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REGULAR ARTICLES

Ingestive behaviour of steers grazing *Brachiaria brizantha* cultivar Marandu and in feedlot in Brazil

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Abstract
The objective of this study was to evaluate the ingestive behaviour of steers grazing *Brachiaria brizantha* cv. Marandu and in feedlot regimen in Brazil. Fifty crossbred steers, with an average weight of 275 ± 8.18 kg, were distributed in a completely randomised design with five treatments and ten replicates per treatment (mineral supplementation, nitrogen supplementation, and concentrate supplementation at 0.1 and 0.2% of body weight and under feedlot conditions). Ingestive behaviour was assessed every 5 min for 24 h. No difference ($P > 0.05$) was found for grazing time among grazing systems. Conversely, rumination, idle, feeding, and chewing times showed differences ($P < 0.05$) only for feedlot animals. The time spent feeding at the trough was higher ($P < 0.05$) in animals receiving concentrate supplementation. The bite rate and the number of bites per day were similar ($P > 0.05$) among grazing systems. Feed and rumination efficiencies of dry matter and neutral detergent fibre corrected for ash and protein showed differences ($P < 0.05$) only in feedlot animals. Therefore, ingestive behaviour of steers varies with the raising system. Overall, feedlot animals showed better performance than grazing animals did, most likely due to longer rest periods.

Keywords Cattle management · Ingestion · Ruminant

Introduction

Livestock production and efficiency are based on animal nutritional management. Diet dry matter intake is the most important variable affecting animal digestibility and performance, regardless of the raising system. Under grazing or feedlot conditions, dry matter intake can be influenced by environmental factors such as temperature, humidity, and airflow, which affect animal health and performance (Litherland et al. 2014). In tropical conditions, large variation in forage dry matter production and quality is already expected, influencing animal productivity, mainly during the dry seasons. Forage production seasonality is a common characteristic of tropical pastures and represents one of the main obstacles in cattle production (Araújo et al. 2017).

In the context of animal ingestive behaviour, studies on pasture-fed or feedlot steers are essential to developing support models for research purposes, enabling the adjustment of feeding and management practices to improve animal performance. Ruminant, as well as in other species, feed intake depends on nutritional needs, and ingestive behaviour responds to changes in the environment (Hodgson 1985).

Cattle kept on pasture are characterised by long feeding times, which can last from 4 to 12 h a day. On the other hand, the time spent feeding by feedlot animals ranges from 1 h, when fed energy-rich diets, until 6 h for low-energy ones (Bürger et al. 2000). Rumination time is longer at night but can be influenced by feed type. However, there are also differences between individuals in terms of length and distribution of ingestion and rumination activities; this is related to anatomical variants and energy requirements for rumen filling. Despite being highly relevant, more studies are needed on the technical and biological implications about this topic.

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Given the above background, this study is aimed at evaluating the ingestive behaviour of steers grazing *Brachiaria brizantha* cv. Marandu and in feedlot regimen in Brazil.

Materials and methods

Fieldwork was conducted at the *Princesa do Mateiro* Farm, located in the city of Ribeirão do Largo, Bahia, Brazil. The geographical coordinates are 15° 26′ 46″ S latitude, 40° 44′ 24″ W longitude. A 14-ha area was divided into 12 paddocks with about 1.17 ha each, formed by *Brachiaria brizantha* cv. Marandu. During the rainy season, in December 2016, pasture was fertilised with nitrogen as topdressing (75 kg N ha^{-1}) to ensure adequate forage supply. The study started in February 2017 and ended in June 2017.

Fifty Holstein × Zebu crossbred steers with an average initial weight of 275 ± 8.18 kg and at 12 months of age were used in the study. These animals were distributed in a completely randomised design (CRD) with ten replicates per treatment. Treatments consisted of mineral supplementation ad libitum (MS), nitrogen supplementation ad libitum (NS), concentrate supplementations at 0.1% of body weight (CS1) and at 0.2% of body weight (CS2), and total feedlot (C3).

