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Full Length Article

Ingestion Behaviour of Feedlot Sheep Fed on Bean Processing Residue

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Abstract

The objective of this study was to evaluate the effect of including bean processing residue as a substitute to cottonseed cake on ingestion behaviour parameters in feedlot sheep diets. Twenty entire male experimental sheep were used with a mean age of 12 months and mean weight of 30 kg. A completely randomised design was used with four treatments and four repetitions. The treatments consisted of cottonseed cake substituted with bean residue at levels of 0, 33, 66 and 100%. The feeding behaviour of the animals was determined in the final two days of the experimental period by over 24 h. Registering feeding, rumination and idling by visual observation of animals every ten min. Ingestion behaviour data was statistically analysed using models based on the significance ($P < 0.05$) of regression parameters. The variable DM and NDFcp consumption (g day^{-1}) showed quadratic behaviour, increasing with levels of cottonseed cake substitution by bean residue ($P < 0.05$). Total feeding time also showed quadratic behaviour ($P < 0.05$), with the maximum time estimated as 5.71 h. The feeding efficiency of DM and NDFcp showed quadratic behaviour, increasing with levels of cottonseed cake substitution with bean residue ($P < 0.05$). The rumination efficiency of DM behaved quadratically ($P < 0.05$), with a maximum of 145.54 g h^{-1}. The estimated time for total idling showed quadratic behaviour ($P < 0.05$), and a mean of 9.21 h. Bean processing residue was found to substitute cottonseed cake in sheep diets up until a level of 60% of the concentrate.

Keywords: Efficiency; Feeding; Idling; Rumination

Introduction

The study of ingestion behaviour is a tool of high importance in diet evaluation, with the possibility to manage animal feeding in order to obtain the optimal productive development (Mendonça *et al.*, 2004; Fonseca *et al.*, 2016).

Ingestion behaviour of animals maintained on pasture is characterised by long feeding periods of 4 to 12 h per day, however for feedlot animals, the feeding periods varied from one to six h with energy-rich to low-energy foods, respectively (Burger *et al.*, 2000; Mendes *et al.*, 2015).

According to Soest (1995), the nature of the diet influences the rumination time, which appears to be proportional to the cell wall content of the roughage. The increase in consumption tends to reduce the rumination time per gram of feed (Oliveira *et al.*, 2015), a factor probably responsible for the increase in faecal particle sizes as elevated consumption influences passage rate in this way.

Animals in a confined feedlot regime generally consume high quantities of concentrate to provide their energy and protein requirements. Corn and soybean meal can be fed for their high biological value, while they provide an excellent combination as sources of energy and protein, respectively. The elevated costs of these however provide a limiting factor in their utilisation, with alternative feeds emerging which can be incorporated partially or totally in feedlot ruminant diets.

Against this context, Carvalho *et al.* (2004) and Ferreira *et al.* (2016) emphasised that the knowledge of animal ingestion behaviour of those that received agroindustrial by products or residues as a part of their diet contributed to the elaboration of rations as well as elucidate problems related to diminished consumption.

The description and prediction of ingestion behaviour can contribute to the understanding of causes of feed initiation or termination, in addition to understanding the voluntary consumption of animals (Fischer *et al.*, 2000; Miranda *et al.*, 2015).

The most commonly ingestion behaviour parameters studied are the feeding, rumination and idling times, feed and rumination efficiency, number of ruminating chews per feed bolus, time spent chewing ruminal boluses and the number of ruminating chews per day (Burger *et al.*, 2000).

This research was developed with the objective to

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evaluate the ingestion behaviour of sheep receiving levels of bean processing residue as a cottonseed cake substitute.

Materials and Methods

The Study Site and Experimental Period

The experiment was carried Instituto de Ciências Agrárias e Tecnológica da Universidade Federal de Mato Grosso, located in the municipality of Rondonópolis-MT, Rondonópolis is situated at 16°28′ south latitude, 50°34′ west longitude and at 757 m altitude, the temperature range was 5.4 to 26.1°C with 1240 mm mean annual rainfall, 80% of which falls from October to April.

