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Article

Different roughage: concentrate ratios in extruded feed, and feeding behavior of growing lambs

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Abstract
Animal performance is directly related to the food quality and intake. Analyzing feeding behavior is an important tool to evaluate diet efficiency. This study aims to evaluate the intake of dry matter, feeding behavior and ruminal movement amongst lambs fed with extruded feed in different roughage (R) : concentrate (C) ratios. An experiment was carried out in the Experimental Farm Capim Branco, Universidade Federal de Uberlandia, from December 7, 2016 to March 22, 2017. It involved 30 3-month-old crossbred lambs (Santa Ines x Dorper) with a mean weight of 20.67 ± 4.57 kg allocated in collective stalls equipped with feeder, water fountain, salt shaker, and wooden slatted floor. The experiment was conducted in a randomized complete design with 2 treatments and 15 replicates per treatment. The treatments consisted of roughage and concentrate extruded and mixed in the following ratio 30R:70C and 70R:30C. The dry matter intake (DMI), 24-hour feeding behavior and 5-minute ruminal movement were evaluated. The findings pointed to reduced DMI in relation to body weight for 30R:70C at the end of the experiment. Reduced rumination time, total chewing and ruminal movement were found for both ratios. However, shorter rumination time and total chewing had been recorded for 30R:70C at the beginning of the experiment. Extruded feed with 70R:30C increased rumination and total chewing and, consequently, ruminal movement.
Keywords: Chewing, Extrusion, Ingestion, *Ovis aries*, Rumination.

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Introduction

Animal performance is a direct function of the digestible dry matter intake. Food intake varies depending on a number of factors, including: the animal (live weight and its variation, production level, physiological state, and size), food (fiber, volume, filling capacity, energy density, and chewing needs), feeding conditions (availability of food, space in the trough, time of access to food, feeding frequency), and climatic conditions (MERTENS, 1994; GESUALDI JR et al., 2000).

The intake of diets with high levels of fiber is controlled by physical factors, such as the passage rate and rumen filling, whereas the intake of diets with high levels of concentrate (high energy density) is controlled by energy demand and metabolic factors (CONRAD et al., 1984; MERTENS, 1987; VAN SOEST, 1994). Therefore, the energy demand of ruminants defines the intake of diets with high caloric density, whereas the physical capacity of the gastrointestinal tract determines the intake of diets of low quality and energy density. As such, balancing an adequate roughage:concentrate ratio is influenced by age, quality of roughage, concentrate, and expected productivity.

One way to evaluate diet efficiency is based on the study of feeding behavior. Such a study provides the animal response to the diet and management methods with a view to improving productivity. Small ruminants have the ability to adapt to the most diverse feeding, management and environmental conditions, changing their parameters of feeding behavior to reach and maintain a certain level of intake compatible with nutritional requirements (CIRNE et al., 2014). Hence, the roughage:concentrate ratio can directly influence the ruminants' feeding behavior.

In addition to the animals' characteristics and the environment, the factors that most affect their feeding behavior are those related to the diet, namely: the amount of fiber, dry matter content, particle size, and digestibility of nutrients (VAN SOEST, 1994). Thus, concentrated and/or finely crushed, pelleted or extruded feed reduces rumination time, while roughages with a high cell wall content tend to increase rumination time (FIGUEIREDO et al., 2013).

The evaluation of ruminal physiological parameters is another way to predict the quality of food.

For example, rumen motility guarantees food mixing inside to be more efficiently digested before leaving the rumen, when it needs to be in adequate particle size for food passage (THIAGO; GILL; SISSONS, 1992).

This study aims to evaluate the effect of 2 roughage:concentrate ratios (30R:70C and 70R:30C) on growing lambs' dry matter intake, feeding behaviour, and ruminal movement.

Material and methods

The experiment was carried out in the Experimental Farm Capim Branco, Universidade Federal de Uberlandia, located in the Municipality of Uberlândia, State of Minas Gerais, from December 7, 2016 to March 22, 2017. The experimental protocol was approved by the UFU Ethics Committee (Approval No. 140/16).

