DOI: 10.5433/1679-0359.2016v37n3p1629

Feeding behavior of lambs fed diets containing peach palm meal

Comportamento ingestivo de cordeiros alimentados com dietas contendo farinha de pupunha

Alana Batista dos Santos[1*]; Mara Lúcia Albuquerque Pereira[2]; Herymá Giovane de Oliveira Silva[2]; Taiala Cristina de Jesus Pereira[1]; Leandro Sampaio Oliveira Ribeiro[3]; José Augusto Gomes Azevêdo[4]; Leandro Borges Sousa[5]; Larisse Borges Sousa[5]; Samille Neres da Silva[5]; Fabiano Andrade Ferreira[5]; Fernando Oliveira Barreto[5]

Abstract

The aim of this study was to evaluate the feeding behavior of lambs fed diets containing peach palm meal replacing maize (0, 10, 40, 60, and 85% DM). Thirty Santa Inês sheep with an average initial body weight of 21.6 ± 0.87 kg were distributed in a completely randomized design with five diets and six replicates. Feeding time in min kg^{-1} DM and min kg^{-1} NDFap increased by 34 min and 99.6 min, respectively, with each level of substitution of maize for the peach palm meal. Rumination and chewing times, in min kg^{-1} DM and min kg^{-1} NDF, also increased in response to the substitution of maize for peach palm meal. When expressed in min day^{-1}, rumination and chewing activities decreased by 12.4 and 14.6 min, respectively, as the amount of peach palm meal in the concentrate was increased. The time spent idle increased linearly ($P<0.05$), by 14.6 min day^{-1}, with the replacement levels, compared with the control diet. Peach palm meal in the composition of sheep diets reduces the intakes of dry matter and fiber and decreases the feed and rumination efficiencies. Replacing maize by peach palm meal increases the feeding time and rumination and chewing activities of feedlot lambs.
Key words: Feed. Ethology. Idle. Rumination.

Resumo

Objetivou-se avaliar o consumo de matéria seca, de fibra e o comportamento ingestivo de cordeiros alimentados com dietas contendo farinha de pupunha em substituição ao milho (0, 10, 40, 60 e 85% da MS do concentrado). Foram utilizados 30 cordeiros, da raça Santa Inês, machos, não castrados, com peso corporal médio inicial de 21,6 ± 0,87 kg, distribuídos em delineamento inteiramente casualizado, com cinco dietas e seis repetições. Os tempos de alimentação em min kg^{-1} de matéria seca (MS) e min kg^{-1} de fibra em detergente neutro corrigida para cinza e proteína (FDNcp) apresentaram, respectivamente, incrementos de 34 minutos e 99,6 minutos para cada nível de substituição do milho pela farinha de pupunha. Assim como os tempos de ruminação e mastigação, em min kg^{-1} de MS e min kg^{-1} de FDNcp

[1] Discentes do Programa de Pós-Graduação em Zootecnia, Universidade Estadual do Sudoeste da Bahia, UESB, Itapetinga, BA, Brasil. E-mail: alanasantos10@hotmail.com; taiala.pereira@hotmail.com;
[2] Prof[as], Programa de Pós-Graduação em Zootecnia, UESB, Itapetinga, BA, Brasil. E-mail: marauesb@yahoo.com.br; heryma@gmail.com;
[3] Prof., Instituto Federal Baiano, IF BAIANO, Uruçuca, BA, Brasil. E-mail: leosampaio-zoo@hotmail.com;
[4] Prof., Universidade Estadual de Santa Cruz, UESC, Ihéus, BA, Brasil. E-mail: augustog@uesc.br;
[5] Discentes do Curso de Graduação em Zootecnia, UESB, Itapetinga, BA, Brasil. E-mail: leandroborgessousa@hotmail.com; larissebs@hotmail.com; samille_neres@hotmail.com; fabinho0845@hotmail.com; nanddo_1@hotmail.com
[*] Author for correspondence

Recebido para publicação 01/06/15 Aprovado em 23/09/15

aumentaram em função dos níveis de substituição do milho pela farinha de pupunha. O tempo gasto com a atividade de ócio apresentou comportamento linear crescente (P<0,05) em função dos níveis de substituição, com aumento de 14,6 min dia^{-1} no dispêndio desta atividade, a cada nível de substituição do milho pela farinha de pupunha. A farinha de pupunha quando utilizada na composição de dietas para ovinos, reduz o consumo de matéria seca e fibra, além diminuir a eficiência de alimentação e ruminação. A substituição do milho pela farinha de pupunha promove aumento no tempo de alimentação, ruminação e mastigação de cordeiros confinados.
Palavras-chave: Alimentação. Etologia. Ócio. Ruminação.

Introduction

The Brazilian sheep herd has 16.8 million animals, and the northeast region of the country holds the largest inventory (56.7%) compared with the other geographic areas (IBGE, 2012). Despite this expressive number, the Brazilian sheep production still does not supply the domestic market with efficiency and quality due to organizational issues in the chain. The main obstacle is related to the lack of a constant supply, which hinders the structuring of the entire sector, including the formation of defined meatpacking operating periods. Thus, importing sheep meat is a necessary practice; in 2013 only, Brazil imported approximately nine thousand tons, almost all of which originated from Uruguay, a country that can provide a product of quality at competitive prices compared with the Brazilian product (ZEN et al., 2014). Therefore, for Brazilian sheep meat producers to become the supplying base of this market, research should be carried out providing technologies to increase the feed efficiency of these herds.

The use of high-concentrate diets, having maize and soybean as base ingredients, improves the uptake of nutrients to ruminants, providing the generation of better yields. However, production costs are ultimately elevated, decreasing the producer's profit margin. Thus, the use of agricultural or agro-industrial by-products has been a promising alternative when properly employed, with the possibility of providing similar weight gain and meat yield to conventional foods at a lower feed cost.

