

Linear correlations between feeding behavior and apparent digestibility in feedlot ram lambs

Maciel, M.S.¹; Santana Júnior, H.A.^{1*}; Santana, E.O.C.¹; Ferreira, A.H.C.¹; Oliveira, A.P.¹; Mendes, F.B.L.¹; Abreu Filho, G.¹ and Freitas, T.B.²

¹State University of Piauí. Department of Animal Sciences. Corrente, Piauí. Brazil.

²Department of Animal Sciences. University of Illinois at Urbana-Champaign. Urbana. EE.UU.

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Correspondencia a los autores/Contact e-mail:

hsantanajunior@hotmail.com

INTRODUCTION

Knowing the digestibility of the nutrients present in the feedstuffs utilized in ruminant feeding is essen-

SUMMARY

The aim of this study was to evaluate the linear correlations between feeding behavior and apparent digestibility in feedlot lambs. Fifty castrated Santa Inês ram lambs with an average body weight of 20 ± 4.38 kg and four months of age were used in this experiment. Animals received different feed levels aiming at promoting variations in feed intake and apparent digestibility. A randomized complete design was adopted. Digestibility and feeding behavior were measured. Analyses were performed using Pearson's linear correlations, applying the *t* test at 5% probability level. A positive correlation was detected between feeding time and apparent digestibility of ether extract and total digestible nutrients (TDN) ($p < 0.05$). The number of feeding and rumination periods and the number of periods spent on other activities, the number of cuds ruminated per day, the number of rumination chews per day, and the feed and rumination efficiencies showed significant correlations ($p < 0.05$) with TDN. The digestibility of nutrients influences behavioral characteristics, indicating the possibility of using these behavioral variables to estimate the apparent digestibility of feedlot ram lambs.

Correlações lineares do comportamento ingestivo e digestibilidade aparente em borregos confinados

RESUMO

Objetivou-se avaliar as correlações lineares do comportamento ingestivo e a digestibilidade aparente em borregos confinados. Foram utilizados 50 ovinos machos, castrados, da raça Santa Inês, com peso corporal médio de $20 \pm 4,38$ kg e quatro meses de idade. Os animais receberam níveis de oferta de dieta com o objetivo de promover variações no consumo alimentar e digestibilidade aparente. Foram mensurados a digestibilidade e o comportamento ingestivo dos animais. As análises foram realizadas usando correlações lineares de Pearson utilizando o teste *t*, a 5% de probabilidade. Verificou-se correlação positiva do tempo de alimentação e a digestibilidade aparente de extrato etéreo e os nutrientes digestíveis totais (NDT) ($p < 0,05$). O número de períodos de alimentação, ruminação, outras atividades, bolos ruminados por dia, mastigações merísticas por dia e as eficiências de alimentação e ruminação, apresentaram correlações ($p < 0,05$) com os NDT. A digestibilidade dos nutrientes exerce influencia sobre as características comportamentais, indicando a possibilidade de uso destas variáveis comportamentais para estimar a digestibilidade aparente de borregos em confinamento.

tial for understanding the nutritional requirements of animals as well as the feed cost, which represents a great share of the total production cost. Digestibility can be influenced by several factors such as the com-

position and preparation of the diet feedstuffs, amount of energy, and presence of fiber. One way to evaluate the quality of feeds is through digestibility, since the nutritive value of feeds is a challenge to nutritionists. According to Cabral *et al.* (2008), the digestibility estimate is recognized as a parameter of the nutritive value of a feed, defined as the fraction of the ingested feed that can be absorbed in the digestive tract and that is not recovered in the fecal output.

According to Moreno *et al.* (2010) and Cruz *et al.* (2011), the intake and digestibility of nutrients can be correlated positively or negatively with each other, depending on the quality of the diet, commonly referred to as associative effects. In the same way, Goularte *et al.* (2011) stated that the intake and digestibility of nutrients might be correlated with each other according to the quality of the diet.

