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REGULAR ARTICLES

Ingestive behavior of grazing steers fed increasing levels of concentrate supplementation with different crude protein contents

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Abstract This study aimed to evaluate the ingestive behavior of steers on *Brachiaria brizantha* pasture fed diets with increasing levels of concentrate supplementation. Thirty-two crossbred steers in the finishing phase with average weight of 420±8 kg were distributed in a completely randomized design with four treatments and eight replicates per treatment. Their behavior was assessed every 5 min for 24 h, in the middle of the experimental period. Variance and regression analyses at 0.05 % probability were adopted. The times spent grazing and ruminating reduced linearly (P <0.05), whereas the times spent at the trough (eating) and on other activities increased linearly (P <0.05) as the supplementation levels were elevated. The total feeding and chewing times decreased linearly (P <0.05) as the concentrate levels in the diet were elevated. By increasing the supplementation levels, the number of bites per day decreased linearly (P <0.05), and the feed efficiency of dry matter increased quadratically. Rumination efficiency of dry matter increased linearly (P <0.05) with increasing levels of concentrate supplementation. Grazing and rumination activities are reduced when the time devoted to other activities and at the trough are increased, as a result of the substitution effect.

Keywords Beef cattle · Concentrate · Intake · Ruminant

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Introduction

Knowing the behavioral patterns of selection, location, and ingestion by grazing cattle is essential when aiming to improve and define management practices. The forage intake by grazing animals is affected by three groups of factors: those affecting the digestion and ingestion processes, and those affecting the nutritional requirements (Berchielli et al. 2006).

When a ruminant ingests food, they chew it superficially, transporting it to the reticulum. After some time, this food returns to its mouth for rumination, which is an activity that reduces the food particle size, facilitating degradation and digestion and improving the absorption of nutrients. The total rumination time is directly correlated with the size of the particles present in the rumen and with the fiber content of the ingested nutrient.

The assessment of the ingestive behavior of supplemented grazing steers is essential for proper animal management, since concentrate supplementation should not be used aiming to substitute the pasture but to complement it. Behavioral alterations have been detected in the activities of grazing cattle fed diets with increasing amounts of supplementation (Silva et al. 2010).

For an efficient use of pasture, it is necessary to know the existing relationships in the plant-animal interface, which involves the study of how the grazing conditions interfere with the ingestive behavior of ruminants and their performance so as to identify the appropriate management conditions for the animal and for the production system adopted (Jochims et al. 2010).

This study aimed to evaluate the ingestive behavior of grazing steers in the finishing phase fed increasing levels of supplementation.

Material and methods

The field work was carried out from September to December 2011, totaling 102 days, conducted in Ribeirão do Largo/BA, Brazil. The climate in that region is tropical (AW), according to the Köppen-Geiger classification.

Thirty-two finishing crossbred steers with average initial weight of 420±8 kg were distributed in a completely randomized design with four treatments and eight replicates per treatment. The diets were formulated according to the NRC (2000) to provide gains of 0.5 kg day^{-1}.

Treatments consisted of four levels of concentrate (0.2, 0.4, 0.6, and 0.8 % of the body weight), formulated with decreasing crude protein (CP) contents (500, 250, 166.6, and 125.0 g CP per kilogram of concentrate). The proportion of ingredients in the concentrates and the chemical composition of forage and concentrates can be visualized in Tables 1 and 2. The roughage-to-concentrate ratios were 91:91, 82:18, 70:30, and 61:39, respectively, for the levels of 0.2, 0.4, 0.6, and 0.8 % of supplementation.

Animals were kept grazing on *Brachiaria brizantha* cv. Marandu pasture. The total used area was 13 ha, divided into ten paddocks, under a rotational grazing system. The stocking rate was 2.41 AU/ha. Forage allowance was 14.0 kg dry matter per 100 kg of body weight.

To estimate the fecal production, one capsule of LIPE® (Isolated, Purified and Enriched Lignin) was administered daily per animal for 7 days as described by Saliba et al. (2005). Fecal samples were shipped to the manufacturer of LIPE® where the daily fecal production was estimated for each animal using infrared spectrophotometry (Saliba et al. 2005).

