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Influence of pasture, silvopastoral, and feedlot production systems and the recording interval of behavioral activities on the ingestive behavior of lambs

Influência dos sistemas de produção em pastagem, silvipastoril e confinamento, e do intervalo de registro das atividades comportamentais no comportamento ingestivo de cordeiros

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Highlights

Feedlot lambs spend four times more time ingesting water than lambs in a SS.
Lambs in FS fed a ration with 20% hay have the same rumination time as grazing lambs.
Lambs on pasture can have their behavior evaluated at intervals of up to 20 minutes.

Abstract

The evaluation of the ingestive behavior of ruminant animals is important to identify the animal response to the particularities of the different production systems. However, the five-minute evaluation technique requires personnel, making it difficult to adhere to farms and research in more complex pastoral systems. Thus, this study objected to evaluating the influence of pasture, silvopastoral, and feedlot production systems on the ingestive behavior of lambs and to defining the behavior recording interval in each of the systems. Twenty-four lambs were distributed in an experimental design in split plots. The plots were the production systems (pasture without shading - PS, silvopastoral - SS, and feedlot systems - FS) and the subplots were the behavior observation intervals (5, 10, 15, and 20 min.). In the pasture without shading

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and silvopastoral systems, the lambs were kept on Aruana grass (*Megathyrsus maximus*) pasture and supplemented with concentrate at 1.5% of body weight per day, on a dry matter (DM) basis. In the feedlot system, the lambs received a diet consisting of 200 g kg DM^{-1} of annual ryegrass hay (*Lolium multiflorum* Lam.) and 800 g kg DM^{-1} of concentrate. There was no interaction ($P > 0.05$) between the production system and the recording interval of behavioral activities. The time spent on food intake was higher ($P < 0.05$) in the pasture (533 min d^{-1}) and silvopastoral (513 min d^{-1}) systems than in the feedlot (225 min d^{-1}). In contrast, for water intake, time was higher ($P < 0.05$) in the feedlot (21 min d^{-1}) and lower in the silvopastoral system (5 min d^{-1}). There was no difference ($P > 0.05$) between the systems for rumination and idle activities, of which daily averages were 378 and 587 min d^{-1}, respectively. There was also no difference ($P > 0.05$) between the observation intervals for feed, water, rumination, and idleness activities. Lambs in pasture-based systems spend more time feeding, and feedlot lambs spend more time ingesting water. Feedlot lambs ruminate as much as grazing animals when fed hay, even though hay represents only 20% of the total diet. The recording interval of behavioral activities in these production systems can be up to 20 minutes.
Key words: Dorper. Observation interval. Rumination. Santa Ines.

Resumo

A avaliação do comportamento ingestivo de animais ruminantes é importante para identificar a resposta animal frente às particularidades dos diferentes sistemas de produção. Entretanto, a técnica de avaliação usualmente utilizada, com intervalos de cinco minutos, requer mão de obra, dificultando sua adesão em propriedades e em pesquisas em sistemas pastoris de maior complexidade. Assim, este estudo foi realizado com os objetivos de avaliar a influência dos sistemas de produção em pastagem, silvipastoril e confinamento sobre o comportamento ingestivo de cordeiros e definir o intervalo de registro do comportamento em cada um dos sistemas. Foram utilizados 24 cordeiros distribuídos em delineamento experimental em parcelas subdivididas, sendo as parcelas os sistemas de produção (pastagem sem sombreamento, sistema silvipastoril e confinamento) e as subparcelas os intervalos de observação do comportamento (5, 10, 15 e 20 min.). Nos sistemas em pastagem sem sombreamento e silvipastoril, os cordeiros permaneceram em pastagem de capim Aruana (*Megathyrsus maximus*) e foram suplementados com concentrado a 1,5% do peso corporal ao dia em base de matéria seca (MS). No sistema em confinamento, os cordeiros receberam ração composta por 200 g kg MS^{-1} de feno de azevém anual (*Lolium multiflorum* Lam.) e 800 g kg MS^{-1} de concentrado. Não houve interação ($P > 0,05$) entre sistema de produção e intervalo de registro das atividades comportamentais. O tempo despendido para a ingestão de alimento foi maior ($P < 0,05$) no sistema de pastagem (533 min d^{-1}) e silvipastoril (513 min d^{-1}) em relação ao confinamento (225 min d^{-1}), enquanto que para ingestão de água foi maior ($P < 0,05$) no confinamento (21 min d^{-1}) e menor no silvipastoril (5 min d^{-1}). Não houve diferença ($P > 0,05$) entre os sistemas para as atividades de ruminação e ócio, cujas médias diárias foram de 378 e 587 min d^{-1}, respectivamente. Também não houve diferença ($P > 0,05$) entre os intervalos de observação para as atividades de ingestão de alimento, água, ruminação e ócio. Cordeiros em sistemas à base de pastagem gastam mais tempo se alimentando, e cordeiros confinados mais tempo ingerindo água. Cordeiros confinados ruminam tanto quanto animais em pastejo quando alimentados com feno, mesmo que este represente apenas 20% da dieta total. O intervalo de registro das atividades comportamentais nestes sistemas de produção pode ser de até 20 minutos.
Palavras-chave: Dorper. Intervalo de observação. Ruminação. Santa Inês.