In this scenario, the peach palm meal, produced from the pulp of the peach palm, emerged as an attractive product. With the expansion of heart-of-palm production in the South of Bahia State, the market and commercialization of seeds for planting an replanting increased, and the result of this process was an increase in the availability of the pulp from the fruit, which does not have added value because the population in these regions does not have the habit of consuming it. Thus, the pulp from the peach palm fruit became a waste, as it did not have a proper disposal; consequently, its use has been proposed in the feeding of ruminants aiming to add value to it as well as improve production in sheep rearing systems, broadening the availability of animal protein.

Evaluating the use of peach palm meal replacing maize in diets for feedlot goat, Ribeiro (2014) found 93.2% dry matter, 7.8% crude protein, 11.5% ether extract, 10.5% neutral detergent fiber, and 80.6% total digestible nutrients. Moreover, that author concluded that peach palm meal has the potential to be used as an ingredient in goat diets, but its use in sheep feeding has not been studied yet. The potential of this by-product as an energy feedstuff in sheep diets is thus yet to be known. The objective of the present study was thus to evaluate the intakes of dry matter and fiber, as well as the feeding behavior of sheep fed diets containing peach palm meal.

Material and Methods

The experiment was conducted in the Sheep Farming Unit of Juvino Oliveira Campus, Universidade Estadual do Sudoeste da Bahia (UESB), located in Itapetinga, BA, Brazil. Thirty Santa Inês uncastrated male sheep at approximately 120 days of age, with an average initial body weight of 21.6 ± 0.87 kg and a body condition score of 2.39 ± 0.06, according to Osório and Osório's (2003) classification, were used in the experiment. After the administration of a vermifuge and ADE vitamin complex, animals were housed in individual 1.5 × 1.0 m stalls with slatted floor, provided with individual troughs and drinkers, distributed in a completely randomized design with five experimental diets: 0, 10, 40, 60, and 85% peach palm meal replacing maize in the concentrate. The experimental period was 87 days, with 15 days for adaptation and three 24-day periods for data and sample collection, totaling 72 days for evaluation of intake, performance, and feeding behavior.

The pulp of the pitted fruit was supplied by Indústria de Alimentos no Mercado de Palmitos (INACERES), located in Uruçuca-BA. The peach palm meal was produced in a flour mill at Instituto Federal Baiano (IF BAIANO), Uruçuca Campus-BA. The obtained pulp was dried in the sun for three consecutive days, with the material being turned over constantly until its moisture content was reduced. Subsequently, it was disintegrated in a cassava grinder, and then the ground mass was roasted in a mechanized flour roaster. This roasting procedure lasted 30 to 40 min, with the mass being turned over using wooden squeegees until its final drying, at approximately 13% moisture.

Diets were balanced according to NRC (2007) requirements for sheep in the finishing phase with a daily weight gain of 250 g. Centesimal and chemical compositions of the diets are shown in Table 1. Diets were supplied daily, at 07h00 and 16h00, *ad libitum*, so as to allow for 10 to 20% as orts. The daily voluntary intake was calculated as the difference between the total feed supplied and the orts, which were collected and weighed in the morning and afternoon, during the 87 experimental days.

Table 1. Centesimal composition of the ingredients and chemical composition (% DM) of the experimental diets

Ingredient (%DM)	Level of substitution (% DM)				
	0	10	40	60	85
Tifton 85 hay	30.0	30.0	30.0	30.0	30.0
Ground maize	50.7	45.6	29.7	20.3	7.6
Soybean meal	17.8	17.8	17.8	17.8	17.8
Peach palm meal	0.0	5.1	21.0	30.4	43.1
Mineral supplement[a]	1.5	1.5	1.5	1.5	1.5
Total	100	100	100	100	100
Chemical composition					
Dry matter	92.9	92.5	92.8	92.2	92.7
Organic matter[b]	93.5	93.1	93.5	93.2	93.5
Crude protein[b]	15.0	15.2	15.1	14.2	14.5
Neutral detergent insoluble protein[c]	31.6	32.5	29.5	31.3	26.8
Acid detergent insoluble protein[c]	20.6	20.0	21.2	20.9	17.9
Ether extract[b]	3.7	3.8	5.4	5.6	6.8
Non-fiber carbohydrates[b]	28.8	31.7	32.7	36.8	36.6
NDF corrected for ash and protein[b]	46.4	43.0	40.7	37.2	35.9
Acid detergent fiber[b]	22.4	22.4	21.4	23.3	23.1
Hemicellulose[b]	27.1	23.6	21.9	16.9	15.6
Cellulose[b]	19.2	19.0	18.0	19.9	19.0
Lignin[b]	3.3	3.3	3.4	3.3	4.1
Total digestible nutrients[b,d]	71.4	71.8	74.2	75.4	75.7
Metabolizable energy (Mcal/kg)	2.7	2.7	2.9	2.9	2.9

[a]/ Amount/kg of product: calcium (max.) - 170 g; phosphorus - 85 g; sodium - 113 g; sulfur - 19 g; magnesium - 13 g; copper - 600 mg; cobalt - 45 mg; chromium - 20 mg; iron - 1,850 mg; iodine - 80 mg; manganese - 1,350 mg; selenium - 16 mg; zinc - 4,000 mg; fluorine (max.) - 850 mg. [b]/ In % of DM. [c]/ In % of CP. [d]/ Estimated according to NRC (2001). *Analyses conducted at the Laboratory of Forage Crops and Pastures of UESB.

In each experimental period, samples of the feed supplied - roughage and concentrate - and orts were placed in labeled plastic bags and stored in a freezer at –20 ºC. After thawing, samples were pre-dried in a forced-air oven at 65 ºC. Next, they were ground in a Wiley knife mill with 1 mm sieves, and a composite sample was formed per animal and period, and labeled for subsequent laboratory analyses.

