ORIGINAL RESEARCH ARTICLES

Heterogeneous Marandu grass (*Urochloa brizantha*) pastures under continuous stocking enhance dry matter intake in sheep

Pastizales heterogéneos de pasto Marandu (*Urochloa brizantha*) bajo pastoreo continuo mejoran el consumo de materia seca en ovejas

Pastagens heterogêneas de capim Marandu (*Urochloa brizantha*) sob lotação contínua melhoram a ingestão de matéria seca em ovinos

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Abstract

Background: Pasture structure directly influences the ingestive behavior and feed intake of grazing ruminants, particularly under continuous stocking systems. More heterogeneous swards, with greater variability in plant height, may increase selectivity and alter intake dynamics and feeding efficiency. **Objective:** To evaluate how different horizontal structures of marandu grass (Urochloa brizantha cv. Marandu) pastures, maintained at an average height of 25 cm, affect feeding behavior and nutrient intake by sheep.**Methods:** The study was conducted from September 2019 to March 2020, using 16 crossbred sheep (Santa Inês × Dorper) allocated to eight paddocks under two treatments: 1) less heterogeneous pasture (plant height CV <35%) and 2) more heterogeneous pasture (CV >35%). Variables evaluated included nutrient intake, digestibility, feeding behavior (grazing, rumination, idleness, meal time, number and interval between meals, and rumination bouts), as well as forage mass, morphological composition, and chemical composition of the pasture. Data were analyzed by analysis of variance (ANOVA), using the F test at a 10% probability level (P<0.10).**Results:** More heterogeneous swards promoted greater dry matter intake by grazing sheep (P<0.10). However, pasture heterogeneity did not significantly affect nutrient digestibility, chemical composition of hand-plucked samples, or behavioral parameters (P>0.10).**Conclusion:** Under continuous stocking, marandu grass pastures with higher structural heterogeneity (CV between 50.32% and 60.64%) increase dry matter intake in sheep. Although heterogeneity did not influence digestibility or quantitative aspects of behavior, animals showed more frequent grazing during the day and concentrated rumination and idleness at night under the same experimental conditions

Keywords: *available forage; ingestive behavior; nutrient intake; pasture intake; pasture structure; rumination; sheep farming; time spent grazing.*

Resumen

Antecedentes: La estructura del pasto influye directamente en el comportamiento de ingestión y el consumo de los rumiantes en pastoreo, especialmente bajo sistemas de pastoreo continuo.

Los pastos más heterogéneos, con mayor variabilidad en la altura de las plantas, pueden aumentar la selectividad y afectar la eficiencia del consumo.**Objetivo:** Evaluar cómo diferentes estructuras horizontales de pastos de marandu (Urochloa brizantha cv. Marandu), mantenidos a una altura media de 25 cm, influyen en el comportamiento alimentario y en el consumo de nutrientes por parte de ovinos.**Métodos:** El estudio se llevó a cabo entre septiembre de 2019 y marzo de 2020, utilizando 16 ovinos mestizos de las razas Santa Inés y Dorper, distribuidos en ocho parcelas, bajo dos tratamientos: 1) pastos menos heterogéneos (coeficiente de variación de altura <35%) y 2) pastos más heterogéneos (CV >35%). Se evaluaron variables como consumo de nutrientes, digestibilidad, comportamiento ingestivo (tiempo de pastoreo, rumia, ocio, comidas, número e intervalo entre comidas y rumiaciones), además de la masa de forraje, la composición morfológica y la composición química del pasto. Los datos se analizaron mediante análisis de varianza (ANOVA), con prueba F al 10% de significancia (P<0,10).**Resultados:** Los pastos más heterogéneos promovieron un mayor consumo de materia seca por parte de los ovinos (P<0,10). No se observaron diferencias significativas (P>0,10) en la digestibilidad de los nutrientes, en la composición química de las muestras simuladas de pastoreo ni en los parámetros de comportamiento.**Conclusión:** En condiciones de pastoreo continuo, los pastos de marandu con mayor heterogeneidad estructural (CV entre 50,32% y 60,64%) favorecen un mayor consumo de materia seca por los ovinos. Aunque la heterogeneidad no afectó la digestibilidad ni el comportamiento de manera cuantitativa, los animales pastaron con mayor frecuencia durante el día, mientras que la rumia y el ocio se concentraron en la noche bajo las mismas condiciones experimentales.
Palabras clave: *comportamiento ingestivo; consumo de pasto; crianza de ovejas; estructura del pasto; forraje disponible; ingesta de nutrientes; rumia; tiempo dedicado al pastoreo.*

Resumo

Antecedentes: A estrutura da pastagem pode afetar diretamente o comportamento ingestivo e o consumo de ruminantes em pastejo, especialmente sob regimes de lotação contínua. Pastos mais heterogêneos, com maior variabilidade na altura das plantas, tendem a promover seletividade, o que pode interferir na ingestão e eficiência alimentar dos animais.