The experimental period occurred during April and May of 2014 and was 21days in duration. The experimental diets consisted of 45% elephant grass (*Pennisetum purpureum* cv. Napier) silage and 55% concentrate, which contained the same 14% crude protein level for a daily gain of 200 grams (NRC, 2007). The silage was reported in silos with 0.2 tons, being offered to the animals after 40 days. The animals throughout the experimental period received mineral salt in the following proportion: phosphorus = 80 g; calcium = 177 g; sulfur = 20 g; sodium = 40 mg; copper = 550 mg; iodine = 60 mg; selenium = 15 mg; manganese = 1200 mg; zinc = 3000 mg; and fluorine (max) = 800 mg.

Ground corn, soybean meal, cottonseed cake, urea and bean residue were used to formulate the concentrate. Twenty entire male experimental sheep of undefined breed were used, with a mean age of 12 months and mean weight of 30 kg. The sheep were distributed in a completely randomized design with four treatments and four repetitions.

Treatments, Manage and Sampling Procedure

The experimental treatments consisted of substitution of cottonseed cake at levels of 0, 33, 66 and 100% by bean residue. The composition of the experimental diets can be viewed in Table 1.

Following weighing and worming, the animals were maintained in individual bays of 1.5 m^2 with water coolers and troughs provided for ration and mineral salt provision. In the adaptation period, the diets were provided *ad libitum* and the consumption was registered daily. The consumption during the final three days of the adaptation period served as a reference point for the provision of diets in the sample collection phase. After the adaptation phase, the diets were provided daily at 08:00 and 16:00 h.

The amount of feed offered was adjusted according to feed intake during the animals' adaptation period, and no orts greater than 10% were allowed. In the final five experimental days, the daily samples of feed provided, left over and faeces excreted were obtained. These were frozen and later homogenised to obtain the respective compositions of the samples.

Bean residue consisted of various grain types: entire (crumpled, wrinkled, stained and unhulled), halves (healthy halves) and cracked (healthy pieces), in addition to impurities such as stems and pods. For concentrate inclusion, the residue was ground using a 5 mm sieve.

To quantify the daily faecal excretion, collection bags were tied to the animal. Faecal collection was made twice daily, one h prior to treatment provision in the morning and afternoon. Immediately following the weighing of faeces, samples were taken and placed in a freezer. Following this, samples were homogenised and one representative sample per animal was taken.

The silage, concentrate, leftovers and faecal samples for each experimental unit were pre-dried in a forced ventilation oven at 60°C for approximately 72 h, and then were ground in a Willey mill using a 1 mm sieve screen.

The samples were guarded in polyethylene recipients for subsequent analyses of dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), neutral detergent fibre (NDF) and indigestible neutral detergent fibre (NDFi), were determined according to (AOAC, 2005). The residual neutral detergent fibre corrected for ash and nitrogenous compounds (NDFcp) was determined according to Licitra *et al.* (1996).

Due to the presence of urea in the diets, the non-fibrous carbohydrates (NFC) of the diet were calculated according to Hall (2003): NFC = 100 – [(%CP - %CP derived from urea) + %EE - %ash]. The indigestible neutral detergent fibre (NDFi) of feed and scraps was obtained through *in situ* incubation for 240 h (Casali *et al.*, 2008), following neutral detergent fibre analysis. The chemical composition of experimental diets is given in Table 2.

Animals' Feeding Behavior

Daily nutrient consumption was determined by the difference between the quantity of nutrients provided and the quantity of nutrients left over. Feeding behaviour of animals was determined in the final two days of the experimental period by time interval quantification over 24 h (Fischer *et al*., 2000).

Animals' feeding behavior was determined in the last five days of the experimental period by quantifying the time intervals, for 24 h (Fischer *et al.*, 2005). In the recorded time spent in feeding, rumination, and resting, the visual observation of the animals for every 10 min is done by six trained observers, in rotation system, strategically placed in order to not bother the animals. During the same period, the counting of cud chews (MMnb, number/piece) was performed using a digital chronometer. To obtain chewing averages and time, cud observations were performed every 30 min, within 24 h of evaluation.

