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Nutrient Intake and Ingestive Behavior in Lambs Fed Hay and Concentrate

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Abstract

This study was carried out with the objective of evaluating the changes in the ingestive behavior and in the intake of crossbred Santa Inês lamb fed Tifton 85 hay associated to levels of concentrate supplementation. Twenty lambs, weaned and uncastrated, with initial body weight (BW) of 20.3 ± 3.6 kg were distributed in four treatments with Tifton 85 hay exclusive or associated with concentrate levels (0.0, 6.6, 13.3 and 20.0 g kg^{-1} d^{-1} BW), in a completely randomized design with five replicates. The ingestive behavior was evaluated through feeding, rumination and idleness parameters, feeding and rumination efficiencies, as well as dry matter (DMI), neutral detergent fiber (NDFI) and crude protein (CPI) intakes. Supplementation did not change the NDFI, but linearly increased the DMI and CPI expressed in g day^{-1}, g kg^{-1} day^{-1} BW and g kg^{-1} day^{-1} BW$^{0.75}$. Despite of this the regressions obtained for time spent with feeding, rumination and total chewing showed decreasing behavior when expressed in minutes day^{-}1 or in minutes kg^{-1} DM. The feeding (g hour^{-1}) and rumination (g hour^{-1} and g cud^{-1}) efficiency of DM and CP also increased linearly. The higher levels of supplementation provided less time spent with feeding and rumination activities and, consequently, longer time with idleness.

Keywords: ethology, feeding efficiency, rumination

1. Introduction

1.1 Sheep farming in Brazil

The Brazilian sheep herd presented growth of 27.03% in the period from 2007 to 2020, coming from 16.24 and reaching the amount of 20.63 million animals this year. However, wool production decreased from 11,160 to 7,978 t in the same period (IBGE, 2021), which indicates the increase in the stock for the meat production.

In a review on the subject, Viana et al. (2015) have confirmed that ovine meat is the main product of sheep production in Brazil in the recent years and, despite the fact that its consumption is still lower than that of other traditional meats, these authors reported excess demand for the product, which in turn, has been met by imports. However, the increasingly demanding market is looking for high-quality meat (REGO et al., 2019).

In order to optimize the production process, it is essential that sheep meat be competitive and, in this sense, the production of lambs and the search for technologies to optimize the production process. New models of breeding have been studied aiming at intensifying the productive process in a sustainable, competitive and economically viable way adopting better management practices, adequate nutrition and genetic improvement (VIANA et al., 2015; REGO et al., 2019; BETTENCOURT et al., 2020).

1.2 Research Justification and Objectives

The study of ingestive behavior of the sheep in tropical pastures can provide a new perspective for the conventional model of zootechnical scientific approach, bringing important advances in the management practices of the herds, since these practices directly influence the natural pattern of intake, feed selection and, consequently, production (CARVALHO et al., 2006a; MEDEIROS et al., 2007a; MOREIRA et al., 2018).

According to Cardoso et al. (2017), the search for new techniques of feeding and nutrition management, together with the study of ingestive behavior, may be of great importance to expand the sheep farming in Brazil. In view of the above, this study was conducted with the objective of evaluating the changes in ingestive behavior and intake by crossbred Santa Inês lambs fed Tifton 85 hay associated with concentrate supplementation levels.

2. Method

2.1 Ethical Animal Experimentation

The research was approved by the local Committee on Animal Research and Ethics (CEUA - UFES) under protocol no. 078/2012, being in accordance with the ethical principles of animal experimentation. The experiment was conducted in the district of Rive, municipality of

Alegre, Espírito Santo State (20º45'30" South latitude, 41º27'23" West longitude and 138 m altitude).

