ORIGINAL ARTICLE

Feeding behavior of beef cattle fed different forages and housed in individual or collective pens

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Abstract The understanding of feeding behavior may be useful to evaluate the performance of animals fed different diets. Twenty-four non-castrated Red Norte × Nelore males with an average initial body weight of 439.8 ± 59.6 kg and 21.7 ± 2.7 months of age were distributed in three experimental groups, and housed in individual (twelve animals) or collective pens (twelve animals in three collective pens) at the Dairy and Beef Research and Education Center of the Instituto Federal Goiano (Iporá Campus). The experiment lasted 84 days (14 of adaptation and 70 days for data collection). Animals were fed diets containing sugar cane in natura (CI), sugar cane silage (SCS) or corn silage (CS) as sources of forage. Feeding behavior was determined every 14 days for one-hour intervals beginning at 0, 1, 5, and 9 hours post-feeding. Eating, resting and rumination activities were monitored for three-minute intervals through visual observations from individual animals. Time spent with eating was greater ($P<0.05$) for CS (21.8 ± 1.2 minutes/hour) and time spent with resting was greater ($P<0.05$) for CI and SCS (38.8 and 36.5 ± 1.5 minutes/hour, respectively). Animals housed individually increased ($P<0.05$) time spent with both eating (19.7 ± 1.0 minutes/hour) and rumination (8.2 ± 0.6 minutes/hour), while time spent with resting was greater ($P<0.05$) for the collective pen-housing (38.9±1.2 minutes/hour). Corn silage can be recommended for beef cattle feeding in feedlot system due to an increased time spent with eating.

Keywords: corn silage, eating, resting, rumination, sugar cane

Introduction

The study of animal behavior has been viewed as an attempt to look at the entire production system, including the individual animal's activities in its social and physical environment. The objective of studying animal behavior is to better understanding the reasons underlying animal actions, and thereby to design more efficient production systems (Stricklin and Kautz-Scanavy 1984).

Some studies have reported that beef cattle in a feedlot system spend from one to six hours/day eating, while time spent eating in grazing animals ranges from four to twelve hours/day (Bürger et al 2000). This shift in the eating activity suggests that ruminants are able to modify their feeding behavior according to different feeding strategies in order to obtain a certain level of intake that is compatible with their nutritional requirements (Forbes 2003).

The time spent eating has been reported to be positively correlated with dry matter intake (DMI) and negatively correlated with the neutral detergent fiber (NDF) concentration of the diet (Mertens 1987). Furthermore, cattle fed fibrous feeds increase the time spent ruminating and consequently the ruminal digestion of the diet is increased, mainly to expose the potentially digestible NDF to the rumen environment due to the reduced particle size shortly after rumination occurs.

Overall, feed intake, feeding rate, number of meals, meal duration, and time spent with eating, ruminating and resting are patterns that change according to the characteristics of the diet, such as source of forage, nutrient composition, physical properties and palatability of feeds (Deswysen et al 1993; Fischer et al 1997, 1998). Therefore accurate measurements of the effects of dietary manipulation (e.g. source of forage) on feeding behavior are necessary to correctly interpret beef cattle performance in a feedlot through frequent observations that can detect even the most rapid fluctuation on animal behavior (Dado and Allen 1993).

The objective of this study was to determine the effects of feeding in natura sugar cane (ISC), sugar cane silage (SCS) or corn silage (CS) on the feeding behavior of 24 non-castrated Red Norte × Nelore males in a feedlot system housed in individual or collective pens. The authors tested the hypothesis that sources of forage (ISC, SCS or CS)

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and housing type (individual or collective pens) may influence the activities of eating, rumination and resting.

Materials and Methods

The present experiment was conducted at the Dairy and Beef Research and Education Center of the Instituto Federal Goiano, Iporá, Goiás State, Brazil, from June 30 through September 22 of 2014. The experiment lasted 84 days, with 14 days of adaptation of the animals for the new facilities and experimental diets, and 70 days for data collection. Twenty-four non-castrated Red Norte × Nelore males with initial body weight of 439.8 ± 26.2 kg and 21.7 ± 2.7 months of age were used in this study.