To determine the intake of dry matter from supplement (SDMI), the external marker titanium dioxide (TiO2) was used. The marker was supplied at 10 g/animal, mixed with the concentrate in the trough daily for 7 days, according to Valadares Filho et al. (2006). Fecal samples were collected as described for LIPE®.

$$\mathrm{SDMI} = (\mathrm{FE} \times \mathrm{TiO_2Feces})/\mathrm{TiOSupplement}$$

Table 1 Proportion of ingredients in the concentrates on a dry matter (DM) basis

Ingredient (g/kg DM)	Concentrate level of the diet (% BW)			
	0.2 %	0.4 %	0.6 %	0.8 %
Ground corn	267.3	733.2	887.2	963.6
Soybean meal	626.3	214.0	77.7	10.0
Urea	60.0	29.8	19.8	14.9
Mineral mix	46.4	23.0	15.3	11.5

Where: FE=fecal excretion and TiOFeces and TiOSupplement=concentration of TiO_2 in the feces and supplement, respectively.

Internal marker indigestible NDF (iNDF) was used to estimate voluntary roughage intake as described by (Casali et al. 2008) and (Detmann 2012). Dry matter intake was calculated as follows:

$$\mathrm{Total\ DMI(kg/day)} = \frac{[(\mathrm{FE} \times \mathrm{CMF}) - \mathrm{MS}] + \mathrm{SDMI}}{\mathrm{CMR}}$$

Where: FE=fecal excretion (kg/day) obtained using LIPE®, CMF=concentration of the marker in the feces (kg/kg), CMR=concentration of the marker in the roughage (kg/kg), MS=concentration of marker in the supplement, and SDMI=supplement DM intake.

The total carbohydrates (TC) were estimated according to Sniffen et al. (1992), as follows: TC=100–(%CP+%EE+%ash), and non-fibrous carbohydrates corrected for the residual ash and protein (NFCap) were calculated as proposed by Hall (2003): NFCap=100–[% EE+%Ash+(%NDFap–%CP)+(%CP−%PBNNP+%NNP)]

Total digestible nutrients (TDN) were calculated according to Weiss (1999) utilizing the NDFap and NFCap by the equation: TDN(%)=DCP+DNDFap+DNFCap+2.25DEE

Where: DCP=digestible CP, DNDFap=digestible NDFap, DNFCap=digestible NFCap, and DEE=digestible EE.

The observations concerning the ingestive behavior were performed for 24 h on days 36 and 50 of the experimental period. The animals were visually assessed every five minutes, and the time of each activities (grazing, ruminating, eating at the trough, and on other activities) were recorded (Almeida et al. 2014). The feeding and rumination times were calculated as a function of DM and NDF intakes (min/kg DM or NDF).

The total feeding (TFT, min) and chewing (TCT, min) times were determined by the following equations: TFT = GRZ + TRH and TCT = GRZ + RUM + TRH, respectively.

Where: GRZ=grazing time (min), RUM=rumination time (min), and TRH=time eating at the trough (min).

The bite rate (BTR) was estimated as described by Hodgson (1982). The results of the observations of biting and swallowing were recorded in six occasions throughout the day as reported by Baggio et al. (2009).

The feed and rumination efficiencies (kg/h) of DM, NDF, NFC, and CP were calculated by dividing the intake of each of these nutrients by the total feeding time (feed efficiency) or rumination time (rumination efficiency).

The results were statistically interpreted by variance and regression analyses using the System for Statistical and Genetic Analyses (SAEG) (Ribeiro Jr 2001). The criteria

Table 2 Chemical composition of simulated grazing sample and concentrates, on a dry matter basis

Item	Simulated grazing	Concentrate			
		0.2 %	0.4 %	0.6 %	0.8 %
Dry matter (g kg^{-1} as fed.)	257	880	876	875	873
Crude protein (g kg^{-1} dry matter)	77.3	500	250	167	125
Ether extract (g kg^{-1} dry matter)	20.0	36.7	37.5	40.4	41.9
Total carbohydrates (g kg^{-1} dry matter)	701	375	655	748	813
NFCap (g kg^{-1} dry matter)	179	328	550	608	604
NDFap (g kg^{-1} dry matter)	521	47.0	105	139	209
iNDF (g kg^{-1} dry matter)	196	17.8	18.6	20.6	25.4
Total digestible nutrients (g kg^{-1} dry matter)	551	618	716	688	712

