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Ingestive behavior of feedlot-finished steers submitted to energy supply patterns

Comportamento ingestivo de novilhos terminados em confinamento submetidos a padrões de fornecimento de energia

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Abstract

This study aimed to verify the effects of supplying different energy patterns on ingestive behavior of feedlot-finished cattle. Twenty-seven pure and crossbred Charolais or Nellore steers with an initial average age and weight of 22 months and 252.8 kg, respectively, were used. Three treatments were carried out, two of them with an increasing rate of concentrate in the diet during the finishing period (IT5 and IT10) and one with constant roughage to concentrate ratio (CT). The experimental design was a completely randomized design with three treatments, five periods, and nine replications. Feeding time was higher for CT (4.31 hours) when compared to IT5 (3.85 hours). Steers from the treatment IT10 remained longer in lying leisure (8.14 hours) when compared to the treatment CT (7.24 hours). A superiority of chewing per ruminated bolus was observed in IT10 (58.59 seconds) when compared to IT5 (54.11 seconds) whereas a higher number of ruminated bolus was observed in TC5 (534.68 ruminated bolus day^{-1}) when compared to IT10 (473.77 ruminated bolus day^{-1}). Animals from CT presented a higher dry matter intake (9.54 kg day^{-1}) than those from IT10 (8.63 kg day^{-1}). Steers from CT and IT5 showed a higher NDF intake (3.63 and 3.58 kg NDF day^{-1}, respectively) when compared to IT10 (3.29 kg NDF day^{-1}). The constant energy pattern increases feeding time and dry matter intake. The one of less vigorous growth increases the number of bolus ruminated per day, while the one of more vigorous growth increases idle time and chews per bolus and decreases the intake of neutral detergent fiber.
Key words: Concentrate. Immunocastration. Resources. Roughage. Variation.

Resumo

O objetivo foi verificar os efeitos do fornecimento de diferentes padrões de energia no comportamento ingestivo de bovinos terminados em confinamento. Foram utilizados 27 novilhos, puros e cruzados das raças Charolês ou Nelore com idade e peso médios iniciais respectivos de 22 meses e 252,8 kg. Utilizaram-se três tratamentos, sendo dois com taxa crescente da participação do concentrado ao longo

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do período de terminação (TC5 e TC10) e um com relação volumoso:concentrado constante (TC). O delineamento experimental foi o inteiramente casualizado, com três tratamentos, cinco períodos e nove repetições. O tempo de alimentação foi maior para o TC (4,31 horas) em relação ao TC5 (3,85 horas). Os novilhos do tratamento TC10 permaneceram mais tempo em ócio deitado (8,14 horas) em relação aos do tratamento TC (7,24 horas). Houve superioridade do tempo de mastigadas por bolo ruminado do TC10 (58,59 segundos) em relação ao TC5 (54,11 segundos) e maior número de bolos ruminados do TC5 (534,68 bolos ruminados por dia) em relação ao TC10 (473,77 bolos ruminados por dia). O TC apresentou maior consumo de matéria seca (9,54 kg dia-1) que o TC10 (8,63 Kg dia-1). O TC e TC5 demonstraram maiores consumos de FDN (3,63 e 3,58 kg de FDN dia-1, respectivamente) que o TC10 (3,29 kg de FDN dia-1). O padrão constante de energia aumenta o tempo de alimentação e consumo de matéria seca, o de crescimento menos acentuado aumenta o número de bolos ruminados por dia, enquanto o crescimento mais acentuado aumenta os tempos de ócio deitado e mastigadas por bolo e diminui o consumo de fibra em detergente neutro.

Palavras-chave: Concentrado. Imunocastração. Recursos. Variação. Volumoso.

Introduction

The study of ingestive behavior is an important tool for the evaluation of ruminant feed management and diet, allowing to understand if they are adequate and will cause no changes in productive performance. Often, with the increase of grain prices and the reduction of live cattle prices, there is a need to look for alternative feeding practices that can be used by producers to reduce feed costs (PEEL, 2011), and aligned with an adequate diet can contribute to the cost-effectiveness of the operation.

The daily activities of confined ruminants are characterized by three basic behaviors: feeding, rumination, and idle time. Food ingestion periods are interspersed with rumination or idle time (PAZDIORA et al., 2011). However, the behavior may be modified due to the type of feed (BÜRGER et al., 2000).

Dry matter intake can affect animal performance, influencing the total amount of nutrients the animal receives for growth and productive performance. The utilization ratio of volumes and concentrates directly affects animal feed intake in the confinement phase (ARRIGONI et al., 2013), and may cause variations. Thus, the study of animal ingestive behavior brings the possibility to evaluate the effects of feed quantity and composition, to establish the relation between ingestive behavior and voluntary intake, and to investigate the potential use of the knowledge on ingestive behavior to improve animal performance (LIMA et al., 2003).

