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Feeding behavior of dairy cows fed different levels of xiquexique (*Pilosocereus gounellei)*

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ABSTRACT. This study evaluated the replacement of Tifton hay with xiquexique (0, 12, 24 and 36%) on feeding behavior of lactating dairy cows. To this end, eight cows with average milk production of 15 kg milk day^{-1} and average body weight of 465.2 ± 39.4 kg were distributed in a double 4x4 Latin square. Each experimental period lasted 16 days, ten for adaptation and six for data collection. The record of behavioral variables was made every five min. for 24 hours. The times spent in feeding, ruminating and total chewing, expressed in hours day^{-1}, as well as feeding (FE) and rumination (RE) efficiencies, expressed in g NDF h^{-1}, the number of cuds and cud chews per day showed a linear decrease according to the levels of xiquexique in the diet. There was a linear increase in time in idleness. Xiquexique levels in the diet for dairy cows did not influence FE and RE, expressed in g DM h^{-1}, number and time spent in chewing per cud. The replacement of Tifton hay with xiquexique in the diet alters the feeding behavior of dairy cows due to the reduction in fiber content.

Keywords: *cactaceous*, fiber, chewing, resting, *Pilosocereus gounellei*, rumination.

Comportamento ingestivo de vacas em lactação alimentadas com diferentes níveis de xiquexique *(Pilosocereus gounellei)*

RESUMO. Este trabalho foi realizado para avaliar a substituição do feno de capim-tifton por xiquexique (0, 12, 24 e 36%) sobre o comportamento ingestivo de vacas leiteiras em lactação. Foram utilizadas oito vacas com produção média de 15 kg de leite dia^{-1} e com peso corporal médio de 465,2 ± 39,4 kg, distribuídas em quadrado latino 4x4, duplo. Cada período experimental teve duração de 16 dias, sendo dez para adaptação e seis para coleta de dados. O registro das variáveis comportamentais foi realizado a intervalos de 5 min. durante 24h. Os tempos de alimentação, ruminação e mastigação total, expressos em hora dia^{-1}, além da eficiência de alimentação (EAL) e de ruminação (ERU) expressas em g FDN h^{-1}, o número de bolos ruminais e de mastigação merícicas por dia, diminuíram linearmente com os níveis de xiquexique nas rações experimentais. Houve aumento linear no tempo em ócio. Os níveis de xiquexique na ração de vacas leiteiras não influenciaram a EAL e ruminação ERU expressas em g MS h^{-1}, número e tempo de mastigação merícica por bolo. A substituição do feno de capim-tifton por xiquexique na ração modifica o comportamento ingestivo de vacas em lactação em decorrência da redução dos teores de fibra.

Palavras-chave: *cactácea*, fibra, mastigação, ócio, *Pilosocereusgounellei*, ruminação.

Introduction

The use of native cacti in ruminant feeding in arid and semiarid regions around the world is a practice carried out by many farmers during critical periods of the year, when forage stocks are low. Xiquexique (*Pilosocereus gounellei*) is one of the main cacti used in the Brazilian semi-arid region for this purpose, it is widely adapted and widespread, and can be consumed during periods of forage and water shortage, working not only as an energy source but also representing an important source of water in this biome, where often this resource becomes scarce.

The use of xiquexique over the centuries has been performed empirically without consistent scientific basis. The inclusion in the formulation of balanced feed for animal production is still poorly explored, as well as, there is only few studies evaluating this and other native species. The assessment of nutritional value and feeding behavior should be conducted for a better contribution of this species in the nutrition of ruminants, especially in years when the rainy season is shortened and the production of conserved forage (hay and silage) is unfeasible.

The animal's feeding behavior consists of times spent in feeding, ruminating, idle, and feeding and rumination efficiencies (Dado & Allen, 1995; Farias et al., 2012; Silva et al., 2006; 2010). The study in ruminants deserves attention for being of great importance in assessing the nutritional quantity and quality of the diet, allowing to establish the relationship with food intake (Albright, 1993), since the voluntary intake is the factor with the strongest impact on productive response of the animal (Mertens, 1994; Van Soest, 1994). Thus, enabling the use of this tool to adjust the feeding management of animals in order to achieve a better production performance.