The experiment involved 30 3-month-old crossbred lambs (Santa Inês and Dorper) with an average weight of 20.67 ± 4.57 kg. All animals were weighed and orally dewormed with Levamisole on the first day of the experiment. Before the experiment, their diet was based on corn silage and bran concentrate (corn bran, soybean meal, urea, and mineral salt).

The experiment lasted 105 days: the first 15 days were used to adapt the animals to both the stalls and the diet, and the subsequent 90 days were used for data collection. The animals were divided into 6 collective stalls (each stall with 5 animals), with 3 stalls for each evaluated treatment. The stalls were approximately 20 m² and located in a masonry shed under a covered area (clay tile). Each stall was equipped with an external feeder, drinking fountain, salt shaker, and suspended slatted floor. The animals had freely access to water and mineral salt troughs.

Only extruded feed was provided, with roughage and concentrate provided in the same pellet. The fibrous part was composed of forages of the genus Urochloa, and the concentrate part was composed of corn bran, soybean meal, starch, minerals, and monensin.

Treatments were divided according to the roughage:concentrate ratio: one with the pellets consisting of 70% roughage and 30% concentrate (70R:30C), and the other one with the pellets made up of 30% roughage and 70% concentrate (30R:70C). Table 1 shows their chemical compositions.

Table 1. Chemical composition of treatments

Nutrient*	70R:30C	30R:70C
Dry Matter (DM)	92.07%	92.05%
Crude Protein (CP)	10.82%	13.64%
Neutral Detergent Fiber (NDF)	34.48%	29.64%
Acid Detergent Fiber (ADF)	20.63%	16.41%
Non-Fibrous Carbohydrate (NFC)	47.60%	49.57%
Mineral Matter (MM)	4.88%	5.06%

* Values obtained after analyses in the animal nutrition laboratory of the Undergraduate Program in Animal Science (UFU) in partnership with Instituto Federal do Triângulo Mineiro (campus Uberaba).

Extruded feed was supplied twice a day (at 8 am and 4 pm). The leftovers were measured daily; whenever the values were equal to zero, the supply was increased until reaching a surplus of 10%. Therefore, the dry matter intake (DMI) was calculated as $DMI = (Intake \times \%DMprovided) - (Leftovers \times \%DMonLeftovers)$. As the food supply and the leftovers were relative to the stall, the DMI of each animal was calculated as the result of the stall's DMI divided by 5 (number of animals in the stall). The DMI in relation to live weight was obtained by dividing the DMI by the average body weight of the animals throughout the evaluation period. Body weight was assessed every 15 days: on the first day of the experiment (0), and later on days 15, 30, 45, 60, 75, 90 and 105.

Feeding behavior was assessed at the beginning of the experiment and every 30 days thereafter, totaling 4 assessments. The day before the evaluation, the animals were painted in different colors with a marker stick for easier identification. They were subjected to visual observation for 24 hours by trained people in a relay system arranged not to disturb them. The environment was artificially lighted at night, with the lights were kept on for 5 days before the evaluation to ensure adaptation. A person checked every 5 minutes if the animals were ingesting food, water or mineral salt (ING), in rumination (RUM) or resting (REST), according to the methodology proposed by Fischer et al. (1998). The total chewing time (CHEW) was determined by summing up eating tim (ING) and rumination time (RUM).

Ruminal movement was determined by auscultation once a week in the last 5 weeks of the experiment. It always took place in the morning, 1 hour after supplying day first food treatment. Auscultation was performed with the aid of a stethoscope for 5 minutes following the method by Radostits et al. (2007).

A randomized design with 2 treatments and 15 repetitions was used with repeated measures over time to assess feeding behavior (4 evaluation periods) and ruminal movement (5 evaluation periods). To evaluate dry matter intake, the bays were used as a repetition, therefore, each treatment had 3 bays as a repetition unit. The treatment averages were evaluated using Tukey's test and regression study. Significant was set at a 5%.

