Trop Anim Health Prod (2016) 48:1315–1321
DOI 10.1007/s11250-016-1090-x

REGULAR ARTICLES

Intake and ingestive behavior in lambs fed low-digestibility forages

Antônio E. Filho[1] · Gleidson G. P. Carvalho[2] · Aureliano J. V. Pires[3] · Robério R. Silva[3] · Paulo E. F. Santos[1] · Rogério M. Murta[1] · Fabiano M. Pereira[1] · Bruna M. A. Carvalho[4] · Camila M. A. Maranhão[2] · Luana M. A. Rufino[2] · Stefanie A. Santos[2] · Douglas S. Pina[2]

Received: 6 November 2015 / Accepted: 8 June 2016 / Published online: 27 June 2016

Abstract Ingestive behavior of lambs fed diets consisting of fresh sugarcane with urea, bagasse treated with calcium oxide, and urea ammoniated sugarcane bagasse supplemented with concentrate mixture in 50:50 ratio were evaluated. For this, 34 wethers Santa Inês in their growing phase, with an average age of 3.0 ± 0.6 months and a mean initial live weight of 17.8 ± 5.2 kg were used. The animals were distributed in a completely randomized design and subjected to visual observation periods of 5 days, for 24 h a day, during the experimental period. Dry matter (DM) intake and intake efficiency of DM were higher ($P < 0.05$) for animals receiving fresh sugarcane with urea. The animals which were fed with bagasse treated with calcium oxide had higher ($P < 0.05$) consumption of neutral detergent fiber, longer feeding and chewing time ($P < 0.05$), and shorter ($P < 0.05$) idling time. The time spent on chewing the ruminal bolus did not differ from one diet to the other ($P > 0.05$). Grams of dry matter per ruminated bolus were similar among animals fed with fresh sugarcane and ammoniated bagasse ($P > 0.05$) but lower ($P < 0.05$) in animals fed with bagasse treated with calcium oxide. Rumination efficiency values, in grams of dry matter per hour, and grams of neutral detergent fiber per hour for all three diets were similar ($P > 0.05$) to those found for feeding efficiency. The number of feeding and rumination periods was not affected ($P > 0.05$) by diet. Based on the intake and ingestive behavior responses, the fresh sugarcane with urea compared to bagasse treated with calcium oxide and ammoniated bagasse was found to be the better alternative feed for use in lamb diets.

Keywords Bagasse · Nutrition · Ruminant · Sheep · Sugarcane

✉ Gleidson G. P. Carvalho
gleidsongiordano@yahoo.com.br

[1] Federal Institute of the North of Minas Gerais, Almenara, Minas Gerais, Brazil

[2] Federal University of Bahia, 40170110 Salvador, Bahia, Brazil

[3] Southwest State University of Bahia, Itapetinga, Bahia, Brazil

[4] Federal University of Minas Gerais, Montes Claros, Minas Gerais, Brazil

Introduction

Small ruminants are capable of selecting their own feed but during times of forage shortage, are often fed low-digestibility feeds that reduce their ingestion of dry matter. Sugarcane is an excellent alternative feed for ruminants during droughts, and although sugarcane is low-quality forage, its use is justified by being an easily implemented perennial crop with high productivity (Carvalho et al. 2013).

Sugarcane bagasse, a byproduct of the milling process employed to extract saccharose and used to produce ethanol, sugar, or cachaça, can be employed efficiently as feed for ruminants. This byproduct is characterized by low protein, vitamin, and mineral levels as well as high-indigestible fiber (Ahmed and Babiker 2015). The use is necessary especially when the objective is to reduce production costs.

There are currently many chemical treatments to improve the fiber quality of such forages, such as calcium oxide treatment and the ammonization process using urea, which are increasingly being used. Therefore, there is a need to study the chemical composition of such feeds and their possible effects on the ingestive behavior of animals.

Ingestive behavior research has received growing attention from many researchers in the animal production sector (Costa et al. 2014, 2015; Correia et al. 2015; Nicory et al. 2015), with the objective of elucidating how different feeding conditions change ingestive behavior parameters.

The physical and chemical properties of byproducts are different from the characteristics of forage plants, with changes to absorption by the gastrointestinal tract (Armentano and Pereira 1997) and possible changes to ingestive behavior, which is influenced by the physical structure and the chemical composition of diets (Carvalho et al. 2004).Van Soest (1994) reported that the time spent ruminating is influenced by the nature of the diet and is probably proportional to the level of cell walls in forages, so that the higher the fiber level in the diet, the higher the rumination time.