Dry matter (DM), mineral matter (MM), crude protein (CP), ether extract (EE) contents were determined (AOAC, 1995) in the samples of orts and supplied feed. For the sequential analyses of neutral (NDF) and acid (ADF) detergent fiber, samples were treated with thermostable alpha-amylase, without sodium sulfate, and corrected for residual ash (MERTENS, 2002). The NDF correction for nitrogen compounds and estimate of the neutral (NDIN) and acid (ADIN) detergent insoluble nitrogen compounds were carried out according to Licitra et al. (1996). Lignin was obtained based on the methodology described by Detmann et al. (2012), with the ADF residue treated with 72% sulfuric acid.

Non-fiber carbohydrates (NFC) contents were calculated by adapting Hall's (2003) recommendation, utilizing NDFap. Total digestible nutrients (TDN) were calculated according to Weiss (1999).

The lipid fraction of the experimental diets was determined at the Center for Chromatographic Analyses (CEACROM) of UESB, according to the method of Bligh and Dyer (1959). Triacylglycerols were transesterified according to ISO (1978) method 5509. Approximately 200 mg of the extracted lipid matter was transferred to test tubes; 2 mL of n-heptane were added, and the mixture was agitated. Next, 2 mL of 2 mol.L^{-1} KOH in methanol were added; the bottle was sealed hermetically, and the mixture was subjected to vigorous agitation. After the phases were separated, the upper layer (heptane and methyl esters of fatty acids) was transferred to an Eppendorf tube and stored for later chromatographic analysis. The methyl esters were analyzed in a gas chromatograph (Thermo-Finnigan) equipped with flame ionization detector and a fused capillary column (BPX-70; 120 m, 0.25 mm d.i). Peak areas were determined by the normalization method, using ChromQuest 4.1 software. Peaks were identified by comparison of the retention times of fatty acid methyl esters (Sigma, USA), and after determining the equivalent chain length (Table 2).

Table 2. Lipid fraction (g/100 g DM) of the experimental diets

Lipid fraction (g/100 DM)	Level of substitution (% DM)				
	0	10	40	60	85
Total lipids	3.25	3.52	4.37	4.87	5.54
Total saturated	0.92	0.94	1.00	1.03	1.08
Total unsaturated	2.34	2.59	3.37	3.83	4.46
Monounsaturated	0.03	0.11	0.34	0.48	0.67
Polyunsaturated	2.30	2.48	3.03	3.36	3.80

In the evaluation of the feeding behavior, animals were subjected to visual observation periods in the three experimental periods. Lambs were observed for 24 h, in five-minute intervals, for the evaluation of the feeding, rumination, and idle times. During the nocturnal observations, the environment was maintained under artificial illumination, and animals were adapted four days before.

To record the mean values of the number and time of chews per ruminal cud, a digital stopwatch was used for each animal, adopting the visual observation of the animals in the intervals of 10h00 to 12h00, 14h00 to 16h00, and 18h00 to 20h00 (BÜRGER et al., 2000).

The results referring to feeding behavior-related factors were obtained by the following divisions:

FE = DMI/FT

RU = DMI/RT

RU = NDFapI/RT

TCT = FT+RT

NRC = TRU/ChTRC

NChRC = NRC/NChRC

where FE (g DM h^{-1} and g NDFap h^{-1}): feed efficiency; DMI (g DM day^{-1}): DM intake; FT (min day^{-1}, min kg^{-1} DM, and min kg^{-1} NDFap): feeding time; RE (g DM h^{-1}; g NDFap h^{-1}): rumination efficiency; RT (min day^{-1}, min kg^{-1} DM, and min kg^{-1} NDFap): rumination time; TCT (min day^{-1}, min kg^{-1} DM, and min kg^{-1} NDFap): total chewing time; NRC (n day^{-1}): number of ruminal cuds; ChTRC (s cud^{-1}): chewing time per ruminal cud; and NChRC (n cud^{-1}): number of chews per ruminal cud (BÜRGER et al., 2000).

The number of feeding, rumination, and idle periods was counted as the sequential number of activities observed in the annotations spreadsheet. The average duration of these periods of activities was calculated by dividing the total duration of each activity (feeding, rumination, and idle, in min day^{-1}) by its respective number of discrete periods.

Data were analyzed by the MIXED procedure of SAS software (SAS, 2006). Polynomial contrasts were performed to compare the means of the diet containing only maize (0% peach palm meal) and diets substituting the maize for the peach palm meal (10, 40, 60, and 85%) (A). Linear- (L) and quadratic (Q)-order effects as a function of substitution of maize for peach palm meal were broken down into polynomial contrasts. The following statistical model was used:

$$Y_{ijk} = (\beta_0 + \beta_1 Tr + \beta_2 Tr^2) + \varepsilon_{ijk};\ NID\ (0; \sigma^2)$$

where: Y= estimated value according to the diets; β0 = intercept; β1 and β2 defined the variation of Y according to the level of substitution; and Tr = level of substitution (0, 10, 40, 60, and 85% peach palm meal). For all statistical procedures, the critical probability level for type-I error was set at 0.05.

Results and Discussion

Dry matter intake at 24 h showed to be affected by the contrast between the group of diets containing peach palm and only maize (P=0.0001), with the former displaying the lowest value: 1119, 919, 766 and 738 g, respectively, for the levels of 10, 40, 60, and 85% of substitution of maize for the meal, as compared with the diet containing maize exclusively (control; 1311 g). Thus, a relationship was established between the intake of DM from the control diet and that from the diet containing peach palm meal (885.5 g), in which a 26.4% decrease was found between the intakes of the contrast (Table 3). Analyzing the regression equation according to the levels of peach palm meal, a decreasing linear effect was thus observed (P=0.0001) for each level of substitution, with DM intake decreasing by 142.5 g day^{-1} in relation to the control diet (Table 3).