Introduction

In beef sheep production, lamb is the category that has the best carcass characteristics and, consequently, greater consumer acceptability (Hopkins et al., 2007; Esteves et al., 2018). Lambs have greater efficiency of gain and carcass quality, especially in the first six months of life, and these characteristics can be optimized using adequate finishing systems (Bettencourt et al., 2020; Menezes et al., 2021).

Nutrition is a determining factor for animal performance. However, factors other than the chemical composition of the food must be considered to nourish an animal effectively. Among these factors are the production system, which determines how food is made available, and the different environmental characteristics that modulate animal response. In addition, knowledge of ingestive behavior is an important tool to guide management practices that enable better animal performance (Tontini et al., 2021).

Currently, there are several ways to assess ingestive behavior within the farm, such as the use of automatic traceability equipment and video cameras. However, these types of equipment have a high investment cost and are not economically viable, especially in sheep farming. On the other hand, visual observations demand time and personnel, which diverges from the reality of most farms. Usually, observations are carried out at five-minute intervals, as they are close to the continuous assessment method (Carvalho et al., 2007). However, the shorter the interval between observations, the greater the need for personnel.

In this sense, this research was carried out with the objective of defining more practical observation protocols for the evaluation of ingestive behavior. Carvalho et al. (2007) evaluated recording intervals of 5, 10, 15, 20, 25, and 30 minutes of behavioral activities in uncastrated Santa Ines male sheep in feedlot. Sheep were distributed in individual pens and received a diet composed of elephant grass (*Pennisetum purpureum* Schum.), ammoniated or not, in addition to different sources of isoprotein concentrates (160 g kg DM^{-1} of CP) in the roughage:concentrate ratio of 60:40. Under the conditions studied, the authors concluded that feeding, rumination, and idleness behaviors might be evaluated at intervals of up to 30 minutes. Marques et al. (2012) worked with uncastrated Santa Ines male sheep on *Megathyrsus maximus* cv. Aruana and evaluated the intervals of 5, 10, 15, 20, and 30 minutes. The authors observed that feeding, rumination, and other activities (all activities but ingesting water and food or rumination) could be evaluated in intervals of up to 30 minutes. However, Marques et al. (2012) used only eight experimental animals, which requires caution when extrapolating such results.

The choice of the appropriate time interval for recording activities in the evaluation of ingestive behavior has been widely discussed since it allows the observation of the largest number of animals and does not compromise the accuracy of measuring the time spent in behavioral activities (Aldrighi et al., 2018). Considering that the diet used (Mazza et al., 2020; Herzog et al., 2021; Valença et al., 2022) and the production system (Poli et al., 2009) in which the animals are inserted can modify the ingestive behavior of sheep, it is suggested that these factors may change the observation interval to be adopted. However, studies that evaluate different intervals of observation of the ingestive behavior of sheep in pasture, with (silvopastoral) and without shading, and that use diets containing a low roughage: concentrate ratio in feedlot are scarce. In this sense, this study was carried out with the objective of evaluating the influence of pasture, silvopastoral, and feedlot production systems on the ingestive behavior of lambs and defining the behavior recording interval in each of the systems. Two hypotheses were formulated: the production system influences the ingestive behavior of lambs, and the behavior of the lambs can be evaluated at intervals longer than five minutes without any decrease in the accuracy of the data collected.

