Correlation between performance and feeding behavior of feedlot lambs fed without roughage diet

Elves de Souza Cardoso[1], Hermógenes Almeida de Santana Júnior[1*], Aracele Prates de Oliveira[1], Antônio Hosmylton Carvalho de Ferreira[1], Zeliana Fernandes de Oliveira[1] and Tiago Brandão Freitas[2]

[1]Universidade Estadual do Piauí, Avenida Joaquina Nogueira, s/n., 64900-000, Corrente, Piauí, Brazil. [2]University of Illinois Urbana-Champaign, Urbana, Illinois, United States of America. *Author for correspondence. E-mail: hsantanajunior@hotmail.com

ABSTRACT. The objective was to evaluate the correlation between performance and feeding behavior of feedlot castrated Santa Inês lambs fed without roughage diet, weighing 20 ± 1.8 kg and four months of age (± 0.34). A completely randomized design was adopted. Correlations were obtained by Pearson's linear correlation analysis and the t test, and processed on SAS software (version 9.2). The variables number of rumination chews per cud, number of cuds ruminated per day, speed of each chew, and number of rumination cuds per day were positively correlated with the variation in body weight (p < 0.05). For number of cuds ruminated per day, a positive correlation was found with the variations in body weight. Initial and final body weights were positively correlated with the feed and rumination efficiencies of the lambs feeding behavior and with the time per period spent feeding and performing other activities. Feeding time had a positive correlation with variation in body weight per day and the relative variation in body weight. Rumination was positively correlated with performance variables. The correlations show that there is influence between eating behavior and performance.

Keywords: concentrate, intake, weight gain, sheep.

Correlação entre o desempenho e o comportamento alimentar de cordeiros confinados recebendo dieta sem volumoso

RESUMO. Objetivou-se estimar correlações entre desempenho e comportamento alimentar de cordeiros castrados da raça Santa Inês alimentados sem volumoso, com peso médio de 20± 1,8 kg e quatro meses de idade (± 0,34). O delineamento inteiramente casualizado foi adotado. As correlações foram obtidas pela análise de correlação linear de Pearson e o teste t, e processados no software SAS (versão 9.2). Os variáveis números de mastigações ruminação por bolo alimentar, número de bolo alimentar ruminado por dia, velocidade de mastigação, e número de bolo alimentar por dia foram positivamente correlacionados com a variação no peso corporal (p < 0,05). Para o número de bolo alimentar ruminado por dia, a correlação positiva foi encontrada com as variações de peso corporal. O peso corporal inicial e o final foram positivamente correlacionados com eficiências da alimentação e da ruminação do comportamento alimentar dos cordeiros, e com o tempo por período de alimentação e de outras atividades. O tempo de alimentação apresentou correlação positiva com a variação de peso corporal por dia e a variação relativa no peso corporal. O tempo de ruminação foi positivamente correlacionado com variáveis do desempenho. As correlações mostram que há influência entre comportamento alimentar e desempenho.

Palavras-chave: concentrado, ingestão, ganho de peso, ovinos.

Introduction

The sheep meat industry has a great potential to contribute to the supply of animal protein in the Brazil. To achieve this purpose, feeding strategies should be better studied aiming to stabilize the supply of this product in the market, which compromises the productive chain of the region. Because of this situation, the use of the feedlot for the ovine species has emerged as a viable option due to the irregular rainfall that reduces the availability of forage, making this an attractive alternative if food sources available in the region are used (Parente et al., 2009, Nicory et al., 2015).

Animal performance is determined by the quantity and quality of food consumed and by the genetic characteristics of the animal under the influence of the environment (Garcia et al., 2011). Voluntary intake, and consequently the production of lambs in the feedlot depend on factors related to the feedstuff and the animal. Therefore, the quantity

and the form in which this feed is supplied to the animals determine different responses and consequently changes in their performance, which may imply behavioral changes due to the possible existence of many correlations between performance and behavior variables.