Results and discussion

The dry matter intake in relation to body weight (DMI%BW) was higher ($p < 0.05$) for treatment 70R:30C, and no difference between treatments was found for intake in kilograms per animal ($p > 0.05$; Table 2). The average dry matter intake (DMI) was 1.13 kg animal^{-1} day^{-1}, which is within the recommended for the animal category, i.e., between 1.0 and 1.3 kg day^{-1} (NRC, 2007). The DMI%BW recommended by the NRC (2007) is 3.51%, i.e., the DMI%BW was 3.4% and 13.9% above the recommended value for the animals that received the 30R:70C and the 70R:30C treatments, respectively.

The lower DMI observed amongst the animals consuming the 30R:70C feed can be explained by the metabolic regulation, since the diet has amounts of energy and protein that are highly fermentable in rumen, in addition to the starch, which is a soluble carbohydrate. About the starch, when in larger quantities (39.36% in the 30R:70C treatment and 33.84% in the 70R:30C treatment, data provided by the manufacturer), physiological mechanisms act to reduce appetite and consequently food intake (OLIVEIRA et al., 2017).

Table 2. Dry matter intake (DMI) per animal and body weight (DMI%BW) according to treatment and period

Treatment	DMI/Animal (kg day^{-1})	DMI%BW (%)	WEIGHT (kg)
30R:70C	1.08	3.63 B	38.48
70R:30C	1.18	4.00 A	30.15
P value	0.1225	0.02987	0.4297
Period (days)	DMI/Animal[1] (kg day^{-1})	DMI%BW[2] (%)	WEIGHT[3] (kg)
0	-	-	20.67
15	0.94	4.27	23.42
30	1.09	4.37	26.50
45	1.21	4.04	29.04

60	1.14	3.78	31.45
75	1.19	3.62	34.50
90	1.23	3.40	37.81
105	1.24	3.20	39.70
Mean	1.13	3.81	30.31
CV	6.48	5.88	6.95
P value	0.0078	0.0085	0.0005

CV: coefficient of variation; Distinct letters in the column shows significant differences according to the Tukey's test at 5%; [1]$Y = 0.872929 + 0.006769x – 0.000031x^2$, $R^2 = 94.91\%$; [2]$Y = 4.613843 – 0.013276x$, $R^2 = 95.86\%$; [3]$Y = 20.740227 + 0.183808x$, $R^2 = 99.82\%$. There was no significant interaction. Only values of $p < 0.005\%$ are provided. The quadratic or linear effect is represented by the equation.

A quadratic effect was found in the DMI per animal in kilograms per day, with greater consumption ($p < 0.05$) towards the end of the experiment. Meanwhile, a negative linear effect was found for the DMI%BW, with reduced DMI%BW at the end of the trial period. An explanation for this response of the DMI%BW is the animals' weight gain (Table 2); therefore, the DMI%BW was reduced despite increases in the intake.

These animals have low nutritional requirements when they are young. As they are lighter, higher DMI%BW values are found even if they eat less food a day, since this intake is relative to body weight. However, as these animals grow, their nutritional needs increase, requiring greater daily intake to meet them; together with the high intake, the animals begin their fattening process, becoming heavier. As a result, the ratio between this intake and their body weight reduces (ZANINE; MACEDO JUNIOR, 2006). Associated with this result, there was a positive linear effect for body weight during the experimental period ($p < 0.05$; Table 2). Therefore, there was a higher body weight of the animals at the end of the experimental period, contributing to the lower DMI%BW found in this work.

There was no difference in average daily weight gain (ADG; p <0.05) both in the experimental period and between treatments (Table 3). The average ADG over the entire experimental period was 182.79 grams day^{-1} (from 0 to 105 days). This ADG was similar to that found by Carvalho et al. (2007), which was 171 g day^{-1}, in lambs fed with Tifton 85 hay and bran concentrate in the 60R: 40C ratio.