It is important to highlight that this research brings new perspectives to the conventional scientific approach in animal science, especially in situations that have not yet been considered or are not well understood such as management practices (Silva et al. 2004). Furthermore, the ingestive behavior can be used as a tool to evaluate diets, enabling the adjustment of feeding managements in order to obtain better performances (Cirne et al. 2016).

This work was carried out with the objective of evaluating the ingestive behavior of feedlot lambs fed diets consisting of fresh sugarcane, dehydrated bagasse treated with calcium oxide, or urea ammoniated sugarcane bagasse.

Material and methods

The experiment was conducted at Federal Institute of North of Minas Gerais (IFNMG), Salinas campus, between the months of December 2010 and February 2011. The municipality of Salinas is located in the north region of Minas Gerais state, Brazil (16° 09′ 12″ S latitude, 42° 18′ 29″ W longitude, and 475 m altitude). The average annual temperature and precipitation in the region are 22.4 °C and 700 mm, respectively (Maciel et al. 2012).

Animals and experimental diets

A total of 34 Santa Inês lambs, castrated 10 days after birth, aged an average 3.0 ± 0.6 months with a mean initial live weight of 17.8 ± 5.2 kg were used for the experimentation. They were distributed in a randomized design, with 12 wethers fed with a fresh sugarcane diet, with 2.6 % urea in dry matter (DM), 11 wethers fed with dehydrated sugarcane bagasse treated with 0.5 % calcium oxide in DM, and 11 wethers fed with ammoniated sugarcane bagasse with 5 % of urea and 1.2 % soybean in DM.

The animals were housed in individual pens with 1.2 m^2. The diets were formulated to comply with daily weight gain requirements of 200 g, according to the NRC (2007). The forage-to-concentrate ratio was 50:50, based on DM (Table 1). The feed was supplied twice a day, at 0800 hours and 16 hours, in the form of a complete mixture (Table 2).

Laboratory analysis

Laboratory analysis was performed in the Forage Laboratory of Southwest Bahia State University (UESB). Samples of each animal's forages, concentrates, and leftovers were dried in a forced ventilation oven (60 °C) and processed in a cutting mill (1-mm mesh sieve). The levels of DM, ash, organic matter (OM), crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin (H_2SO_4 72 % p/p) were obtained according to the procedures described by Silva and Queiroz (2002). The level of neutral detergent fiber corrected for ash and protein (NDFap) was obtained according to recommendations by Licitra et al. (1996) and Mertens (2002).

Total carbohydrate (TC) content was estimated according to Sniffen et al. (1992), as

$$TC = 100-(\%CP + \%EE + \%ash)$$

The level of non-fibrous carbohydrates corrected for ash and protein (NFCap) was calculated as proposed by Hall (2003)

$$NFCap = (100-\%NDFap-\%CP-\%EE-\%\,ash)$$

The levels of estimated total digestible nutrients (TDN) of the total diets were calculated according to equations described by the NRC (2001). To obtain the indigestible neutral detergent fiber (iNDF) levels in the diets, samples of the supplied feed were incubated in the rumen for 240 h (Casali et al. 2008).

Ingestive behavior evaluation

The experiment lasted a total of 74 days. The initial 14 days were used for the animals to adapt to the management, premises, and diets. The data collection period lasted 60 days,

Table 1 Percentage composition of ingredients in the experimental diets

Ingredients (g/kg DM)	Fresh Sugarcane[a]	Treated bagasse with CaO[b]	Ammoniated bagasse[c]
Forage	500	500	500
Corn meal	177	201	270
Soy meal	300	275	204
Urea	–	10	–
Dicalcium phosphate	16	14	20
Limestone	7	–	6

[a] Sugarcane with 2.6 % urea added (% DM)

[b] Sugarcane bagasse treated with calcium oxide (0.5 % DM)

[c] Ammoniated sugarcane bagasse (5 % urea and 1.2 % soybean DM)

Table 2 Bromatological composition of experimental diets

Item (g/kg DM)	Fresh Sugarcane[a]	Treated bagasse with CaO[b]	Ammoniated bagasse[c]
Dry matter (g/kg fresh matter)	383	845	471
Organic matter	931	953	937
Crude protein	146	144	148
Ether extract	28	21	28
Ash	69	47	62
Total carbohydrates	483	803	455
Neutral detergent fiber corrected for ashes and protein	451	614	542
Indigestible neutral detergent fiber	161	383	109
Non-fibrous carbohydrates	305	181	98
Acid detergent fiber	170	413	217
Hemicellulose	307	236	357
Cellulose	146	319	191
Lignin	61	153	83
Total digestible nutrients	619	621	636

[a] Sugarcane with 2.6 % urea added (% DM)

[b] Sugarcane bagasse treated with calcium oxide (0.5 % DM)

[c] Ammoniated sugarcane bagasse (5 % urea and 1.2 % soybean DM)

which was divided into three 20-day periods for evaluation of behavior.