Upon arrival on June 30, animals were treated against ectoparasites with an oral dosage of 10% Fenbendazol and also treated against endoparasites with 5% Cypermetrin, 2.5% Chlorpyrifos and 1% Piperonyl butoxide alongside the backbone. After those applications, animals were ranked for body weight, distributed in three experimental groups according to the source of forage (ISC, SCS or CS), and housed either in individual (twelve animals) or collective pens (twelve animals in three collective pens). Individual pens measured two meters wide by five meters long (10 m²/animal) with provision of shade by a zinc roof of 5 m², whereas collective pens measured five meters wide by 10 meters long (12.5 m²/animal) with no provision of shade. The volumetric capacity of feeders in the individual and collective pens was 0.35 and 1.05 m³, respectively. The length of the feed bunk in each collective pen was 3.8 meters, allowing 0.95 m/animal.

The animals were fed once daily between 05:00 to 07:00 am in amounts that ensured ad libitum intake (10 to 15% of orts). The ingredients of the experimental diets were ISC, SCS or CS as forage sources, disintegrated corncob, ground corn, soybean meal, urea, and mineral/vitamin premix (Table 1). A bacterial inoculant (Lactobacillus plantarum, strains CH6072 and L286) was added (2 g of the commercial product/ton of fresh matter) when sugar cane was ensilaged to reduce ethanol production during the fermentation process (Zopollatto et al 2009).

Table 1 Ingredients and nutritional composition of the experimental diets[a]

Ingredients. % of DM	ISC	SCS	CS
In natura sugar cane (ISC)	22.0	-	-
Sugar cane silage (SCS)	-	22.0	-
Corn silage (SC)	-	-	32.0
Disintegrated corncob	24.0	24.0	26.0
Ground corn	40.5	40.5	29.5
Soybean meal	10.0	10.0	9.0
Urea[b]	1.0	1.0	1.0
Mineral/vitamin premix[c]	2.5	2.5	2.5
Nutritional composition			
DM, %	67.60 ± 3.28	63.88 ± 1.71	57.20 ± 1.97
CP[d], % of DM	13.46 ± 1.06	14.75 ± 0.87	13.86 ± 0.33
NDF[e], % of DM	38.71 ± 2.43	38.77 ± 2.88	39.98 ± 2.32
ADF[f], % of DM	12.33 ± 1.19	12.29 ± 1.44	12.64 ± 1.79
Cellulose[g], % of DM	2.93 ± 0.44	1.66 ± 0.25	2.10 ± 0.51
Hemicellulose[h], % of DM	26.38 ± 1.65	26.49 ± 1.94	27.35 ± 1.79
Lignin, % of DM	9.40 ± 0.86	10.63 ± 1.27	10.47 ± 2.12
Ash, % of DM	4.94 ± 0.65	5.15 ± 0.66	6.11 ± 0.55

[a]Mean analysis of composite samples (n = 5) and associated standard deviations of the experimental diets; [b]256,25% protein equivalent; [c]18% Ca, 20 g/kg P, 17g/kg Mg, 26.7g/kg S, 66.7 g/kg Na, 25.2 mg/kg Co, 416 mg/kg Cu, 490 mg/kg Fe, 25.2 mg/kg I, 832 mg/kg Mn, 7 mg/kg Se, 2,000 mg/kg Zn, 833.5 mg/kg Monenzin, 83,200 IU/kg vitamin A, 10,400 IU/kg vitamin D, 240 IU/kg vitamin E; [d]Crude protein; [e]Neutral detergent fiber; [f]Acid detergent fiber; [g]Cellulose = ADF - lignin; [h]Hemicellulose = NDF – ADF.

The experimental diets were formulated to contain similar levels of NDF and crude protein (CP), and balanced to meet the NRC (2000) guidelines for beef cattle in a feedlot system with an expected weight gain of 1.8 kg/day. All experimental protocols were approved by the IF Goiano Ethical Committee in the Use of Animals (decision # 1/2014).