Objetivo: Avaliar como diferentes estruturas horizontais de pastagens de capim-marandu (Urochloa brizantha cv. Marandu), mantidas com altura média de 25 cm, influenciam o comportamento alimentar e o consumo de ovinos.

Métodos: O estudo foi conduzido entre setembro de 2019 e março de 2020, utilizando 16 ovinos mestiços das raças Santa Inês e Dorper, distribuídos em oito piquetes com dois tratamentos: 1) pastagem menos heterogênea (coeficiente de variação da altura <35%) e 2) pastagem mais heterogênea (coeficiente de variação da altura >35%). Foram avaliadas variáveis de consumo, digestibilidade dos nutrientes, comportamento ingestivo (tempo em pastejo, ruminação, ócio, refeições, número e intervalo entre refeições e ruminações), além da massa de forragem, composição morfológica e composição bromatológica da pastagem. Os dados foram submetidos à análise de variância (ANOVA), adotando-se o teste F a 10% de significância (P<0,10).**Resultados**: Pastagens mais heterogêneas proporcionaram maior consumo de matéria seca pelos ovinos (P<0,10). Entretanto, não foram observadas diferenças significativas (P>0,10) na digestibilidade dos nutrientes, na composição química das amostras simuladas de pastejo, nem nos parâmetros comportamentais dos animais.

Conclusão: Em condições de lotação contínua, pastagens de capim-Marandu com maior heterogeneidade (coeficiente de variação entre 50,32% e 60,64%) favorecem o maior consumo de matéria seca por ovinos. Ainda que a heterogeneidade não tenha afetado a digestibilidade nem o comportamento alimentar em termos quantitativos, os animais pastam com maior frequência durante o dia, concentrando os períodos de ruminação e ócio durante a noite, sob as mesmas condições experimentais.

Palavras-chave: *comportamento ingestivo; consumo de nutrientes; consumo de pasto estrutura do pasto; forragem disponível; ovinocultura; ruminação; tempo em pastejo.*

INTRODUCTION

Despite the growth of the Brazilian sheep herd of 7.09% between 2015 and 2019 (Magalhães et al., 2020), there is still a need to intensify production systems, which are mostly in pastures. Considering ruminants, sheep have a higher nutritional requirement for good-quality forage, and it is necessary to properly manage the pasture to produce forage with high nutritional value and high intake potential (Penning et al., 1991). Under continuous stocking, it is recommended that marandu grass be managed during the rainy season between 20 and 40 cm of average height (Silva et al., 2012). However, the grazing of the animal in continuous stocking causes the formation of areas with taller and shorter plants, in relation to the average height of the pasture, which generates spatial variability of the vegetation. This process can be more intense in pastures used by sheep, which can grasp the forage with their lips and are more selective (Penning et al., 1991) Furthermore, the deposition of feces and urine by animals also contributes to this variability, promoting changes in soil fertility, vegetation growth and nutrient distribution, which can result in more or less productive areas within the pasture. (Santos et al., 2010).

The spatial variability of vegetation determines the responses of plants and grazing animals (Palhano et al., 2007) can be measured using coefficients of variation of plant heights (Hirata, 2002; Santos et al., 2014) or by geostatistical analysis, with the creation of kriging maps (Sales et al., 2018). In the case of animals, the horizontal structure of the pasture modifies their feeding behavior pattern and, consequently, forage intake and animal performance (Hodgson, 1982; Carvalho et al., 2001).

Assessments of feeding behavior of animals in the pasture can be carried out through visual observation of the animals during grazing, rumination and idleness, and it is important to carry out measurements within a period of 24 hours (Oliveira et al., 2014) , to be able to know the pasture intake pattern of the animals.

Until now, the behavioral responses in 24 hours and the forage intake by sheep kept in pastures, whose pastures have the same average height, but different spatial variability of the vegetation, are not known. Thus, the objective was to verify how different horizontal structures of marandu grass pasture kept at an average height of 25 cm, in the summer, influence intake, nutrient digestibility, and feeding behavior in sheep. Also, the influence of the day and night period on the feeding behavior of sheep was evaluated.

MATERIAL AND METHODS

This study was approved by the ethics committee, as it did not involve invasive or stressful procedures for the animals. All management practices were carried out in accordance with animal welfare standards, ensuring the health and comfort of the sheep throughout the experimental period. The research protocol was limited to the observation of natural behaviors and the provision of diets under grazing conditions, without instructions that could cause discomfort, according to analysis nº 112/18 of the ethics committee on the use of animals for the Ceua/UFU registration protocol 011/18.

