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Ingestive behavior and efficacy of male sheep housed in different stocking densities

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ABSTRACT - The objective of this study was to analyze the effect of housing density on ingestive behavior of male Santa Inês sheep housed individually and in double. Forty non-castrated males were used with an average initial weight of 21.33±2.62 kg and an average age of 120 days. The males were housed in two types of covered stalls: double stalls (two males/stall) of 3.0 m^2 and individual stalls of 1.50 m^2. Animals housed in individual stalls spent more time ruminating and less time eating than those in double stalls. These animals also spent more time in idleness. Sheep idled approximately 11.43 hours/day (47% of the time), which can be explained by the shorter time spent in rumination, considering that the diet used in this experiment had adequate nutritional quality. The animals in double stalls consumed more water, which resulted in increased urination. However, this activity did not interfere with total weight gain. Therefore, experiments testing stall density does not interfere with the performance of the animals.

Keywords: behavior, feeding, rumination, sheep

Introduction

Animal behavior can be used to indicate quality of the whole production system, including individual activities of the animal in its social and physical environment (Custodio et al., 2017). There is increasing concern about animal welfare and economically viable productive management (Eustáquio Filho et al., 2014). Sheep feedlot is a strategy capable of satisfying both the producer and the consumer, since it allows the carcasses of young animals and, consequently, better-quality products available in the market (Urano et al., 2006).

One of the objectives of the intensive production system is to make the animal spend more time eating and, consequently, gaining more weight. However, the performance of sheep is known to be influenced by behavioral activities, diet, breeding systems, and gregariousness. Sheep raised in groups have higher feed intake and reduced growth rate variation compared with animals that are fed individually (Titto et al., 2010). Animals in feedlot usually consume a high amount of concentrates to meet their energy and protein requirements (Carvalho et al., 2008). Improvements in the production system result in the reduction of expenses and environmental impact caused by this activity. It also leads to an increase in the space available for production without compromising natural resources.

Research indicates that sheep spend 10 h a day in idleness (Ítavo et al., 2008). Studies on the ingestive behavior of sheep confined in stalls (Alves et al., 2010; Silva et al., 2016; Eustáquio Filho et al., 2014) reported that animals confined in groups of five or more modify their ingestive behavior. The smaller the groups in the stalls, the better the sheep performance, although investigations into smaller groups are scarce. The objective of this study was to analyze the effect of housing density on ingestive behavior of male Santa Inês sheep housed individually and in double.

Material and Methods

The trial was conducted in Bananeiras, Paraíba, Brazil (altitude 552 m, latitude 6°41'11" S, longitude 35°37'41" W). Air temperature (black globe temperature) was 24.97 °C, and relative humidity (RH) was 76.48% in the stalls. This study was certified by the local Animal Ethics Committee (case no. 2305/14).

Forty non-slotted castrated sheep of the Santa Inês breed were used, at an average initial weight of 21.33±2.62 kg and an average age of 120 days. The sheep were distributed in two types of covered stalls (20 sheep in each type): individual stalls of 1.50 m^2 and double stalls of 3.0 m^2 (two sheep/stall). The feeder area used for each animal was 20 cm. Sheep were weighed weekly. Daily weight gain (ADG) was calculated using the following equation (Gowane et al., 2015):

$$ADG = (\text{Final live weight (kg)} - \text{Initial weight (kg)})/\text{Days in feedlot (48 days)}$$

The diet was provided with a forage:concentrate ratio of 50:50 to provide a gain of 250 g/day, as recommended by the NRC (2007). The experimental diet consisted of guava byproduct, Tifton 85 hay (*Cynodon dactylon*), ground corn, soybean meal, and a vitamin and mineral supplement (Table 1). It was calculated to have about 15.0% crude protein (CP) and 2.39 Mcal kg^{-1} concentrated metabolizable energy in the diet. The experimental diet was offered *ad libitum* at 07.30 and 16.30 h, as a complete mixture. Feed offered and leftovers were weighed daily to calculate voluntary intake and readjust the quantity offered, establishing 10% of leftovers based on dry matter.