Table 3. Intakes of dry matter (DMI) and neutral detergent fiber corrected for ash and protein (NDFap), and feeding, rumination, chewing, and idle activities according to levels of substitution of maize for the peach palm meal in feedlot lambs

Item	Level of substitution (% DM)					SEM	P-value[1]		
	0	10	40	60	85		M *vs* P	L	Q
			Intake (g/day)						
DMI	1311	1119	919	766	738	50.7	<0.0001	<0.0001[a]	0.1653
NDFap	623.9	512.1	406.2	310.6	291.0	26.9	<0.0001	<0.0001[b]	0.0922
			Feeding						
(Min day^{-1})[c]	176.4	184.0	192.8	201.4	191.6	6.0	0.3118	0.2889	0.5107
Min kg^{-1}DM	137.5	168.9	212.5	271.4	265.5	13.0	0.0004	<0.0001[d]	0.4364
Min kg^{-1} NDFap	289.3	368.3	480.4	666.2	671.1	35.1	<0.0001	<0.0001[e]	0.6703
			Rumination						
Min day^{-1}	485.8	502.0	492.2	432.5	440.3	10.2	0.4178	0.0224[f]	0.3985
Min kg^{-1} DM	381.2	458.0	540.9	601.4	608.4	26.5	0.0048	0.0008[g]	0.3886
Min kg^{-1} NDFap	802	1000	1222	1471	1535	70.8	0.0005	<0.0001[h]	0.5714
			Chewing						
(Nº cud^{-1})[i]	40.4	38.9	4.4	43.1	38.9	0.8	0.8162	0.8325	0.2242
(Seg cud^{-1})[j]	56.2	53.8	58.8	57.8	56.0	1.2	0.8862	0.6802	0.6280
Min day^{-1}	662.2	686.0	685.0	633.9	631.9	9.1	0.8882	0.0739[l]	0.1663
Min kg^{-1} DM	518.7	626.9	753.4	872.7	874.0	36.1	0.0005	<0.0001[m]	0.3236
Min kg^{-1} NDFap	1091	1369	1703	2137	2206	98.9	<0.0001	<0.0001[n]	0.5297
			Idle						
Min day^{-1}	777.8	754.0	755.0	806	808	9,1	0.8859	0.0733[o]	0.1652

[1]M vs. P - Contrasts between the diet containing only maize vs. diets with levels of substitution of maize for peach palm meal; Significant * (P<0.0001); ** (P<0.001); *** (P<0.01); **** (P<0.05); [a] $\hat{Y}$ = 1390.81* - 142.47X*; [b] $\hat{Y}$ = 661.50* - 78.9327X*; [c] $\hat{Y}$ = 189.89*; *; [d] $\hat{Y}$ = 105.17* + 34.0095X*; [e] $\hat{Y}$ = 186.26* + 99.6487X*; [f] $\hat{Y}$ = 505.26* - 12.4193X****; [g] $\hat{Y}$ = 336.42* + 61.3420X*; [h] $\hat{Y}$ = 624.56* + 191.84X*; [i] $\hat{Y}$ = 39.8523*; [j] $\hat{Y}$ = 57.0922*; * [l] $\hat{Y}$ = 706.68* - 14.5937X****; [m] $\hat{Y}$ = 439.95* + 96.9476X*; [n] $\hat{Y}$ = 803.34* + 293.74X*; [o] $\hat{Y}$ = 733.22* + 14.6399X*.

In view of the results described for the DM intakes over 24 h, we can emphasize that the animals probably accepted the control diet better; besides, they did not select much the ingredients of this diet. This observation was confirmed when the orts from the trough with the diet containing only maize were analyzed, with the leftover material consisting of roughage and concentrate; however, for the diets containing peach palm meal, the animals consumed all the hay, while the orts, which were heterogeneous, contained a greater amount of concentrate. This observation was more frequent for the diets containing 60 and 85% peach palm meal. According to Hill (2007), palatability can be defined as the sensory perception of the feed, which can be influenced by smell, nutrients, or textures. Thus, it is noteworthy that, throughout the experiment, the peach palm meal underwent the oxidation process, which was visible by the change in color. Therefore, this fact was considered to have likely affected DM intake.

Results for NDFap responded similarly to DM intake over 24 h. The peach palm meal levels present in the concentrate led to significant reductions in NDFap, such that the highest percentage consumed was found with the control diet (623.9 g), and the lowest for the diet containing 85% peach palm meal (291.0 g), in which a 53.4% decrease was detected. Thus, the decreasing linear equation was adjusted (P=0.0001), in which every percentage unit of peach palm meal added to the concentrate resulted in a reduction of 78.9 g of NDFap intake for each level of substitution (Table 3). The reduction in the intake of this nutrient over 24 h may be associated with the lower DM intake and to the reduction of NDFap in the diet with the increment in peach palm meal. Furthermore, the increase in the EE content of the diets, with a greater concentration of unsaturated fatty acids (Tables 1 and 2), possibly caused deleterious effects on the ruminal supplementation, reducing the fiber digestibility. Despite not being well elucidated, the mechanisms through which lipid supplementation reduces voluntary intake involve both the effects on the palatability of the feed, rumen fermentation, and intestinal motility, and the release of intestinal hormones and oxidation of fat in the liver (ALLEN, 2000).

The amount of feed consumed in a certain period is always changed according to the number of meals and depending on the duration and speed of ingestion (RIBEIRO, 2014). Understanding the feeding behavior is very important in animal nutrition, because it makes it possible to know how factors inherent to animals participate in the regulation of feed intake, and thus adjustments can be made to improve production (MENDONÇA et al., 2004). A significant effect was thus observed with the substitution of maize for the peach palm meal on feeding time. In the evaluation of the contrast between the group of diets containing peach palm and only maize, no effect of feeding time in min day^{-1} was found, but significant effects (P<0.05) were observed on the feeding times in mg/kg DM and min kg^{-1} of NDFap, in which the animals fed diets containing peach palm meal displayed longer feeding times compared with the control diet (Table 3).

The regression equation for feeding time (min kg^{-1} DM and min kg^{-1} NDFap) showed that this variable increased linearly (P<0.05) with the levels of substitution of maize for the peach palm meal. Thus, the feeding times in min kg^{-1} DM and min kg^{-1} NDFap increased by 34 and 99.6 min, respectively, for each level of substitution, in relation to the control diet (Table 3).