Table 3. Effect of different roughage:concentrate ratio on extruded feed on average daily weight gain (ADG, g day^{-1}) in crossbred lambs

Treatment	Period (days)						
	0–15	15–30	0–30	30–45	0–45	45–60	0–60
30R:70C	197.51	216.68	207.10	173.75	195.88	162.28	181.63
70R:30C	168.97	194.91	181.94	179.24	176.06	206.28	185.64
Mean	183.24	205.80	194.52	176.49	186.02	184.28	183.63
CV	36.30	29.02	23.60	36.81	21.91	34.04	19.00
P value	0.8796	0.6581	0.3611	0.9963	0.7420	0.2530	0.9982
Treatment	Period (days)						
	60–75	0–75	75–90	0–90	90–105	0–105	
30R:70C	235.31	186.04	211.75	193.28	155.57	183.54	
70R:30C	195.04	182.69	194.05	183.54	190.79	182.03	
Mean	215.17	184.37	202.90	188.41	173.18	182.79	
CV	32.29	18.16	28.97	24.29	33.31	17.83	
P value	0.1425	08852	04567	04125	0.1230	0.999	

CV: coefficient of variation. Only values of p<0.005% provided.

According to the literature (CARVALHO et al., 2007; MURTA et al., 2009), the ideal slaughter weight in sheep varies between 30 and 35 kg, when the amount of muscle in the carcass is maximized and the animal has enough fat to provide suitable meat properties that meet consumer preferences. The animals in this study reached slaughter weight between 60 and 75 days of the experiment, which is equal to the period in which they reached the age of approximately 5-6 months.

Table 4 exhibits the results for feeding behavior. All variables showed interaction between the treatment and the analyzed period. A difference between treatments ($p < 0.05$) was found only at the beginning of the experiment, when the animals fed with the 30R:70C ration showed shorter rumination and total chewing time and, consequently, longer resting time. According to Van Soest (1994), the rumination time is influenced by the nature of the diet and is proportional to the cell wall content of roughage. Therefore, concentrated foods, either finely ground or processed (pelletized or extruded), reduces rumination time, while roughages with a high cell wall content increase rumination time. Thus, the animals fed with the 70% roughage showed longer rumination and total chewing times due to the higher fiber content in their diet, even though it was finely ground in the food (fiber size of 2mm, manufacturer data).

Table 4. Effect of different roughage:concentrate ratio in extruded feed on feeding behavior (min day^{-1}) of crossbred lambs, with interaction between treatment and period

Treatment	0 days	30 days	60 days	90 days	P value
			Ingestion		
30R:70C[1]	223.66	177.33	182.85	161.07	0.0212
70R:30C[2]	234.66	191.33	152.00	161.66	0.0142
P value	0.8875	0.6945	0.1258	0.8899	
Mean			185.80		
CV			17.10		
			Rumination		
30R:70C	104.66 B	75.00	77.14	77.85	0.2136
70R:30C[3]	203.00 A	91.33	100.66	110.33	0.0147

P value	0.0425	0.3256	0.2125	0.5478	
Mean	105.46				
CV	47.66				
	Resting				
30R:70C[4]	1111.66 A	1187.66	1180.00	1201.07	0.0025
70R:30C[5]	1002.33 B	1157.33	1187.33	1168.00	0.0014
P value	0.0488	0.5279	0.3692	0.3128	
Mean	1148.72				
CV	4.18				
	Total Chewing				
30R:70C[6]	328.33 B	252.33	252.66	238.92	0.0078
70R:30C[7]	437.66 A	282.66	260.00	272.00	0.0090
P value	0.0149	0.2145	0.9631	0.7845	
Mean	291.27				
CV	16.50				

CV: coefficient of variation; Distinct letters in the column differ by the Tukey test at 5%; [1]Y =213.571429 – 0.607540x, R^2 = 78.16%; [2]Y = 236.916667 – 2.186111x + 0.014722x^2, R^2 = 97.55%; [3]Y = 196.966667 – 3.928889x + 0.033704x^2, R^2 = 90.92%; [4]Y =1117.286905 + 2.241706x – 0.015258x^2, R^2 = 86.78%; [5]Y = 1006.116667 + 6.115000x – 0.048426x^2, R^2 = 98.69%; [6]Y =322.713095 – 2.241706x + 0.015258x^2, R^2 = 86.78%; [7]Y = 433.883333 – 6.115000x + 0.048426x^2, R^2 = 98.69%. In order not to visually pollute the table, only values of P <0.005% were placed. The quadratic or linear effect is represented by the equation.