The evaluation of the animal behavior has emerged as an alternative to understanding nutritional aspects, helping in the management and promoting high impact on the productive system. These benefits have broadened and increased the valuation of these assessments, which are usually aimed at giving bases to scientific/technical knowledge that can be applied to the production systems in order to increase their profitability. Knowing the feeding habits of animals in their rearing environment is paramount for the efficiency of animal-production exploitation, as this knowledge it is aimed at discovering more-effective techniques in management feeding.

The rumen function in cattle is linked to the digestive actions of the food ingested in the grazing processes, which are mainly determined by the canopy structure (Gregorini, 2012). The determination of the physical efficacy of the diets, in turn, promotes the stratification of the digestion in the rumen-reticulum, acting on rumination consumption and activities, as well as the rumination of the rumen (Nasrollahi *et al.*, 2012).

The feeding behavior is a tool of great importance for the evaluation of diets that allows for the ad-

justment of animal feeding management to obtain better productive performance. However, associations between behavioral and metabolic variables have been found in research discussions, most of the times without the proper scientific basis for these correlations (Santana Júnior *et al.*, 2012).

This study aimed to evaluate the correlations between feeding behavior and apparent digestibility in feedlot ram lambs.

MATERIALS AND METHODS

The experiment was conducted in the Laboratory of Animal Nutrition Trials, located on the Dep. Jesualdo Cavalcanti de Barros campus, at the State University of Piauí, in Corrente-PI, Brazil. Fifty castrated Santa Inês ram lambs with a body weight of 20 ± 4.38 kg and four months of age received levels of feed supply aimed at promoting variations in intake and apparent digestibility in their feeding behavior. A randomized complete design was adopted.

The experiment lasted 50 days, which were divided into five 10-day periods, with intake and feeding behavior evaluations undertaken in each period.

Animals were identified by numbered plastic ear-rings, and later allocated to individual 1.0×1.0 m stalls containing individual troughs and bucket-type drinkers. The feed was supplied daily at 07 h 30 and 15 h 45. The diet was composed of concentrate feedstuffs, using ground corn (55.76%), cotton meal (37.17%) and a buffered vitamin-mineral premix (7.07%).

From the 7th to the 10th day of each experimental period, intake was estimated as the difference between the total feed supplied and the orts, measured always in the morning of the next days, before the feed was supplied on those days. Concomitantly to intake estimation, total feces collection was carried out for three days, using a polyethylene screen installed below the slatted floor, free of any contaminations. Samples of feces were weighed in the morning, and approximately 10% of the total were collected. A composite sample was formed from the daily collections referring to the three days of fecal collection. The apparent digestibility coefficients were estimated from the intake and fecal production data (**table I**). For chemical analysis, samples of ingredients, forage and feces were dried at 55°C for 72 h. Samples were then ground in a Wiley mill (Thomas Model 4 Wiley Mill; Thomas Scientific, Swedesboro, NJ, USA) to pass through a 1-mm screen, and analyzed for DM (method # 934.01), OM (method # 942.05), and EE (method # 920.85) in accordance with Association of Official Analytical Chemists (AOAC, 1995). Crude protein was calculated as the percentage of N in the sample multiplied by 6.25. Analyses for NDF were conducted following Van Soest *et al.* (1991) and adapted for the using an Ankom Fiber Analyzer (Ankom Inc., Fairport, NY, USA) with ash correction. Heat-stable α -amylase was included in the NDF solution, without added sodium sulfite. The amount of non-fiber carbohydrates (NFC) was determined as described by Hall (2000), and TDN was calculated according to NRC (2001).

Table I. Apparent digestibility coefficient of dry matter and nutrients in feedlot lambs (Coeficiente de digestibilidade aparente da matéria seca e nutrientes em ovinos confinados).