2.2 Treatments and Feeding Management

Twenty weaned and uncastrated Santa Inês crossbred lambs with an initial body weight (BW) of 20.3 ± 3.6 kg were housed in collective covered pens (2.0 m² animal^{-1}) on clay soil covered with shaving bed. Initially, the animals were weighed, identified and submitted to the sanitary control program of ecto and endoparasites, later, distributed in four experimental treatments: T1 - Tifton 85 hay; T2 - Tifton 85 hay + 6.6 g kg^{-1} day^{-1} BW in concentrate; T3 - Tifton 85 hay + 13.3 g kg^{-1} day^{-1} BW in concentrate; and T4 - Tifton 85 hay + 20.0 g kg^{-1} day^{-1} BW in concentrate, in a completely randomized design with five replicates.

Feeding on T1 treatment was sufficient to meet maintenance requirements and the supplements for T2, T3 and T4 treatments were planned to achieve moderate growth gains (NRC, 2007). The chemical composition and *in vitro* digestibility of the feeds can be seen in Table 1.

Table 1. Chemical composition and *in vitro* digestibility of Tifton 85 hay and concentrate (g kg^{-1})

Chemical composition	Tifton 85 hay	Concentrate
Dry matter	918.7	876.1
Crude protein	152.3	200.2
Neutral Detergent Fiber	649.7	137.5
Acid Detergent Fiber	337.4	53.3
IVDMD	621.6	900.0

IVDMD - In vitro dry matter digestibility.

The roughage was offered in two daily portions at 7h00 am and 5h00 pm, adjusted to keep leftovers around 10% of the supply, in order to guarantee maximum voluntary intake and to allow the selection of feed by the animals. The concentrate was offered only in the morning feeding. The animals had unrestricted access to water and mineral supplement. To correct the amounts of concentrate supplied, the animals were weighed at every 14-day intervals after solids fasting of 16 hours.

The experimental period lasted for 98 days, with the first 14 days destined to adapt the animals to the new environment, handling and feeding conditions. During the experimental period the installations were maintained under nocturnal artificial lighting.

The feeds were sampled for eight consecutive days per experimental pen in two periods (34th to 41st and 76th to the 83rd day of the experiment). The bromatological analyzes were performed according to a methodology described by Silva & Queiroz (2002) and the *in vitro* digestibility of dry matter (IVDMD), according to Tilley & Terry (1963), concomitantly with ingestive behavior and intake evaluations.

The dry matter intake (DMI) was estimated by the relationship between fecal production (FP) and dry matter indigestibility (DMID), according to the following equation:

$$DMI\ (g\ day^{-1}) = FP\ (g\ day^{-1})\ DMID^{-1}, \text{ where:} \quad (1)$$

$$DMID = 1 – IVDMD.$$

Estimates of fecal excretion were performed using Isolated, Purified and Enriched Lignin - LIPE® as an external marker. Indicator capsules (at doses of 250 mg animal^{-1} day^{-1}) were solubilized in 5 ml of water and the liquid was administered orally with the aid of a cannula coupled to an automatic vaccination gun. After each application, the same volume of water was supplied to the animals to clean the cylinder, according to methodology adapted from Godoi et al. (2009).

The administration of the indicator was performed in two distinct periods (35th to 41st and 77th to 83rd day of the experiment at 12h00), with duration of seven days each, being the first two days destined to stabilize the marker excretion flows in the feces and the last five, destined to feces collections directly from the animals' rectal ampulla (LIMA et al., 2008).

2.3 Sampling Procedures and Data Collection

Daily faecal samples, collected from each animal at 13h00, were identified and stored in individual plastic bags at -15°C to compose a composite sample of each animal at the end of each collection period. At the end of the trial, the composite samples were defrosted at room temperature, pre-dried in a forced-ventilation oven at 55°C for 72 hours and milled with Willey® type knives mill with 1 mm mesh sieve. The dry matter (DM) contents of the fecal samples were determined based on the methodology described by Silva & Queiroz (2002), while the FP values with the indicator were obtained from the equations presented by Lanzetta et al. (2009).