Van Soest (1994) reports large amplitude in the time spent in food intake by confined animals, ranging from one to six hours, depending on dietary energy density. Feeding time is one of the limiting factors of intake, varying according to different diets, depending on the number of chewing movements (Albright, 1993). Events of regurgitation, salivation, cud chews and swallow again of the ruminal diet make up the rumination cycle (Silva et al., 2005; 2006), which, added to the interval between these, comprise the rumination period. The rumination time is influenced by diet and seems to be proportional to the cell wall content of roughage, therefore, the greater the contribution of roughage to the diet, the greater the time spent ruminating (Van Soest, 1994).

In this context, this study evaluated the feeding behavior of dairy cows fed diets containing four different levels of replacement of Tifton hay with xiquexique.

Material and methods

The study was conducted from November 2012 to January 2013 in the community of Cachoeirinha do Pai Sinhô, in the municipality of Tauá, state of Ceará, at 6°00'11" South latitude and 40°17'34" West longitude. The municipality of Tauá is inserted in a tropical hot and semi-arid climate with rainy season from February to April and average annual rainfall ranging between 550 and 650 mm (Köppen & Geiger, 1928).

Eight multiparous crossbred cows between the second and fifth lactation, with average milk production of 15 kg of milk day^{-1}and average body weight of 465.2 ± 39.4 kg were distributed in a double 4x4 Latin square (4 periods, 4 levels of xiquexique and 8 animals). Each period lasted 16 days, 10 days for adaptation and six days for data collection, totaling 64 experimental days. The animals were kept in individual stalls of 18 m² each, with masonry floor, equipped with troughs and drinkers for the control of feed and water intake.

The treatments consisted of increasing proportions of replacement of Tifton grass hay with xiquexique (0, 12, 24 and 36%) in the total feed, maintaining forage: concentrate ratio of 60:40, on a dry matter (DM) basis. Xiquexique was collected and transported from the caatinga; the thorns were burned with a flamethrower gas for subsequent grinding in a shredding machine. The Tifton grass hay was purchased at Laranjeira Farm, in Assu, state of Rio Grande do Norte, the grass was cut when about 50 days of age.

The experimental diets were formulated based on the results of the chemical analysis of the ingredients (Tables 1 and 2) to meet the nutritional requirements of dairy cows with average production of 15 kg milk, according to NRC (2001). The weight of the cows was determined at the beginning and end of each collection period.

During the experiment, the diets were supplied as a complete mixture in two meals, at 6 and 16 h, allowing 10% leftovers. Daily, in the collection period, the samples of food and leftovers were collected in the morning, weighed, stored and frozen for later processing. At the end of the collection period, the samples were thawed and homogenized for making composite samples per animal/period. Subsequently, all samples were pre-dried in a forced air oven, ground through a 1 mm sieve, and subjected to chemical analysis at the Animal Nutrition Laboratory, Department of Animal Science, Federal University of Ceará.

Table 1. Chemical composition of ingredients used in the experimental diets.

Ingredients	DM	OM	CP	EE	NDF	ADF	TC	NFC
	g kg^{-1}	g kg DM^{-1}						
Ground corn	905.12	987.02	66.79	42.02	148.79	44.26	878.21	729.43
Soybean meal	898.92	934.75	431.69	18.64	137.50	70.81	484.41	346.91
Wheatbran	912.53	942.45	150.13	44.04	422.64	110.01	748.28	325.64
Xiquexique	122.06	864.87	38.84	7.41	238.54	158.70	818.61	580.08
Tifton hay	862.66	918.28	96.50	19.24	746.47	332.12	802.54	56.08

DM, dry matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fiber; ADF, acid detergent fiber; TC, total carbohydrates and NFC, non-fiber carbohydrates.

Table 2. Proportions of ingredients and composition of the experimental diets (g kg DM^{-1}).

	Xiquexique levels			
Proximate composition	0%	12%	24%	36%
Tifton hay	60.00	48.00	36.00	24.00
Xiquexique	0.00	12.00	24.00	36.00
Ground corn	19.02	17.20	15.39	13.64
Soybean meal	13.64	15.76	17.92	20.06
Wheatbran	6.34	6.04	5.69	5.30
Mineral Premix	1.00	1.00	1.00	1.00
Chemical composition				
Dry matter, g kg^{-1}	870.22	781.19	692.16	603.13
Organic matter, g kg DM^{-1}	925.95	918.56	911.19	903.83
Crude protein, g kg DM^{-1}	139.00	139.57	140.23	140.80
Ether extract, g kg DM^{-1}	24.87	22.95	21.02	19.09
Neutral detergent fiber, g kg DM^{-1}	521.72	459.72	397.56	335.31
Acid detergent fiber, g kg DM^{-1}	224.32	203.88	183.41	162.91
Total carbohydrates, g kg DM^{-1}	762.08	756.04	749.94	743.94
Non-fiber carbohydrates, g kg DM^{-1}	240.35	296.32	352.38	408.63