This variables DM g and NDF/bolus, efficiency of feeding and rumination, expressed in g DM/h and g NDF/h, the number of ruminated boluses per day (NBR), time of total chewing (TMT), and the number of cud chews per day (MMND), were obtained through methodology described

Table 1: Composition of experimental diets

Ingredients	Levels of cottonseed cake substitution with bean residue (%)			
	0	33	66	100
Elephant grass silage	45.00	45.00	45.00	45.00
Ground corn	28.0	27.40	27.38	27.41
Soybean meal	2.86	3.32	3.22	3.29
Cottonseed cake	24.06	16.04	8.02	0.00
Bean residue	0.00	8.02	16.04	23.90
Urea	0.00	0.22	0.34	0.40

Table 2: Chemical composition of experimental diets (% DM)

Components	Levels of cottonseed cake substitution with bean residue (%)				Bean Residue
	0	33	66	100	
Dry matter	59.02	58.72	58.44	58.15	89.94
Organic matter	93.52	93.31	93.23	93.20	95.81
Crude protein	14.13	14.14	13.62	13.00	20.70
Ether extract	6.33	5.35	4.39	3.44	2.49
NDFcp[1]	41.49	40.16	38.84	37.54	19.09
Non-fibrous carbohydrates	31.57	34.29	37.35	40.37	53.54
NDFi[2]	13.96	13.26	12.55	11.84	1.39
TDN_{est}[3]	63.28	64.39	65.64	66.94	78.13

[1]neutral detergent fiber corrected for ash and protein; [2]indigestible neutral detergent fiber; [3]estimated total digestible nutrients

by (Burger *et al*., 2000). During data collection, in the night observation, the environment was keptunder artificial lighting.

The number of feeding periods, rumination, and rest were calculated by the number of activity sequences observed in the note sheet. The average daily duration of these activity periods was calculated dividing the total duration of each activity (feeding, rumination, and rest in min/day) by its respective number of described periods.

The number of feeding, rumination and idling periods was counted by the number of activity sequences observed from the information sheet. The mean diurnal, nocturnal, minimum and maximum temperatures presented values of 27, 23, 21 and 36°C, respectively and were obtained during the observation period of 24 h utilising a maximum and minimum thermometer.

Statistical Analysis

Descriptive analyses of variable behavioural data were made and distributed into diurnal and nocturnal feeding, rumination and idling times. To compare the diurnal and nocturnal periods, each variable such as feeding, rumination and idling time was analysed by analysis of variance and the Tukey test was utilised at 5% significance ($P < 0.05$).

The other behavior data were analyzed based on the significance of the regression parameters, tested by the t test ($P < 0.05$), and the determination coefficients (SAS, 2002).

Results

Feeding, Rumination and Idling Times

The feeding, rumination and idling times in both the diurnal and nocturnal periods were presented in Fig. 1.

The comparative statistical analyses of the feeding, rumination and idling times distributed diurnally and nocturnally were presented in Table 3.

Ingestion Behaviour

The DM, NDFcp consumptions, efficiency of DM rumination, idling time, number of ruminal boluses per day and number of ruminating chews per bolus presented quadratic behaviour with the increased substitution levels of cottonseed cake by bean residue ($P < 0.05$) (Table 4).

The total rumination time and chewing time per ruminal bolus, showed no significant effects ($P > 0.05$) (Table 4).

The number of ruminating chews per day, rumen boluses, hours per day showed quadratic behaviour ($P < 0.05$). The numbers of feeding, rumination and idling times per day did not show significant effects for differing substitution levels ($P > 0.05$). Number per bolus day showed linear behaviour ($P < 0.05$) (Table 5).

Discussion

In general, independent from treatment, the peaks of feeding occurred in the early morning from 07:00 to 09:50 h and in the late afternoon from 16:00 to 18:50 h (Fig. 1), with the highest concentration observed in the morning period. This behaviour can be explained by the time of feed provision and, according to Santos *et al.* (2014), animals confined in feedlots are stimulated to search for food when it is offered, which may have had an influence on the feeding time of this research.