NFCap non-fibrous carbohydrates corrected for ash and protein, *NDF* neutral detergent fiber corrected for ash and protein, *iNDF* indigestible neutral detergent fiber

adopted to choose the model were the coefficient of determination, calculated as the ratio between the sum of squares of the regression and the sum of squares of treatments, and the observed significance of the coefficients of regression by the *T* test, according to the model: Yijk=m+Ti+eijk

Where: Yijk=observed value of the variable, m=overall constant, Ti=effect of treatment i, and Eijk=error associated with each observation.

Results

The increase in the dietary concentrate levels did not change (P >0.05) total dry matter intake (TDM), which averaged 9.40 kg (Table 3). However, with the increasing supplementation levels, the intakes of forage dry matter (FDM), neutral detergent fiber (NDF), and crude protein (CP) decreased, whereas the intake of non-fibrous carbohydrates (NFC) increased.

The increase in the dietary concentrate level caused a linear reduction in (P <0.05) the time spent on grazing (GRZ) and rumination (RUM). In contrast, it linearly increased the time spent by the animal eating at the trough (TRH) and on other activities (OTH) (Table 3).

The number of grazing periods (NGP) and the number of rumination periods (NRP) were not affected (P >0.05) by the treatments (Table 4); however, the number of periods eating at the trough (NTP) and the number of periods on other activities (NOP) were increased linearly (P <0.05) with the increasing supplement levels. The total feeding time (TFT) was reduced linearly with the increasing supplement levels, whereas the total chewing time (TCT) increased linearly (P <0.05) (Table 4).

The bite rate (BTR) increased linearly (P <0.05) and the number of bites per day (NBD) presented a positive quadratic effect (P <0.05) when the concentrate level in the diet was increased (Table 4).

The feed efficiencies of DM, NDF, and CP showed a positive quadratic effect (P <0.05), and NFC increased linearly (P <0.05) when the concentrate level of the diet was increased (Table 5). The rumination efficiencies of NDF and CP were not affected by the treatments (P >0.05), but those of DM and NFC increased linearly (P <0.05) with the increasing levels of supplement in the diet (Table 5).

Discussion

The increase in the dietary concentrate level reduced the grazing time, causing a decrease in the DM and NDF intakes (Table 3). This response is a clear sign of the existence of the substitution effect. When these metabolic changes relative to decreased pasture intake are associated with the behavioral expressions, we have the exact dimension of how the animal modifies its behavior according to what it consumes, how

Table 3 Nutrient intake and ingestive behavior of steers fed diets with different levels of supplementation

Intake	Supplementation level					
	0.2 %	0.4 %	0.6 %	0.8 %	RE	R^2
TDM (kg/day)	9.37	9.89	9.02	9.35	$\hat{Y}$=9.40	–
FDM (kg/day)	8.50	7.89	6.23	5.27	1	0.97
NDFap (kg/day)	5.92	5.66	4.70	4.49	2	0.93
CP (kg/day)	1.09	1.10	0.94	0.91	3	0.82
NFC (kg/day)	1.26	1.87	2.37	2.73	4	0.99
Activity	Min/day					
GRZ (min/day)	479	451	441	335	5	0.82
RUM (min/day)	451	356	318	316	6	0.83
TRH (min/day)	10.9	32.2	47.8	45.6	7	0.87
OTH (min/day)	535	601	633	766	8	0.93

TDM total dry matter intake, *FDM* forage dry matter, *GRZ* grazing, *TRH* eating at the trough, *RUM* rumination, *OTH* others

Regression equations (RE) and respective coefficients of determination (R2): 1Y=9.8170−5.6780X; 2Y=6.5073−2.6216X; 3$\hat{Y}$=1.1905−0.3472X; 4$\hat{Y}$=0.7341+2.9088X; 5$\hat{Y}$=537.031−221.094X; 6$\hat{Y}$=434.719−166.813X; 7$\hat{Y}$=4.2187+59.8438X; 8$\hat{Y}$=452.812+361.719X