Item	Mean (%)	CV ¹ (%)
DDM ²	69.0	17.58
DOM ³	70.1	16.68
DGP ⁴	79.5	10.20
DNDFap ⁵	18.8	169.08
DNFC ⁶	87.3	1.82
DEE ⁷	67.8	19.85
TDN ⁸	64.0	10.52

¹CV: Coefficient of variation; ²DDM: Digestibility of dry matter;

³DOM: Digestibility of organic matter; ⁴DGP: Digestibility of crude protein;

⁵DNDFap: Digestibility of neutral detergent fiber corrected for ash and protein;

⁶DNFC: Digestibility of non-fiber carbohydrates;

⁷DEE: Digestibility of ether extract; ⁸TDN: Total digestible nutrients.

Feeding behavior was evaluated on the 10th day of each experimental period, with observations made every five minutes using watches, as described by Carvalho *et al.* (2011), for 24 h. Animals were evaluated visually by two trained observers who switched shifts every four hours. The time spent on each activity related to the feeding behavior was recorded.

The following behavioral variables were studied: feeding time (FT), rumination time (RT), and time on other activities (OTH). Behavioral activities were considered mutually exclusive.

Feeding time was considered the time spent by the animal to consume the diet. Rumination time corresponded to the processes of regurgitation, re-chewing, re-salivation, and re-swallowing. The time spent on other activities was considered the rest, water consumption, interactions, etc.

Total chewing time (TCT) was determined by the following equation: $TCT = FT + RT$, where: FT (min) = feeding time; RT (min) = rumination time. The discretization of time series was performed directly on data collection spreadsheets, counting the discrete periods of feeding, rumination, and other activities. The average duration of each one of the discrete periods was obtained by dividing the daily time spent on each one of the activities by the number of discrete periods of that activity.

Three observations were made in each period, to determine the number of rumination chews per cud (RChC) and the time spent on the rumination of each cud (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 equations:

$CRD = RT/TRC$, where: CRD (n/day); RT (s/day); TRC (s);

$ChS = RChC/TRC$, where: ChS (s/chew); RChC(n/cud); TRC (s);

$ChT = TRC/RChC$, where: ChT(s); TRC (s); RChC(n/cud); and

$RChD = CRD \times RChC$, where: RChD(n/day); CRD(n/day); RChC(n/cud).

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

Correlations were obtained by Pearson's linear analysis and the *t* test, and processed using SAS software (version 9.2), at 5% significance level.

RESULTS AND DISCUSSION

A weak positive correlation was detected ($p < 0.05$) between feeding time and digestibility of EE and total digestible nutrients (TDN) (table II). The positive effect resulted from the lack of roughage in the diet without, which provides an improvement in the digestibility of these nutrients, due to the increase in EE and TDN intakes caused by the increased amount of total digestible carbohydrates from the diet, thereby increasing the availability of EE and TDN. According to Murta *et al.* (2013), an increase in EE digestibility can be explained by the reduction of the contribution of endogenous losses when a higher intake of this nutrient occurs. However, working with steers, Ítavo *et al.* (2002) did not observe any influence of the concentrate level on TDN intake.

The rumination time showed a moderate positive correlation ($p < 0.05$) with TDN. The diet without roughage results in shorter feeding and consequently rumination times, because of its higher energy density, caused by the low concentration of the fiber that does not stimulate rumination. Missio *et al.* (2010) postulated that the reduction in the time used for ruminating and resting by animals is important, as it implies reduced physical activity, which consumes energy, inferring that the increased level of concentrate in the diet can determine a reduction of the maintenance energy requirements, contributing to increasing the animal performance.

Table II. Linear correlations between feeding behavior and apparent digestibility in feedlot ram lambs (Correlações lineares entre digestibilidade aparente e comportamento ingestivo em ovinos confinados).