The animals were divided into five groups. The first group received mineral salt ad libitum (MS), the second mineral was fed salt with urea ad libitum as nitrogen supplementation (NS), the third and fourth were given concentrate supplementations with the same nutritional composition at 0.01 and 0.02% animal body weight (CS1 and CS2) (both fed the same pasture), and the fifth group had a high-concentrate diet (C3). Table 1 shows the proportion of each ingredient in the diets.

For grazing animals, faecal excretion was estimated using chromium oxide (at 10 g/animal/day). The marker was packed in paper cartridges and delivered orally by hand, at 6:00 a.m. for 12 days. The first 7 days were allowed for stabilisation of marker excretion, and the final 5 for faeces sampling. Faecal production was estimated by the ratio between the amount of marker supplied and its concentration in faeces, as proposed by Smith and Reid (1955). Faecal concentration of chromium oxide was determined by atomic absorption spectrophotometry in the Animal Nutrition Laboratory in the Department of Animal Science (DZO), Federal University of Viçosa (UFV), as described by Willians et al. (1962).

Supplement dry matter intake (SDMI) was determined using titanium dioxide (TiO_2) as an external marker (at 15 g/animal/day). This marker was supplied mixed with the supplement at 10:00 a.m., as described by Valadares Filho et al. (2006). Titanium concentration was estimated as proposed by Detmann et al. (2012).

For feedlot animals, dry matter apparent digestibility (DMAD) and total dry matter intake (TDMI) were estimated from faeces production. Indigestible neutral detergent fibre (iNDF) was used as an internal marker to estimate faeces production. TDMI was estimated, based on daily faecal production and on contents of iNDF in the total diet and in the faeces.

Contents of non-fibrous carbohydrates corrected for ash and protein (NFCap) were estimated by an equation proposed by Hall (2003) as follows: NFCap = 100 − [(%CP − (%CPurea + %urea)) + %NDFap + %EE + % ash], wherein CPurea and NDFap are crude proteins from urea and neutral detergent fibre corrected for ash and protein, respectively; all terms are expressed as % of DM. Total digestible nutrients (TDN) were calculated using NDF and NFCap according to Weiss (1999) in the following equation: TND (%) = DCP + DNDFap + DNFCap + 2.25DEE, wherein DCP, digestible CP; DNFDap, digestible NDFap; DNFCap, digestible NFCap; and DEE, digestible ether extract. Table 2 displays the chemical composition of the offered feedstuffs.

Table 1 Proportion of ingredients (in g per kg of natural matter) in supplementation provided to the different raising systems

	MS	NS	CS1 and CS2	C3
Corn grain	–	–	–	850
Engordim pellet	–	–	–	150
Ground sorghum grain	–	–	560	–
Soybean meal	–	–	200	–
Urea	–	250	150	–
Mineral salt[1]	1000	750	90	–
Total	1000	1000	1000	1000

MS mineral salt, *NS* nitrogen salt, *CS* concentrate supplementation

[1] Guarantee levels: calcium 175 g, phosphorus 60 g, sodium 107 g, sulphur 12 g, magnesium 5000 mg, cobalt 107 mg, copper 1300 mg, iodine 70 mg, manganese 1000 mg, selenium 18 mg, zinc 4000 mg, iron 1400 mg, and fluorine (maximum) 600 mg

Table 2 Dry matter-based chemical composition of roughage and concentrate (in g/kg) (chemical composition (in g/kg) based on roughage and concentrate dry matter)

	Brachiaria brizantha[1]	Concentrate	Feedlot
Dry matter	222	893	900
Mineral matter	976	107	80
Crude protein	95	45	180
Ether extract	175	36.6	1.35
NDFap	652	16	170
NFCap	139	2437	600
ADF	3159	576	482
TDN	5693	5692	600

[1] Simulated grazing

NDFap neutral detergent fibre corrected for ash and protein, *NFCap* non-fibrous carbohydrates corrected for ash and protein, *ADF* acid detergent fibre, *TDN* total digestible nutrients