Table1 - Chemical composition of experimental diets

Item	Diet
Ingredient (g kg^{-1} DM)	
Guava agro-industrial waste (GAW)[1]	150
Tifton hay	350
Ground corn	310
Soybean meal	170
Mineral supplement[2]	15.0
Calcitic limestone	5.00
Chemical composition	
Dry matter (DM; g kg^{-1} as fed)	889
Crude protein (CP; g kg^{-1} DM)	154
Ethereal extract (EE; g kg^{-1} DM)	44.5
Neutral detergent fiber (NDF; g kg^{-1} DM)	479
Acid detergent fiber (ADF; g kg^{-1} DM)	276
Ash (g kg^{-1} DM)	56.2
Total carbohydrates (TC; g kg^{-1} DM)	741
Non-fibrous carbohydrates (NFC; g kg^{-1} DM)	262
Total tannins (TT; g kg^{-1} DM)	9.90
Lignin[3] (g kg^{-1} DM)	55.0
Metabolizable energy (ME; Mcal/kg DM)	2.39

[1] GAW composition: DM, 908.0; CP, 91.8; EE, 107.5; NDF, 730.7; ADF, 620.7; Ash, 21.3; TC, 779.4; NFC, 48.7; Tannin, 6.6%.
[2] Composition of mineral supplement. per kg, P, 70 g; Ca, 140 g; Na, 148 g; S, 12 g; Mg, 1320 mg; F, 700 mg; Zn, 4.700 mg; Mn, 3,690 mg; Fe, 2,200 mg; Co, 140 mg; I, 61 mg; Se, 15 mg; sodium monensin, 100 mg.
[3] 19.7%.

To estimate nutrient intake, the average of the differences between the total quantity of nutrients contained in the diet offered and in the leftovers was used. Dry matter intake (kg day^{-1}) was calculated. Water was offered to each sheep on a daily basis using 5-L buckets placed next to the feeding troughs. Average daily water intake (ADWI) was measured to the nearest 10 mL. Loss of water due to evaporation was assessed by measuring the volume of water lost from a bucket of the same volume placed out of the reach of sheep (Mdletshe et al., 2017).

During the period in the feedlot (48 days), three visual evaluations were performed (for the last three weekends of the confinement, i.e., 31, 38, and 45 days). The behaviors (eating, ruminating, idleness, and drinking activities; Table 2) were recorded according to the methodology proposed by Martin and Bateson (2007) by instantaneous and continuous sampling, using the focal sampling method and sampling intervals of 5 min in a direct fashion, with continuous periods of 24 h from 08.00 to 08.00 h.

The ingestive behavior factors were obtained based on the following equations:

$$FE = DMI/FT \quad (1)$$

$$FE = NDFI/FT \quad (2)$$

$$RE = DMI/RT \quad (3)$$

$$RE = NDFI/RT \quad (4)$$

$$TCT = FT+RT, \quad (5)$$

in which FE = feeding efficiency (g DM min^{-1}); DMI = dry matter intake (g DM min^{-1}); FT = feeding time (min day^{-1}); RE = rumination efficiency (g DM min^{-1}); NDFI = neutral detergent fiber intake (g NDF min^{-1}); RT = rumination time (min day^{-1}); and TCT = total chewing time (min day^{-1}) (Polli et al., 1995).

The number of times the animal defecated, urinated, and sought water was visually and continually observed for 24 h, which was performed by strategically positioned trained observers in an alternation system so as not to promote changes in the routine of the animals. During data collection of the nocturnal observation of the animals, the environment was kept under artificial illumination.

The results are reported as means ± standard error of the mean (SEM) and P-values for the density of stall (one or two sheep per stall). Data were subjected to one-way analysis of variance using the General Linear Model (GLM) procedure of the SAS program (Statistical Analyses System, version 9.1). The mean was compared using a student t test with the level of significance set at $P<0.05$.

