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Effect of grazing management strategies on the yield and nutritional value of Marandu grass in the semiarid of Brazil

Efeito de estratégias de manejo do pastejo na produtividade e valor nutricional do capim-Marandu no semiárido brasileiro

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Highlights

The low intensity (LI) rotational grazing resulted in higher forage mass production.
The LI rotational grazing resulted in higher potentially digestible forage mass.
The LI rotational grazing resulted in higher digestible nutrients pre-grazing.
The LI improve the nutrients intake by cows.

Abstract

The objective of this study was to evaluate the effects of two grazing management strategies on structural, productive and nutritional parameters of Marandu grass (Urochloa brizantha cv. Marandu). A completely randomized block design with two pasture management strategies and eight replications (blocks) was used. The grazing management strategies were: (1) low intensity rotational grazing (LI), with a pre-grazing sward height of 40 cm and a post-grazing sward height of 24 cm, i.e., a defoliation intensity of 50%; (2) High intensity rotational grazing (HI), with a pre-grazing sward height of 40 cm and a post-grazing sward height of 10 cm (±70% defoliation intensity). Pastures were sampled before and after grazing for estimation of forage mass, forage accumulation rate, structural characteristics, nutritional value and dry matter intake.

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The LI strategy resulted in higher dry matter production than HI before (18.33%) and after grazing (49.06%), increasing pre-grazing forage density by 13.21% (P < 0.05). The production of potentially digestible dry matter was highest (P < 0.05) in LI strategy (21.3% before and 39.6% after grazing, respectively). Higher post-grazing green forage mass (45%) increased the residual crude protein in LI. The LI management strategy increased forage mass production and can be used in Marandu grass pastures.
Key words: Cattle. Degradability. Morphology. Sward height. *Urochloa brizantha.*

Resumo

Objetivou-se por meio deste trabalho avaliar os efeitos de duas estratégias de manejo do pastejo sobre os parâmetros estruturais, produtivos e nutricionais do capim-Marandu (Urochloa brizantha cv. Marandu). O delineamento experimental foi em blocos casualizados com duas estratégias de manejo da pastagem e oito repetições (blocos). As estratégias de manejo do pastejo foram: (1) pastejo rotacional menos intensivo (LI), com altura do pasto pré-pastejo de 40 cm e altura do pasto pós-pastejo de 24 cm, ou seja, intensidade de desfolha de 50%; (2) pastejo rotativo mais intensivo (HI), com altura do pasto pré-pastejo de 40 cm e altura do pasto pós-pastejo de 10 cm (±70% densidade de desfolha). As pastagens foram amostradas antes e após o pastejo para estimativa da massa de forragem, taxa de acúmulo de forragem, características estruturais, valor nutricional e consumo de matéria seca. A estratégia LI resultou em maior produção de matéria seca do que HI antes (18,33%) e após pastejo (49,06%), aumentando a densidade de forragem pré-pastejo em 13,21% (P < 0,05). A produção de matéria seca potencialmente digestível foi maior (P < 0,05) na estratégia LI (21,3% antes e 39,6% após o pastejo, respectivamente). Maior matéria seca verde total pós-pastejo (45%) aumentou a proteína bruta residual em LI. A estratégia de manejo da LI aumentou a produção em massa de forragem e pode ser utilizada em pastagens de capim-Marandu.
Palavras-chave: Altura de dossel. Degradabilidade. Gado. Morfologia. *Urochloa brizantha.*

Introduction

Pasture is the primary and most economical source of nutrients for domestic ruminants (Barbero et al., 2020). Thus, it is necessary understand pasture-based systems do consider the plant-animal interface, which involves understanding the grazing conditions and their interference with animal performance. Usually, the objective of the rotational grazing system is to harvest the maximum amount of forage possible per grazing cycle in order to maximize pasture utilization. However, animals may be forced to ingest low-quality forage in the lower stratum, which impairs an effective harvesting process and forage intake (Amaral et al., 2013).

Efficient and alternative management practice is to control pasture sward height and forage mass production (Koscheck et al., 2020). The frequency and intensity of grazing can be combined to monitor the beginning and end of the grazing period without negatively affecting structure and forage accumulation. According to Reis, Ruggieri, Oliveira, Azenha and Casagrande (2012), using sward height as a management criterion allows controlling the forage mass and favors the sustainability of pasture-based systems. In this context, Silva et al. (2013) have shown that it is possible to control the condition of tropical pastures by using grazing management strategies depending on pasture sward height.