The daily intakes of DM expressed in grams per kilogram of live weight and in grams per kilogram of metabolic weight were obtained by the following equations, respectively:

$$DMI\ (g\ kg^{-1}\ day^{-1}\ BW) = DMI\ BW^{-1} \quad (2)$$

$$DMI\ (g\ kg^{-1}\ day^{-1}\ BW^{0.75}) = DMI\ (BW^{0.75})^{-1} \quad (3)$$

Intake of neutral detergent fiber (NDFI) and crude protein (CPI) in DM were obtained from the contents of these fractions present in the diets.

Observations regarding ingestive behavior were performed in two periods, from the 34th to the 35th and from the 76th to the 77th day of the experiment (between 7h00 on the first day of collection and 7h00 on the following day). Simultaneous observations of the animals were done every 10 minutes for 24-hour whole periods (PIRES et al., 2009), for a total of 144 evaluations per animal per period or 720 evaluations per experimental pen per period.

The behavioral variables observed are related to time spent with feeding (FT), rumination (RT) and idleness (IT). From these variables, results were obtained regarding feeding and rumination efficiencies, according to Fontenele et al. (2011). In each evaluation period, the number of mericic chews (no. cud^{-1}) and the time spent in rumination of each cud (sec cud^{-1}), were also counted. Three ruminal cuds were evaluated, using three ruminal periods as analysis standards (10h00 – 12h00, 14h00 – 16h00 and 18h00 – 20h00) to obtain the chewing and time averages. The times spent with the chewing of the cuds were counted via digital timers, concomitantly to the number counting of chews in the same cud. The total chewing time (CT) was obtained by the sum of FT and RT.

Amounts of DM, neutral detergent fiber (NDF) and crude protein (CP) in each rumen (g) were obtained through the relationship between the average consumption of each fraction and the number of ruminated cuds in 24 hours. To obtain the number of daily cuds, the RT was divided by the mean time spent to ruminate each cud (sec cud^{-1}), according to a methodology adapted from Magalhães et al. (2012).

2.4 Statistics and Data Analysis

The results were submitted to the analysis to verify the distribution of the normality of the residues (Shapiro Wilk, P<0.10). Subsequently, the original or transformed data (when necessary) were submitted to analysis of variance, using SAS PROC GLM (v.9.0). The means were studied by regression, via t test. The effects were considered significant when P<0.05.

The statistical model adopted is as follows:

$Yij = \mu + Ti + e_{ii}$; where:

Y_{ij} = variable response of i replicate and j level of supplementation;

μ = overall average;

T_j = effect of the j level of supplementation;

e_{ij} = random error, supposed NID ~ N $(0, \sigma^2)$;

i = 1, 2, 3, 4, 5;

j = 0.0; 6.6; 13.3 and 20.0 g kg^{-1} day^{-1} BW in concentrate supplementation.

3. Results

3.1 Intakes

The results obtained showed a linear effect (P<0.05) in daily DMI expressed in g day^{-1}, g kg^{-1} day^{-1} BW and g kg^{-1} day^{-1} $BW^{0.75}$, with a consistent increase as a function of the increase in the concentrate inclusion. The mean values obtained were 897.43 g day^{-1}, 34.82 g kg^{-1} day^{-1} BW and 78.14 g kg^{-1} day^{-1} $BW^{0.75}$, respectively. On the other hand, no regression model was fitted to the data observed for NDFI due to the inclusion of concentrate in the diet. The CPI presented a linear behavior similar to the DMI, due to the higher levels of concentrate and, consequently, the higher participation of this feed in the diet. Mean CPI ranged from 104.05 to 197.91 g day^{-1} among treatments (Table 2).