The feeding behavior in lambs has been used to guide and underpin many discussions on the intake and thus the performance of experimental animals. In this context, the study of feeding behavior appears to be a tool of great importance in the assessment of diets, as it allows the discovery of the possible existing relationships on the feed-animal interface, and so adjustments can be made in the feeding management of animals to obtain better productive performance (Cavalcanti et al., 2008).

Seeking new feeding and nutritional-management techniques, coupled with the feeding behavior, can be of great importance for broadening the meat-livestock activity in Brazil.

Thus, this study aimed to evaluate the existing correlations between the performance and feeding behavior of feed lot lambs fed without roughage diet.

Material and methods

The experiment was conducted in the Laboratory of Animal Nutrition Trials (*Laboratório de Ensaios Nutricionais em Animais*, Lena), at the Center for Teaching and Research on Animal Nutrition (*Centro de Ensino e Pesquisa em Nutrição Animal*, Cepena) located on the Dep. Jesualdo Cavalcanti de Barros campus, at the State University of Piauí. Fifty castrated Santa Inês male lambs with an average body weight of 20 ± 1.8 kg and four months of age ($\pm$ 0.34) were used in the experiment. All animals were dewormed and evaluated for their health conditions at the time of selection to be included in the trial.

Lambs received the diet in different amounts to provide variations in intake and digestibility so that correlations could be evaluated (diet *ad libitum* to 80% of the amount supplied). A completely randomized design was adopted. The experiment lasted 50 days, consisting of five 10-day periods, with six days for adaptation to the changes in the amount of feed supplied, and four for data collection. Animals were weighed at the beginning and end of each experimental period.

The animals were identified by numbered plastic earrings and later allocated to 1.0×1.0 m individual stalls containing individual bucket-type feeders and drinkers. The diet, composed only of concentrate ingredients, contained ground corn (55.76%),

cottonseed cake (37.17%), and a buffered vitamin-mineral premix (7.07%). This diet was balanced for maintenance and a weight gain of 325 g day^{-1}, *ad libitum*. The feed was supplied daily at 07:00 and 15:45 hour, and contained, in its chemical composition, 914 g dry matter kg^{-1} fresh matter and (per kg DM) 152 g crude protein, 194 g neutral detergent fiber corrected ash and protein, 100 g ether extract, 92 g ash, 432 g non fiber carbohydrates, and 650 g total detergent nutrients.

The feeding behavior was evaluated on the 10th day of each experimental period, with observations made every five minutes, according to the methodology of Carvalho et al., (2011), for a period of 24 hours, to identify the times spent feeding, ruminating, and doing other activities.

Three observations were made in each period, to determine the number of chews per ruminated bolus (RChC) and the time spent rumination per bolus (TRC). The variables number of cuds ruminated per day (CRD), chewing speed (ChS), time per rumination chew (ChT), and number of rumination chews per day (RChD) were calculated by the following Equation 1:

$$CDR = RUM / TRC; ChS = RChS / TRC; \\ ChT = CRD \star RChC; RChC = CRD \star RChC \quad (1)$$

where:
CRD (n day^{-1});
RUM (s day^{-1}) = rumination time;
TRC (s);
ChS (chews s^{-1});
RChC (n cud^{-1});
ChT (s); and
RChD (n day^{-1}).

Feed efficiency, in grams of DM, NDFap, TDN, NFC, and CP per minute; and rumination efficiency, in DM and NDFap, were calculated by dividing the intake of an item by the total feeding time (feed efficiency) or by the rumination time (rumination efficiency).

The number of periods on each activity was recorded directly on the tabulation spreadsheet, and the time per period was calculated by dividing the total time on that activity by the number of periods on the respective activity.

Correlations were obtained by Pearson's linear analysis and the 't' test, and processed using SAS software (version 9.2), and was considered significant when $p < 0.05$.

The following parameters were analyzed (Table 1):

Performance: initial body weight (IBW), final body weight (FBW), variation in body weight per

period (VBWP), variation in body weight per day (VBWD), and relative variation in body weight (VBWR);

Table 1. Mean values of the variables offeedlot lambs fed without roughage diet.