The experiment was conducted from September 2019 to March 2020 at the Experimental Farm. The experimental area consists of a pasture of *Urochloa brizantha* cv. Marandu (marandu grass) was established in 2000, consisting of twelve paddocks (experimental units), each with

800 m^2, in addition to a reserve area, totaling approximately two hectares. The climate of the region is Aw, tropical savannah, with dry winter and hot and humid summer (Alvares et al., 2013). Information regarding climatic conditions during the experimental period was monitored at the meteorological station located approximately 200m from the experimental area (Table 1).

Table 1. Monthly averages of daily temperature and rainfall from September 2019 to March 2020.

Month	Temperature (°C)	Rainfall (mm)
September/2019	25.5	52.7
October/2019	25	82.7
November/2019	24	157.6
December/2019	23.5	192
January/2020	20	282
February/2020	19.5	275
March/2020	19	122

The relief of the experimental area is flat and the soil is classified as Dystrophic Dark Red Latosol. In September 2019, soil samples were taken from the 0 to 10 cm layer, using a probe, to analyze the fertility level, the results of which were: pH in (H_2O): 6.1; P: 4.6 mg/dm^{-3} (Mehlich^{-1}); K: 100 mg/dm^{-3}; Ca2+: 5.1 cmolc/dm-3; Mg2+: 2.1 cmolc/dm-3; Al3+: 0 cmolc/dm-3 (KCl 1 mol L-1); H + Al: 2.9 cmolc/dm-3 and V: 72%. Based on these results, liming and potassium fertilization were not necessary (Cantarutti et al., 2002). Nitrogen fertilization took place on December 15, 2019, with the application of 50 kg. ha^{-1} of N in the form of urea and 50 kg. ha^{-1} of P2O5 in the form of supersimples on each date. Fertilizations were carried out at the end of the afternoon and in coverage. At the end of September 2019, the pastures were cut to a height of 8 cm. Cut forage was not removed from the paddocks. Afterwards, the pastures continued to grow until they reached an average height of 25 cm, which was intended for grazing management in continuous stocking, which occurred in November 2019. From then on, Santa Inês and Dorper crossbred sheep, with an average body weight of 54 kg, were used as grazing animals.

From then on, pasture heights were monitored twice a week, through measurements at 30 points in the paddocks, using a graduated ruler with a metal rod. The criterion for measuring pasture height was the distance from the soil surface to the leaves located at the top of the canopy. To control pasture height, sheep were removed or placed in paddocks when pasture height was below or above the target of 25 cm, respectively. At the beginning of January 2020, it was possible to observe that among the 12 pickets maintained with the same average height of 25 cm, there were pickets with high and low spatial variability of vegetation. Thus, eight paddocks were chosen to carry out the experiment, four paddocks for each treatment. The coefficient of variation (CV) was calculated using the following formula:

$$CV = (Standard\ deviation\ of\ heights/Average\ of\ heights) * 100$$

The standard deviation and average were obtained through punctual measurements of plant height in each paddock (Hirata, 2002). Thus, the treatments were defined, which were two: More heterogeneous pasture, with low CV of plant height values (<35%); and More heterogeneous pasture, with high CV of plant height values (>35%). The experiment was conducted in a completely randomized design, using four paddocks and eight animals per treatment.

Evaluations in the pasture

Forage mass and morphological composition

To determine the amount of pasture available to the animals, the forage mass inside the 50 cm square was cut close to the ground, at three points representing the average height of the pastures in each paddock. Each sample was placed in a plastic bag . Subsequently, they were dried in a forced ventilation oven at 65°C for 72 hours, then weighed. With these data, the forage mass and the morphological composition (live leaf, dead leaf, live stem, dead stem) of the pastures were calculated. This assessment was made at the end of January 2020.

Assessments on the animal

Sixteen pregnant female sheep were used, resulting from the crossing of the Santa Inês and Dorper breeds, with an average body weight of 54 kg, allocated in eight paddocks with marandu grass managed under continuous stocking and an average height of 25 cm. The treatments were: 1) less heterogeneous pasture, with a low coefficient of variation of plant height values (<15%); and 2) more heterogeneous pastures, with a high coefficient of variation in plant height values (>35%).

Simulated grazing

At the end of January 2020, the simulation of animal grazing was carried out by harvesting the forage in the paddock, seeking to simulate, during grazing, the morphological composition of the forage intake by the sheep (Sollenberger and Cherney, 1955). Duly trained people carried out the samplings by observing the forage intake of the animals present in the experimental area. Each sample was placed in an identified plastic bag and, in the laboratory, its morphological components were separated.