For analysis of feeding behavior, the cows were subjected to visual observation on the 15th and 16th days of each experimental period, and the variables were recorded in an ethogram. On the evaluation days, the observers arrived at the observation site with an hour in advance to familiarize the animals. Eight observers were divided into two groups of four, each observer monitored the behavior of two animals. As four behaviors were considered, one in each period, each observer assessed the behavior of all animals in different treatments. On the first day of observation, the animals were evaluated during three periods of two hours (8 to 10, 14 to 16 and 18 to 20 hours) collecting data to estimate the number of chews per cud and time spent in rumination per cud, using a digital stopwatch.

On the second day, feeding behavior was determined visually every five minutes for 24 hours to determine the time spent in feeding, ruminating, idle and other activities (Johnson & Combs, 1991; Silva et al., 2006; 2008). At the same time, in the interval between two observations, punctual activities (water intake, urination and defecation) were recorded. Average temperatures were 29.7; 29.0; 30.3 and 29.9°C, the relative humidity were 50.3; 49.5; 48.0 and 52.8% and the temperature and humidity indices were 77.4; 76.1; 77.7 and 78.0 in the periods 1, 2, 3 and 4 respectively. Data were pooled at intervals of three hours, resulting in eight evaluation periods (6-9, 9-12, 12-15, 15-18, 18-15, 21-15, 21-24, 24-03, 03-06 hours), from the first meal of the day at six in the morning. For continuous activities (feeding time, rumination time, idle time and other activities) within 24 h, data were expressed as percentage of the total time of each period. The punctual activities were expressed by the number of times the activity occurred within three hours. At night observation of animals, the environment was maintained with artificial lighting, after a period of adaptation.

The variables related to feeding behavior were obtained by the equations:

$$FE\ (\mathrm{g}\,DM\ \mathrm{h}^{-1}) = \frac{DMI}{FT}$$

$$FE\ (\mathrm{g}\,FDN\,\mathrm{h}^{-1}) = \frac{NDFI}{FT}$$

$$RE\ (\mathrm{g}\,DM\ \mathrm{h}^{-1}) = \frac{DMI}{RT}$$

$$RE\ (\mathrm{g}\,NDF\,\mathrm{h}^{-1}) = \frac{NDFI}{RT}$$

$$CUD\,\mathrm{nd} = \frac{RT}{MMtb}$$

$$CCnd = \frac{CUDnd}{CCnc}$$

where: FE (g DM h^{-1}, g NDF h^{-1}) is the feeding efficiency; DMI (g DM day^{-1}) is the dry matter intake; FT (h day^{-1}) is the feeding time; RE (g DM h^{-1}, g NDF h^{-1}) is the rumination efficiency; RT (h day^{-1}), rumination time; CUDnd (number day^{-1}), number of cuds per day; CCtc (seconds cud^{-1}), time spent in chewing per cud; CCnd, number of cud chews per day and CCnc (number cud^{-1}) is the number of chews per cud (Polli, Restle, Senna, & Almeida, 1996). The experimental variables were subjected to analysis of variance and regression, using the GLM procedure of SAS (2004).

Results and discussion

Times spent in feeding (FT) and ruminating (RT), expressed in h day^{-1}, showed a linear decrease ($p < 0.05$) with increasing levels of xiquexique (*Pilosocereus gounellei*) in the diet (Table 3). This can be explained by the reduction in neutral detergent fiber content in (NDF) in diets with increasing xiquexique levels. A similar result was reported by Souza et al. (2016), who observed a reduction in RT and FT with decline in NDF content in diets for sheep.

Table 3. Means, coefficient of variation (CV), coefficient of determination (R^2) and significance level for continuous and punctual activities of dairy cows fed diets containing different levels of xiquexique.