In predominantly tropical conditions, studies with different forage species using sward height as a management strategy (Amaral et al., 2013; Savian et al., 2018; Schons et al., 2021) were carried out in order to determine the optimum pasture structure for achieving the highest forage intake. The results showed that in order to maintain high forage intake, the defoliation intensity should not exceed 40% of the pre-grazing height. After this threshold, the forage intake decreases linearly with defoliation intensity and animal production by area increase. As a result, the post-grazing residual mass and total leaf area remaining will be high, favoring the quick recovery of the plant after defoliation. Moreover, it would allow increasing the number of grazing cycles and forage production in some species (i.e., *Urochloa brizantha*) (Barbero et al., 2012, 2015). However, in the semiarid region of Brazil, where there is irregularity in the amount and distribution of rainfall throughout the year (Monção et al., 2019; 2020), there is a need to evaluate strategies for defoliating Marandu grass in order to improve animal performance and by area. Given the above, we hypothesized that a less intensive rotational grazing promotes a better balance between individual and area performance in Marandu grass pastures.

Thus, the aim of this study was to evaluate the effect of two grazing management strategies (LI x HI) on the structural, productive and qualitative characteristics of Marandu grass (*Urochloa brizantha* cv. Marandu).

Material and Methods

The study was approved by the Ethics Committee on Animal Use and Welfare at Universidade Estadual de Montes Claros (Protocol No. 167/2018).

The experiment was conducted in the municipality of Janaúba, MG, Brazil (15°47′50″S latitude and 43°18′31″W longitude, altitude 516 m), from November 2017 to November 2018. According to Köppen's classification, the region has a mesothermal, sub-humid and semiarid tropical climate (Aw) characterized by irregular rainfalls throughout the year and well-defined dry periods in the winter (Antunes, 1986). Climate data during the experimental period were obtained from the weather station of the INMET- Brazilian National Institute of Meteorology in Nova Porteirinha-MG, located 6 km away from the experimental area (Figure 1).

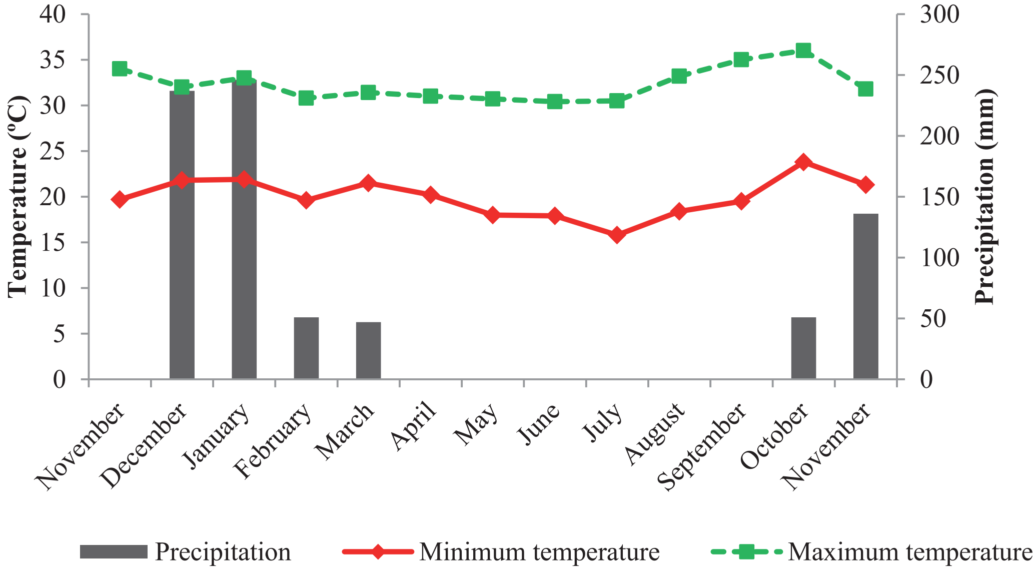

Figure 1. Climate data during the experimental period.