The presented parameters agree with the facts observed at the evaluation of the animal behavior: the animals fed the diets containing peach palm meal sought the food more often, with short feeding periods, whereas those fed the control diet accessed the trough at more specific times and for long periods, demonstrating that the sheep consuming peach palm meal spent more time on the feeding activity.

The animals receiving diets with substitution of maize for peach palm meal had a longer average rumination time, when expressed in min kg^{-1} DM and min kg^{-1} NDFap, which were 552.2 1,307, compared with the control diet, which averaged 381.2 min kg^{-1} DM and 802 min kg^{-1} NDFap. Thus, the percentage increase in rumination time, on average, was 44.9% and 62.9%, respectively (Table 3).

When the rumination activity (min kg^{-1} DM and min kg^{-1} NDFap) was analyzed as a function of the levels of peach palm meal added to the concentrate, regression equations with increasing linear effect were observed (P<0.05), in which every level of substitution of the maize for the peach palm meal generated a 61.3 min kg^{-1} DM and 191.8 min kg^{-1} NDFap increase in the time spent on rumination, in relation to control diet. On the other hand, the rumination time in min day^{-1} was reduced by 12.4 min with the increase in the amount of peach palm meal in the concentrate (Table 3). Thus, it is believed that the increase in this activity, when expressed in min kg^{-1} DM and min kg^{-1} NDFap, may be associated with the quality of the NDFap, in which the concentration of hemicellulose, the most digestible portion of NDFap, decreased with the increase in the amount of peach palm meal in the diet (Table 1), which influenced the digestibility of NDFap, increasing the rumination time (Table 3).

Another interesting inference to be stressed about the presented results is how the concentrate content of the total diet, associated with the elevation in the percentage of fat in the diets with the levels of peach palm meal (Table 1), might have inhibited the action of the fiber-degrading microorganisms and thus compromised the fiber digestibility and passage rate. Moreover, the ingredients that made up the diets have higher levels of unsaturated than saturated fatty acids (Table 2).

The inferences presented and verified for the rumination activities were moderate, and agree with the results published by Ribeiro (2003), who described that small ruminants can spend more than one-third of their time ruminating. The author also reported that characteristics inherent to the feed such as the fiber content, the forage particle length, the amount of forage consumed, and heat stress, are some factors that affect the rumination time and consequently affect other parameters of the feeding behavior secondarily, such as the total feeding and idle time and the feed and rumination efficiencies.

Among the feeding behavior parameters, the periods of feed consumption are alternated with sequences of one or more rumination or idle periods. However, the time used for rumination by animals is usually long at night, but the rumination periods are also paced by the feed supply (SILVA et al., 2011). Therefore, it can be observed that the effectiveness of rumination is one of the important factors in the control of the use of roughages and, thus, an animal ruminating longer during a certain period may consume more roughage and be more productive.

Regarding the times spent on the chewing activity (n cud^{-1} and s cud^{-1}), no interference of the levels of substitution of maize for the meal was found (Table 3). Thus, the mean values, expressed as n cud^{-1} and s cud^{-1}, were 40.7 and 56.5, respectively. The contrast did not have an effect on chewing expressed in min day^{-1}, and so the animals had equal chewing times irrespective of the diet they were fed. Nevertheless, an effect was observed on the chewing rates in min kg^{-1} DM and min kg^{-1} NDFap after the analysis of the contrast, demonstrating that the diets containing peach palm meal differed from the control diet in that they had higher mean values of the referred variables.

These results are reinforced by the regression equations for chewing rate in min kg^{-1} DM and min kg^{-1} NDFap, which increased linearly ($P<0.05$) (Table 3), with every level of substitution of maize for peach palm meal providing an increase of 96.9 min kg^{-1} DM and 293.7 min kg^{-1} NDFap in chewing, compared with control. Although the contrast was not significant for chewing rate in min day^{-1}, a decreasing linear equation ($P=0.0739$) was adjusted, and every level of substitution led to a reduction of 14.6 min in this variable.

The chewing activity has been one of the most studied measurements used to evaluate the effectiveness of the fiber, due to its effect on saliva production, the process of feed grinding, and the dry matter intake (MERTENS, 2001). Thus, the results found for chewing are very consistent: the number of chews per ruminal cud and the time per cud were not changed with the diets, but the chewing times per kg DM and per kg NDF increased (Table 3). Thus, it can be inferred that intake was one of the prevailing factors for the reduction of chewing time in min day^{-1}, whereas the decrease in fiber quality with the increase in the amount of peach palm meal provided an increase in the time spent on this activity, when expressed in min kg^{-1} DM and min kg^{-1} NDFap.

For the time spent idle (min day^{-1}), the contrast between the group of diets containing peach palm meal and the control diet was not significant, averaging 780 min day^{-1} (Table 3). However, when the idle activity was evaluated as a function of the substitution levels, an increasing linear response was observed (P<0.05), with every level of substitution of maize for the peach palm meal resulting in an increase of 14.6 min day^{-1} in the time spent idle, in relation to control diet.

The results presented here can be explained by the fact that the animals took less time at the trough feeding and selecting the food, due to the lower intake of DM provided by the diets containing peach palm meal. Besides, animals spent less time ruminating (min day^{-1}) and, consequently, the highest demand of time was used in idleness (min day^{-1}), since the diets with peach palm meal probably increased the time required to reduce the particle size in the rumen, as a consequence of the increase in the unsaturated fatty acids/NDF ratio that might have affected the activity of the fibrolytic bacteria, especially in the concentrates containing 85% peach palm meal. This effect may be related to the toxicity of the unsaturated fatty acids on the development of microorganisms, especially the cellulolytic ones (NRC, 2007; MARTINELE et al., 2008), associated with a reduction of the NDF quality, which reduced the proportion of hemicellulose of the diets (Table 1). However, as the animals spent more time idle, less time was used for feeding and rumination, since these are mutually exclusive behavioral activities.