The following mathematical model was used to test the effect of the behavioral variables:

$$Y_{ijk} = \mu + S_i + e_{ijk},$$

in which Y_{ijk} is the dependent variable, μ is the overall mean, S_i is the fixed effect of density (one or two animals per stall), and e_{ijk} is the random error with mean 0 and variance σ^2.

Table 2 - Behavioral measures registered to evaluate the ingestive behavior of sheep housed in individual and double stalls (Norouzian, 2015)

Behavior	Description
Feeding	Eating when feed is still in mouth
Ruminating	Chewing regurgitated feed, either in standing or in lying position
Drinking	Swallowing water
Idle	Standing without any movement or behavior
Others	Defecation, urination, drinking

Results

Among the continual activities, rumination, feeding, and drinking were different (P<0.05), in which the animals in individual stalls spent more time ruminating than animals in double stalls. The animals in individual stalls spent more time ruminating and drinking than the animals in double stalls. Feeding time was more considerable in the double stalls (Table 3). Animals in individual stalls visited the trough more frequently, but the amount of water ingested per day was similar for the two situations under study (Table 3). Animals in individual stalls spent three times more time drinking water than animals in double stalls. However, considering total water intake, the animals in both types of stalls consumed the same amount of water.

In the evaluation of rumination efficiency and feeding efficiency (Table 4), there was a significant difference (P<0.05) for dry matter intake and neutral detergent fiber intake. Animals housed in double stalls showed a higher efficiency of rumination, and animals housed in individual stalls showed higher feeding efficiency.

Animals housed in individual stalls showed a higher frequency of urination than animals in double stalls (Figure 1).

Table 3 - Mean occurrences and SEM of performance and ingestive behavior of sheep housed in individual and double stalls, expressed in minutes

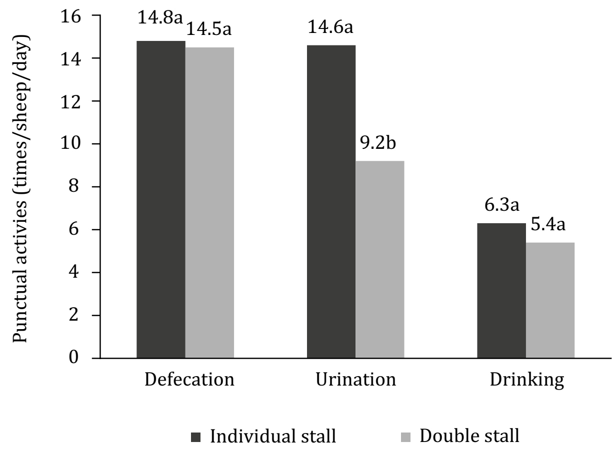
Variable	Stall		SEM	P-value
	Individual	Double		
Performance measure				
Initial weight (kg)	21.36	21.31	0.41	0.957
Final live weight (kg)	36.70	36.16	0.53	0.613
Daily weight gain (kg day^{-1})	0.32	0.31	0.01	0.563
Daily water intake (L day^{-1})	3.14	3.15	0.07	0.927
Dry matter intake (kg day^{-1})	1.27	1.32	0.02	0.308
Neutral detergent fiber intake (kg day^{-1})	0.61	0.65	0.01	0.081
Behavioral measure (min day^{-1})				
Rumination	582.75a	502.75b	14.06	0.008
Idle	666.75	705.50	13.36	0.149
Feeding	165.25b	224.00a	13.59	0.028
Drinking	25.25a	7.75b	3.13	0.003
Total chewing time	748.00	726.75	12.56	0.268

SEM - standard error of the means.
a,b - Means followed by different letters in the same row differ from each other by the t test.

Table 4 - Mean occurrences and SEM of feeding and rumination efficiency of dry matter (DMI) and neutral detergent fiber (NDFI) intake of sheep housed in individual and double stalls

Efficiency	Stall		SEM	P-value
	Individual	Double		
Feeding (g DMI min^{-1})	691.57a	381.62b	61.30	0.008
Rumination (g DMI min^{-1})	131.47b	161.70a	4.94	0.009
Feeding (g NDFI min^{-1})	333.66a	191.92b	29.84	0.012
Rumination (g NDFI min^{-1})	63.71b	79.83a	2.33	0.002

SEM - standard error of the means.
a,b - Means followed by different letters on the same row differ from each other by the t test.



a,b - Means followed by different letters in the same row differ from each other by the t test.