Material and Methods

The experiment was carried out at the Teaching and Research Unit (Unepe) for sheep and goats of the Universidade Tecnológica Federal do Paraná (UTFPR), located in the municipality of Dois Vizinhos/PR (latitude of 25º42' S, longitude of 53º03' W and altitude of 520 m above sea level; Instituto Agronômico do Paraná [IAPAR], 2011). The meteorological variables during the experiment were collected at the UTFPR meteorological station, located 500 meters from the experimental area (Table 1). The study was approved and conducted following the ethical standards of the Ethics Committee on the Use of Animals of UTFPR/DV (protocol number 2016-028).

Table 1
Ambient temperature, relative air humidity, and average precipitation during the periods of evaluation of the ingestive behavior of the lambs

Meteorological variables	18th experimental day	35th experimental day	Total EP[I]
	Temperature (ºC)		
Mean ± SD*	22.28 ± 2.54	24.44 ± 3.16	23.11 ± 1.69
Minimum	18.30	20.40	14.30
Maximum	26.90	30.00	32.80
	Relative air humidity (%)		
Mean ± SD*	86.88 ± 9.43	84.32 ± 13.60	81.74 ± 9.36
Minimum	68.00	61.00	34.00
Maximum	100.00	100.00	100.00
Average precipitation (mm)	5.00	0.60	3.60 ± 5.24*

[I]EP = experimental period (35 days); *Mean ± standard deviation (SD).

Animals, diets, and experimental performance

Twenty-four uncastrated Dorper x Santa Ines crossbred lambs were used, with an average weight and age of 22.97 ± 1.87 kg and 138 days, respectively, distributed in three production systems with eight lambs each. The experimental design was completely randomized in subdivided plots. The plot was composed of the production systems (pasture without shading, silvopastoral system, and feedlot) and the subplots characterized by the observation intervals (5, 10, 15, and 20 min.) of the ingestive behavior.

The production systems evaluated were: Pasture (PS) = lambs finished in Aruana grass (*Megathyrsus maximus*) pasture without shading + concentrated supplementation at 1.5% of body weight (BW) based on dry matter (DM) per day; Silvopastoral (SS) = lambs finished on Aruana grass pasture with shading + concentrated supplementation at 1.5% BW in DM d^{-1}; Feedlot (FS) = feedlot finished lambs with food containing 200 g kg^{-1} of annual ryegrass hay (*Lolium multiflorum* Lam.) and 800 g kg^{-1} of concentrate on a DM basis.

The area of the pasture system corresponded to 1600 m² (0.16 ha), subdivided into four paddocks of 400 m² (0.04 ha) and equipped with feeders, drinkers, and salt troughs. The silvopastoral system was implemented in September 2013 in an east-west direction, with trees of the native laurel species (*Cordia trichotoma*) arranged in double rows (two rows of trees), with a distance between the trees of two meters in the same row and one meter between rows in each of the four 400 m² paddocks. The distance between a row of trees from one paddock to another was approximately ten meters. Two tester lambs were distributed per paddock in the pasture and silvopastoral systems. The grazing method was used with continuous stocking and variable stocking rate for pasture management according to the "put and take" technique (Mott & Lucas, 1952). Pasture evaluations and stocking adjustments were performed at 21-day intervals to maintain a forage supply of 10% (10 kg DM per 100 kg BW per day). Grazing simulation and forage mass estimation ([FM], kg ha^{-1} DM) were performed using the double sampling method (Wilm et al., 1944). Pasture height was measured with a graded ruler (Barthram, 1985) and a representative sampling of 400 ha^{-1} points was obtained (C. J. A. Silva et al., 2020), corresponding to 16 random points per 0.04 ha paddock. The average FM in the pasture and silvopastoral systems was 2.441 kg DM ha^{-1} (average canopy height of 12.4 cm) and 2.049 kg DM ha^{-1} (average canopy height of 13.5 cm), respectively.

Eight lambs were confined in individual pens of 4 m^2 each. The pens were equipped with feeders, automatic drinkers, and individual salt troughs. The food provided was regulated according to the daily consumption of the animals in amounts adjusted to provide 10% of the leftover food in the feeders. The lambs were fed twice a day, with 50% of the food supplied at 08:00 and the remaining at 15:00. Diets were prepared according to the nutritional requirements of finishing lambs, containing 180 g kg^{-1} of crude protein (CP) and 730 g kg^{-1} of total digestible nutrients (TDN) on a DM basis (National Research Council [NRC], 2007).