Determination of Intake and Digestibility of Nutrients

The determination of pasture intake, fecal excretion, and nutrient digestibility was carried out at the end of January 2020. To estimate fecal excretion, purified and enriched lignin (LIPE)® was used through the relationship between dose and concentration of feces from the external indicator. LIPE® was administered through an esophageal tube at a daily dose of 0.5 g/ g/animal/day in capsules provided in the morning, once a day, for 6 days, with two days of adaptation and four days of collection. The collection of feces was carried out on the third day, being collected directly from the animal's rectum, immediately after the supply of LIPE, for 4 days and at the same time as the supply of the capsules. At the end of the collection period, a composite sample of the feces of each animal was made. The samples were dried and ground to a particle size of 1 mm for later analysis of the concentration of LIPE® and other nutrients. Determination of LIPE® concentration was performed by infrared spectroscopy, using the Watson Galaxy model device, FT-IR 3000 series (Saliba et al., 2003). Fecal production was calculated using the equation:

$$\text{Fecal excretion (g/day)} = \text{indicator provided (g/day)} / \text{Tracer concentration in feces}$$

The indigestible neutral detergent fiber (iNDF) was used as an internal indicator to estimate pasture dry matter intake:

$$Intake = (FE * FcCI) / ForCI + IntakeSupe$$

Onde: Intake = dry matter intake (g/day); FE = fecal excretion (g/day); FcCI = concentration of iNDF in feces (g/g); ForCI = iNDF concentration in forage (g/g) and IntakeSupe = estimated supplement DM intake (g/day).

The concentration of iNDF in simulated grazing and feces samples were determined by incubation in TNT bags, in the bovine rumen for 240 h for iNDF (Valente et al., 2011). Forage and feces samples were ground in a knife mill using a 1 mm sieve and placed in plastic pots to determine the levels of dry matter, mineral matter, crude protein, insoluble fiber in neutral detergent, insoluble fiber in acid detergent, and lignin using the methods proposed by INCT-CA (Detmann et al., 2021).

For analyses of in vitro digestibility of dry matter (DIVDM) and NDF (DIVNDF) used as the donor of ruminal content, Santa Inês x Dorper crossbred sheep kept in pens and fed a diet composed of 80% forage and 20% concentrate, and approximately 12% CP. The ruminal content was collected at different points in the rumen, filtered through cotton fabric, and packed in a thermos to preserve the temperature. After placing the contents in a thermos bottle, CO_2 gas was injected in order to maintain the environment in anaerobiosis. The liquid obtained was taken to the Laboratory of Bromatology and Animal Nutrition (LABAN) m the UFU for incubation in the jars of the *in vitro* incubator for the Marconi digestibility test (MA443). The *in vitro* digestibility procedure utilized 400 ml of ruminal inoculum and 1600 ml of McDougall's solution (a 1:4 ratio of inoculum to buffer solution) in each incubator jar. The McDougall solution was prepared 24 hours before the beginning of each incubation battery and maintained at a temperature of 39°C. Soon after, the pH of the solution was reduced to 6.80 using CO2 bubbling for 15 to 20 minutes. After placing the ruminal inoculum and McDougall solution, the free space of the jars was saturated with CO_2, which was closed and placed inside the incubator, previously heated to a temperature of 39°C. After 48 hours, the TNT bags were washed with hot distilled water (temperature greater than 90°C), applying light manual pressure to remove the gases contained therein. After washing, all TNT bags were dried (105°C/24h) and weighed, obtaining the apparently undigested DM residue (DIVDM). To evaluate the *in vitro* digestibility of NDF (DIVNDF), the TNT bags were taken to the NDF determination procedure using a fiber extractor (Tecnal Equipamentos Científicos, model TE-149, Piracicaba SP) to determine the NDF content, according to INCT-CA F002/1 method, according to the method recommended by Detmann et al. (2021). After washing, the TNT bags were dried (105°C/24h) and weighed to obtain the NDF residue.

Determination of DIVDM and DIVNDF were calculated through the equation:

$$D\,(g/kg) = M - (R - B)\,/\,M * 1000$$

Where: M = mass of incubated DM or NDF (g); R = DM or NDF residue from incubation (g); B = residue of DM or NDF obtained in the “white” flasks (g)

Feeding behavior

The feeding behavior was carried out at the end of January 2020 using trained observers positioned so as not to disturb the animals; the activities performed by the animals (grazing, rumination, and idleness) were evaluated every 10 minutes.

Activity checks were made on two animals present in each paddock, totaling 16 animals, for a period of 24 hours. The observation of feeding behavior was divided into two periods: P1 (07:00 to 18:09) and P2 (18:10 to 06:59). During the night, the paddocks were illuminated by reflectors, and the observers used flashlights to observe the animals. Data expressed in minutes per day were recorded as:

- Time in grazing: considering the activities of searching and harvesting forage, with the animal eating.