The experimental area consisted of a pasture of *Urochloa brizantha* cv. Marandu planted in 2012. The soil is classified as clayey eutrophic red-yellow latosol. Soil samples were taken at the 0-20 cm depth and had the following chemical characteristics: pH in H_2O of 5.8; 2.3 dag kg^{-1} of organic matter; P (Mehlich) of 3.6 dm^{-3}, K (Mehlich) of 112 dm^{-3}, and N (Mehlich) of 0.1 mg dm^{-3}; Ca, Mg and Al extracted with 1 mol L^{-1} KCl of 3.7, 1.5 and 0.0 cmolc dm^{-3}, respectively; H + Al 2.9 cmolc dm^{-3}; sum of bases of 532 cmolc dm^{-3}; cation exchange capacity of 8.3 cmolc dm-3 and base saturation of 65%. Overhead irrigation was used (flow rate 1.25 m^3/hour; 17.36 mm/hour; 20 meters range (radius)) for two hours. 2,4D herbicide was used to control invasive plants.

The soil was corrected based on the results of the soil chemical analysis. Dolomitic limestone was applied at a ratio of 500 kg per hectare - 100% total neutralizing value (38% CaO; 17% MgO) to raise the base saturation to 80% as suggested by Santos, Primavesi and Bernardi (2010) for intensive grazing systems and to exploit the maximum productive potential of the forage plant. Phosphate fertilizer in the form of single superphosphate (18% to 21% P, 16% Ca and 10% to 12% sulfur (S)) was applied once at a ratio of 50 kg ha^{-1} P_2O_5 at the beginning of the experimental period, after the standardization cut. Nitrogen fertilization was performed after post-grazing periods at 200 kg ha^{-1} urea nitrogen and 120 kg ha^{-1} potassium divided into four applications in the rainy season (December 2017, January, February and March 2018 for both treatments).

Experimental treatments corresponded to two grazing management strategies: (1) low intensity rotational grazing (LI), with a pre-grazing sward height of 40 cm and a post-grazing sward height of 24 cm, i.e., a defoliation intensity of 50% according to the recommendations of Carvalho (2013); (2) High intensity rotational grazing (HI), with a pre-grazing sward height of 40 cm and a post-grazing sward height of 10 cm aiming at maximum pasture utilization and low post-grazing residual height (±70% defoliation intensity). The treatments were allocated to experimental units (200 m2) in a randomized block design with eight replications. The possible variation in soil fertility was the blocking factor (eight blocks).

The total experimental area of 0.32 hectares was divided into 16 grazing areas of 200 m2 each, where each plot was considered as an experimental unit. At the beginning of the experimental period, the experimental pastures were grazed to an average height of 10 cm for standardization of the sward height, and then the target pre- and post-grazing sward heights were adopted.

A total of 12 F1 Holstein/Zebu cows with a mean body weight of 500 ± 29 kg were used. Grazing was performed by the mob grazing technique for rapid defoliation (lasting from 4 to 20 hours). Each paddock was divided with an electric fence. As the animals grazed, sward height measurements were taken until the sward reached the 10 and 24 cm residue targets.

The average sward height was calculated as the average of 10 points per experimental unit using a graduated ruler (cm), allowing for a range of ± 10% (Nantes et al., 2013). At each point, the sward height was determined as the distance from the soil to the most recent fully expanded leaf (pre-grazing) or to the tip of grazed leaves (post-grazing period). Measurements were taken every five days until the target sward height was reached. Defoliation intensity was evaluated by sward height measurements at intervals that ranged from 30 to 90 minutes during the grazing period. The grazing period in each management strategy lasted until the target post-grazing sward height was achieved.

Forage samples were cut at ground level before and after grazing using a 0.25 m2 (50x50 cm) metal quadrat at representative points of the pasture for determination of the forage mass production (FMP). Subsequently, the samples were weighed, and subsamples of approximately 500 g were taken, weighed and oven-dried at 55 °C for 72 hours to constant weight for evaluation of dry matter content and subsequent determination of DM production per hectare. These samples were used to determine the chemical composition and for the *in situ* degradability assay of the whole plant.