Ingestive behaviour was observed for 24 h. During the experimental period, animals kept on pasture were assessed on the 20th day (April 2017), whilst those in feedlot conditions were monitored on the 9th day (April 2017), when they had adapted to diets and management. The animals were visually assessed every 5 min by recording the time spent on grazing (GRZ), ruminating (RUM), trough feeding (TRH), and idling (IDL), as proposed by Silva et al. (2006). The data were tabulated and calculated. Feeding and rumination times were calculated as a function of DM and NDF intakes (min/kg of DM or NDF). The total feeding time (TFT, min) and total chewing time (TCT, min) spent were determined by the following equations: TFT = GRZ + TRH and TCT = GRZ + RUM + TRH, respectively, wherein GRZ, grazing time (min); RUM, rumination time (min); and TRH, trough feeding time (min).

The time series was discretised into a number of periods, directly on data collection worksheets, by counting discrete times spent on feeding, ruminating, and other activities. The mean time spent on each activity was obtained by dividing the daily time of each activity by the number of discrete periods, as proposed by Silva et al. (2008).

Bite rate (BTR) was estimated as described by Hodgson (1982). Number of bites (NBD) and swallows (NSD) were recorded on six occasions throughout the day, as described by Baggio et al. (2009). Feed and rumination efficiencies were calculated by dividing the mean daily DM and NDF intakes by the total time spent feeding (feed efficiency) or ruminating (rumination efficiency) within 24 h (in kg of DM and NDF/h).

All the data were interpreted by analysis of variance (Proc GLM), with the aid of Statistical Analysis System software (SAS 9.0), adopting 5% as the critical level of probability for a type I error.

Results

The intakes of DM and NDFap showed differences ($P < 0.05$) only in feedlot animals. No difference was found ($P > 0.05$) for GRZ among grazing systems, regardless of the used management. Moreover, RUM, IDL, TFT, and TCT showed differences ($P < 0.05$) only in feedlot animals, and TRH was higher ($P < 0.05$) in animals receiving concentrate supplementation (Table 3).

The numbers of grazing periods (NGP) and rumination periods (NRP) were similar ($P > 0.05$) in grazing animals ($P > 0.05$), regardless of the management. Numbers of idle periods (NIP) and trough feeding periods (NTP) showed differences ($P < 0.05$) in animals receiving mineral supplementation if compared with those receiving concentrate. The number of bites per day and BTR were similar ($P > 0.05$) among the grazing systems (Table 4).

The feeding efficiencies of DM and NDFap and rumination efficiency of DM showed no difference ($P > 0.05$) in grazing animals but showed differences in feedlot animals. Rumination efficiency of NDFap also showed no difference ($P > 0.05$), regardless of the raising system (Table 5).

Discussion

Feedlot steers showed higher TDMI if compared with grazing animals; however, NDF intake was lower in the former system. This can be explained by the lower fibre content in the diet of these animals. Undoubtedly, TDMI is one of the most influencing factors on animal performance since it is the starting point for ingestion of nutrients, especially protein and energy, which are needed to meet the requirements for animal maintenance and production. According to Neves et al. (2018), concentrate feedstuffs are rich in starch, which is a highly fermentable substrate in the rumen. This polysaccharide produces large amounts of volatile fatty acids (VFAs), which in turn are responsible for increasing the energy used for animal maintenance and weight gain, then contributing to performance response.

The similarity in GRZ among grazing systems can be justified by the use of a single forage species and the pasture quality. This might have been influenced by diet composition since the diets offered to the grazing animals were similar in terms of roughage. Yet, the similarity in NGP among grazing animals may be due to the same forage TDMI and the low supplementation levels, reducing forage selectivity by animals. For Scaglia et al. (2009), the time spent grazing can be influenced by many factors such as pasture quality and quantity, as well as animal metabolism.

Feedlot steers had a RUM lower than grazing animals did. This is because the former group received a diet with lower fibre content and high proportions of non-fibrous carbohydrates. According to Van Soest (1994), the time spent ruminating is affected by diet type, wherein concentrate feedstuffs reduce RUM and highly fibrous roughages increase it.