- Time in rumination: considered the period in which the animal was not grazing, but was chewing the regurgitated food bolus, characterized by cyclic and repetitive movements.

- Idle time: the period in which the animal was not grazing or ruminating was considered.

- Meal time: a sequence of periods during which the animal was grazing. - Number of meals: number of periods in which the animal was grazing.

- Meal break: a period in which the animal was ruminating or idling.

- Number of meal intervals: number of periods in which the animal was ruminating or idling.

- Number of ruminations: number of periods that the animal was ruminating.

The points measured in the paddocks for the construction of the kriging maps were collected through a Cartesian plane traced in each paddock with the aid of a string, where the height of the pasture was measured at the point of intersection of the X and Y coordinates. rectangular formats, with 20 meters on the X axis (points every 2 meters) and 40 meters on the Y axis (points every 4 meters). Totaling 121 points collected in each paddock (11 points horizontally and 11 points vertically). After adjusting the semivariograms, data interpolation was processed by ordinary "kriging", in order to enable the visualization of spatial distribution patterns of different pasture heights. "Kriging" to obtain the maps is an interpolation technique for estimating the values of a property in unsampled locations, based on neighboring values resulting from the sampling carried out (Cressie, 1991). The GS+ v.7.0® program was used to adjust the semivariograms and plot the kriging maps.

The variables of feeding behavior, nutrient intake, and digestibility were evaluated according to the assumptions of normality and homogeneity of variance. When they met these criteria, they were subjected to analysis of variance (ANOVA), followed by the ANOVA test of means (F test). The variables that did not meet the assumptions were analyzed using nonparametric tests, including the Kruskal-Wallis test for comparison between groups and the Wilcoxon test for paired comparisons. A significance level of 10% was adopted for type I error, considering the variability inherent in biological data and the need for greater sensitivity in detecting possible trends, avoiding the rejection of relevant hypotheses due to high data variation. This statistical approach allows a more flexible evaluation of the effects of the treatment, respecting the particularities of the sample. The processing and statistical analysis of the data were performed using the R software through the appropriate statistical packages. This software was chosen due to its robustness in the analysis of biological data and the diversity of tests available, ensuring accuracy in the interpretation of the results.

RESULTS

The different structures, described by the heterogeneity of plant height in the *Urochloa brizantha* cv. Marandu pasture, with an average height of 25 cm, influenced the ingestive behavior, consumption, and digestibility of nutrients in sheep. In this sense, it was found that there was an effect of pasture heterogeneity on nutrient intake ($P<0.10$; Table 2), despite the absence of effect on the chemical composition of simulated grazing samples, nutrient digestibility, and sheep feeding behavior ($P>0.10$; Tables 3 and 4). Dry matter intake (DMI) of pasture using LIPE as an external indicator and internal indicator, the iNDF was 1.10 and 1.32% BW, in the less and more heterogeneous pastures, respectively (Table 2).

Table 2. Effect of different pasture heterogeneities on nutrient intake ($g.kg^{-1}$) in sheep grazing marandu grass.

	More heterogeneous	Less heterogeneous	P-Value
Intake ($g.day^{-1}$)	690.9a ± 55.12	604.0b ± 41.04	0.006
Intake (%BW)	1.32a ± 0.18	1.10b ±0.09	0.015
Intake ($BW^{0.75}$)	13.43a ± 0.64	12.20b ± 1.39	0.056
Intake MO	622.55a ± 51.84	544.49b ± 37.00	0.007
Intake CP	76.58a ± 9.16	66.22b ± 8.57	0.04
Intake NDF	439.27a ± 8.38	390.45b ± 37.23	0.025

Intake NDF (%BW)	0.8411a ± 0.10	0.7145b ± 0.08	0.033
Intake ADF	208.73a ± 16.77	185.84b ± 17.84	0.029
Intake TC	533.22a ± 46.32	467.37b ± 34.24	0.010
Intake iNDF	80.27a ± 4.57	73.13b ± 6.55	0.063

Caption: Intake (%BW): intake expressed as a percentage of body weight; Intake(Wmet): intake expressed in metabolic weight; Intake OM: organic matter consumption; Intake CP: crude protein intake; Intake NDF: intake of neutral detergent fiber; Intake NDF (%BW): neutral detergent fiber intake expressed as a percentage of body weight; Intake ADF: intake of acid detergent fiber; Intake TC: total carbohydrate intake; Intake iNDF: intake of indigestible neutral detergent fiber. Means followed by distinct letters differ from each other by the F Test at the 10% probability level.