A second subsample was used to evaluate the pre- and post-grazing morphological composition of the pasture. The material was manually separated into leaf blades, stems (sheath + stem) and dead material (leaves or stems with more than 50% of dry area). After separation, all components were weighed and oven-dried at 55ºC to constant weight for determination of the dry weight. After drying, the proportions of each component were determined and expressed as a percentage of the total dry weight.

The pre- and post-grazing green forage mass production (GFMP) were calculated by the sum of leaf blade mass and stem mass (kg ha^{-1} of DM). The leaf blade: stem ratio was obtained by dividing the leaf blade mass by the stem mass, while the pre- and post-grazing pasture density was calculated by dividing the total dry matter mass by the average sward height (Paulino, Detmann, & Valadares, 2006).

The average forage accumulation rate (kg ha^{-1} day^{-1} DM) of each plot for each grazing cycle was calculated as the difference between the pre-grazing mass of one cycle and the post-grazing forage mass from the previous grazing cycle, divided by the number of days between samplings (Davies, Futhergill, & Morgam, 1993).

The potentially digestible dry matter (pdDDM) was calculated using the equation: pdDDM (kg ha-1) = DMP* DDM; where: DMP = dry matter production, in kg ha^{-1}; DDM = digestible dry matter (%). Pasture DDM was obtained as described by Paulino et al. (2006): DDM = 0.98 (100 - %NDF) + (%NDF -% iNDF). The iNDF (indigestible neutral detergent fiber) was estimated by in situ incubation of samples of both management strategies for 288 hours, according to Detmann et al. (2012).

The cows used in mob grazing were also used to evaluate forage dry matter intake. Forage intake (kg ha^{-1} DM) was calculated as the difference between total forage production (kg^{-1} DM) in pre-grazing and post-grazing periods for both strategies. The results were multiplied by the total pasture area (0.16 hectares) and divided by the number of animals (12 cows) and the number of grazing days in each strategy to obtain the DM intake per animal per day (kg ha^{-1} animal day). Subsequently, the CP, NDF, and TDN intakes were calculated (McMeniman, 1997).

Whole-plant forage samples (average of ten cuts in the HI and eight cuts in the LI) were oven-dried at 55ºC to constant weight. After drying, each sample was divided into two aliquots: the first aliquot was ground in a Willey knife mill to pass a 1 mm screen for chemical composition analysis and the second aliquot was ground to pass a 2 mm screen for the *in situ* degradability assay.

Whole-plant samples were analyzed for dry matter (DM; 934.01), ash (942.05), ether extract (EE; 920.39), crude protein (CP; 978.04), neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were determined by the sequential method, according to procedures described by Detmann et al. (2012) using the TECNAL® TE-149 fiber analyzer (Piracicaba, SP, Brazil). Cellulose was solubilized in 72% sulfuric acid and lignin content was obtained by difference (Detmann et al., 2012). Total carbohydrate (TC) content was estimated by the equation: TC (%) = 100 - (CP + EE + ash) and non-fibrous carbohydrates (NFC) were determined according to described by Detmann et al. (2012). Total digestible nutrients (TDN) were estimated by the formula: TDN = 40.2625 + 0.1969*CP + 0.4028*NFC + 1.903*EE - 0.1379*ADF (Weiss, 1998).

Four rumen-cannulated crossbred steers with an average weight of 500±45 kg were used to estimate the rumen degradation kinetics. The animals received 3.0 kg of concentrate in two equal amounts in the morning and afternoon, in addition to Marandu grass-based diets. The *in situ* degradability assay was performed using 7.5 x 15 cm non-woven fabric bags (100 g m^{-2}; Pore size 50 microns), according to Valente et al. (2011); the number of samples was based on the sample size to bag surface area ratio of 20 mg DM/ cm^{-2} (Valente et al., 2011).

The samples were placed in the ventral sac of the rumen for 0, 3, 6, 12, 24, 48, 72, 96, 120 and 144 hours in bags measuring 20 x 30 cm attached to a 1 m nylon cord with a lead weight of 100 g tied to one end. Therefore, the bags could move freely in the solid and liquid phases of the rumen. The bags were placed in reverse order, starting with the time of 144 hours. Samples for time 0 were placed in the rumen for five minutes. All samples were removed and washed in ice water to stop fermentation. Subsequently, the samples were oven-dried at 55 oC to constant weight, cooled in a desiccator, and weighed.