During the ingestive behavior evaluation, the animals were subjected to five 24-h periods of visual observation (Fischer et al. 1998), with one observation on the 15th day of each period and an intermediate observation consisting of two consecutive days, on the 30th and 31st days of experiment, when the time spent feeding, ruminating, and idling was observed.

Visual observation of the animals took place every 5 min (totaling 288 observations per data collection day) and was performed in turn by four trained observers. During night observations, the environment was kept under artificial light.

In order to obtain cud chew time means, three ruminal boli were filmed during three different periods in the day, according to the methodology described by Burger et al. (2000). The number of cud chews/bolus and the time spent to ruminate each bolus were determined from the film.

In order to calculate behavior variables, feeding, and rumination in minutes per kilograms of DM and NDFap, feeding efficiency (g DM and NDFap/h), rumination efficiency (in g DM and NDFap/bolus and g DM and NDFap/h), and mean intake of DM and NDFap per feeding period. We considered the voluntary intake of DM and NDFap on the 15th day of each period and the 30th and 31st days, computing the leftovers of the 16th day of each period and the 31st and 32nd experimental days.

The number of boli ruminated daily was calculated as the total rumination time obtained at each interval (minute) divided by the mean time spent ruminating one bolus. The concentration of DM and NDFap in each ruminated bolus (grams) was obtained by dividing the quantity of DM and NDFap consumed in 24 h (grams per day) by the boli ruminated daily.

Feeding efficiency, rumination, and total chewing time were calculated as outlined by Bürger et al. (2000)

$$\mathrm{EALDM} = \mathrm{DMI}/\mathrm{TF}$$

$$\mathrm{EALNDF} = \mathrm{NDFapI}/\mathrm{TF}$$

where EALDM (g DM consumed/hour) and EALNDF (g NDFap consumed/hour) = feeding efficiency, DMI (g) = daily dry matter intake, NDFapI (g) = daily NDFap intake, and TF = time spent feeding every day.

$$\mathrm{ERUDM} = \mathrm{DMI}/\mathrm{TRU}$$

$$\mathrm{ERUNDF} = \mathrm{NDFapI}/\mathrm{TRU}$$

where ERUDM (g DM ruminated/hour) and ERUNDF (g NDFap ruminated/hour) = rumination efficiency and TRU (hour/day) = rumination time.

$$\mathrm{TCT} = \mathrm{TF} + \mathrm{TRU}$$

where TCT (min/day) = total chewing time.

The number of feeding, rumination, and idling periods was counted by the number of activity sequences observed in the comments spreadsheet. The mean daily duration of these activity periods was calculated by dividing the total duration of each activity (feeding, rumination, and idling in minutes per day) at each interval between observations by its respective number of discrete periods.

Statistical analysis

The results were analyzed using ANOVA and Tukey's test at 5 % probability. All statistical analyses were performed using the SAEG program (Statistical and Genetic Analysis System, UFV 2000).

Results

The ingestion of DM in 24 h varied by diet. The highest consumption value ($P < 0.05$) was obtained for animals receiving fresh sugarcane consumed 45.99 and 38.99 % more DM in comparison the animals receiving treated bagasse with CaO and ammoniated bagasse, respectively (Table 3). The NDFap intake varied with the diet as well, animals fed with treated bagasse with CaO had the larger ($P < 0.05$) consumption of NDFap followed by animals fed with ammoniated bagasse and those fed fresh sugarcane (Table 3).

Table 3 Ingestive behavior and performance of lambs fed diets containing fresh sugarcane, dehydrated bagasse treated with calcium oxide, or bagasse ammoniated with urea

Item	Forages			SEM
	Fresh Sugarcane[a]	Treated bagasse with CaO[b]	Ammoniated bagasse[c]	
	Consumption in 24 h (kg of DM)			
DM Intake	0.984a	0.711b	0.674b	0.021
NDF Intake	0.135c	0.453a	0.195b	0.008
	Feeding			
Minutes/day	302.83b	419.54a	308.18b	7.069
	Rumination			
Minutes/day	510.41ab	570.18a	495.63b	10.542
	Chewing			
Minutes/day	813.25b	989.72a	803.81b	11.921
Seconds/bolus	42.52	44.18	46.63	1.341
	Idling			
Minutes/day	626.50a	450.09b	635.90a	11.943
	Daily weight gain			
Kilograms/day	0.155a	0.096c	0.127b	0.004

Means followed by the same letter in the same line do not differ from one another with the use of Tukey's test at 5 % probability

SEM standard error of the mean

[a] Sugarcane with 2.6 % urea added (% DM)

[b] Sugarcane bagasse treated with calcium oxide (0.5 % DM)

[c] Ammoniated sugarcane bagasse (5 % urea and 1.2 % soybean DM)

Table 4 Feeding and rumination efficiency (g DM and NDF/hour) in lambs fed diets containing fresh sugarcane, dehydrated bagasse treated with calcium oxide, or bagasse ammoniated with urea.