There was no interaction effect between pasture heterogeneity and evaluation periods (day and night) on feeding behavior evaluations. Pasture heterogeneity did not affect feeding behavior (Table 3; P<0.10). On the other hand, the evaluation period (day or night) of the feeding behavior influenced all the measured variables (Table 3, P<0.10). During the day (7:00 am to 6:00 pm), the animals remained 48.5% of the time grazing, 19% ruminating and 32% idling. A greater number of meals, meal times, and number of meal intervals during the day were also observed (P<0.10; Table 3).

Table 3. Effect of daytime and nighttime on feeding behavior of sheep at Marandu grass pasture managed under continuous stocking.

	Daytime	**Nighttime**	**P-value**
Grazing time (min/d)	330.62a ± 138.7	28.12b ± 38.44	P<0.01
Rumination time (min/d)	130.6b ± 63.09	224.4a ± 73.05	P <0.01
Idle time (min/d)	220.6b ± 133.50	518.1a ± 93.48	P<0.01
Meal number (n°/d)	4.8a ± 1.13	0.6b ± 2.26	P<0.01
Meal duration (min/d)	77.7a ± 24.30	32.8b ± 28.72	P<0.01
Meal intervals number (n°/d)	4.2a ± 1.51	2.2b ± 1.54	P<0.01
Meal intervals time (min/d)	61.1b ± 18.45	336.9a ± 133.23	P<0.01
Ruminations numbers (n°/d)	5.8b ± 2.02	9.4a ± 3.33	P<0.01

Means followed by distinct letters differ from each other by the F Test at the 10% probability level.

There was no effect of different pasture heterogeneities on nutrient digestibility (Table 4; P<0.10) and on forage mass, marandu grass morphological composition, and chemical-bromatological composition of simulated grazing samples (Table 5; P<0.10).

Table 4. Effect of different pasture heterogeneities on nutrient digestibility in sheep grazing marandu grass.

	More heterogeneous		
	Minimum	**Maximum**	**Average**
DMD	58.75	69.32	65.12
OMD	61.50	71.60	67.65
CPD	46.55	68.89	55.61
NDFD	46.52	65.13	56.49
ADFD	13.66	62.66	36.92
	Less heterogeneous		
	Minimum	**Maximum**	**Average**
DMS	58.15	69.44	62.66
OMD	60.72	71.24	64.94
CPD	47.91	62.20	55.42
NDFD	42.08	68.14	56.44
ADFD	22.94	64.42	42.01

Caption: DMD: dry matter digestibility; OMD: organic matter digestibility; CPD: crude protein digestibility; NDFD: neutral detergent insoluble fiber digestibility; ADFD: acid detergent insoluble fiber digestibility.

Table 5. Bromatological chemical composition of simulated grazing samples of sheep grazing marandu grass with different height heterogeneities.

	More heterogeneous pasture		
	Minimum	**Maximum**	**Average**
DM	23.3	25.75	24.41
OM	88.87	90.74	90.07
CP	9.73	12.62	10.98
NDF	61.03	67.34	63.39

ADF	27.65	31.79	29.93
Hem	31.60	35.54	33.46
NFC	10.85	17.23	13.87
TC	75.15	78.60	77.26
TDN	63.62	65.38	64.41
iNDF	11.22	14.71	12.47
DMpd	84.52	88.08	86.80
DIVDM	58.75	69.32	65.12
	Less heterogeneous pasture		
	Minimum	**Maximum**	**Average**
DM	22.93	26.92	24.91
OM	89.31	90.94	90.05
CP	9.60	13.10	10.98
NDF	59.09	67.41	64.73
ADF	27.54	32.56	30.92
Hem	31.54	36.03	33.80
NFC	6.75	17.44	12.56
TC	73.86	79.20	77.29
TDN	63.30	65.42	63.99
iNDF	10.99	13.01	12.22
DMpd	86.31	88.24	87.08
DIVDM	61.98	75.15	71.35

Caption: DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; Hem: Hemicellulose; NFC: non-fibrous carbohydrate; TC: total carbohydrates; TDN: total digestible nutrients; NDFi: indigestible neutral detergent fiber; DMpd: potentially digestible dry matter; DIVDM: *in vitro* dry matter digestibility

DISCUSSION

The higher intake of dry matter and other nutrients by animals kept in paddocks with more heterogeneous pastures possibly occurred due to the greater presence of grazing sites with lower plants (Figure 01). In the most heterogeneous pastures, we can observe the predominance of low plants, with 15% of class 1 plants, with up to 10 cm in height. Compared to less heterogeneous pastures, which had only 8.1% of plants measuring up to 10 cm (Figure 02).