A decreasing linear effect (p <0.05) on ingestion time for the 70% concentrate treatment and a quadratic effect (p <0.05) for the 30% concentrate treatment were found over the period, with a reduced time spent on this activity at the end of the experiment. Ingestion time was related to the DMI, since both ingestion time and the DMI%BW decreased during the evaluation period (Table 2), i.e., the animals were close to meeting their nutritional requirements and as a result there was a decrease in food intake.

A quadratic effect ($p < 0.05$) was observed in the rumination time for the 70R:30C treatment. When associated with the DMI%BW, which also decreased at the end of the experimental period (Table 2), this effect indicates that even when animals ingest extruded feed with a higher content of structural carbohydrates, with the intake decrease there is less fiber in rumen to stimulate rumination. In the experiment, quadratic effect ($p < 0.05$) was observed during the time spent with chewing and resting, and at the end of the experiment the animals reduced the total time of chewing and increased the resting time. That is, when intake is reduced, ingestion and rumination also decrease; consequently, the time that the animal spends on other activities (such as resting) increases.

Confined animals tend to concentrate their period of ingestion shortly after the food is provided in the trough – between 1 and 3 hours, with variable intervals of small meals (FISCHER et al., 1997). Van Soest, Robertson and Lewis (1991) reported that rumination in adult animals lasts about 8 hours a day with variations between 4 and 9 hours. They observed that this behavior was mainly influenced by the nature of the diet, i.e., the more concentrated the diet, the shorter the time spent on rumination.

At the beginning of the experiment with 30R:70C, the animals spent on average 3.7 hours on ingestion, 1.7 hours on rumination, and 18.6 hours on resting; at the end, they spent on average 2.7 hours on ingestion, 1.3 hours on rumination, and 20.0 hours on resting. In turn, at the beginning of the experiment with 70R:30C, they spent on average 3.9 hours on ingestion, 3.4 hours on rumination, and 16.7 hours on resting. at the end, 2.7 hours on ingestion, 1.8 hours on rumination, and 19.5 hours on resting. The rumination values were below those proposed in the literature, but this did not influence either their weight gain, which remained constant throughout the experimental period (Table 3), or their DMI. This can be attributed to the extrusion process, which changed the food matrix and made its nutrients more digestible, thus improving their use by the animal.

The animals fed with the 30R:70C ration had less ruminal movement than those that received the 70R:30C ration (p <0.05; Table 5), which was due to the higher non-fibrous carbohydrate (NFC) and lower neutral detergent fiber (NDF) content of the treatment with greater amount of concentrate (Table 1). These characteristics lead to reduced ruminal pH and therefore reduced ruminal motility (NOCEK et al., 1984). However, it can be inferred that the use of extruded feed does not cause digestive problems in animals, as the ruminal movement of sheep in thermal comfort is 1 to 2 movements per minute (mov min^{-1}) (FARIA, 2010), and the values found were 1.10 mov min^{-1} for the 30R:70C treatment and 1.15 mov min^{-1} for the 70R: 30C treatment. Therefore, the values found in this study are within the recommended.

Table 5. Effect of different roughage:concentrate ratio in extruded feed on ruminal movement (mov $5min^{-1}$) in crossbred lambs.

Treatment	Ruminal Movement
30R:70C	5.49 B
70R:30C	5.77 A
P value	0,0478
Week	Ruminal Movement[1]
1	5.83
2	5.83
3	5.56
4	5.46
5	5.46
Mean	5.63
CV	10.79
P value	0.0023

CV: coefficient of variation; Distinct letters in the column differ by the Tukey test at 5%; [1]Y = 5.963333 – 0.1100x, R^2 = 86.43%. In order not to visually pollute the table, only values of P <0.005% were placed. The quadratic or linear effect is represented by the equation.