Item	Forages			SEM
	Fresh Sugarcane[a]	Treated bagasse with CaO[b]	Ammoniated bagasse[c]	
	Feeding efficiency			
g DM/hour	205.40a	103.07b	140.07b	6.718
g NDF/hour	28.27c	65.46a	40.27b	1.777
	Rumination efficiency			
g DM/bolus	1.38a	0.92b	1.06a	0.049
g NDF/bolus	0.18c	0.30b	0.59a	0.019
g DM/hour	117.73a	75.93b	84.89b	3.137
g NDF/hour	16.15c	48.51a	24.51b	1.178

Means followed by the same letter in the same line do not differ from one another with the use of Tukey's test at 5 % probability

SEM standard error of the mean

[a] Sugarcane with 2.6 % urea added (% DM)

[b] Sugarcane bagasse treated with calcium oxide (0.5 % DM)

[c] Ammoniated sugarcane bagasse (5 % urea and 1.2 % soybean DM)

The animals fed with treated bagasse with CaO had significantly longer times in feeding and chewing ($P < 0.05$) compared with those on the fresh sugarcane diet and ammoniated bagasse (Table 3). The time spent in rumination was higher ($P < 0.05$) for animals fed with bagasse treated with CaO compared to bagasse ammoniated, and the time spent in idling was higher ($P < 0.05$) for animals fed with sugarcane and bagasse ammoniated. In addition, the daily weight gain was lower ($P < 0.05$) for animals fed bagasse treated with CaO (Table 3).

The feeding and rumination efficiency, expressed as grams of DM per hour and in grams of NDFap per hour, was affected by the experimental diets, with the fresh sugarcane diet having the best ($P < 0.05$) feeding and rumination efficiency in grams of dry matter per hour in relation to the other diets. However, all diets were different ($P < 0.05$) from one another in the feeding and rumination efficiency in grams of NDF per hour, with higher values observed ($P < 0.05$) for treated bagasse with CaO, ammoniated bagasse, and fresh sugarcane, respectively (Table 4). This confirms the lower quality of sugarcane NDF and shows us a possible improvement in the NDF profile of the bagasse treated with calcium oxide and the bagasse ammoniated with urea.

The values related to grams of dry matter per ruminated bolus were similar ($P > 0.05$) between animals that received sugarcane and ammoniated bagasse but were significantly lower ($P < 0.05$) for animals fed with treated bagasse with calcium oxide (Table 4).

There were statistically significant differences in rumination efficiency (g of NDF per ruminated bolus) among all the diets evaluated, with the efficiency being highest in animals fed with ammoniated bagasse, followed by those fed with treated bagasse, and finally, those fed with fresh sugarcane (Table 4).

The number of feeding and rumination periods was not changed significantly ($P > 0.05$) by the diets. However, the number of idling periods for the treated bagasse with calcium oxide diet was shorter ($P < 0.05$) than for other diets, due to the longer time spent on feeding and ruminating, as described previously.

With regard to the time spent per period of activity (Table 5), we observed significantly longer ($P < 0.05$) times spent per feeding and rumination period and shorter ($P < 0.05$) times spent per idling period in animals fed with treated bagasse with CaO, while animals fed with the other two diets showed no significant differences ($P > 0.05$) from each other. The longer feeding and rumination period and shorter idling period in animals fed with dehydrated and treated bagasse can be attributed to the high quantity of NDF present in the diet and the low quality of fiber.