Hendricksen and Minson (1980) observed a negative correlation between the height of the sward and It is possible that in places with shorter plants, the volumetric density of the sward was higher. the forage density. The high density of the forage contributes to an increase in the bitten mass by the animals. Thus, the higher forage density in places with low plants, present in greater predominance in more heterogeneous pastures, compensated for the possible reduction in the depth of the sheep bite in these grazing sites. With that, there may have been a bit of an increase when the sheep grazed the lower reaches of the more heterogeneous pastures. In line with these arguments, Gonçalves et al. (2009) evaluated the effect of the structure of native pasture composed of *P. notatum, A.affinis, D. incanum,* and *P. plicatulum*, kept at four heights (4, 8, 12, and 16 cm) on the mass and depth of the bit and the time intake in grazing ewes and calves. The authors observed that at heights above 9.5 cm for ewes and 11.4 cm for heifers, the depth of the bite did not compensate for the low forage density in the upper strata, which reduced the mass of the bite.

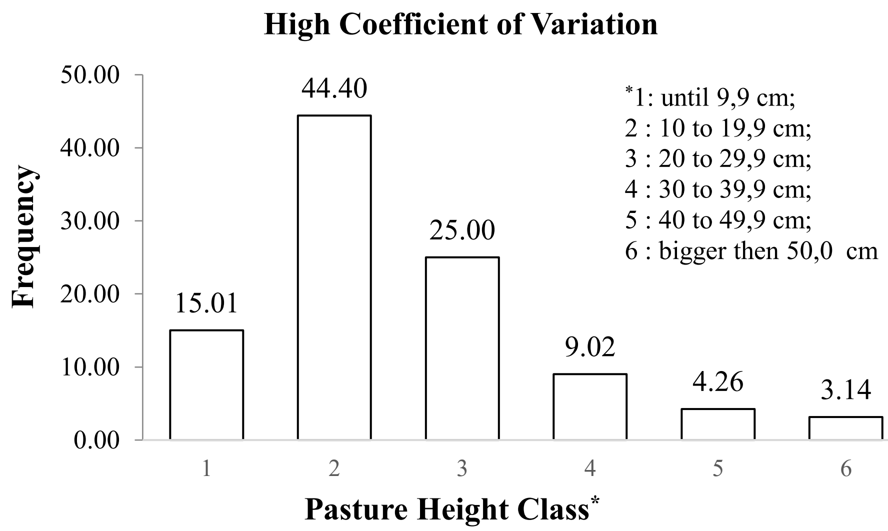

Figure 1 - Relative frequency (%) of different height classes of marandu grass pasture with a high coefficient of variation

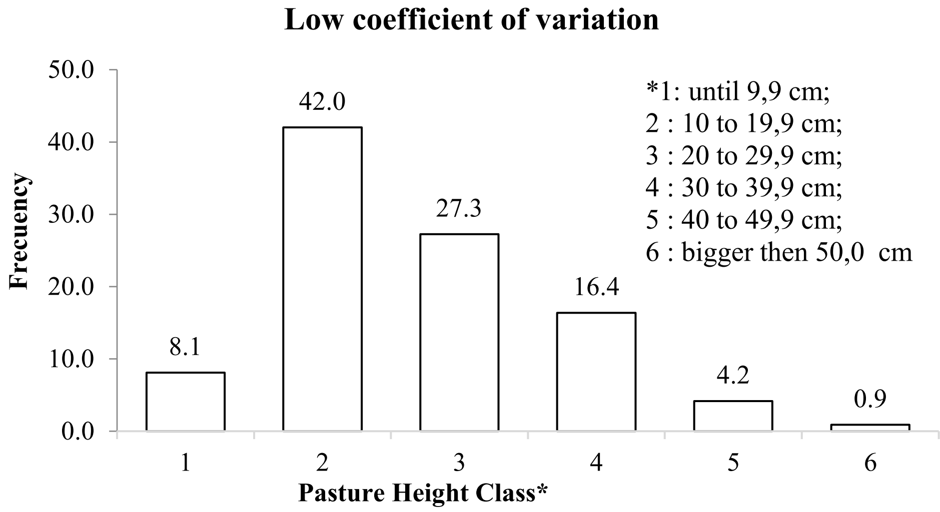

Figure 2: Relative frequency (%) of different height classes of marandu grass pasture with a low coefficient of variation.

Therefore, it is possible that the higher forage density in the pastures with lower plants in the more heterogeneous pastures, caused by the greater number of tillers, increased the bit mass of the animals, consequently, caused greater forage intake in the animals, in compared to animals using less heterogeneous pastures. Fagundes et al. (2011)observed a positive correlation between the animals' weight gain and the volumetric density of the pasture, caused by higher forage intake. Thus, forage volumetric density is one of the main components of the pasture structure capable of modifying the intake of animals on pasture (Stobbs, 1973).