Feed efficiency was influenced by the substitution of maize for the peach palm meal in feedlot-sheep diets. Lower feed efficiencies were observed with the diets containing peach palm meal compared with the diet containing only maize, both in DM h^{-1} and g NDFap h^{-1}. Thus, it was possible to establish relationships and observe dramatic reductions in feed efficiency of 49.5 and 58.1%, in g DM h^{-1} and g NDFap h^{-1}, respectively, when the control diet was compared with that containing 85% peach palm meal (Table 4).

Table 4. Feed and rumination efficiencies according to levels of substitution of maize for the peach palm meal in feedlot lambs

Item	Level of substitution (% DM)					SEM	P-value[1]		
	0	10	40	60	85		M *vs* P	L	Q
	Feed efficiency								
gDM h^{-1}	458.0	378.8	293.3	231.5	231.2	21.6	<0.0001	<0.0001[a]	0.1454
gNDFap h^{-1}	218.1	173.3	129.9	94.2	91.3	11.1	<0.0001	<0.0001[b]	0.1101
	Rumination efficiency								
Cuds (nº day^{-1})[c]	532.2	567.2	501.9	456.6	476.1	16.3	0.4217	0.1149	0.9338
gDM Cud^{-1}	2.5	2.0	1.8	1.8	1.6	0.1	0.0036	0.0025[d]	0.3343
NDFap cud^{-1}	1.2	0.9	0.8	0.7	0.6	0.1	<0.0001	<0.0001[e]	0.2431
gDM h^{1}	163.1	133.9	112.6	108.4	101.3	6.0	0.0002	<0.0001[f]	0.1195
gNDFap h^{-1}	77.6	61.3	49.8	43.9	39.9	3.2	<0.0001	<0.0001[g]	0.1188

[1]M vs. P - Contrasts between the diet containing only maize vs. diets with levels of substitution of maize for peach palm meal; Significant * (P<0.0001); ** (P<0.001); *** (P<0.01); **** (P<0.05); [a] $\hat{Y}$ = 459.35* - 49.2754X*; [b] $\hat{Y}$ = 216.58* - 26.3047 X*; [c] $\hat{Y}$ = 501.54*; [d] $\hat{Y}$ = 2.4394* - 0.1845X***; [e] $\hat{Y}$ = 1.1716* - 0.1143X*; [f] $\hat{Y}$ = 159.40* - 12.5635X**; [g] $\hat{Y}$ = 76.3497* - 7.6222X.

Another possibility of evaluation that enables a better analysis of the feed-efficiency results is through the regression equation, which displayed a decreasing linear response (P<0.05), with each level of substitution of the maize for the peach meal leading to a decrease of 49.3 g DM h^{-1} and 26.3 g NDFap h^{-1} in relation to the control diet (Table 4). These results may be explained by the reduction of DM and NDFap intakes without an equitable reduction in the feeding time (min day^{-1}). Thus, it can be stated that, throughout the experiment, when the animals were fed diets containing peach palm meal they consumed less DM and NDFap then those fed the control diet, in the same time interval, consequently reducing the feed and rumination efficiencies.

Rumination efficiency was significantly changed by the use of the peach palm meal in the composition of the sheep diet. However, the number of cuds ruminated in 24 h (cuds, n day^{-1}) was not influenced by the levels of replacement of maize by the peach palm meal, averaging 501.5 cuds day^{-1}. This result indicates that although the animals fed the diets containing peach palm meal consumed less DM and NDFap (Table 3), the amount of cuds ruminated was balanced, probably in an attempt to promote higher digestibility and passage rate to these diets.

An effect of the contrast was found on the rumination efficiency (g DM cud^{-1} and g NDFap cud^{-1}), and thus marked reductions were detected between the diet that contained only maize and those with levels of substitution of this ingredient for the meal, whose values were 36% and 50%, respectively, in g DM cud^{-1} and g NDFap cud^{-1} (Table 4). The regression equations for rumination efficiency, in g DM cud^{-1} and g NDFap cud^{-1}, showed a decreasing linear response (P<0.05), with reductions of 0.18 and 0.11, respectively, for each level of maize substituted for the peach palm meal, demonstrating that the control diet was well accepted by the animals, because they consumed more DM and consequently had better efficiencies.

In the evaluation of the contrast for the rumination efficiency (g DM h^{-1} and g NDFap h^{-1}), the use of peach palm meal in the concentrate influenced the results, with the control diet standing out in comparison with those containing the meal (Table 4). Thus, the diets containing 0, 10, 40, 60, and 85% peach palm meal showed mean values of 163.1, 133.9, 112.6, 108.4, and 101.3 g DM h^{-1}; and 77.6, 61.3, 49.8, 43.9, and 39.9 g NDFap h^{-1} (Table 4). When relationships were established, significant reductions were found in rumination efficiency (DM h^{-1} and g NDFap h^{-1}): 37.9 and 48.6%, respectively when the control diet was contrasted with that containing 85% peach palm meal.

Agreeing with the results, the regression equations showed a decreasing linear effect (P<0.05), with each level of substitution of the maize for the peach palm meal providing a decrease of 12.6 g DM h^{-1} and 7.6 g NDFap h^{-1} in rumination efficiency (Table 4). These facts were probably evidenced by the lower intakes of DM and NDFap, associated with the increase in the EE contents and reduction of the quality of the ingested fiber.

In a study developed by Mertens (2001), the chewing time was related to DM intake, to the dietary NDFap concentration, and the latter associated with the particle size. As regards the present experiment, it can be stated that although DM intake was higher with the control diet, which, in turn had the highest fiber concentration (46.4%), the diets containing peach palm meal provided the longest chewing time (kg DM and NDFap h^{-1}) (Table 3) and lowest feed and rumination efficiencies (Table 4). These results can be explained by the reduction of the fiber quality (lower hemicellulose content and increased cellulose and lignin) (Table 1).