The residues in bags collected in the rumen were analyzed for DM and NDF contents. The percentage disappearance was calculated from the proportion of food remaining after ruminal incubation, while the NDF was analyzed according to the methods described by Detmann et al. (2012), without α-amylase.

Data were adjusted to a non-linear regression model using the Gauss-Newton method using SAS software, version 9.0 (SAS Institute, Inc., Cary, NC, USA), according to the equation proposed by (Orskov & McDonald, 1979): $\hat{Y} = a + b\,(1\text{-}e^{-ct})$, where: $\hat{Y}$ = disappearance (%) at time t; a = intercept of degradation curve when t = 0, which corresponds to the water-soluble fraction of the analyzed constituent; b = is the slowly-degradable fraction; a + b = potential degradation (PD) of the nutritional component analyzed when time is not a limiting factor; c = fractional degradation rate of disappearance of fraction b in the rumen; t = incubation time. Once calculated, the coefficients a, b and c were applied to the equation proposed by Orskov and Mcdonald (1979): ED = a + (bxc/c+k), where: ED = effective ruminal degradation of the analyzed nutritional component; k = passage rate. Ruminal passage rates were assumed to be 5% h^{-1}.

The NDF degradability was estimated using the model of Mertens and Loften (1980): Rt = B x e-ct + I, where R = NDF remaining at time t; B = potentially digested insoluble fraction and I = indigestible fraction. After adjusting the NDF degradation equation, the fractions were standardized as proposed by Waldo et al. (1972) using the equations: Bp = B / (B + I) × 100; Ip = I / (B + I) × 100, where: B_P = standardized potentially digestible fraction (%); Ip = standardized indigestible fraction (%); B = potentially digestible insoluble fraction and I = indigestible fraction. The effective degradability (ED) of NDF was calculated according to the following model: ED = (Bp x c)/(c + k), where Bp is the standardized potentially digestible fraction (%).

Data on plant structure, productivity, chemical composition and feed intake was analyzed as a completely randomized block design with two treatments and eight blocks. Data were subjected to analysis of variance using PROC GLM of SAS. Significant means were compared by the F test with α = 0.05. The following statistical model was used: Yijk = μ + τi + Bj + εijk, where Yijk is the response variable; μ is the overall mean; T is the effect of treatment (i = 1 and 2); B is the effect of block; and ε is the random error.

Data relative to *in situ* degradability were analyzed as a split-plot randomized complete block design with two treatments (plots), ten incubation times (subplots) and four blocks. Animals were blocked by body weight. Data were subjected to analysis of variance using the GLM procedure of SAS, with α = 0.05 according to the model: Yijk = μ + τi + Time j + τi x Time j + εijk, where: Yijk is the response variable; μ, the overall mean; τi, the fixed effect of treatment applied to plot i, with i = 1 and 2; Time j, fixed effect of incubation time j to treatment the random effect from animal k; Ti x Time j, the interaction between treatment i and time j; εijk, the random error with mean 0 and variance σ^2.

Results and Discussion

The number of grazing cycles in Marandu grass pastures were different between grazing management strategies. The LI and HI allowed ten and eight cuts (grazing cycles/year), respectively. The pre-grazing sward heights were 41.9 and 40.8 cm, while in the post-grazing period it was 23.9 and 12.1 cm for LI and HI strategies, respectively. There was a significant effect (P<0.05) of pasture management strategy on FMP, green forage mass production (GFMP), pasture density, leaf blade:stem ratio, potentially digestible FMP (pdFMP) and forage accumulation rate. The HI was superior to LI only for leaf blade:stem ratio and forage accumulation rate. The proportions of leaf blade, stem and dead material were not affected by pasture management strategies, averaging 44.57; 36.43 and 18.99%, respectively (Table 1).