Samples of ISC, SCS and CS were collected weekly and dried in a forced-air oven for 72 hours at 65ºC for dry matter (DM) analysis (AOAC 2000) with the objective to maintain the nutritional value of the diets constant throughout the entire experiment. After the end of the research, samples of forages were ground using a Willey mill to pass a 1-mm screen, and analyzed for CP, ash (AOAC 2000), and NDF (Goering and Van Soest 1970). NDF residues were sequentially analyzed for acid detergent fiber (ADF) and lignin (Goering and Van Soest 1970). Cellulose concentration was determined by difference between ADF minus lignin, and hemicellulose concentration was calculated by difference between NDF minus ADF (Table 2).

Table 2 Nutritional composition of sources of forage[a]

Item	ISC[g]	SCS[h]	CS[i]
DM, %	33.38 ± 3.06	29.06 ± 1.86	32.07 ± 1.90
CP[b], % of DM	1.20 ± 0.15	1.81 ± 0.19	6.31 ± 0.51
NDF[c], % of DM	59.24 ± 3.45	61.19 ± 6.53	56.78 ± 2.12
ADF[d], % of DM	32.45 ± 2.00	34.17 ± 3.93	27.95 ± 1.70
Celullose[e], % of DM	20.42 ± 2.42	21.89 ± 3.50	13.06 ± 1.90
Hemicellulose[f], % of DM	26.80 ± 1.58	27.02 ± 2.82	28.83 ± 1.18
Lignin, % of DM	12.03 ± 1.30	12.22 ± 1.61	14.87 ± 2.01
Ash, % of DM	1.92 ± 0.29	3.86 ± 1.19	6.82 ± 1.47

Mean analysis of samples (n = 10) and associated standard deviations of sources of forage; [b]Crude protein; [c]Neutral detergent fiber; [d]Acid detergent fiber; [e]Cellulose = ADF - lignin; [f]Hemicellulose = NDF - ADF; [g]*In natura* sugar cane; [h]Sugar cane silage; [i]Corn silage.

Samples of diets were collected every two weeks and stored frozen at -4ºC. Soon after the of the experiment, samples were thawed at room temperature, merged to form one composite sample of each treatment/14 days, and dried in a forced-air oven for 72 hours at 65ºC for dry matter (DM) analysis (AOAC 2000). Subsequently, samples of diets were ground using a Willey mill to pass a 1-mm screen, and analyzed for CP, ash (AOAC 2000), and NDF (Goering and Van Soest 1970). NDF residues were sequentially analyzed for acid detergent fiber (ADF) and lignin (Goering and Van Soest 1970). Cellulose concentration was determined by difference between ADF minus lignin, and hemicellulose concentration was calculated by difference between NDF minus ADF (Table 1).

Feeding behavior was determined every 14 days after the beginning of the experiment for one-hour intervals beginning at feed delivery, one, five, and nine hours post-feeding. Eating, rumination, and resting activities were monitored for three-minute intervals through visual observations from individual animals (Martin and Bateson 2007).

An ethogram (Carvalho et al 2014) was developed to determine a time budget for eating, resting, and rumination of the animals (the latter two activities both standing and lying). Eating was defined as obtaining or manipulating feed, chewing feed with thhe head in the feed bunk, or chewing feed with the head away from the feed bunk. The end of an eating bout was defined as the cessation, for more than three minutes, of the feeding behaviors described above.

Rumination was defined as manipulating a cud with repetitive jaw movements (clockwise or anticlockwise direction) that were not categorized as eating based on the description above. The end of a rumination bout was defined as the cessation, for more than three minutes, of the feeding behaviors described above.

Resting was defined as inactivity, and was terminated with the initiation of either an eating or a rumination bout. The characterization of the feeding behaviors described above was utilized to calculate the total time spent with eating, rumination and resting activities.

The experimental design utilized was a completely randomized in a factorial scheme 3 × 2 (three sources of forage and two types of housing). The data were analyze using the open system “R” (R Core Team 2014) in a double repeated mixed model measurements in time, considering forage source and housing type as fixed effects, and animal as random. The model accounted for the effects of forage source (f), housing type (h), days of evaluation (d), hours post-feeding (t), forage source × days of evaluation, forage source × hours post-feeding, forage source × days of evaluation × hours post-feeding, housing type × days of evaluation, housing type × hours post-feeding, housing type × days of evaluation × hours post-feeding, forage source × housing type, forage source × housing × days of evaluation, forage source × housing type × hours post-feeding, days of evaluation × hours post-feeding, and forage source × housing type × days of evaluation × hours post-feeding, according to the following equation:

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$$Y_{ijklm} = \mu + f_i + h_j + d_k + t_l + fd_{ik} + ft_{il} + fdt_{ikl} + hd_{jk} + ht_{jl} + hdt_{jkl} + fh_{ij} + fhd_{ijk} + fht_{ijl} + dt_{kl} + fhdt_{ijkl} + e_{ijklm};$$

where Y = independent variable, μ = mean, and e = experimental error.