Table 5 Numbers for feeding (#/day), rumination and idling periods, and time spent per feeding, ruminating, and idling period (minutes) in lambs fed diets containing fresh sugarcane, dehydrated bagasse treated with calcium oxide, or bagasse ammoniated with urea

Item	Forages			SEM
	Fresh Sugarcane[a]	Treated bagasse with CaO[b]	Ammoniated bagasse[c]	
	Number of periods (per day)			
Feeding	19.95	18.9	21.23	0.566
Rumination	28.85	27.05	29.65	0.682
Idling	40.38a	35.30b	40.50a	0.782
	Time spent per period (minutes)			
Feeding	15.72b	24.08a	14.89b	0.753
Rumination	18.52ab	21.49a	17.68b	0.533
Idling	15.76a	13.04b	16.01a	0.286

Means followed by the same letter in the same line do not differ from one another with the use of Tukey's test at 5 % probability

SEM standard error of the mean

[a] Sugarcane with 2.6 % urea added (% DM)

[b] Sugarcane bagasse treated with calcium oxide (0.5 % DM)

[c] Ammoniated sugarcane bagasse (5 % urea and 1.2 % soybean DM)

Discussion

The higher intake of fresh sugarcane with urea diet is possibly due to a better synchronization between sources of energy and protein used simultaneously by ruminal microorganisms for their growth, with saccharose and urea being sources of quickly available energy and protein, respectively. The average daily gain for sugarcane, treated bagasse with CaO, and ammoniated bagasse was 0.155, 0.096, and 0.127 kg/day, respectively (Table 3). The increase in fresh sugarcane consumption reflected in average daily gain of 61 and 22 % more in comparison the animals receiving treated bagasse with CaO and ammoniated bagasse, respectively. The intake of treated bagasse with calcium oxide was limited by the high level NDF in the diet (Table 2), while the ingestion of ammoniated sugarcane bagasse may have been reduced because of the strong smell of ammonia, even after aeration, which is characteristic of this feed.

The dry matter intake by animals fed with treated sugarcane bagasse with calcium oxide was similar to that of animals fed with ammoniated sugarcane bagasse. This similarity may be due to the similarity of the fibers in these feeds because the forage used was the same (sugarcane bagasse) and differed only in the type of chemical treatment (Table 2).

The significantly longer time the animals on the treated bagasse diet spent feeding, chewing, and ruminating is related to the digestibility of the treated bagasse with calcium oxide and to the level of this nutrient in the diet (Table 3). Van Soest (1994) commented that the rumination time consists of a variable that is directly and proportionally related to the level of NDF and the physical form of the diets; therefore, the time spent ruminating is proportional to the level of cell walls in the feeds, that is, diets with very different levels of NDF usually predispose the animals to different rumination times.

The values of NDF intake for wethers fed with fresh sugarcane and ammoniated bagasse were close to 0.33 kg of sugarcane consumed by caprines and described by Carvalho et al. (2011) and Carvalho et al. (2010), and the same is the case for the 0.15 and 0.28 kg of NDF, respectively, of sugarcane bagasse consumed by lambs and observed by Mendes et al. (2010) and Freitas et al. (2008). However, the consumption value of NDF for animals fed with the dehydrated and treated bagasse was higher than that reported in literature. According to Barros et al. (2011), the increased feeding and rumination time in animals fed with treated bagasse with calcium oxide can be explained by the increase in NDF level in the diet, which probably caused a lower rate of passage with subsequent ruminal fill.

Silva et al. (2015) evaluating the sugarcane bagasse in diets for lambs observed quadratic effect on feeding, ruminating, and idle times, with the decrease of bagasse in the diet. The lack of a significant difference in chewing activities (seconds per bolus) can be attributed to the similarity in processing for all the experimental diets and thus, the similarity in feed particle size as Saenz (2005) has shown that the size of feed particles has a great effect on ruminating and chewing activities. In addition, McLeod and Minson (1988) note that chewing activities are important mechanisms in the process of reducing feed particle size, answering for over 80 % of the total particle breakdown.

Although the chewing time in seconds per bolus did not differ significantly from one diet to the other, a significantly longer chewing time in minutes per day was observed for animals fed with dehydrated and treated bagasse compared with the other diets (Table 3), this is due to the higher fiber content of this diet compared to fresh sugarcane and ammoniated bagasse.

Increased total chewing activity was reported by Carvalho et al. (2006) for the use of growing levels of NDF of Tifton-85 hay (*Cynodon* sp.) in the diets of female goats, the authors recorded values of 546.9, 631.7, 687.5, 764.2, and 819.4 min/day for NDF levels of 20, 27, 34, 41, and 48 %, respectively. In this study, although the total chewing value of the treated bagasse was different from the other diets, the values related to the fresh sugarcane and ammoniated bagasse diets were distinctly higher (Table 3). Because this activity consisted of a weighing between feeding and ruminating activities, it is possible that the sugarcane and bagasse used in this experiment, predominantly fibrous forage, increased the chewing values found.