Table 2. Average daily intake of dry matter (DM), neutral detergent fiber (NDF) and crude protein (CP) of Santa Inês crossbreed lambs, according to the concentrate level on the feed

Variable	Concentrate level ($g\ kg^{-1}\ d^{-1}$ BW as fed)				Regression equation	R^2	CV (%)
	0.0	6.6	13.3	20.0			
	Intake ($g\ d^{-1}$)						
DM	683.17	812.99	973.27	1,120.29	$\hat{Y} = 677.32 + 220.68X$	0.87	5.24
NDF	443.86	443.66	445.34	436.13	$\hat{Y} = 442.25$	0.45	1.34
CP	104.05	131.73	165.72	197.91	$\hat{Y} = 102.65 + 47.32X$	0.88	6.81
	Intake ($g\ kg^{-1}\ d^{-1}$ BW)						
DM	28.99	33.05	36.66	40.57	$\hat{Y} = 29.1 + 5.7X$	0.41	13.38
NDF	18.84	18.09	17.01	15.84	$\hat{Y} = 17.4$	0.41	17.84
CP	4.42	5.35	6.22	7.14	$\hat{Y} = 4.4 +1.4X$	0.62	12.31
	Intake ($g\ kg^{-1}\ d^{-1}\ BW^{0.75}$)						
DM	63.70	73.45	82.83	92.57	$\hat{Y} = 63.78 + 14.39X$	0.66	9.12
NDF	41.39	40.18	38.30	36.59	$\hat{Y} = 39.11$	0.41	13.19
CP	9.70	11.89	14.07	16.30	$\hat{Y} = 9.70 + 3.29X$	0.83	7.99

BW - body weight; $BW^{0.75}$ - metabolic body weight; R^2 - coefficient of determination; CV - coefficient of variation.

3.2 Times

The time spent with feeding, rumination and idleness activities (min day^{-1}), as well as the time spent in feeding and rumination of DM, NDF and CP (min kg^{-1}) were influenced ($P<0.05$) by the concentrate level in the diets. It was observed that lambs fed a diet of higher concentrate ratio spent less time on FT and CT, remaining longer on IT. Despite the increase in DMI with increasing inclusion of concentrate and ruminal development of lambs throughout the experiment, the regressions obtained for the time spent with feeding, rumination and total chewing presented a decreasing behavior, in general, both when

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expressed in min d^{-1} or when in min kg^{-1} DM, which resulted in increased idleness time for the animals (Table 3).

Table 3. Average time spent on activities by Santa Inês crossbreed lambs, according to the concentrate level on the feed

Variable	Concentrate level (g kg^{-1} d^{-1} BW as fed)				Regression equation
	0.0	6.6	13.3	20.0	
	Feeding				
Min day^{-1}	429.00	507.00	431.00	389.00	$\hat{Y} = 438.60 + 104.86X - 67.18X^2$
Min kg^{-1} DM	632.89	628.07	448.81	353.82	$\hat{Y} = 668.07 - 152.56X$
Min kg^{-1} NDF	974.13	1148.22	968.91	892.13	$\hat{Y} = 974.14 + 752.93X - 910.69X^2 + 256.86X^3$
Min kg^{-1} CP	4775.06	3880.02	2647.24	2014.74	$\hat{Y} = 5707.69 - 951.37X$
	Rumination				
Min day^{-1}	575.00	564.00	649.00	577.00	$\hat{Y} = 575.00 - 212.01X + 389.30X^2 - 141.40X^3$
Min kg^{-1} DM	844.12	696.44	669.25	519.40	$\hat{Y} = 832.00 - 150.07X$
Min kg^{-1} NDF	1299.25	1274.67	1457.64	1317.81	$\hat{Y} = 1299.25 - 451.45X + 823.23X^2 - 296.43X^3$
Min kg^{-1} CP	5542.58	4300.76	3938.72	2950.96	$\hat{Y} = 6217.49 - 813.69X$
	Chewing				
Nº cud^{-1}	56.02	63.10	70.69	64.38	$\hat{Y} = 58.68 + 4.89X$
Sec cud^{-1}	41.31	44.68	53.54	45.45	$\hat{Y} = 46.25$
No. min^{-1}	82.59	87.69	83.47	87.09	$\hat{Y} = 85.21$
No. day^{-1}	47 991.11	49 091.17	53 894.72	50 346.91	$\hat{Y} = 50,330.98$
CT (min day^{-1})	1004.00	1071.00	1080.00	966.00	$\hat{Y} = 1000.79 + 188.04X - 101.93X^2$
Min kg^{-1} DM	1477.02	1324.51	1118.06	873.22	$\hat{Y} = 1500.07 - 302.63X$
Min kg^{-1} NDF	2273.39	2422.89	2426.55	2216.77	$\hat{Y} = 2270.15 + 379.48X - 202.30X^2$
Min kg^{-1} CP	9698.22	8180.78	6585.95	4965.69	$\hat{Y} = 11\ 306.00 - 1579.24X$
	Idleness				
Min/day	436.00	369.00	360.00	494.00	$\hat{Y} = 440.21 - 201.51X + 113.17X^2$