Therefore, adequate feed management is fundamental to the success of animal production, which seeks to adjust nutritional intake to animal requirements (RIBEIRO et al., 2011). Consequantly, the study of different feeding strategies, through the manipulation of the volume: concentrate ratio along animal finishing becomes important. It allows to manipulate the diet, offering higher energy level at the finishing period, without changing the total inputs provided.

Thus, the objective was to study the ingestive behavior of steers submitted to diets with different energy supply patterns throughout the animals' finishing, since there are few studies about this subject in the literature.

Material and Methods

The Ethics Committee on the Use of Animals of the Federal University of Santa Maria (UFSM) approved this research, under the protocol nº 5813030715.

The experiment was carried out at the Cattle Breeding Laboratory of the Department of Animal Science of the Federal University of Santa Maria, municipality of Santa Maria, located in the Central Depression of the State of Rio Grande do Sul, at an average altitude of 95 m, with 29° 43' south latitude and 53° 42' west longitude. The climate of the region is the "Cfa" (humid subtropical), as classified by Köppen (ALVARES et al., 2013).

Twenty-seven pure-bred steers of the Charolais and Nellore breeds were used, and also animals from the crossing of these two breeds. Their respective initial mean ages and weights were of 22 ± 2 months and 252.8 ± 34.91 kg, and they belonged to the experimental stock of the Cattle Breeding Laboratory of UFSM. The steers were balanced so that each treatment contained the same number of pure and crossed Charolais x Nellore animals.

Three treatments were used, two of them denominated according to the increasing rate of the volume: concentrate ratio, and the other one with constant ratio. The increasing treatments were stipulated in such a way that, on average, the volume: concentrate ratio was the same as that of the constant treatment and consequently, using the same feeding resources - the diet of the increasing treatments - were manipulated as a variation of the control diet of the constant treatment, and which presented, on average, the same chemical composition and volume: concentrated ratio, which is:

Constant Treatment (CT) - volume:concentrate ratio 60:40 in all periods.

Increasing Treatment 5 (IT5) - volume:concentrate ratio 70:30 at the beginning of the experiment, with the removal of 5 parts of the volume and addition of 5 parts of the concentrate at each 21-day period, ending the experimental period with volume:concentrate ratio 50:50. Mean overall ratio 60:40.

Increasing Treatment 10 (IT10) - volume:concentrate ratio 80:20 at the beginning of the experiment, with the removal of 10 parts of volume and addition of 10 parts of the concentrate at each 21-day period, ending the experimental period with volume:concentrate ratio 40:60. Mean overall ratio 60:40.

The constant diet was formulated based on the NRC (1996) to meet animal nutritional requirements, with crude protein level of 13%, estimating a dry matter intake of 2.5 kg 100 kg^{-1} live weight, and increasing diets were manipulated from this.

Table 1 shows the proportions and nutritional compositions of the experimental diets. The volume used was corn silage, and the concentrate fraction was formulated for all treatments with ground corn, soybean meal, calcitic lime and common salt.

Animal finishing was carried out in confinement covered with boxes of 9,5 m^2, paved, provided with feeders for food supply and drinkers with water at will, regulated with faucet. Treatments were randomly assigned, with one steer in each box. Prior to the experimental period, animals were adapted to the facilities and diets for 14 days. The control of endo and ectoparasites was performed within this period, with subcutaneous application of ivermectin based product (1% concentration), at the dosage recommended by the manufacturer. The experimental period lasted 105 days and was divided into five periods of 21 days. Afterwards, the animals who had reached an average live weight of 400 kg were sent to slaughter.

Animals were fed twice a day at 8:00 a.m. and 2:00 p.m. Ingestive behavior evaluations were performed at close to half of each period, during 24 continuous hours, beginning and ending at 8:00 am. Table 2 shows the data of maximum and minimum temperatures and the relative humidity on the days of ingestive behavior evaluation.

Feeding, idle time, and rumination activities were recorded every 10 minutes. Feeding time was characterized by the presence of the animal in the trough, eating the food. Rumination time was considered the period when the animal was not feeding but chewing the regurgitated rumen food bolus. Idle time represents the period when the animal was not feeding, ruminating, or ingesting water.

Table 1. Proportion of dietary ingredients and nutritional composition of experimental diets based on dry matter percentage (DM).