Variable	Mean	Standard deviation	Minimum	Maximum
IBW (kg)	20.1	1.8	18.9	20.9
FBW (kg)	34.6	4.2	32.5	36.7
VBWP (g)	1484.2	1133.4	210.1	5000.7
VBWD (g)	148.4	113.3	21.0	500.0
VBWR (% BW)	0.65	0.52	0.31	2.27
RChC (nº)	57.7	8.0	44.7	79.8
CRD (nº)	15792.5	5847.0	4674.4	30853.2
ChS (nº s^{-1})	1.20	0.19	0.78	1.59
ChT (nº)	0.86	0.14	0.63	1.28
RChD (nº)	273.3	88.8	103.4	434.3
FE$_{DM}$(g min.$^{-1}$)	14.9	12.2	4.0	77.1
FE$_{NDFap}$(g min.$^{-1}$)	2.9	2.3	0.78	14.9
FE$_{NFC}$(g min.$^{-1}$)	6.4	5.2	1.7	33.3
RE$_{DM}$(g min.$^{-1}$)	4.1	1.3	2.0	9.5
FE$_{NDFap}$(g min.$^{-1}$)	0.8	0.2	0.4	1.8
NFP (nº)	7.9	6.7	1.0	25.0
NRP (nº)	19.4	5.1	10.0	36.0
NOP (nº)	26.7	8.3	13.0	48.0
TFP (min)	13.8	6.0	5.9	30.0
TRP (min)	11.3	2.7	7.3	18.0
TOP (min)	47.5	18.1	20.1	98.4
TCT (min)	302.7	107.2	130.0	565.0

IBW - initial body weight; FBW - final body weight; VBWP - variation in body weight per period; VBWD - variation in body weight per day; VBWR - relative variation in body weight; RChC - number of rumination chews per cud; CRD - number of cruds ruminated per day; ChS - chewing speed; ChT - time pr chew; RChD - number of rumination chews per day; FE$_{DM}$ - feed efficiency of dry matter; FE$_{NDFap}$ - feed efficiency of neutral detergent fiber corrected for ash and protein; FE$_{NFC}$ - feed efficiency of non-fiber carbohydrates; FE$_{CP}$ - feed efficiency of crude protein; RE$_{DM}$ - rumination efficiency of dry matter; RE$_{NDFap}$ - rumination efficiency of neutral detergent fiber corrected for ash and protein; NFP - number of feeding periods; NRP - number of rumination periods; NOP - number of periods performing other activities; TFP - time per feeding period; TRP - time per rumination period; TOP - time per period performing other activities; TCT - total chewing time.

Feeding behavior: time spent feeding (Feeding), ruminating (Rumination), and performing other activities (Other activities); total chewing time (TCT); number of feeding periods (NFP), rumination periods (NRP), and periods performing other activities (NOP); time per feeding period (TFP), per rumination period (TRP), and per period performing other activities (TOP); number of chews per ruminated bolus (RChC); chewing speed (ChS); time per chew (ChT); number of rumination chews per day (RChD); number of cuds ruminated per day (CRD); feed efficiency of dry matter (FE$_{DM}$), neutral detergent fiber corrected for ash and protein (FE$_{NDFap}$), non-fiber carbohydrates (FE$_{NFC}$), and crude protein (FE$_{CP}$); and rumination efficiency of dry matter (RE$_{DM}$) and neutral detergent fiber corrected for ash and protein (RE$_{NDFap}$).