Item	Xiquexique levels 0%	12%	24%	36%	CV%	R^2	p
Continuous activities (h day^{-1})							
Feeding time[1]	7.05	7.06	6.33	5.08	10.67	0.66	<0.0001
Ruminating time[2]	8.20	7.85	7.66	6.26	15.39	0.27	0.0025
Total chewing time[3]	15.25	14.91	13.99	11.34	9.79	0.54	<0.0001
Idle[4]	7.95	8.33	9.24	11.46	14.43	0.49	<0.0001
Activity[5]	0.80	0.76	0.77	1.20	55.21	-	NS
Punctual activities (number of times day^{-1})							
Water intake[6]	17.63	15.25	11.5	13	47.85	-	NS
Urination[7]	8.63	11.25	10.5	9.75	32.97	-	NS
Defecation[8]	15.75	16.25	14.13	12.63	28.67	-	NS

NS: non-significant. [1]$\hat{Y}=7.38-0.06X$; [2]$\hat{Y}=8.39-0.05X$; [3]$\hat{Y}=15.77-0.11X$; [4]$\hat{Y}=7.53+0.10X$; [5]$\hat{Y}=0.88^{NS}$; [6]$\hat{Y}=14.34^{NS}$; [7]$\hat{Y}=10.03^{NS}$; [8]$\hat{Y}=14.69^{NS}$.

Fiber is very important in ruminant feed, as it is associated with chewing stimuli, rumen motility, maintenance of rumen stability, intake of dry matter (DM), supply of energy, among others (Mertens, 1994). The time spent ruminating takes, on average, about 8 hours per day with variation between 4 and 9 hours (Silva et al., 2005; 2007; 2010, and this behavior is influenced by the diet, where diets with higher amount of fiber stimulate the chewing (Mertens, 1997). This was confirmed by Carvalho, Pires, and Silva (2004), who evaluated the effect of five NDF levels on the feeding of goats and found longer times spent feeding and ruminating in diets with higher amounts of NDF, similar to that observed in this study. Different results were reported by Monção et al. (2014), who observed a linear increase in the feeding time with the increase in the levels of spineless cactus and urea in sheep diet, however, this result was attributed to the increase in DM intake.

The total chewing time (TCT), expressed in h^{-1} day^{-1}, decreased linearly with the replacement of hay with xiquexique in experimental diets. The response pattern of this variable is due to reductions in FT and RT, comprising the TCT.

There was a linear increase in idle time with the rise of xiquexique levels in the diet, with estimated values of 7.5 and 11.1 h^{-1} day^{-1} for levels 0 and 36% replacement, respectively. By means of the regression equation, it was found that for each percentage point of xiquexique added, the idle time increased 0.10 h^{-1} day^{-1}. This is related to the reductions in the FT and RT, caused by the reduction in NDF content with increasing xiquexique levels that favored the increase of idle time. Similarly, Bürger et al. (2000), working with dairy cows fed different sources of forage, registered shorter times spent in feeding and ruminating and longer idle time in the diets with lower content and intake of NDF. The time spent in other activities was not influenced by experimental diets, with mean values of 0.88 h^{-1} day^{-1}.

The frequency of water intake, measured by the number of times the animal visited the drinker, did not change with increasing levels of xiquexique in the diet. Probably, there was a reduction in water intake at higher levels of xiquexique replacement, without any change in the frequency of water intake. Similar results were reported by Carvalho et al. (2008), who studied increasing levels of spineless cactus replacing Tifton grass hay for lactating cows, and found no influence of treatments on the frequency of water intake, despite the reduction in water intake.

There was no effect of xiquexique levels in the diet on urination and defecation. The urination frequency was lower than the defecation frequency, regardless of xiquexique level, with mean values of 10.03 and 14.69 times day^{-1}, respectively.

The time spent with intake was affected by periods of the day (Figure 1), showing higher consumption in the periods of 6-9 and 15-18 hours, with values of 63.14 and 64.47% of the time of each period used in intake activity. Peaks of feeding activity coincident with the meal time (6 and 16 hours) were commented by Dado and Allen (1995) as attributed to intake stimuli that affects the animal, after the feed supply, when food is still fresh. In turn, night periods had the lowest values for the intake activity, with the period 24-3 hours presenting only 2.95% of the time spent in this activity.

When considering the period from 6 to 18 hours, it was observed that the intake was concentrated during the day, corresponding to 78% of the total feeding time over 24 hours. As ruminants are diurnal animals, the feeding activity occurs most frequently during the day. The concentration of feeding activity during the daytime was also reported in studies with dairy cows by Antunes et al. (2014). Freitas et al. (2010) found that the presence of animals in the trough at night was more dispersed and less concentrated than in the daytime.