Period	Ingredients				
	Corn Sillage	Ground Corn	Soybean Meal	Calcytic Limestone	White Salt
Constant Treatment (CT)					
1	60.00	24.18	14.58	0.84	0.40
2	60.00	24.50	14.26	0.84	0.40
3	60.00	24.60	14.16	0.84	0.40
4	60.00	23.80	14.96	0.84	0.40
5	60.00	23.28	15.48	0.84	0.40
Increasing Treatment 5 (IC5)					
1	70.00	13.67	15.29	0.75	0.30
2	65.00	18.99	14.86	0.81	0.35
3	60.00	24.60	14.16	0.84	0.40
4	55.00	29.12	14.54	0.90	0.45
5	50.00	33.70	14.85	0.95	0.50
Increasing Treatment 10 (IT10)					
1	80.00	3.17	15.98	0.65	0.20
2	70.00	13.73	15.20	0.78	0.30
3	60.00	24.60	14.16	0.84	0.40
4	50.00	34.45	14.10	0.95	0.50
5	40.00	44.16	14.22	1.02	0.60
Nutritional Content					
DM	33.05	91.23	91.76	-	-
CP	5.31	9.19	50.48	-	-
EE	2.06	4.68	2.01	-	-
MM	3.58	1.50	6.84	-	-
NDF	55.04	9.54	10.53	-	-
DOM	61.48	90.52	81.74	-	-

CT = Volume:concentrate ratio 60:40 in all periods; IT5 = Volume:concentrate ratio 70:30 at the beginning of the experiment and 50:50 at the end, with a general mean ratio of 60:40; IT10 = Volume:concentrate ratio 80:20 at the beginning of the experiment and 40:60 at the end, with a general mean ratio of 60:40; CP = crude protein; EE = ethereal extract; MM = mineral matter; NDF = neutral detergent fiber; DOM = digestible organic matter.

Table 2. Data on temperature, mean air humidity, wind speed and insolation on days of ingestive behavior observation.

Day	Temperature (ºC)			Relative air humidity (%)	Wind speed (m/s)	Insolation (hours)
	Max.	Min.	Mean			
08/21	28.2	14.2	18.1	82.8	0.90	6.5
09/13	26.4	16.0	20.8	90.0	1.71	4.9
10/03	21.8	12.8	17.0	70.0	4.80	7.6
10/22	28.0	12.8	20.1	68.3	2.06	10.7
11/14	25.0	12.0	18.0	64.5	1.20	12.0

Source: (INMET, 2016).

The environment was maintained with artificial lighting in the nocturnal animal observations. The mean number of mericyclic chews per ruminal bolus (NCB) and the mean time spent on mericyclic chews per ruminal bolus (TCB) were obtained through 16 observations, and 4 observations were taken every 6 hours to obtain the representation of all day times, per repetition on each evaluation day.

The results regarding ingestive behavior were obtained through the adapted ratios of Bürger et al. (2000), described below: feed efficiency (g dry matter hour^{-1}) = dry matter intake (g day^{-1})/time consuming feed (h day^{-1}); dry matter rumination efficiency (g DM hour^{-1}) = dry matter intake (g day^{-1})/total rumination time (hours day^{-1}); neutral detergent fiber rumination efficiency (g NDF^{-1}) = neutral detergent fiber intake (g NDF day^{-1})/total rumination time (hours day^{-1}); daily chewing time (hours day^{-1}) = time consuming feed (hours day^{-1}) + total rumination time (hours day^{-1}); number of bolus chewed per day = total rumination time (seconds day^{-1})/chewing time per bolus (seconds day^{-1}); number of daily chews = number of chews per bolus * number of boluses chewed per day; total rumination time (hours day^{-1}) = standing rumination time (hours day^{-1}) + lying rumination time (hours day^{-1}), and total idle time (hours day^{-1}) = standing idle time (hours day$^{-1)}$ + lying idle time (hours day^{-1}).

During the experimental period, samples of dietary ingredients and leftovers were collected and weighed per animal, and then pre-dried in a forced air oven at 55° C for 72 h. They were then weighed to obtain the pre-dry mass. Subsequently, the samples were stored and milled in a “Willey” type mill with a 1 mm screen, and then packed in plastic bags free of air and humidity for further laboratory chemical analyses. Samples of feed leftovers were taken three times a week and well homogenized for better sampling. Dry matter content (DM) was determined by oven drying at 105ºC, and ash by calcining in muffle at 550ºC, for 4 hours, until constant weight. Organic matter content (OM) was calculated by decreasing the dry matter value found by the ash value found. The dry matter, organic matter, mineral matter, and crude protein (CP) contents were obtained according to the AOAC methodology (1996). Ethereal extract (EE) content was determined after treating the samples with ether in reflux at 180°C for 2 hours. Neutral detergent fiber (NDF) contents were determined according to Van Soest (1994). Digestible organic matter content (DOM) was obtained through the *in situ* digestibility technique, evaluating the feed degradation in porous sacks incubated in the real conditions of the ruminal environment during 24 hours, which resulted in the organic matter digestibility.