Results and discussion

A positive correlation ($p < 0.05$) was detected between number of cuds ruminated per day (CRD), number of rumination chews per day (RChD) and the variation in body weight in the different units

(per period, per day, and relative) as showed in Table 2. Additionally time per chew showed a positive correlation with initial and final body weight ($p < 0.05$). The number of rumination chews per day is associated with the amount of neutral detergent fiber (NDF) in the diet, aiming to reduce its particle to widen its contact surface with the rumen cellulolytic bacteria; this occurred in the present study due to the presence of the NDF from the cottonseed cake. Neutral detergent fiber is easily assimilated by ruminants with the aid of the microbial flora present within the rumen, which, when degrading this fiber fraction (NDF), can extract volatile fatty acids, especially acetic acid, which is highly energetic and easily absorbed by the rumen and assimilated by the organism. Dias et al. (2014) found positive correlations between the rumination-related aspects and the performance variable average daily gain in supplemented crossbred steers.

Table 2. Correlation between performance and rumination-related aspects of feedlot lambs fed without roughage diet.

Variable	RChC	CRD	ChS	ChT	RChD
IBW	-	-	-0.31[*]	0.31[*]	-
FBW	-	-	-0.27[*]	0.29[*]	-
VBWP	-	0.44[**]	-	-	0.47[**]
VBWD	-	0.44[**]	-	-	0.47[**]
VBWR	-	0.53[***]	-	-	0.55[***]

RChC - number of rumination chews per cud; CRD - number of cruds ruminated per day; ChS - chewing speed; ChT - time pr chew; RChD - number of rumination chews per day IBW - initial body weight; FBW - final body weight; VBWP - variation in body weight per period; VBWD - variation in body weight per day; VBWR - relative variation in body weight; [*]$p < 0.05$; [**]$p < 0.01$; [***]$p < 0.0001$.

The connection between body weight and the rumination-process variables is associated with the volume capacity of the rumen, as it is known that the rumen development occurs as the animal ages, and it is linked to body weight increase (Santana Júnior et al., 2013a). In this study the efficiency in the use of the material ingested through an improvement in the rumination process probably was benefited by the cottonseed cake, a source of effective fiber and protein: energy to the animals. A correlation between CRD and performance was found by Dias et al. (2014), who found a high degree of correlation ($r > 90$) between rumination efficiency and daily weight gain in steers on pasture during their post-weaning stage. The increase in rumination efficiency improves the digestibility of NDF, thereby providing a greater feed intake and consequently better performance (Dias et al., 2014).

The correlations found in the present study were of medium to high magnitude, thus increasing the possibility of interference of external factors, making it impossible to utilize the behavior aspects to formulate performance prediction equations.

The initial and final body weights were positively correlated with the feed and rumination efficiencies of lambs (Table 3).

Table 3. Correlation between feeding-behavior efficiencies and performance of feedlot ram lambs fed without roughage diet.

Variable	FE_{DM}	FE_{NDFap}	FE_{NFC}	FE_{CP}	RE_{DM}	RE_{NDFap}
IBW	0.38**	0.38**	0.38**	0.38**	0.48**	0.48**
FBW	0.36**	0.36**	0.36**	0.36**	0.46**	0.46**
VBWP	-	-	-	-	-	-
VBWD	-	-	-	-	-	-
VBWR	-	-	-	-	-	-

FE_{DM} - feed efficiency of dry matter; FE_{NDFap} - feed efficiency of neutral detergent fiber corrected for ash and protein; FE_{NFC} - feed efficiency of non-fiber carbohydrates; FE_{CP} - feed efficiency of crude protein; RE_{DM} - rumination efficiency of dry matter; RE_{NDFap} - rumination efficiency of neutral detergent fiber corrected for ash and protein; IBW - initial body weight; FBW - final body weight; VBWP - variation in body weight per period; VBWD - variation in body weight per day; VBWR - relative variation in body weight; $^*p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.0001$.

Dry matter intake is positively related to the NDF digestibility, and, thus, as the feed and rumination efficiencies of the fibrous fraction are increased, the chances of there being an increase in nutrient intake are also increased. Diets with lower NDF contents provide a greater dry matter intake, since NDF is one of the factors that limit intake, requiring a longer total time of ingestion per kg of DM by the animal, which indicates better feed and rumination efficiencies. When the amount of concentrate supplied is increased, rumination efficiency is increased due to the lower NDF content available to the animal.