BW - body weight; Min - minutes; No. - number; Sec - seconds; CT - total chewing time; DM - dry matter; NDF - neutral detergent fiber; CP - crude protein.

Concerning to mericic chews, the amount per cud was positively influenced ($P<0.05$) by the increase of concentrate levels in the diet, presenting an average value of 63.55 chews. However, the parameters sec cud^{-1}, no. min^{-1} and no. day^{-1} found in this study were not influenced by the levels of concentrate in the diets ($P>0.05$). For the total chewing times per kg of DM and CP, regression analyzes showed that the inclusion of concentrate in the diet led to a reduction in the time spent at 302.63 and 1,579.24 min kg^{-1}, respectively (Table 3).

3.3 Feeding Efficiency

The mean results of Table 4 show that the feeding efficiencies of DM and CP ingested per hour presented better adjustment by a linear model as a function of the concentrate levels. Animals that did not receive a concentrate supplement had a lower intake efficiency of DM and CP (107.06 and 16.30 g DM and CP $hour^{-1}$, respectively) than supplemented animals

(141.28 and 24.22 g DM and CP hour^{-1}, respectively). In general, the regression obtained showed that the supplementation allowed the animals to increase the efficiency in the intake of DM in 40.96 g hour^{-1}.

Table 4. Feeding and rumination efficiency in Santa Inês crossbreed lambs, according to the concentrate level on the feed

Variable	Concentrate level (g kg^{-1} d^{-1} BW as fed)				Regression equation
	0.0	6.6	13.3	20.0	
	Feeding efficiency (g hour^{-1})				
DM	107.06	99.48	139.85	184.52	$\hat{Y}$ = 91.87 + 40.96X
NDF	69.55	54.22	63.48	70.86	$\hat{Y}$ = 64.54
CP	16.30	16.12	23.86	32.68	$\hat{Y}$ = 13.72 + 8.54X
	Rumination efficiency (g hour^{-1})				
DM	72.46	87.32	90.32	117.55	$\hat{Y}$ = 71.23 + 20.73X
NDF	47.08	47.63	41.37	45.73	$\hat{Y}$ = 45.45
CP	11.04	14.15	15.38	20.77	$\hat{Y}$ = 7.73 + 3.04X
	Rumination efficiency (g cud^{-1})				
DM	0.84	1.08	1.35	1.50	$\hat{Y}$ = 0.86 + 0.34X
NDF	0.55	0.59	0.61	0.58	$\hat{Y}$ = 0.58
CP	0.13	0.18	0.23	0.27	$\hat{Y}$ = 0.13 + 0.07X
No. cuds day^{-1}	859.88	773.64	797.85	789.05	$\hat{Y}$ = 805.10

BW - body weight; No. - number; DM - dry matter; NDF - neutral detergent fiber; CP - crude protein.

The feeding efficiencies of NDF were not affected by the increase of concentrate in the diet (P>0.05), reflecting the similarity of NDF intakes. However, it was found that animals that received concentrated supplementation presented lower mean values for the feeding efficiency of NDF. The rumination efficiencies of DM and CP were adjusted by linear model, with an increase in rumination efficiency as a function of the concentrate levels present in the diets. Adjusted regressions showed that supplemented animals showed higher rumination efficiency of DM and CP (20.73 and 3.04 g hour^{-1}, respectively). On the other hand, there was no adjustment of the NDF data from the regression models analyzed (Table 4).