When a fixed effect was significant (P≤0.05), means were compared using the Tukey test. Values are reported as least square means and associated standard errors of means (SEM).

Results and Discussion

Eating (Table 3) and resting (Table 4) activities were influenced (P<0.05) by sources of forage. Animals fed CS increased (P<0.05) time spent eating (21.8 ± 1.2 minutes/hour) compared with animals fed ISC (15.0 ± 1.2 minutes/hour) or SCS (16.2 ± 1.2 minutes/hour) (Table 3). Contrarily, there was an increase (P<0.05) in time spent resting in animals fed ISC (38.8 ± 1.5 minutes/hour) or SCS (36.5 ± 1.5 minutes/hour), in comparison with animals fed CS (31.2 ± 1.5 minutes/hour) (Table 4). There was no response (P>0.05) of source of forage on the rumination activity (Table 5).

A meal duration or time spent eating may be affected by the animal appetite, energy level and NDF concentration of the diet, NDF ruminal repletion, and digestibility and passage rate of the diet ingredients, however, all these variables are influenced by the forage-to-concentrate ratio (Harvatine et al 2002; Lima et al 2014). Increasing levels of forage-to-concentrate ratio resulted in more time spent with eating and rumination and less time spent with resting (Gonçalves et al 2001). Nevertheless, this is only possible when the NDF concentration of the diet and/or the proportion of forages with low potentially digestible NDF are not able to alter the DMI through the NDF ruminal repletion effect, and consequently there will be no reduction in time spent with eating (Oliveira et al 2011).

In the present work the experimental diets were formulated to contain equivalent amounts of NDF and CP, which meant a higher inclusion of CS and lower proportion of both ISC and SCS due to the variation of the nutritional composition of forages (Table 2). Thus, the differences in the forage-to-concentrate ratio of the diets in the preset study may elucidate the increased (P<0.05) time spent with eating for animals fed CS (Table 3). However, this increase (P<0.05) was not accompanied by an increased feed intake and growth performance (Custodio et al 2015).

There was a forage source × days of evaluation (Figure 1a) and forage source × hours post-feeding (Figure 1b) effect (P<0.05) on time spent eating. Animals fed CS remained more time (P<0.05) eating at 56 (22.1 ± 1.9 minutes/hour) and 70 (24.1 ± 1.6 minutes/hour) days after the beginning of the experiment, compared with animals fed ISC or SCS (Figure 1a). When the data were collapsed across source of forage × hours post-feeding (Figure 1b), animals fed CS increased (P<0.05) time spent eating between 0-1 (44.7 ± 1.8 minutes/hour) and 1-2 (22.4 ± 1.8 minutes/hour) hours relative to feed delivery.