High-concentrate diets concentrate a larger mass in kilograms per volume supplied, thereby allowing a greater efficiency in dry matter intake.

The time per period on other activities (TOP) had a negative correlation with the variations in body weight (Table 4), because the longer animals stay on other activities, the shorter will be the time used to feed and ruminate. According to National Research Council (National Research Council [NRC], 2001) an increase in body weight elevates the nutritional requirements for the same weight gain. Thus, a larger body weight leads to a higher number of feeding activities, which are mutually exclusive with other activities.

Table 4. Correlation between feeding-behavior periods and performance of feedlot ram lambs fed without roughage diet.

Variable	NFP	NRP	NOP	TFP	TRP	TOP
IBW	-	-	-	-	-	0.37**
FBW	-	-	-	-	-	0.27*
VBWP	0.62***	0.13	0.52**	-0.47**	0.50**	-0.44**
VBWD	0.62***	0.13	0.52**	-0.47**	0.50**	-0.44**
VBWR	0.65***	0.14	0.55***	-0.51**	0.59***	-0.48**

NFP - number of feeding periods; NRP - number of rumination periods; NOP - number of periods performing other activities; TFP - time per feeding period; TRP - time per rumination period; TOP - time per period performing other activities; IBW - initial body weight; FBW - final body weight; VBWP - variation in body weight per period; VBWD - variation in body weight per day; VBWR - relative variation in body weight; $^*p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.0001$.

The variation in body weight, in all evaluated units, showed positive correlations with the number of feeding and ruminating periods and periods on other activities. In this study, the gain was intentional, and it was noted that the elevation in body weight results in longer discrete periods of that behavior. The diet composed of concentrate exclusively facilitates the process of capture and ingestion of the feed, providing a short intake time, which results in longer periods, since an increase in number of periods reduces the time per period, and vice-versa. Another factor that contributes to increasing the number of periods has been the use of young animals at perfect functioning of the digestive system.

A positive correlation was found between the times spent ruminating (RUM), performing other activities (OTH), total chewing time (TCT) and the performance variables (Table 5). A body-weight increase means greater rumen capacity and consequently greater rumination. Greater chewing activity is probably a result of the increase in the fiber content of the diet, and thus the animal will consume more daily units of dry matter per unit of weight gain. The longer an animal feeds and ruminates, the longer will likely be the intake of nutrients, and also the better the processing of the ingested particles due to the rumination process, which will consequently lead to better performance, as demonstrated in this correlation.

Table 5. Correlation between feeding behavior and performance of feedlot ram lambs fed without roughage diet.

Variable	Feeding time	Rumination time	Other activities	TCT
IBW	---	0.51**	0.43**	0.43**
FBW	---	0.40**	0.30*	0.30*
VBWD	0.43**	0.48**	0.53***	0.53***
VBWR	0.43**	0.55***	0.59***	0.58***

TCT - total chewing time; IBW - initial body weight; FBW - final body weight; VBWD - variation in body weight per day; VBWR - relative variation in body weight; IBW - initial body weight; FBW - final body weight; VBWD - variation in body weight per day; VBWR - relative variation in body weight; $^*p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.0001$.

The variable feeding, however, only had correlations with the variations in body weight (VBWD and VBWR), which were positive. This proves the existing relationship between weight gain and feeding, wherein a greater intake will increase weight gain.

The time spent performing other activities (OTH) and TCT had positive correlations with the performance variables. Although OTH comprises activities without nutritional relevance (rest, interactions, etc.), the behavioral activities are mutually exclusive; therefore, a greater feed intake requires a longer feeding time, reducing the time spent on other activities. This fact can be explained if we assume that the longer the time on other

activates, the better the nutritional conditions and the feed supply, which provide better performance.

A longer chewing time improves the rumination efficiency; thus, the longer the chewing time is, the better the performance will be. Chewing is the mechanical digestion whose function is to break down the fiber, improving its degradation in the rumen.