The rumination efficiency of the fractions DM, NDF and CP, expressed in g cud^{-1}, presented similar behavior to feed efficiency and rumination expressed in g hour^{-1}. The mean values of rumination efficiency per cud were 1.19 and 0.58 g for the DM and NDF fractions, respectively (Table 4).

4. Discussion

Greater DMI are critical for gains in productivity, since higher growth rates of young animals are expected to be associated with higher feed intakes, such as those obtained at higher levels of supplementation in this experiment (Table 2). Medeiros et al. (2007b) and Bernardino et al. (2009) studying concentrate levels in the diet of Morada Nova sheep and coffee husks inclusion levels in the silage offered to non-breed sheep, respectively, found DMI values similar to those obtained in this research, which reinforces the importance of concentrate to ensure higher intake.

The increase found in DMI expressed in g kg^{-1} day^{-1} BW probably can be explained by the fact that this variable is closely related to the size and the capacity of the animal's digestive tract and also because the increasing inclusion of concentrate increased the digestibility of DM as a result of the reduction of the fibrous fraction in the diet. The mean DMI obtained (34.82 g kg^{-1} day^{-1} BW) is considered adequate to meet the requirements for moderate gains, as recommended by NRC (2007) for this animal category, and was similar to that obtained by Urano et al. (2006), who evaluated the influence of soybean (0, 70, 140 and 210 g kg^{-1}) inclusion on Santa Inês sheep diet.

Cardoso et al. (2017) also confirmed that DMI is positively related to NDF digestibility and that diets with lower NDF content provide higher DMI, since that the fibrous fraction as a function of its digestibility is one of the limiting factors of intake. In the present experiment, the acid detergent fiber (ADF) fraction, which due to lignin participation has a high influence on the cell wall digestibility, corresponded to 51.93 and 38.88% of the NDF in hay and concentrate, respectively. Considering the lower NDF content in the concentrate and the lower proportional participation of ADF in it, the increase in DMI with the increasing inclusion of concentrate is justified.

The non-adjustment of regression equations for NDFI in the present experiment (Table 2) can be attributed to the reduction of this fraction proportion in the total dietary DM with the increasing inclusion of concentrates, considering that the DMI have increased, but the NDFI remained relatively constant. Similar result for the mean NDFI (442.25 g day^{-1}) was described by Fontenele et al. (2011), who studied levels of metabolizable energy in the diet of Santa Inês sheep (413.76 g day^{-1}).

About the CPI, according to NRC (2007), the protein intake for lambs under similar conditions should be approximately 156 g day^{-1}, a value obtained in this experiment only with the inclusion of 13.3 and 20.0 g kg^{-1} day^{-1} BW in concentrated feed (Table 2), which shows the relevance of the concentrated supplementation to attend the nutritional requirements of protein, especially in tropical conditions where the forage usually do not present satisfactory protein levels for good productivities. Regadas Filho et al. (2011) estimated protein requirements for moderate-growth Santa Inês lambs at 16.94 g kg^{-1} d^{-1} $BW^{0.75}$, a value close to that obtained in the diet with inclusion of 20.0 g kg^{-1} d^{-1} BW of concentrate.

Considering that the diets were not isoproteic and that despite the good quality of the Tifton 85 hay offered, the concentrate had a higher protein content than the hay, it would be also expected that there would be an increase in CPI in the treatments with higher concentrate inclusion. In a similar experiment with Santa Inês lambs in feedlot fed with cotton seed levels for moderate gains, Cunha et al. (2008) reported the mean CPI of 186 g day^{-1}, a similar value to that found at the highest level of supplementation in this experiment.

The results showed in the Table 3 are quite similar to the obtained by Pinho et al. (2016) evaluating levels of inclusion of palm meal in the diet of non-breed sheep, who also found the same behavior as the level of inclusion of concentrate increased in the diet. These results are corroborated by França et al. (2009) as well, who observed decreases in FT and RT and increase in CT in Morada Nova sheep in the final third of gestation with the increase of concentrate levels and the energy density of the diet. Is well known that concentrate feeds and highly ground or pelleted hay reduce the time the RT, while roughage with high cellular wall contents tend to increase the time spent with rumination activity (VAN SOEST, 1994; MOREIRA et al., 2018).