The experimental design was a completely randomized design with three treatments, five periods and nine replicates, and the animal was the experimental unit. The data were tested for normality using the Shapiro-Wilk test. Analyses were performed through PROC GLM. When significant differences were found, the means were compared through the Tukey test, at 5% significance level between the treatments and between the periods of each treatment. Variables that did not demonstrate normality were analyzed using the Kruskal-Wallis test. Spearman correlation analysis was performed using the CORR procedure. Analyses were performed using the statistical package SAS (Statistical Analysis System - SAS Studio University Edition version 3.5).

The mathematical model used for ingestive behavior analyses was the following:

$$\gamma jk = \mu + \tau j + \varepsilon jk$$

In which:

γ_{jk}= dependent variables;

μ= mean of all observations;

τ_j= effect of the jth treatment or period;

ε_{jk}= residual random error.

Results and Discussion

There was a significant difference for feeding and rumination times between treatments and periods (Table 3).

Table 3. Behavioral feeding and rumination activities of confined steers with constant and increasing diet energy levels.

Activity, hours	Period					SE	P
	1	2	3	4	5		
			Feeding				
CT	4.65	4.19	4.45	4.43	3.83A	0.26	0.153
IT5	4.32	4.11	3.65	3.74	3.44AB	0.24	0.099
IT10	4.61a	4.24a	4.42a	3.98ab	3.18bB	0.22	0.0003
SE	0.22	0.23	0.31	0.25	0.18		
P	0.524	0.923	0.061	0.162	0.049		
			Total rumination				
CT	8.52	7.18	8.67	7.91A	8.04	0.38	0.065
IT5	8.83a	7.19ab	8.74a	7.04bAB	7.81ab	0.37	0.009
IT10	8.68a	7.28ab	8.22a	6.65bB	7.22ab	0.37	0.003
SE	0.40	0.46	0.41	0.31	0.26		
P	0.861	0.491	0.626	0.026	0.099		
			Lying rumination				
CT	7.69a	5.61b	8.00a	6.98ab	7.30a	0.40	0.002
IT5	8.19a	6.72ab	7.31ab	6.33b	7.13ab	0.44	0.021
IT10	7.93a	6.07b	7.67a	5.89b	6.76ab	0.39	0.001
SE	0.44	0.59	0.37	0.35	0.22		
P	0.725	0.420	0.441	0.110	0.229		
			Standing rumination				
CT	0.83ab	1.57a	0.67bB	0.92ab	0.74b	0.20	0.024
IT5	0.65	1.19	1.42A	0.70	0.69	0.24	0.061
IT10	0.76	1.20	0.56B	0.76	0.46	0.25	0.371
SE	0.20	0.36	0.25	0.14	0.15		
P	0.798	0.314	0.045	0.535	0.386		

CT = Volume:concentrate ratio 60:40 in all periods; IT5 = Volume:concentrate ratio 70:30 at the beginning of the experiment and 50:50 at the end, with a general mean ratio of 60:40; IT10 = Volume:concentrate ratio 80:20 at the beginning of the experiment and 40:60 at the end, with a general mean ratio of 60:40.
Lowercase letters in the row and upper case in the column differ at the 5% level by the Tukey test; SE = Standard error; P = Probability ($P < 0.05$).

In treatment IT10, animals spent more time feeding in the first three experimental periods, which corresponded to the volume:concentrate ratio of 80:20, 70:30, and 60:40, respectively, compared to the fourth (volume:concentrate ratio 50:50). These results were expected due to the reduction of the volume fraction and increase of concentrate in the diet. Feeding time decreased with the increase in the amount of concentrate in the diet (BÜRGER et al., 2000), due to the higher energy intake in shorter time (MISSIO et al., 2010) which resulted from volume reduction and concentrate increase.

The same happened when evaluations between periods were in the fifth period, in which there was longer feeding time for CT treatment (volume:concentrate ratio: 60:40) compared to IT10 (volume:concentrate ratio: concentrate 40:60), not different from IT5 (volume:concentrate ratio 50:50), which was expected due to the higher proportion of silage in the CT treatment. According to Van Soest (1994) confined animals spend about one hour consuming energy-rich foods, or up to six hours for low-energy sources, which can confirm the results obtained because the higher the volume part in the diet, the longer the feeding time observed.