Table 4 Mean values for the ingestive behavior of steers fed diets with increasing levels of concentrate supplementation

Item	Supplementation level					
	0.2 %	0.4 %	0.6 %	0.8 %	RE	R^2
NGP (n)	14.8	16.0	18.2	15.8	$\hat{Y}$=16.2	–
NTP (n)	1.68	3.56	3.75	3.93	1	0.74
NRP (n)	16.2	13.9	16.2	16.6	$\hat{Y}$=15.7	–
NOP (n)	27.0	26.7	30.9	29.9	2	0.64
TFT (min)	490	483	489	381	3	0.61
TCT (min)	905	839	807	674	4	0.93
BTR (n/s)	37.6	40.3	53.5	53.2	5	0.86
NBD (n/day)	18,063	18,131	23,593	17,238	6	0.42

NGP number of grazing periods, *NTP* number of periods at the trough, *NRP* number of rumination periods, *NOP* number of periods on other activities, *TFT* total feeding time, *TCT* total chewing time, *BTR* bite rate, *NBD* number of bites per day

Regression equations (RE) and respective coefficients of determination (R2): 1Y=1.50000+3.46875X; 2$\hat{Y}$=25.5000+6.31250X; 3$\hat{Y}$=541.250−161.250X; 4$\hat{Y}$=987.188 361.719X; 5$\hat{Y}$=31.1410+30.0199X; 6$\hat{Y}$=10480.1+41642.8X−40149.1X2

much it consumes, and how much it digests. The daily grazing times (GRZ) reported in this study (Table 3) are below the 9.75 h for *Brachiaria brizantha* and the 11.31 h for *Brachiaria decumbens* reported by Zanine et al. (2006).

Due to the reduction in the daily intakes of DM and NDFap, the rumination time was affected linearly and negatively (Table 3). When present inside the rumen, these constituents stimulate the rumination process, which is directly related to the rumen buffering and maintenance of a pH close to 6.5 for animals feeding pasture only. Supplement intake changes this dynamics, promoting a reduction in the rumen buffering and in the rumen pH and a change in the acetate:propionate ratio wherein the former is reduced while the latter is increased.

Table 5 Feed and rumination efficiencies of dry matter (DM), neutral detergent fiber (NDF), crude protein (CP) and non-fibrous carbohydrates (NFC) in steers fed diets with different levels of concentrate supplementation

Item	Supplementation level					
	0.2 %	0.4 %	0.6 %	0.8 %	RE	R^2
	Feed efficiency (kg/h)					
DM	1.17	1.23	1.12	1.49	1	0.74
NDF	0.74	0.70	0.58	0.71	2	0.60
CP	0.13	0.13	0.11	0.14	3	0.53
NFC	0.15	0.24	0.29	0.46	4	0.94
	Rumination efficiency (kg/h)					
DM	1.36	1.72	1.74	1.85	5	0.81
NDF	0.86	0.99	0.90	0.88	$\hat{Y}$=0.91	–
CP	0.16	0.18	0.18	0.17	$\hat{Y}$=0.17	–
NFC	0.18	0.33	0.46	0.57	6	1.00

Regression equations (RE) and respective coefficients of determination (R2):1Y=1.42845–1.50619X+1.93943X2; 2$\hat{Y}$=0.936344–1.09294X+0.988604X2; 3$\hat{Y}$=0.166030–0.168186X+0.168285X2; 4$\hat{Y}$=0.0442619+0.493778X; 5$\hat{Y}$=1.30224+0.739185X; 6$\hat{Y}$=0.0651374+0.647110X

The time spent by the animal eating at the trough (TRH) increased linearly (P <0.05) because when increasing amounts of feed (Table 3) are supplied, animals need to remain longer at the trough to consume all supplement. These results agree with those reported by Mendes et al. (2013), who found an increasing linear effect as they increased the concentrate levels in the diets.

The time on other activities increased linearly (P <0.05) as the supplement levels were increased (Table 3). The time animals devote to other activities is inversely proportional to the time spent ruminating and grazing. Thus, when animals spend less time grazing and ruminating, this behavior is normal and expected. These results agree with Silva et al. (2010), who found an increasing linear effect on other activities when they increased the level of concentrate in the diet of finishing steers on pasture.