No effect was observed for the contrast (P>0.05) between the diet containing only maize and the diets with levels of substitution of maize for the peach palm meal on the variables number of feeding, rumination, and idle periods. Similarly, the number of feeding, rumination, and idle periods (n day^{-1}) was not influenced by the levels of substitution, averaging 8.8, 14.4, and 20.9 (Table 5), respectively, with the animals requiring a higher number of idle periods, followed by rumination and feeding.

Table 5. Number and average time spent per period on the feeding, rumination, and idle activities, and intakes of DM and NDFap per feeding period according to the levels of substitution of maize for the peach palm meal in feedlot lambs

Item	Level of substitution (% DM)					SEM	P-value[1]		
	0	10	40	60	85		M *vs* P	L	Q
	Number of periods (nº day^{-1})								
Feeding [a]	8.8	7.8	8.8	9.0	9.0	0.3	0.8281	0.5050	0.6575
Rumination [b]	14.8	14.0	14.2	14.2	15.0	0.3	0.4507	0.7896	0.1606
Idle [c]	20.8	20.0	21.0	20.5	22.0	0.3	0.9593	0.2289	0.2536
	Time spent by period (min)								
Feeding [d]	20.2	24.0	21.8	22.9	21.6	0.6	0.1361	0.7045	0.1885
Rumination	32.9	36.6	35.1	30.5	29.4	0.9	0.9897	0.0442[e]	0.1162
Idle [f]	37.5	38.2	36.2	39.4	36.9	0.7	0.9017	0.9961	0.8159
	Intake per feeding period (kg)								
DM	0.16	0.15	0.11	0.09	0.08	0.1	0.0040	<0.0001[g]	0.6301
NDFap	0.07	0.07	0.05	0.04	0.03	0.1	0.0009	<0.0001[h]	0.6060

[1]M vs. P - Contrasts between the diet containing only maize vs. diets with levels of substitution of maize for peach palm meal; Significant * (P<0.0001); ** (P<0.001); *** (P<0.01); **** (P<0.05); [a] $\hat{Y}$ = 8.8444*; [b] $\hat{Y}$ = 14.3788; [c] $\hat{Y}$ = 20.9009*; [d] $\hat{Y}$ = 21.8175; [e] $\hat{Y}$ = 34.9101* - 1.0151X****; [f] $\hat{Y}$ = 38.2494; [g] $\hat{Y}$ = 0.1693* - 0.01947X*; [h] $\hat{Y}$ = 0.07950* - 0.01028X*.

Several factors can affect feed intake by ruminants, having a direct impact on their feeding behavior, among which are the neutral detergent fiber content (VAN SOEST, 1994), the fat content, and the physical form of the diet. Because the diets of the present experiment showed fiber contents that were reduced in quantity and quality with the substitution of maize for the peach palm meal (Table 1), the feed and rumination efficiencies were affected in a decreasing manner, having their processing rate per hour decreased. In addition, the number of rumination periods should decrease according to the fiber content of the diets, but this was not observed in this study, indicating that the peach palm meal did not lead to alterations in the feeding, rumination, or idle periods.

The similarity between the diets for the feeding, rumination, and idle periods and the time spent per feeding and idle period can be explained by the combined analysis of factors like the reduced DM and NDFap intakes with the diets containing peach palm meal, associated with the lack of effects for the feeding activities. These were offset by the rumination and idle activities and the time spent per period (min), which was significant only for rumination. The latter was a diluted effect between the times spent per feeding and idle period, which reflected in a similarity in the number of periods on each activity (n day^{-1}) between the levels of peach palm meal tested, demonstrating that the supply of peach palm meal does not affect the discretization of time series in sheep, in the feeding conditions of this experiment.

The time spent per feeding and idle period was not influenced by the substitution of maize for the peach palm meal. However, the time spent per rumination period had an effect, whose results demonstrate that the groups of animals fed diets containing peach palm meal spent less time ruminating - 11.9% less than control. Thus, irrespective of the diet supplied to the animals, the average time spent per feeding period was 21.8 min, while the average time spent idle was 38.2 min (Table 5).

For the times spent per period as a function of the levels of peach palm meal, only the rumination activity was affected, and thus decreasing-linear-effect equations were adjusted (P<0.05), with every level of substitution leading to a reduction of 1.0 min in the time spent per rumination period (Table 5). These results are consistent with and originate from the results observed for NDFap intake (g) and rumination activity (min day^{-1}), corroborating the assertions about the limitation of the fiber and EE of the peach palm meal on the feeding behavior of sheep.

The diets in which maize was substituted for the peach palm meal provided lower intakes of DM and NDFap per feeding period in relation to the control diet. Thus, for the diets containing 0, 10, 40, 60, and 85% of the meal, mean values of 0.16, 0.15, 0.11, 0.09, and 0.08 kg DM; and 0.07, 0.07, 0.05, 0.04, and 0.03 kg NDFap were consumed per feeding period (Table 5). However, establishing relationships, reductions of 50.0 and 57.1% were observed, respectively, when the control diet was compared with that containing 85% peach palm meal. These results were supported by the regression equations, which showed a linear decrease (P<0.05), with every level of substitution causing reductions of 0.02 kg DM and 0.01 kg NDFap in relation to the control diet (Table 5). These responses probably stemmed from the observed values for the intake DM and NDFap at 24 h, which were affected by the substitution of maize for the peach palm meal, directly related to the fiber quality, EE content, and density of the diet.

Conclusions

When utilized in the composition of sheep diets, peach palm meal reduces the intakes of dry matte and fiber and reduces the feed and rumination efficiencies.

Substitution of maize for peach palm meal provides an increase in the time feedlot lambs spend feeding, ruminating, and chewing.

Acknowledgments

To Fundação de Amparo à Pesquisa do Estado da Bahia - FAPESB, for the financial support granted for the project.

References

ALLEN, M. S. Effects of diet on short-term regulation of feed intake by lactating dairy cattle. *Journal of Dairy Science*, Champaign, v. 83, n. 7, p. 1598-1624, 2000.