The total rumination times in the periods were higher than feeding times, with mean time of 7.91 hours of rumination and 4.08 hours of feeding per day. The time spent in rumination is influenced by the nature of the diet and is probably proportional to the cell wall content of the volumes. Thus, the greater the participation of volumes in the diet, the longer the time spent with rumination (VAN SOEST, 1994). This may explain the longer rumination time demonstrated in the fourth evaluation period of treatment CT (volume:concentrate ratio 60:40) compared to IT10 (volume:concentrate ratio 50:50), not different from IT5 (volume:concentrate ratio 55:45), in which there is the highest proportion of silage compared to the other treatments. When evaluated within each treatment, the total rumination times of treatments IT5 and IT10 were higher in the first (volume:concentrate ratio 70:30 and 80:20, respectively, for IT5 and IT10) and third evaluation periods (volume:concentrate ratio 60:40) when compared to the fourth (volume:concentrate ratio 55:45 and 50:50 for IT5 and IT10).

Meanwhile, CT steers spent more time ruminating and lying in the first, third and fifth periods compared to the second, which was not expected due to dietary equality. On the other hand, animals from IT5 showed higher times in the first period (volume:concentrate ratio 70:30) compared to the fourth (volume:concentrate ratio 55:45). In the IT10 treatment, longer times were observed for the first (volume:concentrate ratio 80:20 concentrate) and third periods (volume:concentrate ratio 60:40) compared to the second (volume:concentrate ratio 70:30) and fourth (volume:concentrate ratio 50:50), not different from the fifth (volume:concentrate ratio 40:60) one. According to Argenta et al. (2013), lying rumination activity may favor lower energy expenditure with physical activity, due to the lower movement of these animals inside the bays, which could lead to a greater energy accumulation for the deposition of muscle and fat in the carcass.

In general, standing rumination times were lower than lying rumination ones, i.e. the animals were in a quiet condition, since they assumed that position to ruminate because they were not under any threat (OLIVEIRA et al., 2011), indicating comfort and well-being (PINTO et al., 2010). In the third period, animals spent more time chewing standing up on the IT5 treatment compared to the CT and IT10, however this fact is not related to any discomfort that might have been caused by the diet, since in this period animals were fed the same proportion of volume and concentrate. No differences were observed for treatments IT5 and IT10, nor behavior uniformity for the CT, within the respective periods according to the volume:concentrate ratio.

Table 4 shows the idle activities of steers, with significant differences. Idle time is when the animal is not ingesting feed, water or ruminating, and is usually spent mostly lying down (ARGENTA et al., 2013), when in comfort (ALMEIDA et al., 2013).

Total idle time was higher for IT5 (volume:concentrate ratio 55:45) and IT10 (volume:concentrate ratio 50:50) compared to CT (volume:concentrate ratio 60:40) in the fourth period, and higher for IT10 (volume:concentrate ratio 40:60) compared to CT (volume:concentrate ratio 60:40) in the fifth period, not differing from IT5 (volume:concentrate ratio 50:50), which corroborates Missio et al. (2010) who verified that idle times increased with higher concentrate levels and, therefore, energy in the diet. IT10 also showed higher idle times in the last two experimental periods compared to the first and third, which reflects shorter feeding time due to higher proportion of concentrate and less volume in the diet.

Table 4. Idle behavioral activities of confined steers with constant and increasing diet energy levels.

Activities, hours	Period					SE	P
	1	2	3	4	5		
Total idle time							
CT	10.83b	12.63a	10.89ab	11.67abB	12.13abB	0.44	0.026
IT5	10.85b	11.98ab	11.61ab	13.22aA	12.74aAB	0.42	0.002
IT10	10.70b	12.48ab	11.35b	13.37aA	13.59aA	0.46	0.0001
SE	0.51	0.53	0.42	0.39	0.31		
P	0.976	0.666	0.424	0.008	0.011		
Lying idle time							
CT	6.39b	7.57ab	6.81ab	7.33abB	8.09a	0.35	0.016
IT5	7.19	7.54	7.61	8.50AB	8.59	0.42	0.085
IT10	7.41ab	8.41ab	7.02b	9.02aA	8.83a	0.44	0.008
SE	0.34	0.45	0.42	0.44	0.37		
P	0.109	0.320	0.394	0.014	0.367		
Standing idle time							
CT	4.44	5.06	4.07	4.33	4.04	0.40	0.646
IT5	3.67	4.44	4.00	4.72	4.15	0.46	0.560
IT10	3.30	4.07	4.33	4.35	4.76	0.37	0.098
SE	0.41	0.60	0.26	0.42	0.29		
P	0.092	0.423	0.642	0.764	0.188		

CT = Volume:concentrate ratio 60:40 in all periods; IT5 = Volume:concentrate ratio 70:30 at the beginning of the experiment and 50:50 at the end, with a general mean ratio of 60:40; IT10 = Volume:concentrate ratio 80:20 at the beginning of the experiment and 40:60 at the end, with a general mean ratio of 60:40.
Lowercase letters in the row and upper case in the column differ at the 5% level by the Tukey test; SE = Standard error; P = Probability (P <0.05).