The feeding behavior had a positive correlation with the variables variation in body weight per day (VBWD) and relative variation in body weight (VBWR). An increase in sheep body weight increases the nutritional requirements for maintenance of these animals. Thus, a greater body weight leads to longer feeding periods.

Total chewing time (TCT) was positively correlated with the performance variables. For Santana Júnior et al. (2013b), greater chewing activity probably stems from the increase in the dietary fiber content; consequently, the animal will consume more daily units of DM per unit of weight gain.

A mechanism that restricts feed intake is the time necessary to break down the feed particles, which is measured by the rumination time, since it determines the feed's residence time in the gastrointestinal tract.

Conclusion

The correlations found with the rumination-related aspects demonstrate that rumination interferes with the performance results of the animals, which is influenced by the discrete periods of feeding behavior. The feeding behavior is directly related to the performance of feedlot lambs fed without roughage diet, and so intake-prediction equations can be formulated based on the feeding behavior.

Statement of animal rights: The use of the lambs in the experiment was approved by the Ethics Committee on Animal Use of the State University of Piauí, under the Protocol 10922/15.

References

Carvalho, G. G. P., Garcia, R., Pires, A. J. V., Silva, R. R., Detmann, E., & Ribeiro, E. L. O. (2011). Evaluation of intervals between observations on estimation of eating behavior of cattle. *Revista Brasileira de Zootecnia, 40*(1), 2502-2509.

Cavalcanti, M. C. A., Batista, A. M. V., Guim, A., Lira, M. A., Ribeiro, V. L., & Ribeiro Neto, A. C. (2008). Consumo e comportamento ingestivo de caprinos e ovinos alimentados com palma gigante (*Opuntiaficus-indica Mill*) e palma orelha-de-elefante (*Opuntia*sp.). *Acta Scientiarum. Animal Sciences, 30*(2), 173-179.

Dias, D. L. S., Silva, R. R., Silva, F. F., Carvalho, G. G. P., Barroso, D. S., & Carvalho, V. M. (2014). Correlation between performance and ingestive behavior of steers post-weaned on pastures. *Acta Scientiarum. Animal Sciences, 36*(1), 85-91.

Garcia, C. S., Fernandes, A. M., Fontes, C. A. A., Vieira, R. A. M., Ana, N. F. S., & Pimentel, V. A. (2011). Desempenho de novilhos mantidos em pastagens de capim-elefante e capim-mombaça. *Revista Brasileira de Zootecnia, 40*(2), 403-410.

National Research Council [NRC]. (2001). *Nutrient requirements of dairy cattle* (7th ed.). Washington, DC: National Academic Press.

Nicory, I. M. C., Carvalho, G. G. P., Ribeiro, O. L., Silva, R. R., Tosto, M. S. L., Costa-Lopes, L. S., … Nascimento, C. O. (2015). Ingestive behavior of lambs fed diets containing castor seed meal. *Tropical Animal Health and Production, 47*(5), 939-944.

Parente, H. N., Machado, T. M. M., Carvalho, F. C., Garcia, R., Rogério, M. C. P., Barros, N. N. N., & Zanine, A. M. (2009). Desempenho produtivo de ovinos em confinamento alimentados com diferentes dietas. *Arquivo Brasileiro Medicina Veterinária e Zootecnia, 61*(2), 460-466.

Santana Júnior, H. A., Silva, R. R., Carvalho, G. G. P., Silva, F. F., Barroso, D. S., Pinheiro, A. A., … Trindade Júnior, G. (2013a). Correlação entre desempenho e comportamento ingestivo de novilhas suplementadas a pasto. *Semina: Ciências Agrárias, 34*(1), 367-376.

Santana Júnior, H. A., Silva, R. R., Carvalho, G. G. P., Silva, F. F., Trindade Júnior, G., Pinheiro, A. A., … Mendes, F. B. L. (2013b). Correlation between intake and ingestive behavior of pasture-grazed heifers. *Semina: Ciências Agrárias, 34*(6), 2963-2976.