The lower ruminal movement observed in the 30R: 70C treatment can be explained by the lower DMI obtained by the lambs (Table 2). When consuming a higher content of concentrate, the animals reduced the DMI%BW due to a greater amount of nutrients with greater rumen fermentation capacity, thus reducing rumen movement and, consequently, the time spent on rumination (Table 3). In contrast, the treatment with 70% roughage showed greater ruminal movement, which is explained by the higher DMI along with the higher fiber quantity in this treatment (Table 1), which influences the chewing activity and the biphasic nature ruminal content (the floating ruminal match made up of large particles and a pool of liquids and small particles) (MERTENS, 1997). The ruminal match is a "mattress" just below the gas phase inside the rumen formed by a tangle of floating particles of food, freshly ingested and in the process of fermentation by ruminal microorganisms. Its function is to control the pH and the ruminal movement by physical stimulus, and, consequently, rumination and salivation (OLIVEIRA et al., 2008).

A negative linear effect ($p < 0.05$) was found for ruminal movement over time, since the animals had the lowest values for this variable at the end of the experiment (Table 5). This response pattern can also be associated with a reduction in DMI%BW in the period (Table 2) and a reduction in the times spent on ingestion, rumination and total chewing (Table 4).

The findings seem to show that the DMI, the feeding behavior and the ruminal movement are influenced by the roughage:concentrate ratio of the diet and the food composition (physical form associated with the quantity of nutrients). Concentrated diets promote metabolic regulation of the DMI, reducing the amount of food eaten; and the greater solubility and fermentability of nutrients promotes less ruminal movement, which consequently reduces rumination and total chewing. The opposite happens in diets with a higher fiber content, since the physical stimulus caused by the fibrous fraction inside the rumen increases rumen movement and consequently the total rumination and chewing; as the food stays longer inside the rumen to be fermented and degraded, the DMI increases to meet the animal's nutritional requirements.

Conclusion

Extruded feed with 70% roughage and 30% concentrate increases the time spent on rumination and total chewing, and consequently ruminal movement. Besides, it is more economically viable, since it promotes the same performance in animals with lower cost due to the higher proportion of roughage in the food.

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Diferentes relações volumoso:concentrado de ração extrusada e comportamento ingestivo de borregas em crescimento

Resumo
Objetivou-se com o presente trabalho avaliar o consumo de matéria seca comportamento ingestivo e movimentação ruminal de cordeiros alimentados com ração extrusada em diferentes relações volumoso(V):concentrado(C). O experimento foi realizado na Universidade Federal de Uberlândia (UFU), Fazenda Experimental Capim Branco, no período de 07 de dezembro de 2016 a 22 de março de 2017. Foram utilizados 30 borregas, mestiças (Santa Inês x Dorper), com idade de três meses, e peso médio de 20,67 ± 4,57 kg. Os animais foram alocados em baias coletivas providas de comedouro, bebedouro, saleiro e piso ripado de madeira. O experimento foi conduzido em delineamento inteiramente casualizado com dois tratamentos e quinze repetições por tratamento totalizando 30 unidades experimentais. Os tratamentos consistiam de volumosos e concentrado extrusados e misturados na seguinte proporção 30V:70C e 70V:30C. Foram avaliados o consumo de matéria seca (CMS), comportamento ingestivo durante 24 horas e movimentação ruminal durante 5 minutos. Houve menor CMS para o tratamento 30V:70C, e redução do CMS em relação ao peso corporal no final do experimento. Os animais apresentaram redução no tempo gasto com ruminação e mastigação total e, também menor movimentação ruminal para as duas rações analisadas. Porém, no início de experimento houve menor tempo gasto com ruminação e mastigação total para o tratamento 30V:70C. O uso de ração extrusada com 70V:30C promove maior tempo dispendido em atividades de ruminação e mastigação total, e, consequentemente maior movimentação ruminal nos animais.
Palavras-chave: Extrusão, Ingestão, Mastigação, *Ovis aries,* Ruminação.

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