According to Rabelo et al. (2008), the time spent chewing increases as the NDF level of the fiber source increases, resulting in a reduced ingestion of DM. In the present research, the animals fed with dehydrated and treated bagasse spent longer periods chewing, expressed in minutes per day.

Therefore, the experimental values of 735, 800, and 648 boli per day, related to the fresh sugarcane, treated bagasse, and ammoniated bagasse diets, respectively, are considered high and are attributed to the increased difficulty the animals have in reducing the sugarcane and the bagasse particle and fiber. However, the increased time spent chewing can positively influence the balance between the acids produced in the rumen and the secretion of saliva, which is what influences rumen pH the most. Therefore, the longer time spent chewing for animals fed with the diet containing high levels of concentrate can be a way of improving the rumen environment (Mendes et al. 2010).

The intake in grams of dry matter per hour is directly related to the consumption expressed in kilograms per day (Table 3). The results found in the present work confirm the findings by Cardoso et al. (2006) who affirmed that ingestion and rumination efficiency of the NDF fraction increases as the level of fiber in the diet increases.

Rumination can be considered a physiological resource triggered most frequently by forage quality to improve feed use. The significantly higher mass of NDF per hour in dehydrated and treated bagasse with calcium oxide explains the reduction in intake of feed (g DM/hour), the increased number of ruminated boli per day, the significantly lower consumption of dry matter per bolus, and the significantly lower mass of dry matter per hour.

For rumination efficiency, the results were similar to those found for feeding efficiency (g DM/hour and g NDF/hour), possibly because they were directly related to one another. The improved NDF profile for the ammoniated bagasse, probably caused by the ammonization process, enabled higher consumption of NDF per bolus and a lower number of boli ruminated per day, improving rumination efficiency.

Rumination efficiency is an important mechanism in the control of low-digestibility feed use (Carvalho et al. 2004). Welch (1982) highlighted that rumination efficiency has great importance in the control of low-digestibility feed use; the animal can ruminate larger quantities of low digestibility feed during eight or nine ordinary rumination hours, enabling higher intake of feed and better productive performance.

The time spent in daily rumination, close to 13 h, was longer than reported by Welch (1982), which may be related to the low rate of passage of sugarcane and bagasse. Although the dry matter intake was higher for sugarcane, the animals adjusted the number of daily meals in similar form, indicating similarity as to the chemical profile among the diets. The absence of effect for the number of feeding and rumination periods was also observed by Carvalho et al. (2008). Chewing time has been one of the most studied and used measures to evaluate fiber effectiveness resulting from its effects on production of saliva, feed grinding, and consumption of DM and ruminal environment (Colenbrander et al. 1991).

Cardoso et al. (2006) affirmed that the level of NDF, when less than 44 % in the diet of feedlot lambs, has no influence on the time spent ingesting, ruminating, and idling. In the present study, only the diet with dehydrated and treated bagasse had levels of NDF higher than those described by Cardoso et al. (2006), which justifies the significant variation for this diet.

In a study involving Santa Inês lambs fed diets containing cocoa meal, Carvalho et al. (2008) observed that the mean time spent per feeding, rumination, and idling period was 22.5, 23.4, and 24.5, respectively. This is higher than the values found in this work, the probable cause being quick ruminal fill, enabled by the low quality of the forage used in this experiment, resulting in a shorter, more frequent periods of feeding, rumination, and idling. According to Dado and Allen (1994), the number of rumination periods increases with the level of fiber in the diet in order to process the ruminal digesta and improve digestive efficiency as was observed in this study.

Based on the intake and animal ingestive behavior, we recommend that feedlot lambs be fed the following feed types in order of forage quality: fresh sugarcane with urea, bagasse ammoniated with urea, or dehydrated bagasse treated with calcium oxide.

Compliance with ethical standards

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

References

Ahmed, M.H., Babiker, S.A., 2015. Effect of feeding urea-treated sugarcane bagasse on properties and quality of fresh meat of Sudan Baggara Zebu bulls. International Journal of Animal Biology, 1, 45-49.

Armentano, L., Pereira, M., 1997. Measuring the effectiveness of fiber by animal response trials. Journal of Dairy Science, 80, 1416-1425.

Barros, R.C., Rocha Júnior, V.R., Saraiva, E.P., Mendes, G.A., Meneses, G.C.C., Oliveira, C.R., Rocha, W.J.B., Aguiar, A.C.R., Santos, C.C.R., 2011. Ingestive behavior of feedlot Nellore cattle with different levels of substitution of sorghum silage for sugarcane or sugarcane bagasse ammoniated with urea. Revista Brasileira de Ciência Veterinária, 18, 6-13.