According to Freitas *et al.* (2010), ruminants generally present a diurnal standard of feeding whether on pasture or in feedlots, though the time of feed distribution and the

Table 3: Distributions of ingestion behavior in the diurnal and nocturnal periods according with levels of substitution, coefficient of variation (CV), regression equation and coefficient of determination (R^2)

Behaviour	Levels of cottonseed cake substitution with bean residue (%)				CV (%)	Equation	R^2
	0	33	66	100			
Diurnal feeding	3.75a	4.06a	4.25a	4.16a	15.06	$Y = 3.7428 + 0.0133X - 0.00009X^2$	99.31
Nocturnal feeding	1.62b	1.71b	1.27b	1.54b	18.36	Y = 1.536	-
Diurnal idling	4.56b	4.25b	3.64b	4.08b	19.08	Y= 4.4380 - 0.0060X	89.9
Nocturnal idling	6.29a	5.72a	5.60a	5.81a	14.96	Y = 5.85	-
Diurnal rumination	3.68a	3.69a	4.10a	3.75a	17.03	Y = 3.8067	-
Nocturnal rumination	4.10a	4.58a	5.12a	4.71a	18.03	Y = 4.63	-

Means followed by different letters in the same row are significantly different by the Tukey test ($P < 0.05$)

Table 4: Ingestion behavior, coefficients of variation (CV), regression equations and coefficients of determination (R^2) at different levels of substitution

Behaviour	Levels of cottonseed cake substitution with bean residue (%)				CV (%)	Equation	R^2
	0	33	66	100			
	g day^{-1}						
DM consumption	1009.8	1188.2	1210.63	1135.30	15.93	$Y = 1013.0528 + 6.9073X - 0.0571X^2$	99.19
NDFcp consumption	424.59	444.12	485.46	404.38	18.27	$Y = 417.4020 + 2.2097X - 0.0227X^2$	71.95
	hours day^{-1}						
Feeding	5.37	5.77	5.52	5.70	10.31	$Y = 5.4299 + 0.0068X - 0.00004X^2$	69.66
Rumination	7.78	8.27	9.22	8.45	20.56	Y = 8.4368	-
Idling	10.85	9.97	9.24	9.89	11.15	$Y = 10.9149 - 0.0452X + 0.0003X^2$	94.42
	g hour^{-1}						
DM feeding efficiency	198.33	212.39	253.3	213.1	9.95	$Y = 192.9052 + 1.4892X - 0.0123X^2$	65.94
NDFcp feeding efficiency	84.56	78.23	91.13	82.30	14.77	$Y = 82.4872 + 0.0784X - 0.0006X^2$	64.12
DM rumination efficiency	136.65	149.34	139.7	137.6	9.75	$Y = 138.1860 + 0.3069X - 0.0032X^2$	64.58
NDFcp rumination efficiency	59.35	57.15	48.40	54.40	32.84	Y = 54.8268	-