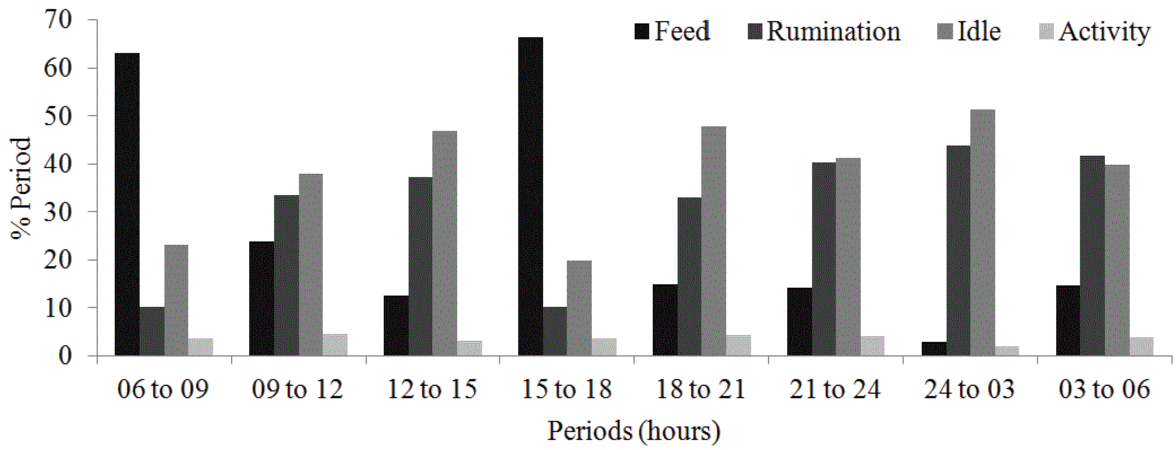

Figure 1. Percentage distribution of the continuous activities of dairy cows fed diets with xiquexique in eight periods of the day.

Time spent with rumination was also influenced by time of the day. Rumination was concentrated mainly in the periods including the night shift (18 to 6 hours), with 63.5% of the total rumination time within 24 concentrated in that period, with peak rumination in the 24-3 hours period (43.8 % of the time of this period spent in rumination). Shorter rumination times were verified in periods of 6-9 and 15-18 hours, with respective values of 10.2 and 10.2% of the time of each period spent in rumination. These results can be attributed to longer time spent in feeding in the respective periods. In periods after the supply of feed (9-12 and 18-21 hours), there was an increase in the time spent ruminating, with intermediate values (33.6 and 32.9% of the time of each period, respectively).

The distribution of ruminating activity is greatly influenced by feeding (Polli et al., 1996), whereas rumination takes place shortly after the meal periods, when the animal is at rest (Campana et al., 2015). Similar results were reported in a study on lactating cows fed diets with sunflower cake by Cirne et al. (2014), which registered rumination activity concentrated during the night. Miotto et al. (2014) found significant rumination activity between the two meals in young bulls finished in feedlot fed diets containing levels of whole corn germ.

The period of the day also influenced the time in idle, with peak in 24-3 hours. Similar to rumination, idleness was more intense in periods of 18-21, 21-24, 24-3 and 3-6 hours, which correspond to the night shift, with values of 47.8; 41.4; 51.4 and 39.8% of the time of periods spent in idle. On the other hand, during the day, were observed the shortest times spent in idle with mean values of 23.1 and 19.8% in the periods of 6-9 and 15-18 hours, respectively.

Other activities, which represent the activities of the animal that are not linked to intake, rumination and idle, were not affected by period of the day, with a mean value of 3.7% of the total time within 24 hours, representing the time used in other activities.

Water intake (number of times per day) was influenced by the time of the day and was more frequent in the periods of 6-9 and 15-18 hours (Table 4). This is due to feeding activity that occurred with greater intensity in these periods, stimulating greater demand for water, because the peak consumption of water and DM coincided. During the nighttime, it was found the lowest water intake frequency in the period of 24-03h, being statistically similar to periods of 12-15, 21-24 and 03-06 hours. These results are explained by the fact that daytime is warmer and according to Berchielli, Pires, and Oliveira (2011), water intake rates are higher during the hottest hours of the day, when the animals seek this resource to aid in thermoregulation.

Urination was also altered by the time of the day, with peak in the period of 15-18 hours and lower frequency at 24-3 hours, and the other periods showed intermediate values. Defecation was not affected by the periods of the day, with a mean value of 1.79 times period^{-1}.