Bürger, P.J., Pereira, J.C., Queiroz, A.C., Silva, J.F.C., Valadares Filho, S.C., Cecon, P.R., Casali, A.D.P., 2000. Ingestive Behavior in Holstein Calves Fed Diets with Different Concentrate Levels. Revista Brasileira de Zootecnia, 29, 236-242.

Cardoso, A.R., Carvalho, S., Galvani, D.B., Pires, C.C., Gasperin, B.G., Garcia, R.P.A., 2006. Ingestive behavior of lambs fed with a diet of different levels of fiber in neutrol detergent. Ciência Rural, 36, 604-609.

Carvalho, G.G.P., Pires, A.J.V., Silva, F.F., Veloso, C.M., Silva, R.R., Silva, H.G.O., Bonomo, P., Mendonça, S.S., 2004. Ingestive behavior of dairy goats fed on cocoa meal or palm cake. Pesquisa Agropecuária Brasileira, 39, 919-925.

Carvalho, S., Rodrigues, M.T., Branco, R.H., Aparecida, C., Rodrigues, F., 2006. Feeding behavior of lactating Alpine goats fed diets containing diferente dietary levels of forage neutral detergent fiber. Revista Brasileira de Zootecnia, 35, 562-568.

Carvalho, G.G.P., Pires, A.J.V., Silva, R.R., Veloso, C.M., Silva, H.G.O., 2008. Ingestive behaviour of sheep fed with ammoniated or non-ammoniated elephant grass silage and agro industrial by-products. Revista Brasileira de Zootecnia, 37, 660-665.

Carvalho, G.G.P., Garcia, R., Pires, A.J.V., Silva, R.R., Ribeiro, L.S.O., Chagas, D.M.T., Pinho, B.D., Domiciano, E.M.B., 2010. Intake, apparent digestibility and days of collection in digestibility estimate in goats fed diets containing sugar cane treated with calcium oxide. Revista Brasileira de Zootecnia, 39, 2714-2723.

Carvalho, G.G.P., Garcia, R., Pires, A.J.V., Detmann, E., Ribeiro, L.S.O., Chagas, D.M.T., Silva, R.R., Pinho, B.D., 2011. Ingestive behavior in goats fed diets containing sugar cane treated with calcium oxide. Revista Brasileira de Zootecnia, 40, 1767-1773.

Carvalho, G.G.P., Garcia, R., Pires, A.J.V., Silva, R.R., Detmann, E., Eustáquio Filho, A., Ribeiro, L.S.O., Carvalho, L.M., 2013. Diets Based on Sugar Cane Treated with Calcium Oxide for Lambs. Asian-Australasian Journal Animal Science, 26, 218-226.

Casali, A.O., Detmann, E., Valadares Filho, S.C., Pereira, J.C., Henriques, L.T., Freitas, S.G., Paulino, M.F., 2008. Influence of incubation time and particles size on indigestible compounds contents in cattle feeds and feces obtained by in situ procedures. Revista Brasileira de Zootecnia, 37, 335-342.

Cirne, L.G, A., Baroni, M.R., Oliveira, G.J.C., Jaeger, S.M.P.L., Bagaldo, A.R., Oliveira, P.A.., Oliveira, R.L., Lêdo, A.S., Carvalho, G.G.P. 2016. Feed value of Gliricidia fodder salt for sheep. Semina: Ciências Agrárias, 37, 921-932.

Colenbrander, V.F., Noller, C.H., Grant, R.J., 1991. Effect of fiber content and particle size of alfalfa silage on performance and chewing behavior. Journal of Dairy Science, 74, 2681-2690.

Correia, B.R., Carvalho, G.G.P., Oliveira, R.L., Pires, A.J.V., Ribeiro, O.L., Silva, R.R., Leão, A.G., Rodrigues, C.S., 2015. Feeding behavior of feedlot-finished young bulls fed diets containing peanut cake. Tropical Animal Health and Production, 47, 1075-1081.

Costa, L.T., Silva, F.F., Pires, A.J.V., Bonomo, P., Rodrigues, E.S.O., Souza, D.D., Mateus, R., Silva, R.R., Schio, A.R., 2014. Ingestive behavior of lactating cows fed sugarcane and crude glycerin levels on the diet. Semina: Ciências Agrárias, 35, 2597-2604.

Costa, E.I, S., Carvalho, G.G.P., Pires, A.J.V., Dias, C.A.S., Cerutti, W.G., Oliveira, R.L., Barbosa, A.M., Maranhão, C.M.A. 2015., Feeding behavior and responses in grazing lactating cows supplemented with peanut cake. Revista Brasileira de Zootecnia, 44, 138-145.