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS - AOAC. Official methods of analysis. 16th ed. Arlington, Virginia: AOAC International, 1995. 1141 p.

BLIGH, E. G.; DYER, W. J. A rapid method of total lipid extraction and purification. *Journal Biochemistry and Physiology*, Foster, v. 37, n. 8, p. 911-917, 1959.

BÜRGER, P. J.; PEREIRA, J. C.; QUEIROZ, A. C.; SILVA, J. F. C.; VALADARES FILHO, S. C.; CECON, P. R.; CASALI, A. D. P. Comportamento ingestivo em bezerros holandeses alimentados com dietas contendo diferentes níveis de concentrado. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 29, n. 1, p. 236-242, 2000.

DETMANN, E.; SOUZA, M. A.; VALADARES FILHO, S. C.; QUEIROZ, A. C.; BERCHIELLI, T. T.; SALIBA, E. O. S.; CABRAL, L. S.; PINA, D. S.; LADEIRA, M. M.; AZEVEDO, J. A. G. *Métodos para análise de alimentos:* INCT - Ciência Animal. Viçosa, MG: Suprema, 2012. 214 p.

HALL, M. B. Challenges with non-fiber carbohydrate methods. *Journal of Animal Science*, Champaign, v. 81, n. 12, p. 3226-3232, 2003.

HILL, J. Impacts of nutritional technology on feeds offered to horses: a review of effects of processing on voluntary intake, digest characteristics and feed utilization. *Animal Feed Science and Technology*, Amsterdam, v. 138, n. 2, p. 92-117, 2007.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA - IBGE. Produção da pecuária municipal. Rio de Janeiro: IBGE, 2012. Disponível em: <ftp://ftp.ibge.gov.br/Producao_Pecuaria/Producao_da_Pecuaria_Municipal/2012/ppm2012.pdf>. Acesso em: 2 out. 2013.

ISO - International Standard ISO 5509; International. Organization for Standardization 1978, 1.

LICITRA, G.; HERNANDEZ, T. M.; VAN SOEST, P. J. Standardization of procedures for nitrogen fractionation of ruminant feed. *Animal Feed Science and Technology*, Amsterdam, v. 57, n. 4, p. 347-358, 1996.

MARTINELE, I.; EIFERT, E. C.; LANA, R. P. Efeito da monensina e do óleo de soja sobre os protozoários ciliados do rúmen e correlação dos protozoários com parâmetros da fermentação ruminal e digestivos. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 37, n. 6, p. 1129-1136, 2008.

MENDONÇA, S. S.; CAMPOS, J. M. S.; VALADARES FILHO, S. C.; VALADARES, R. F. D.; SOARES, C. A.; LANA, R. P.; QUEIROZ, A. C.; ASSIS, A. J.; PEREIRA, M. L. A. Comportamento ingestivo de vacas leiteiras alimentadas com dietas à base de cana-de-açúcar ou silagem de milho. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 33, n. 3, p. 723-728, 2004.

MERTENS, D. R. FDN fisicamente efetivo e seu uso na formulação de ração para vacas leiteiras In: SIMPÓSIO INTERNACIONAL DE BOVINOCULTURA DE LEITE: NOVOS CONCEITOS EM NUTRIÇÃO, 2., 2001, Lavras. *Anais*... Lavras: Universidade Federal de Lavras, 2001. p. 38.

MERTENS, D. R. Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beakers or crucibles: collaborative study. *Journal of AOAC International*, Gaithersburg, v. 85, n. 6, p. 1217-1240, 2002.

NATIONAL RESEARCH COUNCIL - NRC. *Nutrient requirements of dairy cattle*. 7 ed. Washington: National Academy Press, 2001. 450 p.

NATIONAL RESEARCH COUNCIL – NRC. *Nutrient requirements of small ruminants*: sheep, goats, cervids and New World Camelids. Washington: National Academies Press, 2007. 362 p.

OSÓRIO, J. C. S.; OSÓRIO, M. T. M. *Produção de carne ovina:* técnicas de avaliação *in vivo* e na carcaça. Pelotas: UFP, 2003. 73 p.

RIBEIRO, L. S. O. *Farinha de pupunha na alimentação de caprinos confinados*. 2014. Tese (Doutorado em Zootecnia) - Universidade Estadual do Sudoeste da Bahia, UESB, Itapetinga.

RIBEIRO, S. D. A. Pastagens para caprinos. In: VOLUMOSOS NA PRODUÇÃO DE RUMINANTES: VALOR ALIMENTÍCIO DE FORRAGENS, 1., 2003, Jaboticabal. *Anais*... Jaboticabal: Funep. 2003. p. 241-264.

STATISTICAL ANALYSIS SYSTEM INSTITUTE - SAS Institute. Statistical analysis system. User's guide. Cary: SAS Institute, 2006.

SILVA, V. L.; ROGÉRIO, M. C. P.; ALVES, A. A.; BOMFIM, M. A. D.; LANDIM, A. V.; LEITE, E. R.; COSTA, H. H. A.; FREIRE, A. P. A. Comportamento ingestivo de cordeiros alimentados com dietas contendo a inclusão de farelo de castanha de caju. *Revista da Faculdade de Zootecnia e Veterinária e Agronomia*, Uruguaiana, v. 18, n. 1, p. 165-181, 2011.

VAN SOEST, P. J. *Nutritional ecology of the ruminant*. 2th ed. Ithaca: Cornell University Press, 1994. 476 p.

WEISS, W. Energy prediction equations for ruminant. In: CORNELL NUTRITION CONFERENCE FOR FEED MANUFACTURERS, 61., 1999, Ithaca. *Proceeding*... Ithaca: Cornell University, 1999. p. 176-185.

ZEN, S.; SANTOS, M. C.; MONTEIRO, C. M. *Evolução da caprina e ovinocultura*. Brasília: Boletim Senar, 2014. 3 p.