In the fourth evaluation period, IT10 steers presented longer lying idle time than in CT, and IT5 presented intermediate behavior. This fact may be related to the decrease in feeding times (Table 3), due to the higher diet energy density.

The mean animal feeding time (Table 5) was affected by the treatments, and the animals in the constant treatment spent more time feeding than the animals in treatment IT5.

Table 5. Means of behavioral activities, in hours, of confined steers with constant and increasing diet energy levels.

Activity	Treatment			SE	P
	CT	IT5	IT10		
Feeding	4.31a	3.85b	4.09ab	0.12	0.025
Total rumination	8.06	8.07	7.61	0.19	0.145
Lying rumination time	7.12	7.14	6.86	0.21	0.542
Standing rumination time	0.95	0.93	0.75	0.11	0.343
Total idle time	11.63	12.08	12.30	0.23	0.118
Lying idle time	7.24b	7.89ab	8.14a	0.20	0.006
Standing idle time	4.39	4.20	4.16	0.19	0.494

CT = Volume:concentrate ratio 60:40 in all periods; IT5 = Volume:concentrate ratio 70:30 at the beginning of the experiment and 50:50 at the end, with a general mean ratio of 60:40; IT10 = Volume:concentrate ratio 80:20 at the beginning of the experiment and 40:60 at the end, with a general mean ratio of 60:40.
Lowercase letters in the row differ at 5% level by the Tukey test; SE = Standard error; P = Probability (P <0.05).

IT10 steers remained longer in lying position than those in CT treatment. In general, idle times were longer than rumination times. The decrease in rumination time and the increase in animal down time are important, since they imply in a decrease in physical activity, which is an energy expenditure source, inferring that the increase of concentrate in the diet can determine a decrease in maintenance energy requirements, contributing to an increase in animal performance (MISSIO et al., 2010).

According to Dado and Allen (1995), the increase in the proportion of volume in the diet also leads to an increase in food components, such as NDF, which promotes filling of the reticulum-rumen, causing a greater number of chews per day, rumination time, chewing time per dry matter unit, and higher NDF content consumed, of the frequency of reticulum-rumen contractions during rumination and of the rumen NDF passage rate. This is corroborated by some results demonstrated since, in general, there were higher rumination times (Table 3) in the first periods, leading to lower idle times (Table 4).

Table 6 shows the results of activities related to rumination per evaluation period. Generally, in diets with lower concentrate portions, the number of boluses per day and chews per regurgitated food bolus usually increases, since the regurgitated bolus has lower weight, but larger volume, as it is mostly composed of forage (MISSIO et al., 2010). Treatment IT5 presented a higher number of ruminative chews per day compared to the other treatments in the first period. And when evaluated in the periods, the superiority of the number of chews occurred in the first period compared to the others. In treatment IT10 this superiority occurred in the first period when compared to the fourth. These results relate to the number of chews per minute, the more chews in a shorter time, the more ruminative chews per day.

Table 7 shows the averages of rumination-related activities evaluated by treatment. The superiority of chews per ruminated bolus in seconds of IT10 animals compared to the ones of IT5 can be visualized, which ended up influencing the number of ruminated boluses per day, with inverse behavior, because the larger the number of chews per bolus, the smaller the number of boluses.

There were significant differences in intake and rumination efficiency of dry matter (DM) and neutral detergent fiber (NDF) (Table 8). Dry matter intakes of CT and IT10 treatments were higher in the third evaluation period compared to the first one. On the other hand, animals in IT5 showed higher intake in the third and fourth periods compared to the first.

NDF intake in kg day^{-1} was higher for CT when compared to IT10 in the fourth period, and it was also higher than the others in the fifth evaluation period, in which IT5 presented intermediate behavior and IT10 lower behavior. When evaluated in the periods, CT presented higher NDF intakes in the last two evaluation periods when compared to the first one, while IT10 presented higher intakes in the first three periods compared to the last one, due to the diet with a larger volume proportion.