Dado, R.G., Allen, M.S., 1994. Nutrition, feeding and calves: Variation in and relationships among feeding, chewing and drinking variables for lactating dairy cows. Journal of Dairy Science, 77, 132-144.

Fischer, V., Deswysen, A.G., Dèspres, L., Dutilleul, P., Lobato, J.F.P., 1998. Nycterohemeral Patterns of Ingestive Behavior of Sheep. Revista Brasileira de Zootecnia, 27, 362-369.

Freitas, A.W.P., Rocha, F.C., Zonta, A., Fagundes, J.L., Fonseca, R.F., Zonta, M.C.M., Macedo. F.L., 2008. Nutrient consumption and performance by sheep fed with diets based on hydrolyzed sugarcane. Pesquisa. Agropecuária Brasileira, 43, 1569-1574.

Hall, M. B., 2003. Challenges with nonfiber carbohydrate methods. Journal of Animal Science, 81, 3226–3232.

Licitra, G. Hernandez, T.M., Van Soest, P.J., 1996. Standardization of procedures for nitrogen fractionation of ruminant feed. Animal Feed Science and Technology, 57, 347-358.

Maciel, S. A., Barcelos, B. F., Oliveira, L. A., 2012. A análise da influência da altitude na temperatura e na precipitação da mesorregião Norte de Minas Gerais. Revista Geonorte, 1, 250-261.

Mcleod, M.N., Minson, D.J., 1988. Large particle breakdown by cattle eating ryegrass and alfalfa. Journal of Animal Science, 66, 992-999.

Mendes, C.Q., Turino, V.F., Susin, I., Pires, A.V., Morais, J.B., Gentil, R.S., 2010. Lamb feeding behavior and nutrient digestibility of high concentrate diets with different neutral detergent fiber sources. Revista Brasileira de Zootecnia, 39, 594-600.

Mertens, D.R., 2002. Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beakers or crucibles: collaborative study. Journal of AOAC International, 85, 1217-1240.

National Research Council - NRC. 2001. Nutrient requirements of dairy cattle. 7.ed. Washington: National Academy Press. 450p.

National Research Council - NRC. 2007. Nutrient requirements of small ruminants. Washington, D.C.: National Academy Press. 362p.

Nicory, I.M.C., Carvalho, G.G.P., Ribeiro, O.L., Silva, R.R., Tosto, M.S.L., Costa-Lopes, L.S., Souza, F.N.C., Nascimento, C.O., 2015. Ingestive behavior of lambs fed diets containing castor seed meal. Tropical Animal Health and Production, 47, 939-944.

Rabelo, M.M.A., Pires, A.V., Susin, I., Mendes, C.Q., Oliveira Junior., R.C., Gentil, R.S., Ferreira, E.M., 2008. Effect of raw sugar cane bagasse on performance and ingestive behavior of beef cattle. Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 60, 698-704.

SAEG, 2000. Sistema de análises estatísticas e genéticas. Federal University of Viçosa. Versão 8.0. Viçosa, MG.

Saenz, E.A.C., 2005. Modeling of feed particle size reduction in the ruminants nutrition. Ciência e Agrotecnologia, 29, 886-893.

Silva, D.J., Queiroz, A.C., 2002. Análise de alimentos: métodos químicos e biológicos. Viçosa: UFV. 235p.

Silva, R.R., Magalhães, A.F., Carvalho, G.G.P., Silva, F.F., Prado, I.N., Franco, I.L., Veloso, C.M., Chaves, M.A., Panizza, J.C.J., 2004. Comportamento ingestivo de novilhas mestiças de holandês suplementadas em pastejo de Brachiaria decumbens. Aspectos metodológicos. Revista Electrónica de Veterinaria, 5, 1-7.

Silva, A.E.M., Lira, A.T., Ferreira, M.A., Barros, L.J.A., Melo, T.T.B., Siqueira, T.D.Q., Soares, L.F.P., Costa, C.T.F., 2015. Sugar cane bagasse as roughage in sheep diet. Revista Brasileira de Saúde e Produção Animal,16, 118-129

Sniffen, C.J., O'Connor, D.J., Van Soest, P.J., Sniffen, C.J., 1992. A net carbohydrate and protein system for evaluating cattle diets: carbohydrate and protein availability. Journal of Animal Science, 70, 3562-3577.

Van Soest, P.J., 1994. Nutritional ecology of the ruminant. 2.ed. Ithaca: Cornell University Press. 476p.

Welch, J.G. 1982. Rumination, particle size and passage from the rumen. Journal of Animal Science, 54, 885-895.