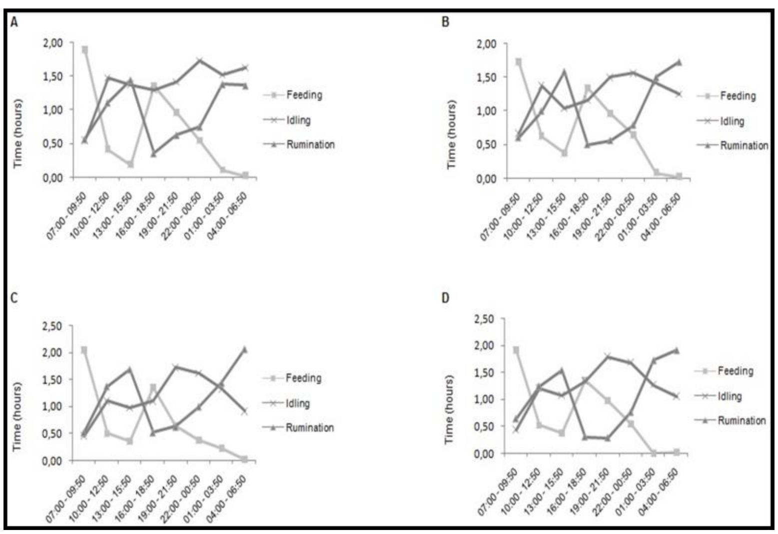

Fig. 1: Daily variation in feeding, rumination and idling behaviour of sheep fed on diets with (A) 0%, (B) 33%, (C) 66% and (D) 100% substitution of cottonseed cake by bean residue

quantity provided can influence the instances of the peaks of ingestion activity. In this study, idling time was always observed to be prior to feeding time (Fig. 1), with a rumination peak occurring from 13:00 to 15:50 h followed by resting. Analysis of Fig. 1 shows that ruminants possess a diurnal feeding habit and a nocturnal rumination habit, with intercalated idling time.

The ruminants in this study presented this habit of nocturnal rumination due to an evolutionary advance in relation to other herbivores, their post-gastric fermentation, which enables the same feeding pattern during the day by being more prepared for possible predatory attacks, and rumination during the night as a form of adaptation (Soest, 1995).

Diurnal feeding time was statistically different from nocturnal feeding time regardless of the level of cottonseed

Table 5: Ingestion behavior, coefficients of variation (CV), regression equations and coefficients of determination (R^2) at different levels of substitution

Item	Levels of cottonseed cake substitution with bean residue (%)				CV (%)	Equation	R^2 (%)
	0	33	66	100			
Rumen boluses (number day^{-1})	677.2	752.1	805.1	756.2	10.38	$Y = 673.3162 + 3.6721X - 0.0280X^2$	96.33
Mastication time per bolus (seconds)	42.41	40.09	41.52	40.47	16.06	$Y = 41.1278$	-
	Ruminating chews						
Hours per day	13.16	14.04	14.74	14.16	8.69	$Y = 13.1088 + 0.0442X - 0.0003X^2$	95.28
Number per bolus	60.97	60.73	66.26	63.99	10.81	$Y = 60.8203 + 0.0436X$	50.43
Number per day	40933	45160	53281	48159	10.63	$Y = 40071.1299 + 302.6737X - 2.1354X^2$	82.11
	Feeding. rumination and idling periods (number day^{-1})						
Feeding	32.24	34.62	33.12	34.24	26.31	$Y = 33.56$	-
Rumination	46.73	49.62	55.37	50.74	20.56	$Y = 50.62$	-
Idling	65.12	59.87	55.49	59.37	12.15	$Y = 59.96$	-

cake substitution with bean residue ($P < 0.05$), showing a longer average feeding time by more than 100% (Table 3). Mendes Neto *et al.* (2007) studied ingestion behaviour of lactating feedlot heifers and also observed a longer feeding time during the day (75.68%) compared to the nocturnal period.

The diurnal rumination time was not statistically different from the nocturnal rumination time independent of the tested diet in this study ($P > 0.05$) (Table 3), despite the accreditation that ruminants have a nocturnal rumination habit as a form of protection from predators. The non-difference between the diurnal and nocturnal rumination times may have occurred due to the physical and chemical characteristics of the diets being very close to each other (Table 1 and 2).

The diurnal idling time was statistically different from the nocturnal idling time ($P < 0.05$), with the nocturnal time being, on average, 40% longer than the diurnal idling time (Table 3). This situation indicates that the idling time was dispersed between the feeding times as there was no difference between the rumination times based on treatment.

Diurnal feeding time showed quadratic behaviour ($P < 0.05$), while the diurnal idling time showed a negative linear effect ($P < 0.05$), with the increased levels of inclusion of bean residue as a substitute for cottonseed cake (Table 3). The nocturnal feeding, diurnal and nocturnal rumination and nocturnal idling time variables did not result in significant effects ($P > 0.05$), presenting means of 1.53; 3.80; 4.63 and 5.85 h, respectively.