In addition, accordingly to Carvalho et al. (2009), it is possible that in the most heterogeneous pastures, the ruminant is able to more easily visualize and select the grazing sites, identifying the preferred locations, with a pasture structure that facilitates its apprehension and intake. In works carried out with grazing sheep using the LIPE as an external indicator and the iNDF as an internal indicator, researchers obtained pasture DMI values close to those obtained in the present study. Freitas (2021) measured the intake of Andropogon grass in Santa Inês crossbred sheep, with an average body weight of 17 kg and an average age of 90 days, and obtained DMI pasture between 1.28 and 1.54 %BW, this variation being obtained as a function of the frequency of supplementation. Also, Sousa et al. (2018) measured the intake of Massai grass (% BW) in Santa Inês ewes, with an initial body weight of 52.6 kg, receiving supplementation from 75 days of gestation to 75 days of lactation, and obtained DMI pasture values of 1.08 and 1.09 % BW, when using the iNDF and iADF indicators, respectively.

Sheep consumed more forage in heterogeneous pastures, but there was no change in grazing time (P>0.10; Table 3), which indicates that sheep were more efficient in ingesting forage from pastures with greater spatial variability of vegetation. The feeding behavior of the animals showed a preference for grazing during the day, probably due to an adaptive and evolutionary response, in order to avoid possible predators (Jensen, 2002). In addition, during the day, the animal can better visualize the food for selective grazing. (Dias-Silva & Abdalla Filho, 2021). Corroborating this result, Calviello et al. (2013) also observed in their work with Santa Inês ewes grazing Coast Cross grass that grazing activity was greater during the day than at night.

Digestibility, passage rate (Kp), and intake have a strong association (Coleman et al., 2003) so that the increase in the amount of food that enters the digestive tract causes an increase in the rate of passage, but a reduction in the average time of retention of food in the digestive tract and in the digestibility of nutrients. Both systems (confinement and pasture) are dependent on the chemical and physical characteristics of the diet (density, particle size, and bromatological chemical composition). However, in several studies with cattle (Chizzotti et al., 2005; Ramos et al., 2000), buffaloes (Maeda et al., 2007), and sheep (Oliveira et al., 2007), the influence of the intake level on the digestibility of the nutrients was not verified, as verified in the present study. Although animals on more heterogeneous pastures had higher DMI, this increase in intake was not able to change nutrient digestibility.

The lack of effect of the different heterogeneities of the pastures on the forage mass, the morphological composition of the marandu grass and the chemical-bromatological composition of the simulated grazing samples, is due to the fact that the structural characteristics of the pastures, such as the forage mass and morphological composition, having been evaluated in places of the pastures where the plants were with the same average height of 25 cm. In the case of the chemical-bromatological composition of the simulated grazing samples, the selectivity of grazing sheep may also have contributed to the absence of effects of the different horizontal structures of the pastures on these variables.

Pastures of *Urochloa brizantha* cv. Marandu, under continuous stocking and more heterogeneous, with a coefficient of variation between 50.3% and 60.6%, promotes higher intake of dry matter and nutrients in grazing sheep compared to less heterogeneous pastures, with a coefficient of variation between 21.6% and 32.7%. However, these degrees of pasture heterogeneity do not alter the feeding behavior, digestibility, and chemical composition of the forage potentially ingested by the sheep. In summer, sheep on pastures with *Urochloa brizantha* cv. Marandu with different horizontal structures graze more frequently during the day, and rumination and idleness occur with greater prevalence at night.

Declaration

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Conflicts of interest

The authors declare that they have no conflicts of interest with respect to the work presented in this report.

Author contributions

Jhonatan Gonçalves Silva: Responsible for the design and development of the study, including the analysis of grazing behavior in sheep and pasture management strategies. Simone Pedro Da Silva: Led the overall cooperation of the study, contributing to the design of the project, data analysis, and writing of the article. Laura Andrade Reis: Actively contributed to the execution of the project, assisting in the implementation of methodologies and data collection. Yuri Cleber Souza Silva: Participated in the execution of the project, assisting in the application of methodologies and the collection of information. Romário Celso Oliveira Moura Junior: Active in the execution of the project, collaborating in the collection of data and implementation of the techniques used. Natascha Almeida Marques Da Silva: Contributed to the statistical analysis of the data, assisting in the interpretation of the results. Gilberto De Lima Macedo Junior: Assisted in the writing and correction of the article, ensuring accuracy and clarity in the presentation of the results. Manoel Eduardo Rozalino Santos: Led the overall cooperation of the study, contributing to the design of the project, data analysis, and writing of the article.

Use of artificial intelligence (AI)

No AI or AI-assisted technologies were used during the preparation of this work.

Data availability

The data sets used in this study are available from the corresponding author upon request.

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