Variable	Feeding		Rumination		Other activities		TCT ¹	
	r	p	r	p	r	p	r	p
DDM ²	-	-	-	-	-	-	-	-
DGP ³	-	-	-	-	-	-	-	-
DNDFap ⁴	-	-	-	-	-	-	-	-
DEE ⁵	0.27	0.0296	-	-	-	-	-	-
DOM ⁶	-	-	-	-	-	-	-	-
DNFC ⁷	-	-	-	-	-	-	-	-
TDN ⁸	0.26	0.0332	0.43	0.0008	-0.41	0.0014	0.41	0.0014

¹TCT: Total chewing time; ²DDM: Digestibility of dry matter; ³DOM: Digestibility of organic matter; ⁴DGP: Digestibility of crude protein; ⁵DNDFap: Digestibility of neutral detergent fiber corrected for ash and protein; ⁶DNFC: Digestibility of non-fiber carbohydrates; ⁷DEE: Digestibility of ether extract; ⁸TDN: Total digestible nutrients.

Table III. Linear correlations between discrete periods of feeding behavior and apparent digestibility in feedlot ram lambs (Correlações lineares entre digestibilidade aparente e períodos discretos do comportamento ingestivo em ovinos confinados).

Variable	NFP ¹		NRP ²		NOP ³		TFP ⁴		TRP ⁵		TOP ⁶	
	r	p	r	p	r	p	r	p	r	p	r	p
DDM ⁷	-	-	-	-	-	-	0.29	0.0215	-	-	-	-
DCP ⁸	-	-	-	-	-	-	0.29	0.0210	-	-	-	-
DNDFap ⁹	-	-	-	-	-	-	0.29	0.0205	-	-	-	-
DEE ¹⁰	-	-	-	-	-	-	-	-	-	-	-	-
DOM ¹¹	-	-	-	-	-	-	0.28	0.0229	-	-	-	-
DNFC ¹²	-	-	-	-	-	-	-	-	-0.31	0.0133	-	-
TDN ¹³	0.25	0.0410	0.41	0.0016	0.40	0.0020	-	-	-	-	-0.40	0.0018

¹NFP: Number of feeding periods; ²NRP: Number of rumination periods; ³NOP: Number of periods on other activities; ⁴TFP: Time per feeding period; ⁵TRP: Time per rumination period; ⁶TOP: Time per period on other activities; ⁷DDM: Digestibility of dry matter; ⁸DCP: Digestibility of crude protein; ⁹DNDFAP: Digestibility of neutral detergent fiber corrected for ash and protein; ¹⁰DEE: Digestibility of ether extract; ¹¹DOM: Digestibility of organic matter; ¹²DNFC: Digestibility of non-fiber carbohydrates; ¹³TDN: Total digestible nutrients.

A moderate negative correlation ($p < 0.05$) was found between the time spent on other activities (OTH) and TDN. The feeding and rumination times were reduced with the diet without roughage, which has high energy density and a lower content of physically effective fiber and greater TDN content, shortening the time used for both of these activities and thus increasing available time for OTH. This observation corroborates Mendes Neto *et al.* (2007), who stated that the rumination time differs for concentrates and finely ground or pelleted foods compared with the same food in its natural form. Working with dairy goats fed diets with different roughage:concentrate ratios (100:0, 80:20, 60:40, 40:60, and 20:80), A moderate positive correlation was observed ($p < 0.05$) between total chewing time (TCT) and TDN. The TCT is related to the feeding and rumination times, which indicates a coherent result, since the feeding and rumination times interfere directly with it, since the obtained mean values result from the distribution of both behavioral activities.

The number of feeding periods (NFP) was positively but weakly correlated, while the number of rumination periods (NRP) and periods on other activities (NPO) showed positive, moderate correlations ($p < 0.05$) with TDN (table III). The number of periods is controlled by the feed supply, which can be influenced by the animal characteristics, which raises the hypothesis that the fractionation of the number of periods may be related to appetite, anatomical differences, and the energy requirements being met.