The maximum time spent feeding in the diurnal period was 4.23 h at a substitution level of 73.88% cottonseed cake in the concentrate by bean residue, estimated by a regression equation (Table 3). Meanwhile, the diurnal idling time presented a reduction of 0.006 h for each unit of bean residue added to the concentrate as a cottonseed cake substitute.

Using a regression equation allowed the estimations of the maximum DM and NDFcp consumptions to be 1221.94 and 471.17 g day^{-1}, corresponding to concentrate substitution levels of 60.48 and 48.67%, respectively (Table 4).

The DM consumption behaviour presented can be associated with the presence of anti-nutritional compounds in the bean residue which affect the palatability and the meeting of the energy demands of the animal. At a 65.1% level of cottonseed cake substitution by bean residue, the TDN consumption was estimated to be 888.29 g day^{-1}, a value higher than that recommended by the NRC (2001) by 720 g day^{-1}.

Total feeding time showed quadratic behaviour ($P < 0.05$), with a maximum of 5.71 h occurring at a level of substitution of 85% cottonseed cake by bean residue in the concentrate (Table 4). Considering the energetic requirements of animals, it has been seen that when animals presented their maximum DM consumption at a 60.48% level of substitution, this increase in feeding time occurred until an 85% level of substitution. This can be justified by the quadratic behaviour of the feeding efficiency of DM ($P < 0.05$), which had its maximum at a 60.5% level of substitution (Table 4), where the animals continued to consume but at lower quantities.

The NDFcp feeding efficiency also showed quadratic behaviour with increased levels of cottonseed substitution by bean residue ($P < 0.05$), with the maximum feeding efficiency obtained at a 65.33% level of substitution (Table 4).

The total rumination time showed no significant effects ($P > 0.05$), with a mean of 8.43 h (Table 4). Carvalho *et al.* (2004) also observed no effect on total rumination time when testing levels of agroindustrial by products in lactating goat diets, with a mean time of 7.6 h. Carvalho *et al.* (2006) found a mean total rumination time of 10.56 h with the inclusion of 40% cocoa meal or palm kernel cake in feedlot lamb diets.

Despite the NDFcp consumption showing quadratic behaviour with a mean consumption of 471.17 g day^{-1}, the fibrous fraction did not limit the ingestion behaviour of animals as the total rumination time did not differ among the diet treatments (Table 4). According to Soest (1995), rumination time is influenced by the nature of the diet and appears to be proportional to the cell wall content of the roughage portion.

Rumination is an important process for ruminants because it allows the food bolus to be re-masticated and salivated until reaching an adequate size for subsequent ruminal fermentation (Freitas *et al.*, 2010). The efficiency of DM rumination showed quadratic behaviour ($P < 0.05$), with a maximum efficiency of 145.54 g h^{-1} at a 47.95% level of substitution. The efficiency of NDFcp rumination did not show a significant effect when cottonseed cake was substituted for bean residue ($P > 0.05$), with a mean value of 54.82 g h^{-1} (Table 4).

Idling time showed quadratic behaviour ($P < 0.05$), with the minimum value estimated as 9.21 h (Table 4), at a substitution level of 75.33%. This value was similar to those found in literature, such as 11.35 h, as observed by Carvalho *et al.* (2008) and 7.66 h by Macedo *et al.* (2007). In general, the idling time was observed to be shaped by the feeding and rumination times, with similar values always calculated.

The number of ruminal boluses per day showed quadratic behaviour ($P < 0.05$), with an estimated maximum value of 793.71 boluses per day at a bean residue substitution level of 65.57% (Table 5). This quadratic behaviour was very similar to that observed by Carvalho *et al.* (2008), who fed sheep on levels of 0, 10, 20 and 30% cocoa meal inclusion to concentrate and estimated the maximum value to be 882.31 boluses per day at a level of 14.17% cocoa meal inclusion.