Compared with grazing animals, feedlot animals showed higher IDL. It might be correlated to the diet composition in feedlot regimen, which caused satiety more quickly due to greater production and absorption of short-chain fatty acids in the rumen. Mendes et al. (2014) affirm that animals fed diets with high levels of concentrate tend to rest longer, whilst those fed diets with low levels or without concentrate supplementation spend more time grazing and ruminating. Steers supplemented with concentrate had higher TRH than did animals receiving only mineral supplementation. As animals were offered increasing amounts of feed, they remained longer in the trough to consume all the supplement. According to Santana Junior et al. (2013), the time spent at the trough for

Table 3 Nutrient intake, feeding time, rumination time, idle time and trough time, total feeding time (TFT), and total chewing time (TCT) of steers in grazing and feedlot systems

Nutritional management	MS	NS	CS1	CS2	C3	Mean	CV (%)	*P*
Variable								
Total DM (kg/day)	6.31b	6.42b	6.45b	6.59b	9.10a	6.97	18.33	< 0.0001
NDFap (kg/day)	4.11a	4.52a	4.07a	3.97a	1.54b	3.64	19.19	< 0.0001
Activity (min/day)								
Grazing	600.43a	555.64a	589.51a	561.00a	–	481.92	9.43	0.0571
Rumination	462.37a	489.87a	442.50a	435.00a	260.65b	390.96	45.36	< 0.0001
Idle	375.12b	389.37b	391.62b	425.75b	949.00a	537.91	44.48	< 0.0001
Trough	2.08d	5.10c	16.37b	18.25b	230.35a	9.47	27.37	< 0.0001
TFT	602.51a	560.74a	605.88a	579.25a	230.35b	485.80	9.33	< 0.0001
TCT	1064.88a	1050.61a	1048.38a	1014.25a	491.00b	873.74	22.24	< 0.0001

Means followed by the same letter in the row do not differ from each other by Tukey's test (> 0.05 probability)

MS mineral supplementation, *NS* nitrogen supplementation, *CS1* concentrate supplementation at 0.1% of body weight, *CS2* concentrate supplementation at 0.2% of body weight, *C3* feedlot

supplement intake shows a correlation with the amount of supplement offered to the animal.

Grazing animals presented higher TFT and TCT than feedlot animals did. This is because grazing animals need to spend longer times in feeding activities to meet their nutritional demands. On the contrary, feedlot animals, which consumed a low-fibre diet, spent less time ruminating and, hence, TCT was lower than that of grazing steers. Dulphy et al. (1980) stated that when the contents of cell wall constituents of diets decrease and starch contents increase, the time spent chewing decreases due to a resulting decline in dietary fibre contents. As the amount of concentrate in diets increases, TFT, and hence TCT, reduces (Mendes et al. 2014).

Concentrate supplementation promoted higher NIP in animals, which tend to spend most of the day resting. This fact was because these animals reach their nutritional requirements due to the higher content of nutrients in their diet. By way of contrast, animals supplemented with MS only tended to graze longer to achieve nutritional requirements, thus spending more time feeding and ruminating. Therefore, the animals fed concentrate had their energy requirements supplied faster, which allowed them to alternate between idle and trough feeding activities. In turn, these animals spent longer times biting and swallowing the supplement provided to them.

The similarity in the number of rumination periods (NRP) is related to the long length of such activity. As the fibre

Table 4 Means of number of discrete periods for ingestive behaviour of steers in grazing and feedlot systems, time spent grazing (GRZ) and number of grazing periods (NGP), idle periods (NIP), number of rumination periods (NRP), number of periods feeding at the trough (NTP), bite rate (BTR), and daily bites (NBD)