According to Paixão *et al.* (2007), increasing the concentrate content leads to the replacement of NDF from the carbohydrates of medium digestion by the fully digestible carbohydrates, which evidently has a higher digestibility, probably related to an improved nutrient intake.

The time per rumination period (TRP) showed a weak negative correlation ($p < 0.05$) with the digestibility of non-fiber carbohydrates. The high NFC content facilitates the accumulation of lactic-acid-producing bacteria, which are responsible for the decline of the rumen pH, interfering negatively with rumination.

This is associated with the cellulolytic bacteria, which are linked to the use of fibrous carbohydrates. The low concentration of physically effective fiber in the diet without roughage benefits the development of microorganisms that utilize the NFC as substrate.

The time spent per period on other activities (TOP) had a moderate negative correlation ($p < 0.05$) with TDN. This may result from the total division of OTH by NOP. The correlation appears to be coherent, because the time per period is reduced as NOP is increased. Thus, the response shown by NOP reflected in TOP, which had a negative correlation ($p < 0.05$) with TDN. This result, in turn, can be attributed to the chemical characteristics of the diet such as low concentration of physically effective fiber and high digestible energy content.

Weak positive correlations ($p < 0.05$) were found between time per ruminated cud (TRC) and the digestibilities of DM, NDFap, EE, and OM (table IV). This result can be attributed to the chemical properties of the diet, which does not stimulate rumination due to the low fiber content.

The number of cuds ruminated per day (CRD) had a weak positive correlation ($p < 0.05$) with TDN, suggesting that the low physically effective fiber and high TDN stimulated the animals to eat several times during the day, providing an increase in CRD.

The chewing speed (ChS) and time per rumination chew (ChT) had positive correlations ($p < 0.05$) with the digestibilities of DM, CP, NDFap, EE, and OM, with weak but positive values for ChT and weak negative values for ChS. The diet without roughage favored ChT as a result of a better apparent digestibility, interfering directly with ChS, which is more closely related to the diet with high fiber content.

The number of rumination chews per day (RChD) had a weak positive correlation with TDN ($p < 0.05$). The diet without roughage was found to imply a reduction of the NDF content and consequently an increase in the TDN content, leading to a lower number of chews throughout the day. According to Missio

Table IV. Linear correlation between the rumination-related aspects and apparent digestibility in feedlot ram lambs (Correlações lineares entre digestibilidade aparente e aspectos da ruminação em ovinos confinados).

Variable	TRC ¹		RChC ²		CRD ³		ChS ⁴		ChT ⁵		RChD ⁶	
	r	p	r	p	r	p	r	p	r	p	r	p
DDM ⁷	0.26	0.0333	-	-	-	-	-0.34	0.0085	0.30	0.0177	-	-
DCP ⁸	-	-	-	-	-	-	-0.29	0.0220	0.26	0.0364	-	-
DNDFap ⁹	0.26	0.0368	-	-	-	-	-0.33	0.0105	0.29	0.0207	-	-
DEE ¹⁰	0.33	0.0106	-	-	-	-	-0.32	0.0109	0.30	0.0186	-	-
DOM ¹¹	0.27	0.0289	-	-	-	-	-0.34	0.0078	0.30	0.0162	-	-
DNFC ¹²	-	-	-	-	-	-	-	-	-	-	-	-
TDN ¹³	-	-	-	-	0.31	0.0138	-	-	-	-	0.24	0.0486

¹TRC: Time per ruminated cud; ²RChC: Number of rumination chews per cud; ³CRD: Number of cuds ruminated per day; ⁴ChS: Chewing speed; ⁵ChT: Time per rumination chew; ⁶RChD: Number of rumination chews per day; ⁷DDM: Digestibility of dry matter; ⁸DCP: Digestibility of crude protein; ⁹DNDFap: Digestibility of neutral detergent fiber corrected for ash and protein; ¹⁰DEE: Digestibility of ether extract; ¹¹DOM: Digestibility of organic matter; ¹²DNFC: Digestibility of non-fiber carbohydrates; ¹³TDN: Total digestible nutrients.

