purine-derivatives-by-ruminants-effect-of-microbial-nucleic-acid-infusion-on-purine-derivative-excretion-by-steers/AC5FAC5D5479233B0CA140B316F90E27>. Accessed: May, 18, 2020. doi: 10.1017/S0021859600072610.

ZHANG, S. et al. Short-term feed restriction impairs the absorptive function of the reticulo-rumen and total tract barrier function in beef cattle. **Journal of Animal Science**, v.91, p.1685-1695, 2013. Available from: <https://academic.oup.com/jas/article-abstract/91/4/1685/4716991?redirectedFrom=PDF>. Accessed: May, 18, 2020. doi: 10.2527/jas.2012-5669.