Animals in CT treatment presented higher dry matter rumination efficiency in the second, third and fourth periods, and lower in the first one. Those in IT5 presented greater efficiency in the third, fourth and fifth periods compared to the first one. The ones in IT10 were more efficient in the fourth period. According to Marques (2008) rumination efficiency is increased when the concentrate level in the diet is increased. In this study, steers showed no constant behavior in relation to this variable.

NDF rumination efficiency was higher in CT than in IT10 in the fifth period, which can be justified by the higher content of volume and, consequently, of NDF (Table 1) in CT (60% volume) compared to IT10 (40% volume) in this period. The reduction of neutral detergent fiber rumination efficiency at higher concentrate levels is associated with the reduction of neutral detergent fiber contents of diets, since for calculations, in these diets the lower concentrations of neutral detergent fiber in the boluses caused smaller amounts of the cell wall components breakage in rumination (MISSIO et al., 2010).

Table 6. Activities inherent to rumination of confined steers with constant and increasing diet energy levels.

Var.	Period					SE	P
	1	2	3	4	5		
	Number of chews/bolus						
CT	59.61	58.71	63.17	57.64	59.47	2.84	0.708
IT5	59.45	57.70	59.13	57.57	59.07	2.29	0.964
IT10	65.18	61.00	61.77	58.34	62.30	2.57	0.462
SE	2.71	2.90	2.50	2.29	2.43		
P	0.254	0.717	0.520	0.966	0.597		
	Chews/bolus, seconds						
CT	56.92	56.91	58.91	57.35	55.97	2.75	0.960
IT5	53.60	54.14	53.90	54.48	54.43	2.17	0.998
IT10	59.79	58.50	59.29	56.85	58.51	2.61	0.946
SE	2.43	2.86	2.41	2.21	2.65		
P	0.218	0.560	0.231	0.623	0.554		
	Ruminated boluses/day						
CT	541.79	465.58	534.66	503.89	522.30	32.49	0.486
IT5	603.03a	532.27ab	593.93a	470.93b	473.23b	36.66	0.030
IT10	527.74	456.90	508.13	422.69	453.42	30.17	0.108
SE	30.49	36.84	36.00	26.36	35.18		
P	0.199	0.304	0.246	0.112	0.377		

continue

continuation

	-------------------------------------*Chews/minute*	----------------------------------					
CT	62.78	62.04	64.47	57.64	64.10	1.79	0.073
IT5	66.75a	64.09a	65.98a	57.57b	65.32[a]	1.61	0.016*
IT10	65.41a	62.72ab	62.77ab	58.34b	64.06ab	1.42	0.015
SE	1.22	1.57	1.56	2.29	1.19		
P	0.083	0.645	0.363	0.966	0.703		
	---------------------------------------*Chews/day*	-------------------------------------					
CT	32248B	26823	33578	28583	30401	1690	0.051
IT5	42701aA	26214b	30735b	25341b	28659b	2120	<.0001
IT10	34135aB	26459ab	31164ab	24643b	27688ab	1664	0.003
SE	2152	1954	2048	1333	1563		
P	0.002	0.904	0.579	0.104	0.473		

CT = Volume:concentrate ratio 60:40 in all periods; IT5 = Volume:concentrate ratio 70:30 at the beginning of the experiment and 50:50 at the end, with a general mean ratio of 60:40; IT10 = Volume:concentrate ratio 80:20 at the beginning of the experiment and 40:60 at the end, with a general mean ratio of 60:40.
Lowercase letters in the row and upper case in the column differ at the 5% level by the Tukey test; SE = Standard error; P = Probability (P <0.05); * = Kruskal-Wallis Test.

Table 7. Means of activities inherent to rumination of confined steers with constant and increasing diet energy levels.

Variable	Treatment			SE	P
	CT	IT5	IT10		
Number of chews/ bolus	59.72	58.58	61.72	1.13	0.143
Chews/ bolus, seconds	57.21ab	54.11b	58.59a	1.08	0.013
Ruminated boluses/ day	513.60ab	534.68a	473.77b	15.55	0.021
Chews/ minute	62.20	63.94	62.66	0.80	0.288
Chews/ day	30327.15	30730.73	29018.11	1019.25	0.581

CT = Volume:concentrate ratio 60:40 in all periods; IT5 = Volume:concentrate ratio 70:30 at the beginning of the experiment and 50:50 at the end, with a general mean ratio of 60:40; IT10 = Volume:concentrate ratio 80:20 at the beginning of the experiment and 40:60 at the end, with a general mean ratio of 60:40.
Lowercase letters in the row differ at 5% level by the Tukey test; SE = Standard error; P = Probability (P <0.05).

Table 8. Intake and efficiency of rumination of dry matter (DM) and neutral detergent fiber (NDF) verified on days of ingestive behavior of steers confined with constant and increasing diet energy levels.