Table V. Linear correlations between the efficiencies of the feeding behavior and apparent digestibility in feedlot ram lambs (Correlações lineares entre digestibilidade aparente e eficiências do comportamento ingestivo em ovinos confinados).

Variable	FE _{DM} ¹		FE _{NDFap} ²		FE _{NFC} ³		FE _{CP} ⁴		RE _{DM} ⁵		RE _{NDFap} ⁶	
	r	p	r	p	r	p	r	p	r	p	r	p
DDM ⁷	-0.46	0.0003	-0.46	0.0003	-0.46	0.0003	-0.46	0.0003	-	-	-	-
DCP ⁸	-0.44	0.0006	-0.44	0.0006	-0.44	0.0006	-0.44	0.0003	-	-	-	-
DNDFap ⁹	-0.46	0.0004	-0.46	0.0004	-0.46	0.0004	-0.46	0.0004	-	-	-	-
DEE ¹⁰	-0.50	0.0001	-0.50	0.0001	-0.50	0.0001	-0.50	0.0001	-	-	-	-
DOM ¹¹	-0.47	0.0003	-0.47	0.0003	-0.47	0.0003	-0.47	0.0003	-	-	-	-
DNFC ¹²	-	-	-	-	-	-	-	-	-	-	-	-
TDN ¹³	-0.28	0.0249	-0.28	0.0249	-0.28	0.0249	-0.28	0.0249	-0.46	0.0003	-0.46	0.0003

¹FE_{DM}: Feed efficiency of dry matter; ²FE_{NDFap}: Feed efficiency of neutral detergent fiber corrected for ash and protein; ³FE_{NFC}: Feed efficiency of non-fiber carbohydrates; ⁴FE_{CP}: Feed efficiency of crude protein; ⁵RE_{DM}: Rumination efficiency of dry matter; ⁶RE_{NDFap}: Rumination efficiency of neutral detergent fiber corrected for ash and protein; ⁷DDM: Digestibility of dry matter; ⁸DCP: Digestibility of crude protein; ⁹DNDFap: Digestibility of neutral detergent fiber corrected for ash and protein; ¹⁰DEE: Digestibility of ether extract; ¹¹DOM: Digestibility of organic matter; ¹²DNFC: Digestibility of non-fiber carbohydrates; ¹³TDN: Total digestible nutrients.

et al. (2010), there is a negative association between the supplement and the activities of the rumination-related aspects of the feeding behavior (Missio *et al.*, 2010).

The number of rumination chews per cud (RChC) did not show correlations ($p > 0.05$) with any of the evaluated nutrients. This response may be associated with the decreased NDF intake. According to Júnior *et al.* (2013), this effect raises the hypothesis that the rumination-related variables are associated with unproductive nutritional results.

Moderate negative correlations were observed ($p < 0.05$) between feed efficiencies of DM, NDFap, NFC, and CP (with the digestibilities of DM, CP, NDFap, EE, and OM and TDN (table V). Missio *et al.* (2010) mentioned that the rumination efficiency in DM is associated with the higher specific weight of

the concentrated portion and with the NDF contents of the diet, since the feed bolus regurgitated by the animal fed diets with greater proportions of concentrate is usually heavier and has a lower NDF content.

The rumination efficiency in NDFap may be attributed to a reduction in the physically effective fiber, providing lower amounts of components that stimulate rumination. According to Silva *et al.* (2005), the rumination efficiency depends on the magnitude of the variation of the content of dietary fibrous components.

The rumination efficiency in DM and NDFap had moderate negative correlations with TDN, because this variable is increased as the level of concentrate in the diet is increased.

CONCLUSION

The digestibility of nutrients influences the behavioral characteristics, indicating that these variables can be used to estimate the apparent digestibility of feedlot ram lambs.

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