In all production systems, water was provided *ad libitum* and commercial mineral salt in an amount of 20 g $animal^{-1}$ d^{-1}. Supplementation of animals in pasture-based systems was provided twice a day, at 08:00 and 15:00, as well as the total diet of the feedlot animals. The ingredients proportions and the chemical composition of the concentrated supplement fed on pasture and food supplied in the feedlot are presented in Tables 2 and 3, respectively. The experimental period corresponded to 35 days. The first 17 days were considered for adapting the lambs to the paddocks in the pasture-based systems and adapting them to the stalls and diet in the feedlot system. Data collection was performed during the next 18 days after the adaptation period.

Table 2
Ingredient content of concentrates supplied to lambs in production systems

Ingredients (g kg^{-1})	Production systems		
	Pasture	Silvopastoral	Feedlot*
Ground corn	661.5	661.5	634.9
Wheat bran	98.5	98.5	64.5
Soybean meal	228.9	228.9	294.2
Calcitic limestone	11.1	11.1	6.4
Total	1000.0	1000.0	1000.0

* Diet composed of 800 g kg^{-1} of concentrate and 200 g k^{g-1} of ryegrass hay.

Table 3
Chemical composition of ingredients and experimental diets of lambs in different production systems

Composition[I] (g kg^{-1})	Experimental diet		
	Ground corn	Soybean meal	Wheat bran
DM*	898.3	873.7	883.8
CP	97.5	487.7	145.6
NDF	162.0	165.2	453.7
ADF	38.9	104.1	154.3
TDN**	878.0	790.7	770.4*

	Production systems[§]					
	Concentrate			Bulk[§§]		
	Pasture	Silvopastoral	Feedlot	Pasture	Silvopastoral	Feedlot
DM*	881.3	881.3	884.4	270.1	250.5	898.4
CP	190.5	190.5	214.8	139.0	151.0	62.0
NDF	121.6	121.6	145.0	578.9	551.1	684.4
ADF	64.8	64.8	65.3	430.2	432.1	439.8
TDN**	837.7	837.7	839.8	577.3	575.9	545.9

[I]DM: dry matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; TDN: total digestible nutrients. [§]Chemical composition of concentrate and roughage fractions per treatment. [§§] Chemical composition of simulation of continuous grazing (pasture and silvopastoral) and ryegrass hay (feedlot). *g kg^{-1} of natural matter; **Estimative of TDN according to Rodrigues (2009): TDN: 87.84 - (0.70 x ADF).

Behavior evaluation

Ingestive behavior was evaluated in two 24-hour periods (Fischer et al., 2000) on the 18th and 35th experimental days. The activities of food intake, rumination, idleness, water intake, salt intake, and other activities (Table 4) were evaluated at intervals of 5, 10, 15, and 20 minutes. The observations were carried out by four trained observers strategically positioned at a distance of approximately 5 meters from the lambs to not interfere with the natural behavior of the animals. During the night period, the environment was maintained with artificial lighting. The animals from all production systems were submitted to artificial night lighting seven days before each evaluation period.

Table 4
Description of behavioral activities evaluated in Dorper x Santa Ines lambs in different production systems

Activity	Behavioral description
Food intake	Animal grazing or in front of the feeder, with its head down or not, chewing after apprehension, or chewing with the muzzle dirty with feed without appearing apprehension
Rumination	Animal chewing, swallowing, regurgitating, and rechewing with the presence of an apparent bolus on the flank of the cheek
Idleness	Animal not moving, standing, or lying down without performing any activity
Water intake	Animal in front of the drinking fountain, with its head down, ingesting water
Salt intake	Animal in front of the salt troughs, head down or not, licking it
Other activities	Lying or standing animal licking its body, scratching itself, or in agonistic interactions

Source: Adapted from Aldrighi et al. (2018).

Statistical analysis

Data concerning days of evaluation of the ingestive behavior were used as repetition. Therefore, the mean of the two evaluation days was calculated for all the variables studied. Analyses were performed using RStudio® software. Data were submitted to the Shapiro-Wilk test to verify normality. All data presented normal distribution, proceeding to the analysis of variance (ANOVA), followed by Tukey's test at 5% probability for the comparison of means, according to the statistical model:

$$Y_{ijk} = \mu + T_i + e_i + A_j + TA_{ij} + e_{ijk}$$

where: μ = overall mean; T_i = main effect of the i-th production system, i= 1, 2, 3; e_i = error associated with the parcel of the i-th production system; A_j = secondary effect of the j-th evaluation time, j= 1, 2, 3 and 4; TA_{ij} = interaction effect of the production system i with the evaluation time j; e_{ijk} = the error associated with the Y_{ijk} observation whose variation is not explained (experimental error or residual) at the subplot level.