Chewing time per ruminal bolus did not show significant changes with increased inclusion of bean residue substitution in diets ($P < 0.05$), with a mean value of 41.12 sec (Table 5). Total mastication time showed quadratic behaviour ($P < 0.05$), with the maximum value estimated at 73.66% substitution of cottonseed cake by bean residue (Table 5). According to Mendes Neto *et al.* (2007), mastication is associated with the rate of salivary secretion, the solubilisation of feed components and the breaking of particles to facilitate the colonisation processes of these particles by ruminal and digestive microorganisms which influence the rate of passage, retention time and, consequently, the digestion of the feed.

The number of ruminating chews per bolus showed a linear increase with increasing substitution levels (Table 5). According to Beauchemin *et al.* (1994), chewing reduces particle size and hydrates the food during salivation, which frees soluble nutrients for fermentation, influencing microbial growth and exposing the fibrous feed fraction to microbial colonisation. Ruminating chews are therefore related to the reduction in particle size, the increased probability of leakage from the reticulo-omasal orifice and the passage through the lower digestive tract (Mendes Neto *et al.*, 2007).

The number of ruminating chews per day showed quadratic behaviour ($P < 0.05$), with the maximum number of daily chews being 50796.44 occurring at a substitution level of 70.87% (Table 5). This value was higher than those obtained by Burger *et al.* (2000) when testing the levels of concentrate in calf diets, obtaining 31490 and 26580 daily ruminating chews at concentrate levels of 45 and 60%, respectively. This reduction could possibly be related to the quadratic behaviour observed for DM consumption.

The numbers of feeding, rumination and idling times per day did not show significant effects for differing substitution levels, with respective mean values of 33.56, 50.62 and 59.96 periods per day (Table 5).

Conclusion

Bean processing residue can successfully substitute cottonseed cake in concentrate fed to sheep at levels up to 60.48%.

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References

AOAC (Association of Official Analytical Chemists), 2005. *Official Methods of Analyses*, 18th edition. Urbana, USA

Beauchemin, K.A., T.A. Mcllister and Y. Dong, 1994. Effects of mastication on digestion of whole cereal grains by cattle. *J. Anim. Sci.*, 72: 236–246

Burger, P.J., J.C. Pereira, J. Coelho and J.F. Silva, 2000. Comportamento ingestivo em bezerros holandeses alimentados com dietas contendo diferentes níveis de concentrado. *Braz. J. Anim. Sci.*, 29: 236–242

Carvalho, G.G.P., A.J.V. Pires and R.R. Silva, 2008. Ingestive behavior of Santa Inês sheep fed diets containing cocoa meal. *Braz. J. Anim. Sci.*, 37: 660–665

Carvalho, G.G.P., A.J.V. Pires and R.R. Silva, 2006. Ingestive behavior of sheep fed diets composed of ammoniated or non-ammoniated grass silage and agroindustrial by-products. *Braz. J. Anim. Sci.*, 35: 1805–1812

Carvalho, G.G.P., A.J.V. Pires, F.F. Silva, C.M. Veloso, R.R. Silva, H.G.O., Silva and P.S.S. Bonomo, 2004. Mendonça, Ingestive behavior of dairy goats fed with cocoa meal or palm pie. *Braz. Agric. Res.*, 39: 919–925

Casali, A.O., E. Detmann, S.C.V. Filho, J.C. Pereira, L.T. Henriques, S.G. Freitas and M.F. Paulino, 2008. Influence of incubation time and particle size on the content of indigestible compounds in foods and dung obtained by *in situ* procedures. *Braz. J. Anim. Sci.*, 37: 335–342

Ferreira, D.D.J., A.D.M. Zanine, R.D.P. Lana, A.L.D. Souza, M.D. Ribeiro, F.M. Negrao, W.J.R. Castro, H.N. Parente, L.J.V. Geron and L.R.D.A. Camara, 2016. Ingestive Behavior of Ovine Fed with Marandu Grass Silage Added with Naturally Dehydrated Brewery Residue. *Sci. World J.*, 2016: 1–7

Fischer, V., A. Deswysen and A.G. Dutilleul, 2005. Patterns of the nontechnical distribution of ingestive behavior of dairy cows, at the beginning and at the end of lactation, fed corn silage diet. *Braz. J. Anim. Sci.*, 31: 2129–2138