When the amount of supplement is increased, the animals find in the supplement the nutrients that are necessary to meet their requirements, and thus they decreased forage intake, characterizing a substitutive effect, which caused a reduction in the time of grazing (GRZ) (Table 3).

The increase in the number of periods feeding at the trough (NTP) and the time per period at the trough (TTP) were caused by the greater supply of concentrate to the animals that were fed the greatest level of supplementation, so they needed more time to consume all the available supplement. Similar results to those presented herein were found by Silva et al. (2005), who, in a study with the levels of 0.25, 0.50, 0.75, and 1.0 % of body weight, found a variation of 6.56 to 13.85 min per period.

The number of rumination periods (NRP) was not affected (P <0.05) by the increase in the dietary concentrate level; however, the total chewing time (TCT) (Table 4) and the rumination time (RUM) (Table 3) decreased linearly. This effect can be explained by the reduction of forage intake, and consequently of NDFap intake (Table 3). In this situation, the needs to ruminate and chew are reduced, since the fiber content and particle size of feed reduces when the supplement intake is increased.

The number of periods on other activities (NOP) was affected linearly (P <0.05) by the treatments. This result demonstrates that animals fed with increasing levels of supplement tend to rest longer, while those fed with lower amounts of supplement spend more time with the activities of grazing and rumination (Table 3).

The group of animals fed 0.2 % of body weight showed the longest grazing time (GRZ), while the grazing time was reduced when increased the supplement offer (Table 3). Therefore, the total feeding time (TFT) and total chewing time (TCT) reduced linearly (P <0.05) as the supplementation levels increased (Table 4). The TCT is the sum of the feeding time and the rumination time. Thus, when animals consumed less forage, they ruminated less and showed lower TCT than those observed at the lower supplementation levels.

The bite rate (BTR) of animals reared on pasture is characterized as the basic unit to obtain nutrients, and this variable increased linearly (P<0.05) according to the supplementation levels (Table 4). This happened due to a smaller selection for grazing, since, due to the quantity of nutrients ingested via supplement, the animals from the 0.8 % BW group consumed less forage DM. On the other hand, the animals that consumed the lower supplement levels grazed longer, as they needed to select more digestible plant components so as to meet their nutritional requirements, because the supplemental input of nutrients was restricted to a small portion of the daily dietary requirements.

The number of bites per day (NBD) presented had a quadratic effect (P <0.05) when the concentrate level of the diet was elevated. Knowing that the grazing and rumination times were changed with increase in the supplement content (P <0.05), the number of bites (NBD) and the number of cuds ruminated per day followed the same trend.

The minimum estimated values for the feed efficiencies of DM, NDF, and CP were 1.13, 0.63, and 0.12 kg/h for the levels of 0.38, 0.55, and 0.49 % of body weight, respectively. The feed efficiency of non-fibrous carbohydrates increased linearly (P <0.05). This result might have been caused by the intake of concentrate with greater amount of non-fibrous carbohydrates, capable of providing a more efficient ingestion of these components.

The results for rumination efficiencies of DM and non-fibrous carbohydrates (Table 5) are correlated with the effect of substitution of forage for concentrate. In this context, the increase in the level of concentrate facilitates the rumination process, since the average particle size of the total diet is smaller as compared with that of diets containing a greater proportion of forage. In this situation, there will be lower need for this material to be ruminated, thereby increasing the rumination efficiency.

The rumination efficiencies of NDF and CP were not affected by the treatments (P >0.05). The forage lignification degree can affect the rumination efficiency, because forages with a high level of lignification can extend the rumination time, thus reducing the nutritional efficiency. This behavior was not observed in the present study, which indicates the quality of the forage consumed by the steers during the evaluation of their behavior.

Conclusions

The feeding behavior of cattle finished on pasture is directly influenced by the increase in the supply of concentrate supplementation in the diet.

Conflicts of interest The authors declare that none of them have any potential conflicts of interest including any financial, personal, or other relationship with other people/organization that could inappropriately influence the current scientific work.

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