Figure 1 - Distribution of the punctual activities defecation, urination, and drinking in number of times/sheep/day comparing sheep Santa Inês housed in individual and double stalls.

Discussion

Sheep are gregarious animals–that is, living in groups–, and this seems to be so important that individuals isolated from the herd become stressed (Leme et al., 2013). When an animal is eating, the others can be stimulated even if they are not hungry (Curtis and Houpt, 1983).

The NDFI is consistent with an increase in the rumination activity performed by the animals in double stalls, since rumination is considered a physiological feature that reduces fiber particle size, according to the diet, for the best usage of the feed, and it is triggered and timed by when the diet is provided (Miranda et al., 1999). The increase in intake tends to reduce the ruminating time per gram of food consumed (Van Soest, 1994). It is known that when animals are fed in groups, the social facilitation results in a higher feed intake reducing the growth rate variation in the group and better social behavior compared with animals that are fed individually (Titto et al., 2010).

Animals housed in individual and double stalls spent an average of 11 h a day in idleness, which corresponds to 48% of the day. Research has indicated that animals spend an average of 10 h a day in idleness (Ítavo et al., 2008). Young animals when housed in pairs spend around 2% of the day in social contact, and the incidence of agonistic behavior is reduced (Chua et al., 2002). The incidence of aggressive behavior increases as the number of lambs in the stalls is increased (Van et al., 2007).

Sheep and goats housed in groups of five animals per stall consume more feed than animals housed in individual stalls (Van et al., 2007). The number of animals per stall influences behavior and feed intake, which means that animals in double stalls have better weight gain (Leme et al., 2013). The animals should be free from fear and distress and free to express normal behaviors by means of sufficient space, proper facilities, and company of congeners (Animal Welfare, 2011).

Although this did not interfere in the number of times the animal went to the trough to eat, Cirne et al. (2014), working with restriced concentrated diets, found that rumination time was lower than in our research and that the idle time was 64.26% higher. These authors attributed those results achieved due to particle size that did not have greater need for rumination and due to the high energy content in the diet. Our results differ from this because of the concentrate ratio and the particle size of the hay being around 2 cm.

Fiber content and physical form of the diet are the main factors affecting rumination time (Van Soest, 1994). Diets composed of fiber sources from forage provide a favorable environment for the proper functioning of the rumen, in addition to the fact that particle size determines the time in the rumen, which maintains mastication activity. According to Mertens (1997), feed particles smaller than

1.18 mm pass through the rumen without the need for rumination, and this is the minimum size for stimulating mastication.

The time spent in rumination, idleness, and feeding activities are in agreement with Alves et al. (2010), regardless of animal species. Among the behavioral activities, idleness represented the most time, regardless of stall type. The animals that spent more time consuming obtained less rumination time, even with higher NDFI (kg day^{-1}). This higher efficiency can be attributed to the fact that the feed was supplied with a 2-cm hay particle size, favoring the mastication activity of the animals.

Conclusions

When fed in individual and double stalls, the performance measures are similar for sheep. Behavior measures, rumination, and drinking are lower and the feeding measure is greater in the double stalls.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: R.G. Costa, P.T. Nobre and F.F.R. Carvalho. Data curation: N.L. Ribeiro and P.T. Nobre. Formal analysis: N.L. Ribeiro and F.E. Martins. Investigation: N.L. Ribeiro, P.T. Nobre and A.N. Medeiros. Methodology: N.L. Ribeiro, P.T. Nobre, A.N. Medeiros and F.E. Martins. Project administration: R.G. Costa and F.F.R. Carvalho. Resources: R.G. Costa and F.F.R. Carvalho. Writing-original draft: P.T. Nobre and F.F.R. Carvalho. Writing-review & editing: F.F.R. Carvalho.

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