Fischer, V., P. Dutilleul and A.G. Deswysen, 2000. Aplicação de probabilidades de transição de estado dependente do tempo na analise quantitativa do comportamento ingestivo de ovinos. *Braz. J. Anim. Sci.*, 29: 1811–1820

Fonseca, A.A., A.M. Zanine, M.D. Ribeiro, F.P. Leonel, D.J. Ferreira, A.L. Souza, F.F.G. Silva and C.R.C. Neto, 2016. Desempenho produtivo e parâmetros sanguíneos de vacas leiteiras em pastejo suplementadas com resíduos de feijão. *Pesq. Agrop. Bras.*, 51: 76–85

Freitas, L.S.J., H.S. Silva, L.R. Segabinazzi, V.S. Silva, D.C.A. Filho and I.L. Brondani, 2010. Replacement of corn silage by sunflower silage in the diet of confined steers: ingestive behavior. *Braz. J. Anim. Sci.*, 39: 225–232
Hall, M.B., 2003. Challenges with non–fiber carbohydrate methods. *J Anim Sci.*, 81: 3226–3232
Licitra, G., T.M. Hernandez and P.J.V. Soest, 1996. Standardization of procedures for nitrogen fractionation of ruminant feeds. *Anim. Feed Sci. Technol.*, 57: 347–358
Macedo, C.A.B., I.Y. Mizubuti, F.B. Moreira, E.S. Pereira, E.L.A. Ribeiro, M.A. Rocha, B.M.O. Ramos and T.R. Casimiro, 2007. Ingestive behavior of sheep receiving diets with different levels of orange pomace instead of sorghum silage in the diet. *Braz. J. Anim. Sci.*, 36: 1910–1916
Mendes Neto, J., J.M.S. Campos, S.C.V. Filho, R.P. Lana, A.C. Queiroz and R.F. Euclydes, 2007. Ingestive behavior of dairy heifers fed citrus pulp replacing tifton 85 hay. *Braz. J. Anim. Sci.*, 36: 618–625
Mendes, F.B.L., G.G.P. Silva, R.R. Carvalho, F.F. Silva, T.O.J. Lins and A.L.N. Silva, 2015. Ingestive behavior of grazing steers fed increasing levels of concentrate supplementation with different crude protein contents. *Trop. Anim. Hlth. Prod.*, 47: 423–428
Mendonça, S.D.S., J.M.D.S. Campos, S.D.C.V. Filho, R.F.D. Valadares, C.A. Soares, R.D.P. Lana, A.C.D. Queiroz, A.J.D. Assis and M.L.A. Pereira, 2004. Ingestive behavior of dairy cows fed sugarcane or corn silage based diets. *Braz. J. Anim. Sci.*, 33: 723–728
Miranda, N.I., G.G.P. Silva, R. Lolato and N.C. Oliveira, 2015. Ingestive behavior of lambs fed diets containing castor seed meal. *Trop. Anim. Hlth. Prod.*, 47: 939–944
NRC - National Research Council, 2001. *Nutrients Requirements of Dairy Cattle*, 7th edition, p: 381. Washington DC, USA
Oliveira, R.L., A.D. Palmieri, A.G. Carvalho, C.V.L. Mambro and P.E. Sales, 2015. Commercial cuts and chemical and sensory attributes of meat from crossbred Boer goats fed sunflower cake-based diets". *Anim. Sci. J.*, 86: 557–562
Santos, A.B., M.L.A. Pereira, H.G.O. Silva, M.S. Pedreira and G.G.P. Carvalho, 2014. Nitrogen metabolism in lactating goats fed with diets containing different protein sources. *Anim. Sci. J.*, 27: 658–666
Soest, P.J.V., 1995. *Nutritional Ecology of the Ruminant*, 2nd edition, p: 476. Cornell, Ithaca, USA
SAS Institute, 2002. *SAS/STAT User's Guide: Version 8.2* (Cary, North Carolina, USA

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