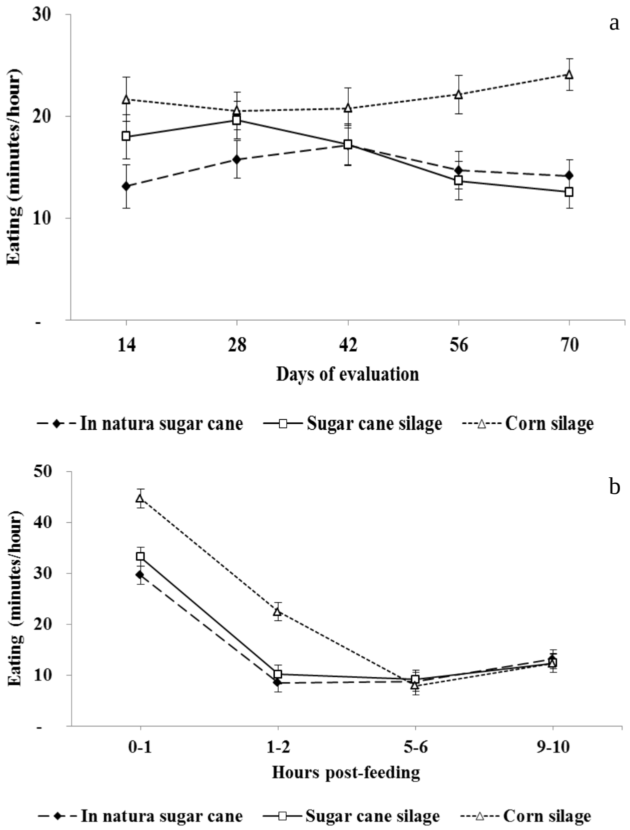

Figure 1 Effect of source of forage × days of evaluation (a) and source of forage × hours post-feeding (b) on time spent eating of 24 non-castrated Red Norte × Nelore males.

Regardless the source of forage, time spent with eating was increased (P<0.05) within the first hour after feed delivery (Table 3 and Figure 1b), which is in agreement with previous studies with dairy cows (Bhandari et al 2008; Carvalho et al 2014).

There was no effect (P>0.05) of source of forage on time spent with rumination (Table 5), however, there was a source of forage × hours post-feeding effect (P<0.05) on rumination activity (Figure 2). Due to an increased (P<0.05) time spent eating for animals fed CS during the first two hours after feed delivery (Figure 1b), animals fed CS remained less time (P<0.05) ruminating between 1-2 hours post-feeding (1.0 ± 1.3 minutes/hour), in comparison with animals fed ISC and SCS (5.2 and 4.9 ± 1.3 minutes/hour, respectively) (Figure 2). This delay was subsequently compensated by an increase (P<0.05) in time spent with rumination for animals fed CS between 5-6 hours post-feeding (18.5 ± 1.3 minutes/hour), compared with animals fed ISC or SCS (13.5 and 15.0 ± 1.3 minutes/hour, respectively) (Figure 2).

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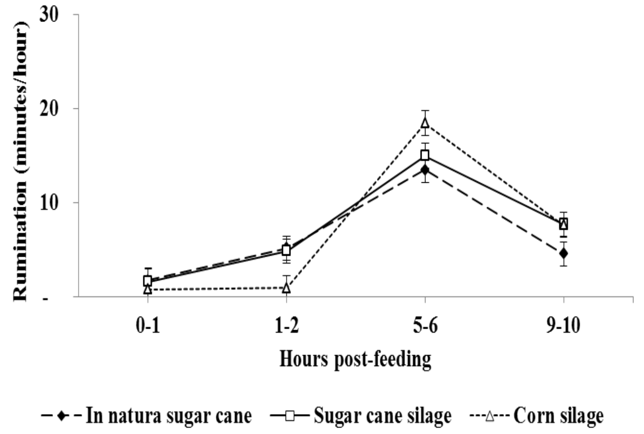

Figure 2 Effect of forage source × hours post-feeding on time spent with rumination of 24 non-castrated Red Norte × Nelore males.

There was an effect (P<0.05) of type of housing on the eating, resting and rumination activities (Tables 3, 4, and 5, respectively). Animals housed in the individual pens spent more time (P<0.05) eating (19.7 ± 1.0 minutes/hour) in comparison with animals housed in collective pens (15.7 ± 1.0 minutes/hour) (Table 3). Through the type of housing × hours post-feeding interaction it was possible to detect that this increase (P<0.05) occurred between 0-1 and 1-2 hours relative to feed delivery (Figure 3a).