Results and Discussion

The production system was separated from the time interval (5, 10, 15, and 20 minutes) since the interaction of the production system versus time was not significant (P > 0.05), except for salt intake. Thus, the time spent in behavioral activities (in minutes) in relation to the production system is presented in Table 5.

Table 5
Time spent in activities (minutes day^{-1}) related to the behavior of Dorper x Santa Ines lambs submitted to different production systems

Variables[I]	Production systems			P-value
	Pasture	Silvopastoral	Feedlot*	
Food intake	533 ± 11 a	513 ± 21 a	225 ± 11 b	0.017
Water intake	12 ± 2 ab	5 ± 1 b	21 ± 1 a	0.032
Rumination	341 ± 8	366 ± 8	425 ± 12	0.174
Idleness	535 ± 19	525 ± 28	699 ± 8	0.164
Other activities	17 ± 2 b	22 ± 4 ab	61 ± 6 a	0.037

[I]Values are expressed in mean and standard error.
Means followed by different letters in the same line differ by Tukey's test (P<0.05).

Regarding rumination and idleness activities, there was no significant difference between the production systems (P > 0.05); the average time of activities was 378 and 587 min day^{-1}, respectively (Table 5). This result found for the rumination time can be explained by the supply of hay to the feedlot lambs. According to Pazdiora et al. (2019), rumination time is a variable influenced by the nature of the diet, as the higher the fiber content, the greater the time spent on rumination. In Table 3, it is possible to observe that the hay supplied to the feedlot animals presented 684 g kg DM^{-1} of neutral detergent fiber (NDF). In contrast, the bulky fraction of the pasture and silvopastoral systems presented, respectively, 579 and 551 g kg DM^{-1}. The time spent chewing increases with the NDF content (Mendes et al., 2008), contributing to the feedlot animals ruminating as much as the grazing animals. For acid detergent fiber (ADF), the values of the roughage fraction of the diet offered in the three systems were similar, being 430, 432 and 440 g kg DM^{-1} for pasture without shading system, silvopastoral system and feedlot system, respectively.

It was expected that feedlot lambs would spend more time in idleness due to space restriction and the total supply of diet in the feeder, in addition to individual housing preventing social behaviors (Costa et al., 2019). Feedlot sheep normally consume less fiber than grazing animals, which causes them to spend less time ruminating and, consequently, more time in idleness or other activities (Aguayo-Ulloa et al., 2014). However, in this study, as the hay supply favored the rumination behavior of the lambs, they had less time in their daily behavioral repertoire to remain in idleness. Ruminants are strongly motivated to forage and, when possible, tend to dedicate more time to this activity, so the supply of hay to feedlot lambs may also have acted as an environmental enrichment (Campion & Leek, 1996; Aguayo-Ulloa et al., 2014). D. L. Teixeira et al. (2012) observed an increase in stereotypies in lambs when there was no straw in the corral.

There was a difference (P < 0.05) for other activities between the production systems (Table 5). The feedlot animals spent more time performing other activities than the animals in pasture without shading. The silvopastoral system did not differ from the others. In the present study, other activities such as stereotypies were considered, but also scratching and licking behaviors, whether the animals were standing or lying down, so it is difficult to associate this variable with stress since licking and scratching behaviors can be considered as self-care (Fraser, 1989).