Nutritional management								
Variable	MS	NS	CS1	CS2	C3	Mean	CV (%)	*P*
NGP	15.5a	13.6a	15.0a	11.9a	–	14.00	20.44	0.1889
NIP	17.4b	17.6b	22.8a	21.6a	19.37a	18.95	17.26	0.0006
NRP	13.5a	14.7a	15.6a	15.9a	16.8a	15.3	13.19	0.2088
NTP	1.00b	2.00b	4.37a	5.00a	9.96a	4.46	23.34	< 0.0001
TGP	39.56a	41.49a	40.79a	50.79a	–	43.15	18.35	0.4001
BTR (n/s)	49.00a	48.70a	50.90a	52.00a	–	50.15	14.47	0.9895
NBD	29,159.0a	29,652.7a	29,192.9a	29,280.9a	–	24,189	13.47	0.4595

Means followed by the same letter in the row do not differ from each other by Tukey's test (> 0.05 probability)

MS mineral supplementation, *NS* nitrogen supplementation, *CS1* concentrate supplementation at 0.1% of body weight, *CS2* concentrate supplementation at 0.2% of body weight, *C3* feedlot

Table 5 Feed and rumination efficiencies of dry matter (DM) and neutral detergent fibre corrected for ash and protein (NDFap) of steers in grazing and feedlot systems

Nutritional management								
	MS	NS	CS1	CS2	C3	Mean	CV (%)	*P*
Variable								
DM	0.651b	0.709b	0.586b	0.601b	3.703a	1.401	21.55	< 0.0001
NDF	0.381b	0.413b	0.386b	0.382b	0.630a	0.514	32.98	< 0.0001
Rumination efficiency								
DM	0.852b	0.805b	0.804b	0.799b	2.727a	1.415	18.65	< 0.0001
NDF	0.56a	0.55a	0.56a	0.61a	0.59a	0.578	17.60	0.5206

Means followed by the same letter in the row do not differ from each other by Tukey's test (> 0.05 probability)

MS mineral supplementation, *NS* nitrogen supplementation, *CS1* concentrate supplementation at 0.1% of body weight, *CS2* concentrate supplementation at 0.2% of body weight, *C3* feedlot

content in the diet increased, NRP increased, reflecting the need to improve ruminal digestion and digestive efficiency.

The similar BTR values in grazing animals can be explained because this is a basic activity to obtain nutrients to meet their nutritional requirements. This outcome may be justified by the presence of a single forage species. In grazing animals, BTR and bite apprehension are related to forage canopy characteristics (Berchielli et al. 2011). The similar number of bites observed in grazing animals can be explained by the fact that these animals had no qualitative and quantitative limitations by selecting the most nutritive parts of forage, and in this case, the leaves were selected. The BTR is a measure able to estimate how easily forage is grazed, and, as per Hodgson (1985), bite weight is the most important variable to determine grazing animal intake, which is limited by forage structure.

The similarity in feed and rumination efficiencies of dry matter and NDFap among grazing systems may be due to the TDMI of animals within 24 h. Ingestion and rumination efficiencies of DM and NDF are influenced by the type of roughage. However, the differences found in feedlot animals can be explained by the fact that the diets containing lower NDF contents increase DM intake (in kg per animal) and decrease feeding time, which indicates better feeding efficiency. For Nicory et al. (2015), rumination efficiency is an important mechanism to evaluate low-digestibility feeds. Feed and rumination efficiencies of DM and NDF are determined from total feeding and rumination times, respectively, as well as their respective daily intake quantities (in kg/day).

Van Soest (1994) points out that feed efficiency is related to changes in dietary fibre components. Moreover, Silva et al. (2005) assert that feed efficiency can be affected by significant changes in dietary NDF levels, whereas rumination efficiency depends on DM content in diets. For Dulphy et al. (1980), the addition of concentrate to the total diet reduces NDF intake and increases rumination efficiency. When evaluating the ingestive behaviour in calves fed diets containing different levels of concentrate, Bürger et al. (2000) observed that rumination efficiency tends to increase linearly with concentrate inclusion in the diet.

Conclusion

In short, behavioural activities, diet types, and raising systems influence animal performance, which justifies the importance of studying such parameters. Feedlot animals performed better compared with grazing animals, which is due to their longer idle periods. Despite the relevance, there is still a need for more studies on the technical and biological implications of these observations.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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