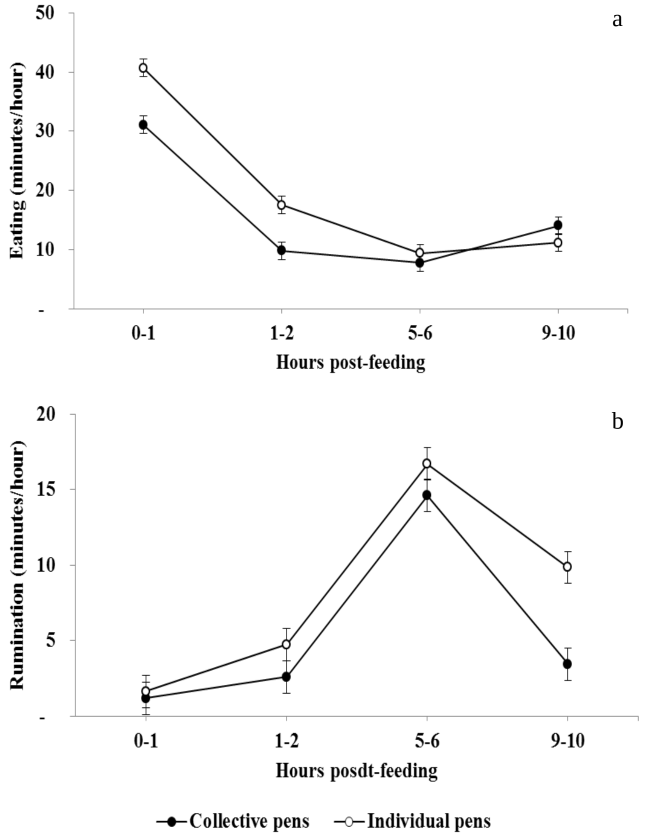

Figure 3 Effect of housing type × hours post-feeding on time spent eating (a) e ruminating (b) of 24 non-castrated Red Norte × Nelore males.

Likewise with the eating activity, time spent ruminating was greater (P<0.05) in individual pens (8.2 ± 0.6 minutes/hour) compared with collective pens (5.5 ± 0.6 minutes/hour) (Table 5). Such increase (P<0.05) happened between 9-10 hours post-feeding, as demonstrated by the type of housing × hours post-feeding interaction (Figure 3b).

The time spent with resting was greater (P<0.05) for animals housed in collective pens (38.9 ± 1.2 minutes/hour) compared with individual housing (32.1 ± 1.2 minutes/hour) (Table 4). The type of housing × hours post-feeding interaction (Figure 4) demonstrates that the increase (P<0.05) in time spent resting in animas housed collectively occurred during the first two hours after feed delivery, suggesting that social hierarchy among animals within the same pen may have been the possible reason for this effect, which has been previously reported with dairy cows (Hosseinkhani et al 2008; Olofsson 1999).

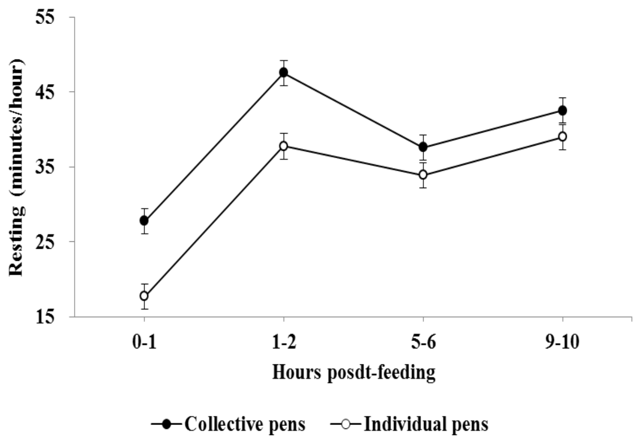

Figure 4 Effect of housing type × hours post-feeding on time spent resting of 24 non-castrated Red Norte × Nelore males.

Obviously there is no intention here to recommend individual pens in commercial feedlots, but the adoption of shade in collective pens (Sullivan et al 2011) and increased feed delivery frequency, in conjunction with already known animal-welfare measures, such as the correct area/animal in each pen, homogeneous groups of animals, and adequate feed bunk space may mitigate the effect of the social hierarchy between animals and competition for the feed, aiming for a potential increase in growth performance of beef cattle in feedlot systems.

Conclusions

Animals fed CS spent more time eating as opposed to animals fed ISC and SCS, which spent more time resting. Nevertheless, all three sources of forage did not alter animal performance, therefore CS, ISC and SCS can be recommended for beef cattle feeding in feedlot systems.