Lambs from pasture and silvopastoral systems spent more time ingesting food ($P < 0.05$) than feedlot lambs (Table 5). Feedlot herbivorous animals exploit the diet faster and, consequently, select more efficiently (choice time vs. consumption). On the other hand, grazing herbivores need to make several decisions during the foraging process, deciding what to eat (diet selection), where to eat (feeding site selection), and when to eat (ingestion) (Launchbaugh, 2020). Sheep consume approximately 2 to 5% BW in DM day^{-1}, with grazing time varying according to food availability and type (NRC, 2007; Moreira et al., 2018). Associated with this, sheep are very selective animals compared to other ruminants. They tend to select food based on its nutrient content, which requires an average of 8 h of daily grazing, and changes in other activities, such as rumination and idleness, can cause grazing times longer than 12-13 h day^{-1} (Dias-Silva & Abdalla, 2021). Selectivity is an animal strategy to avoid nutritional deficiencies (Ginane et al., 2015). Feedlot lambs are even easier to select food based on nutrient content. A. B. M. Teixeira et al. (2021) observed that individually feedlot Dorper x Santa Ines lambs increased their non-fibrous carbohydrate intake from 169 ± 17 to 460 ± 9 g day^{-1} as the metabolizable energy supply increased from 115 to 288 kcal/kg$^{0.75}$/day even though there was no change in the roughage:concentrate ratio (40:60) in the diet. On the other hand, Herzog et al. (2021) offered increasing sucrose levels in the diet of Dorper x Santa Ines lambs. The authors observed a greater NDF intake with the increase in sucrose levels, demonstrating high sensitivity and selectivity of lambs since the sucrose flavor seems to be rejected by sheep even though its energy density is higher in relation to the roughage fraction offered (Tifton 85 hay).

Another activity that differed ($P < 0.05$) between production systems was the time spent drinking water (Table 5). In this case, feedlot lambs spent more time ingesting water than lambs in a silvopastoral system, while those kept in pasture without shading showed no difference compared to the other systems. The longer time spent in the consumption of water by the feedlot animals may have been influenced by the high proportion of concentrated feed with high DM content. Neiva et al. (2004) worked with two roughage: concentrate ratios in the diet of uncastrated male Santa Ines sheep in feedlot, one of 30:70 and the other 70:30. In the treatment with high concentrate content, which is the most similar to that offered in the present study (80%), the total diet showed 160, 380, and 760 g kg DM^{-1} of CP, NDF, and TDN, respectively. In the present study, the total diet presented values of 228, 253, and 781 g kg DM^{-1} of CP, NDF, and TDN, respectively. The authors observed that the concentrated content of the diet had an effect on the water consumption of the sheep and associated it with the high-energy diet that provided higher DM consumption, which, in turn, showed a positive correlation with water consumption. The findings by Neiva et al. (2004) corroborate the results of the present study since the DM content of ryegrass hay fed to feedlot lambs was 898 g kg^{-1}, while forage in pasture systems presented a mean of 260 g kg^{-1}. However, caution is necessary when evaluating the data since the time spent ingesting water and/or food is not always representative of consumption. Costa et al. (2019) evaluated the ingestive behavior of sheep housed alone or in pairs and observed that sheep in single pens spent more time ingesting water than those housed in pairs (25 vs 8 min.; $P < 0.05$), although consumption showed no significant difference.

On the other hand, there was no difference in the time for water intake in the silvopastoral system and the pasture system without shading. One of the main advantages of the silvopastoral system is providing shade for the animals, reducing the heat load to which the animals are exposed (Dada et al., 2021). In this sense, sheep in a silvopastoral system have the potential to store less heat throughout the day, requiring less water to dissipate heat through evaporative cooling mechanisms (Vieira et al., 2021). In this study, the mean temperature over the experimental period was 23.1 ± 1.69 °C. However, the maximum temperature reached a peak of 32.8 °C (Table 1), above the thermal comfort temperature for sheep (Vieira et al., 2021). It was not possible to assess the microclimate within each grazing system to verify the impact of shading on the time allocated by the lambs to water intake. Nevertheless, Dada et al. (2021) developed an experiment in the same area where the present study was carried out and found a significant difference between the microclimatic data obtained in the silvopastoral system and pasture without shading. The average temperature was 1.1°C lower in silvopastoral, while the relative humidity and wind speed presented values of 65 ± 12.4% and 63 ± 12.2%, and 1.4 ± 0.06 ms^{-1} and 1.1 ± 0.03 ms^{-1} for silvopastoral and unshaded pasture, respectively. The temperature and humidity index (THI), although higher than recommended in both systems, was also lower (better) in silvopastoral (77 ± 0.10) in relation to pasture without shading (78 ± 0.22). Even with the microclimate of the systems differing, the authors also did not observe a difference in the time of water intake between silvopastoral and pasture without shading.

There was no difference ($P > 0.05$) for the quantification of the time of food and water intake, rumination, and idleness activities in the different recording intervals of behavioral activities (Table 6), indicating that these activities can be evaluated at intervals of up to 20 minutes.