Variable	Period					SE	P
	1	2	3	4	5		
	---------------------------------------*Dry matter intake, kg/day*	------------------------------					
CT	8.09b	9.20ab	10.88a	9.94ab	9.62ab	0.43	0.006
IT5	7.54b	9.02ab	10.42a	9.92[a]	9.56ab	0.54	0.006
IT10	6.86c	8.10bc	9.96a	9.34ab	8.88ab	0.39	<0.0001
SE	0.56	0.58	0.47	0.44	0.43		
P	0.314	0.372	0.393	0.432	0.413		

continue

continuation

	---NDF intake, kg/day---						
CT	3.17b	3.49ab	3.67ab	3.84aA	3.99aA	0.17	0.006
IT5	3.40	3.69	3.74	3.55AB	3.52B	0.22	0.344
IT10	3.39a	3.51a	3.52a	3.11abB	2.90bC	0.19	0.040
SE	0.22	0.20	0.17	0.13	0.13		
P	0.731	0.563	0.650	0.001	<0.0001		
	---DM Rumination efficiency, g/h---						
CT	952.76b	1306.66a	1267.75a	1261.55[a]	1200.59ab	60.35	0.003
IT5	847.99b	1129.81ab	1230.14a	1428.97[a]	1243.14a	82.88	0.0002
IT10	798.91c	1126.49b	1241.18ab	1429.11[a]	1241.22ab	73.40	<0.0001
SE	60.96	66.06	90.43	77.45	67.86		
P	0.209	0.109	0.955	0.231	0.883		
	---NDF Rumination efficiency, g/h---						
CT	376.40b	501.81a	429.22ab	487.24a	499.64aA	27.71	0.004
IT5	383.67	463.10	440.79	512.76	458.42AB	31.07	0.051
IT10	394.64	495.53	440.04	476.98	405.25B	33.31	00.89
SE	26.24	29.45	33.60	26.84	23.41		
P	0.885	0.614	0.964	0.630	0.030		

CT = Volume:concentrate ratio 60:40 in all periods; IT5 = Volume:concentrate ratio 70:30 at the beginning of the experiment and 50:50 at the end, with a general mean ratio of 60:40; IT10 = Volume:concentrate ratio 80:20 at the beginning of the experiment and 40:60 at the end, with a general mean ratio of 60:40.
Lowercase letters in the row and upper case in the column differ at the 5% level by the Tukey test; SE = Standard error; P = Probability (P <0.05).

Table 9 shows the means of intake and rumination efficiency of DM and NDF verified in the ingestive behaviors. Dry matter intake was higher in the CT treatment and lower in IT10, which also reflected in similar behavior in NDF intake.

Table 9. Means of intake and efficiency of rumination of dry matter (DM) and neutral detergent fiber (NDF) verified on days of ingestive behavior of steers confined with constant and increasing levels of energy in the diet.

Variable	Treatment			SE	P
	CT	IT5	IT10		
Dry matter intake, kg day^{-1}	9.54a	9.29ab	8.63b	0.26	0.025
Dry matter intake, kg PV^{-1}	2.66	2.76	2.67	0.06	0.067
NDF intake, kg day^{-1}	3.63a	3.58a	3.29b	0.08	0.005
NDF intake PV	1.09	1.07	1.04	0.03	0.331*
RE DM, grams hour^{-1}	1197.86	1176.01	1167.26	41.27	0.864
RE NDF, grams hour^{-1}	458.86	451.75	442.49	13.66	0.698

CT = Volume:concentrate ratio 60:40 in all periods; IT5 = Volume:concentrate ratio 70:30 at the beginning of the experiment and 50:50 at the end, with a general mean ratio of 60:40; IT10 = Volume:concentrate ratio 80:20 at the beginning of the experiment and 40:60 at the end, with a general mean ratio of 60:40; RE = rumination efficiency;
Lowercase letters in the row differ at 5% level by the Tukey test; SE = Standard error; P = Probability (P <0.05); * = Kruskal-Wallis Test.

When ruminants are fed diets with high fiber content, intake is controlled by physical factors such as feed passage rate and ruminal filling. Meanwhile, in diets with high concentrate contents, intake is controlled by energy demand and metabolic factors (NRC, 1996).

Conclusion

The constant energy supply throughout the finishing of steers results in increased feeding time and dry matter intake.

The pattern with less accentuated energy supply results in shorter chewing time per bolus and higher number of boluses ruminated per day.

The more pronounced energy level increase along finishing increases lying idle time and decreases the animals' neutral detergent fiber intake.

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