Ingestion Behaviour of Feedlot Sheep Fed on Bean Processing Residue

Mariane Moreno Ferro1, Anderson de Moura Zanine2, Daniele de Jesus Ferreira2, Alexandre Lima de Souza1, Luiz Juliano Valério Geron3, Wanderson José Rodrigues de Castro1, Henrique Nunes Parente2, Michelle de Oliveira Maia Parente and Guilherme Ribeiro Alves1

1Department of Animal Science, Federal University of Mato Grosso, MT, Brazil
2Department of Animal Science, Federal University of Maranhão, MA, Brazil
3Department of Animal Science, State University of Mato Grosso, Pontes e Lacerda, MT, Brazil
1For correspondence: marianeferro544@gmail.com

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. © 2018 Friends Science Publishers

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 Van 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), 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 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 21 days 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 2.

Following weighing and worming, the animals were maintained in individual bays of 1.5 m² 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.

Beans 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 (2000): \[ NFC = 100 - \left[ \%CP - \%CP \text{ derived from urea} \right] - \%EE - \%ash \]. 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 composition Chemical composition of experimental diets 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/hour and g NDF/hour, 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 by (Burger et al., 2005). During data collection, in the night observation, the environment was kept under 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.

### Table 1: Composition of experimental diets

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Levels of cottonseed cake substitution with bean residue (%)</th>
<th>Bean Residue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td>Elephant grass silage</td>
<td>45.00</td>
<td>45.00</td>
</tr>
<tr>
<td>Ground corn</td>
<td>28.0</td>
<td>27.40</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>2.86</td>
<td>3.32</td>
</tr>
<tr>
<td>Cottonseed cake</td>
<td>24.06</td>
<td>16.04</td>
</tr>
<tr>
<td>Bean residue</td>
<td>0.00</td>
<td>8.02</td>
</tr>
<tr>
<td>Urea</td>
<td>0.00</td>
<td>0.22</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Components</th>
<th>Levels of cottonseed cake substitution with bean residue (%)</th>
<th>Bean Residue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td>Dry matter</td>
<td>59.02</td>
<td>58.72</td>
</tr>
<tr>
<td>Organic matter</td>
<td>93.52</td>
<td>93.31</td>
</tr>
<tr>
<td>Ether extract</td>
<td>6.33</td>
<td>5.35</td>
</tr>
<tr>
<td>NDFcp¹</td>
<td>41.49</td>
<td>40.16</td>
</tr>
<tr>
<td>Non-fibrous carbohydrates</td>
<td>31.57</td>
<td>34.29</td>
</tr>
<tr>
<td>NDFi²¹</td>
<td>13.96</td>
<td>13.26</td>
</tr>
<tr>
<td>TDN₃¹</td>
<td>63.28</td>
<td>64.39</td>
</tr>
</tbody>
</table>

¹neutral detergent fibre corrected for ash and protein; ²indigestible neutral detergent fibre; ³estimated total digestible nutrients.

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

<table>
<thead>
<tr>
<th>Components</th>
<th>Levels of cottonseed cake substitution with bean residue (%)</th>
<th>Bean Residue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td>DM</td>
<td>78.13</td>
<td>77.28</td>
</tr>
<tr>
<td>Organic matter</td>
<td>66.94</td>
<td>66.74</td>
</tr>
<tr>
<td>Crude protein</td>
<td>53.54</td>
<td>53.23</td>
</tr>
<tr>
<td>Ether extract</td>
<td>20.70</td>
<td>20.40</td>
</tr>
<tr>
<td>NDFcp¹</td>
<td>19.09</td>
<td>18.80</td>
</tr>
<tr>
<td>Non-fibrous carbohydrates</td>
<td>53.54</td>
<td>53.23</td>
</tr>
<tr>
<td>NDFi²¹</td>
<td>1.39</td>
<td>1.39</td>
</tr>
<tr>
<td>TDN₃¹</td>
<td>78.13</td>
<td>77.28</td>
</tr>
</tbody>
</table>

¹neutral detergent fibre corrected for ash and protein; ²indigestible neutral detergent fibre; ³estimated total digestible nutrients.
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 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.
Ingestion Behaviour of Feedlot Sheep / Int. J. Agric. Biol., Vol. 00, No. 0, 201x

Table 5: Ingestion behaviour, coefficients of variation (CV), regression equations and coefficients of determination (R²) at different levels of substitution

<table>
<thead>
<tr>
<th>Item</th>
<th>Levels of cottonseed cake substitution with bean residue (%)</th>
<th>CV (%)</th>
<th>Equation</th>
<th>R² (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rumen boluses (number day⁻¹)</td>
<td>677.2 752.1 805.1 762.2 10.38 Y = 673.3162 + 3.6721X - 0.0280X²</td>
<td>96.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mastication time per bolus (seconds)</td>
<td>42.41 40.09 41.52 40.47 16.06 Y = 41.1278</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeding</td>
<td>32.24 34.63 3.12 34.24 26.31 Y = 33.56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ruminating chews</td>
<td>10.81 60.8203 + 0.0436X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idling</td>
<td>46.73 49.62 55.37 50.74 20.56 Y = 50.62</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idling</td>
<td>65.12 59.87 55.49 59.37 12.15 Y = 59.96</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 (Van Soest, 1995).

The nocturnal feeding, diurnal and nocturnal rumination and idling periods (number day⁻¹) showed a negative quadratic behaviour regardless of the level of substitution (Table 3). Mendes Neto et al. (2007) studied ingestion behaviour of lactating fedlot heifers and also observed a longer feeding 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.

The DM consumption behaviour presented can be attributed to each 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 (Van Soest, 1995).

Diurnal feeding time was statistically different from the nocturnal feeding time regardless of the level of cottonseed 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 fedlot heifers and also observed a longer feeding 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.

The DM consumption behaviour presented can be attributed to each 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 (Van Soest, 1995).

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 concentration 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 Van 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 concentration 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%.

**Acknowledgments**

The authors thank the Fundação de Amparo à Pesquisa do Estado do Estado de Mato Grosso; Fundação de Amparo à Pesquisa e ao Desenvolvimento Científico e Tecnológico do Maranhão for their financial support.

**References**


(Received 28 March 2018; Accepted 21 May 2018)