Table 6
Time spent in activities (minutes day^{-1}) related to the behavior of Dorper x Santa Ines lambs recorded at different observation intervals

Variables[I]	Observation intervals (min)				P-value
	5	10	15	20	
Food intake	426 ± 66	424 ± 67	420 ± 63	425 ± 66	0.882
Water intake	12 ± 3	13 ± 3	13 ± 3	13 ± 4	0.980
Rumination	375 ± 20	376 ± 18	383 ± 18	377 ± 20	0.288
Idleness	582 ± 40	589 ± 45	581 ± 41	593 ± 45	0.249
Other activities	38 ± 11 a	35 ± 11 ab	38 ± 8 a	22 ± 9 b	0.029

[I]Values are expressed in mean and standard error; Means followed by different letters in the same line differ by Tukey's test ($P<0.05$).

The results shown in Table 6 are in agreement with other studies that sought to quantify the duration of behavioral activities in sheep, such as Carvalho et al. (2007), who worked with Santa Ines sheep in feedlot and concluded that the observation of these animals could be performed at intervals of up to 30 minutes for feeding, rumination, and idleness activities. Marques et al. (2012) observed that Santa Ines lambs in Aruana grass pasture could be evaluated at intervals of 5, 10, 15, 20, and 30 minutes. The authors found no significant difference in time spent on feeding, rumination, and other activities. However, when discriminating the time spent on activities throughout the day into periods, they found that observation intervals longer than 5 minutes differed from the others, indicating that as the interval between observations increases, there is a loss in the number of daily events by behavioral activity. In the present study, the number of periods was not considered. However, it is important to note that the observation interval adopted when evaluating the ingestive behavior of herbivores should be considered with caution if the aim is evaluating periods and time per period since studies with sheep (Fischer et al., 2000; Carvalho et al., 2007; Marques et al., 2012) and cattle (R. R. Silva et al., 2005; Aldrighi et al., 2018) showed that intervals greater than 5 minutes underestimate the quantification of periods and time by period. The choice of observation interval affects the perception of the observer concerning the heterogeneity of a system, and the use of an inappropriate scale can compromise the interpretation of results (Dutilleul, 1997).

There was a difference (P = 0.013) for quantifying the time of salt intake activity in the different observation intervals for the animals in feedlot (Table 7).

Table 7
Result of the interaction between the production system and the recording interval of behavioral activities in the time spent on salt intake

Interval (min)	Production systems		
	Pasture	Silvopastoral	Feedlot
5	1.9 ± 0.6	2.2 ± 0.9	9.4 ± 2.5 b
10	1.3 ± 0.0	1.9 ± 1.9	6.9 ± 1.9 bc
15	1.9 ± 0.0	0.9 ± 0.9	14.1 ± 4.7 a
20	1.2 ± 1.2	0.0 ± 0.0	5.0 ± 2.5 c

Values are expressed in mean and standard error.
Means followed by different letters in the same line differ by Tukey's test (P<0.05).

The 5-minute interval, considered the most appropriate and used in research as it is the closest to continuous assessment, did not differ only from the 10-minute interval. Therefore, in conditions similar to the feedlot system of this study, it would not be a reliable alternative for experimentation to quantify the time related to this activity at intervals greater than 10 minutes. Salt intake is limited and occurs punctually, unlike food intake, which occurs in a more concentrated form throughout the day (Dulphy & Faverdin, 1987). Therefore, longer observation intervals may incur substantial losses in quantifying time spent on salt intake, as the time used for this activity in all production systems did not exceed 15 minutes throughout the day (Table 7). If we consider that this consumption time may not have been performed in a single meal, it is evident that longer intervals can compromise the quantification of the activity.

Conclusion

The behavior of sheep undergoes changes depending on the production systems. Lambs in an unshaded pasture system and a silvopastoral system spend time for ingestive behavior activities similarly. Lambs in pasture-based systems spend more time feeding, and feedlot lambs spend more time ingesting water. When fed hay, feedlot lambs ruminate as much as grazing animals, even though hay represents only 20% of the total diet.

In the conditions of the studied production systems, the quantification of the time of the activities of food and water ingestion, rumination, and idleness can be carried out in intervals of up to 20 minutes. Mineral supplement intake should not be evaluated at intervals greater than 10 minutes in the feedlot system.

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