The different levels of xiquexique in the diet for lactating cows did not affect the feeding (FE) and rumination (RE) efficiencies, expressed in g DM h^{-1}, the number of chews per cud (CCnc) and time spent in chewing per cud (CCtc), as can be seen in (Table 5). Probably, the FE and RE were not affected by the experimental feed because FT and RT were reduced along with the DM intake, variables that make up the FE and RE. Martins et al. (2011) assessed the feeding behavior of lactating cows fed concentrate and spineless cactus composing 50% of the feed, and detected no effect on the FE and RE according to DM intake.

Table 4. Punctual activities of dairy cows fed diets containing xiquexique in eight periods of the day.

Periods								
6-9 hours	9-12 hours	12-15 hours	15-18 hours	18-21 hours	21-24 hours	24-03 hours	03-06 hours	Mean
Water intake (number of times day^{-1})								
3.82a	2.28b	1.03cd	3.77a	1.45bc	1.07cd	0.10d	0.81cd	1.25
Urination								
1.32ab	1.19ab	1.25ab	1.68a	1.15ab	1.29ab	0.82b	1.33ab	1.84
Defecation								
1.81a	1.73a	1.60a	2.27a	2.02a	1.91a	1.53a	1.81a	1.79

Different lowercases in the same row indicate significant difference by Tukey's test at 5%.

Table 5. Feed efficiency parameters of dairy cows fed diets containing different levels of xiquexique

Item	Xiquexique levels				CV%	R^2	P
	0%	12%	24%	36%			
FE, g DM h^{-1},[1]	2401,40	2597,40	2449,96	2862,88	19,55	-	NS
FE, g NDFh^{-1},[2]	1391.03	1194.09	987.8	976.84	16.6	0.44	<0.0001
RE, g DM h^{-1},[3]	2068.29	2376.41	2047.7	2296.12	16.53	-	NS
RE, g NDF h^{-1},[4]	1191.87	1097.1	827.73	787.31	16.05	0.54	<0.0001
CCnc[5]	45.64	52.67	54.76	51.72	25.21	-	NS
CCtc[6]	50.83	57.42	61.29	60.82	21.6	-	NS
CUDnd[7]	591.75	509.25	471.13	385.63	22.74	0.32	0.0008
CCnd[8]	26488	25747	24811	19332	23.11	0.18	0.0163

NS: non-significant. [1]FE: Feeding efficiency, $\hat{Y}$=2577.91; [2]$\hat{Y}$=1354.77-12.07X; [3]RE: Rumination efficiency, $\hat{Y}$=2197.13; [4]$\hat{Y}$=1198.46-12.36X; [5]CCnc: number of chews per cud, $\hat{Y}$=51.29; [6]CCtc: Time spent in chewing per cud, $\hat{Y}$ =57.59; [7]CUDnd: Number of cuds per day, $\hat{Y}$=587.91- 5.47X; [8]CCnd: Number of cud chews per day, $\hat{Y}$ = 27455-186.71X.

The FE and RE, expressed in g NDF h^{-1}, showed a linear decrease according to the levels of xiquexique in the diets. Each percentage unit of xiquexique added to the diet reduced the FE and RE in 12.1 and 12.4 g NDF h^{-1}, respectively. This result is due to lower amount of NDF in diets with higher levels of xiquexique and therefore lower content of physically effective NDF (NDFpe). According to Carvalho et al. (2008), reductions in NDFpe content of the feed promote decrease in time spent chewing (feeding and rumination).

The number of cuds per day (CUDnd) showed a decreasing linear effect ($p < 0.05$), as a function of xiquexique level in the feed. For each percentage unit of xiquexique added in feed, there was a reduction of 5.47 cuds per day. With the reduction in CUDnd, the number of cud chews per day (CCnd) also decreased linearly with the levels of xiquexique in the diet, ranging from 27.5 to 20.7 for the 0 and 36% levels, respectively. These results show that the decrease in dietary fiber due to the inclusion of xiquexique in diets inhibited the rumination and the main mechanism of adaptation of animals to a decreased dietary fiber content was the reduction in CUDnd and consequently in CCnd. Neumann, Restle, and Brondani (2004) evaluated diets with different levels of replacement of sorghum silage with orange bagasse in diets for sheep and reported a decreasing linear effect on CCnd. In turn, CCtc and CCnc were not affected by the treatments, demonstrating that, probably, the size of each cud and fiber proportion of these have not been altered, because there was no modification in these variables. Thus, the variable that responded to the lower intake of NDF, promoting adjustment in RT, was CUDnd.

Conclusion

The replacement of Tifton hay with xiquexique in the diet alters the feeding behavior of lactating dairy cows due to the reduction in fiber content.

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