According to Mertens (1996), FT is correlated to fiber content in the diet, inversely related to the net energy content. When the NDF level of the diet increases, an increase in the time spent for ingestion occurs so that the animal can meet its energy requirements. Similarly, RT, according to Van Soest (1994), is proportional to the cell wall content of feeds; thus, increasing the NDF level of the diets will increase the rumination time. These statements are corroborated by Carvalho et al. (2006b), who studied levels of NDF in the diet of lactating goats and by Figueiredo et al. (2013) and Mendes et al. (2010), who evaluated the effect of diets with different NDF sources on the ingestive behavior of sheep, observing a linear increase in the time spent ingestion and rumination as the fiber level in the diets increased.

For the mericic chews expressed in number cud^{-1}, an increasing linear regression was adjusted (Table 3), which may be explained mainly by the increase of DMI with the inclusion of concentrate than by the NDFI expressed in g d^{-1}, since this was very similar between treatments. Similar results were obtained by Magalhães et al. (2012) who evaluated the intake of sugarcane silage with calcium oxide or urea in the diet of sheep.

The parameters sec cud^{-1}, no. min^{-1} and no. d^{-1} (Table 3) were not influenced ($P>0.05$) by the level of concentrate in the diet, which is probably justified by the similar NDFI among the treatments, as mentioned previously. In their experiment, Magalhães et al. (2012), also found no differences for these parameters. Results corroborated by Carvalho et al. (2006a) as well when evaluating the ingestive behavior of sheep fed with diets composed of grass silage ammoniated or not, and agriculture by-products. Other factors besides DMI and NDFI are associated with rumination behavior and their interaction may lead to different results. Thermal comfort, water intake, social interaction aspects, size of animal groups, type of establishment or breeding environment, effectiveness of NDF, ruminal microbiota, among others, may influence the results obtained and are difficult to be fully controlled or monitored.

The reduction in chewing time expressed in min kg^{-1} of DM and CP due to the increase in concentrate level would be expected due to the lower concentration of NDF in the diet and the regressions generated for these parameters were linear. However, considering that the fibrous fraction of the diet is a determinant of chewing time (VAN SOEST, 1994), this parameter expressed in min kg^{-1} NDF, showed a quadratic regression equation with a slight decrease in the variable at the highest level of supplementation (Table 3).

The increase in the intake and rumination efficiency of the DM presented a linear behavior for the parameters g hour^{-1} and g cud^{-1} (Table 4), which again should be justified by the non-increase in the level of NDF in the diets. Cardoso et al. (2017) stated that when the proportion of concentrate supplied is increased, the intake and rumination efficiency of DM is increased concomitantly, due to the low NDF content. The results show behavior consistent with the findings of França et al. (2009) in their experiment with sheep. Barreto et al. (2011), in research with Moxotó and Canindé goats receiving two levels of metabolizable energy, also observed a linear increase in feed efficiency and rumination with increasing levels of concentrate and energy density of the diet.

The efficiency of intake and rumination of the CP followed the same behavior of the DM, a fact justifiable by the greater protein contribution of the concentrate in the diet. However, as expected for the reasons explained above, the same efficiency standard for NDF, which presented relatively constant values between treatments, was not observed, without adjustment of regression equations. There was no regression adjustment for mean values of rumination efficiency expressed in no. cuds day^{-1} and the mean values found in this study were similar to those obtained by Magalhães et al. (2012).

5. Conclusions

Consumption of dry matter and crude protein increases as the levels of concentrate in the diet increase. A similar response is observed for feeding and rumination efficiencies of dry matter and crude protein.

As the concentrate is included in the diet, reductions in time spent with feeding and rumination activities and increases in idleness time are observed.

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