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Table 3 Effect of sources of forage and type of housing on eating activity

Item	Forage	Days[4]	Hours post-feeding				SEM[5]	P					
			0-1	1-2	5-6	9-10		Forage	Days	Hours[6]	Forage × days	Forage × hours	Forage × days × hours
Eating (minutes/hour)	ISC[1]	14	22.1b	11.3b	12.0b	7.1b	3.9	<0.05	0.47	<0.05	<0.05	<0.05	0.86
	SCS[2]		37.5b	17.3b	8.6b	8.6b							
	CS[3]		46.1a	27.0a	5.6a	7.9a							
	ISC	28	37.5b	6.0b	8.6b	10.9b	3.4						
	SCS		36.4b	16.5b	13.1b	12.4b							
	CS		45.4a	19.5a	8.6a	8.6a							
	ISC	42	35.6b	12.0b	4.1b	16.9b	3.8						
	SCS		35.6b	8.6b	7.9b	16.9b							
	CS		48.4a	19.5a	4.5a	10.9a							
	ISC	56	26.6b	7.1b	10.5b	14.6b	3.3						
	SCS		30.4b	6.4b	5.6b	12.4b							
	CS		42.4a	21.0a	7.9a	17.3a							
	ISC	70	26.3b	6.0b	8.3b	16.1b	3.2						
	SCS		26.3b	1.9b	10.5b	11.6b							
	CS		41.3a	25.1a	13.1a	16.9a							
Item	Housing	Days	Hours post-feeding				SEM	P					
			0-1	1-2	5-6	9-10		Housing	Days	Hours	Housing × days	Housing × hours	Housing × days × hours
Eating (minutes/hour)	Individual	14	37.8a	26.8a	11.7a	5.7a	3.2	<0.05	0.47	<0.05	0.10	<0.05	<0.05
	Collective		32.8b	10.3b	5.7b	10.0b							
	Individual	28	47.8a	16.8a	7.5a	4.5a	2.7						
	Collective		31.8b	11.3b	12.7b	16.7b							
	Individual	42	43.8a	12.5a	5.7a	14.5a	3.1						
	Collective		36.0b	14.3b	5.3b	15.3b							
	Individual	56	37.5a	16.5a	9.5a	17.8a	2.7						
	Collective		28.8b	6.5b	6.5b	11.7b							
	Individual	70	36.5a	15.0a	12.5a	13.3a	2.6						
	Collective		26.0b	7.0b	8.9b	16.5b							

[1]In natura sugar cane; [2]Sugar cane silage; [3]Corn silage; [4]Days of evaluation (14, 28, 42, 56, and 70); [5]Standard error of means; [6]Hours post-feeding (0-1, 1-2, 5-6, 9-10); a, b: different letters in the same column indicate statistical difference (P≤0.05) by Tukey test

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Table 4 Effect of sources of forage and type of housing on resting activity

Item	Forage	Days[4]	Hours post-feeding				SEM[5]	P					
			0-1	1-2	5-6	9-10		Forage	Days	Hours[6]	Forage × days	Forage × hours	Forage × days × hours
Resting (minutes/hour)	ISC[1]		33.4a	46.1a	31.1a	43.5a							
	SCS[2]	14	21.0a	40.5a	31.1a	45.0a	4.0						
	CS[3]		13.9b	33.0b	35.3b	40.5b							
	ISC		22.5a	48.4a	35.3a	44.6a							
	SCS	28	23.6a	39.8a	27.8a	40.9a	3.6						
	CS		14.6b	40.5b	32.3b	36.4b							
	ISC		20.6a	43.1a	42.0a	39.4a							
	SCS	42	23.6a	46.1a	38.6a	37.9a	4.4	<0.05	0.06	<0.05	0.19	<0.05	0.43
	CS		11.3b	40.1b	36.0b	43.5b							
	ISC		32.6a	47.6a	36.4a	41.3a							
	SCS	56	27.4a	43.1a	36.8a	38.3a	3.9						
	CS		16.5b	37.1b	32.3b	39.8b							
	ISC		33.8a	46.5a	44.3a	42.8a							
	SCS	70	30.0a	55.5a	45.0a	37.5a	3.7						
	CS		16.1b	32.3b	32.3b	40.1b							

Item	Housing	Days	Hours post-feeding				SEM	P					
			0-1	1-2	5-6	9-10		Housing	Days	Hours	Housing × days	Housing × hours	Housing × days × hours
Resting (minutes/hour)	Individual	14	18.3b	30.0b	34.3b	44.0b	3.2						
	Collective		27.3a	49.8a	30.8a	42.0a							
	Individual	28	12.3b	41.5b	25.5b	39.8b	3.0						
	Collective		28.3a	44.3a	38.0a	41.5a							
	Individual	42	13.8b	43.0b	36.0b	36.8b	3.6	<0.05	0.06	<0.05	0.38	<0.05	<0.05
	Collective		23.3a	43.3a	41.8a	43.8a							
	Individual	56	21.0b	34.3b	35.0b	33.5b	3.2						
	Collective		30.0a	51.0a	35.3a	46.0a							
	Individual	70	23.3b	40.0b	38.8b	41.0b	3.0						
	Collective		30.0a	49.5a	42.3a	39.3a							

[1]In natura sugar cane; [2]Sugar cane silage; [3]Corn silage; [4]Days of evaluation (14, 28, 42, 56, and 70); [5]Standard error of means; [6]Hours post-feeding (0-1, 1-2, 5-6, 9-10); a, b: different letters in the same column indicate statistical difference (P≤0.05) by Tukey test

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Table 5 Effect of source of forage and type of housing on rumination activity

Item	Forage	Days[4]	Hours post-feeding				SEM[5]	P					
			0-1	1-2	5-6	9-10		Forage	Days	Hours[6]	Forage × days	Forage × hours	Forage × days × hours
Rumination (minutes/hour)	ISC[1]	14	4.5	2.6	16.9	9.4	3.0	0.60	0.12	<0.05	0.78	<0.05	0.48
	SCS[2]		1.5	2.3	20.3	6.4							
	CS[3]		0.0	0.0	19.1	11.6							
	ISC	28	0.0	5.6	16.1	4.5	2.1						
	SCS		2.0	3.4	19.1	6.8							
	CS		2.1	0.0	19.1	15.0							
	ISC	42	3.8	4.9	13.9	3.8	2.6						
	SCS		0.8	5.3	13.5	5.3							
	CS		0.4	0.4	19.5	5.6							
	ISC	56	0.8	5.3	13.1	4.1	3.1						
	SCS		2.3	10.5	17.6	9.4							
	CS		1.1	1.9	19.9	3.0							
	ISC	70	0.0	7.5	7.5	1.1	3.1						
	SCS		3.4	2.6	4.5	10.9							
	CS		2.6	2.6	14.6	3.0							
Item	**Housing**	**Days**	**Hours post-feeding**				**SEM**	**P**					
			0-1	1-2	5-6	9-10		Housing	Days	Hours	Housing × days	Housing × hours	Housing × days × hours
Rumination (minutes/hour)	Individual	14	4.0a	3.3a	14.0a	10.3a	2.5	<0.05	0.12	<0.05	<0.05	<0.05	<0.05
	Collective		1.8b	0.0b	23.5b	8.0b							
	Individual	28	1.1a	1.8a	27.0a	15.8a	1.8						
	Collective		1.8b	4.5b	9.3b	1.8b							
	Individual	42	2.5a	4.5a	18.3a	8.8a	2.2						
	Collective		0.8b	2.5b	13.0b	1.0b							
	Individual	56	1.5a	9.3a	15.5a	8.8a	2.5						
	Collective		1.3b	2.5b	18.3b	2.3b							
	Individual	70	0.3a	5.0a	8.8a	5.8a	2.5						
	Collective		4.0b	3.5b	9.0b	4.3b							

[1]In natura sugar cane; [2]Sugar cane silage; [3]Corn silage; [4]Days of evaluation (14, 28, 42, 56, and 70); [5]Standard error of means; [6]Hours post-feeding (0-1, 1-2, 5-6, 9-10); a, b: different letters in the same column indicate statistical difference (P≤0.05) by Tukey test

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More research with beef cattle housed in individual or collective pens under different conditions is needed in order to corroborate the data presented here on eating, rumination and resting activities.

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