Table 1
Structural and productive characteristics of pre-grazing Marandu grass pasture under two grazing management strategies

Item	Strategies[1]		SEM	P-value
	Low intensity (LI)	High intensity (HI)		
Forage mass production (t ha^{-1})	11.62 a	9.82 b		
Green forage mass production (t ha^{-1} DM)	9.39 a	7.98 b	0.26	0.006
Volume density (t ha^{-1} cm^{-1} DM)	0.277 a	0.241 b	0.09	0.016
Leaf (% DM)	42.56	46.59	1.49	0.061
Stem (% DM)	38.53	34.34	1.75	0.096
Senescent material (% DM)	18.92	19.07	1.35	0.936
Leaf: Stem ratio	1.11 b	1.36 a	0.06	0.001
pdDMP (t ha^{-1})	8.70 a	6.85 b	1.93	0.001
Accumulation Rate (kg ha^{-1} day^{-1} DM)	87.17 b	137.31 a	6.40	0.001

Means followed by distinct letters on the line differ from each other by the F test at 5% probability.
SEM: standard error of the mean; P: probability.
DM: dry matter; pdFMP: Potentially digestible forage mass production.
[1]LI - Pre-grazing and post-grazing sward height of 40 cm and 24 cm, respectively (defoliation intensity of 50%). HI - Pre-grazing and post-grazing sward height of 40 cm and 10 cm, respectively (defoliation intensity of ±70%).

The FMP, pdDMP and GFMP in the post-grazing period were higher in LI than in HI strategy (P<0.05). Pasture density, leaf proportion, stem proportion, dead material proportion and leaf blade: stem ratio were similar between treatments (P>0.05), with means of 0.380; 23.31; 48.72; 27.95 and 0.48, respectively (Table 2).

The contents of ash, ADF and lignin were higher, while those of CP, OM, EE and TDN were lower in the pre-grazing period in pastures managed under the LI strategy compared with the HI (P<0.05). There was no difference between strategies (P>0.05) for DM, NDF, hemicellulose, TC and NFC contents, with means of 300; 689; 285; 816 and 126 g kg^{-1} DM, respectively (Table 3).

There was no difference between strategies for ash, hemicellulose, lignin and total carbohydrates in the post-grazing period (P>0.05), with means of 106; 288; 575 and 845, 57 g kg^{-1} DM, respectively (Table 4). Pastures managed under the LI strategy had higher values of CP, NDF, ADF and EE and lower values of DM, TDN and NFC compared with the HI strategy (P<0.05).

Fraction "a" was highest in HI pastures (P<0.05). There were no significant differences between treatments for fraction "b", fraction "c", ED, uF and ruminal degradation of DM in the pre-grazing period (P>0.05), with means of 52.78; 1.94; 74.03; 34.57 and 25.96%, respectively (Table 5). However, the dry matter disappearance rate of the soluble fraction was similar between strategies. No significant differences were observed for the *in situ* ruminal degradability of NDF in the pre-grazing period (P>0.05), with means of 69.99; 1.40; 15.06 and 30% for Bp, fraction "c", ED and uF, respectively.

Table 2
Structural and productive characteristics of post-grazing Marandu grass pasture under two grazing management strategies

Item	Strategies[1]		SEM	P-value
	Low intensity (LI)	High intensity (HI)		
Forage mass produtction (t ha^{-1})	9.07 a	4.62 b	0.24	0.001
Green forage mass production (t ha^{-1} DM)	6.29 a	3.46 b	0.28	0.001
Volume density (t ha^{-1} cm^{-1} DM)	0.38	0.38	0.02	0.718
Leaf (% DM)	22.22	24.40	2.09	0.464
Stem (% DM)	51.13	46.32	2.56	0.189
Senescent material (% DM)	26.64	29.27	1.16	0.117
Leaf: Stem ratio	0.43	0.53	0.03	0.120
pdFMP (t ha^{-1})	5.41 a	3.27 b	0.23	0.001

Means followed by distinct letters on the line differ from each other by the F test at 5% probability.
SEM: standard error of the mean; P: probability.
DM: dry matter; pdFMP: Potentially digestible forage mass production.
[1]LI - Pre-grazing and post-grazing sward height of 40 cm and 24 cm, respectively (defoliation intensity of 50%). HI - Pre-grazing and post-grazing sward height of 40 cm and 10 cm, respectively (defoliation intensity of ±70%).

Table 3
Chemical composition of Marandu grass pre-grazing under two grazing management strategies

Item (g kg^{-1} DM)	Strategies[1]		SEM	P-value
	Low intensity (LI)	High intensity (HI)		
Dry matter	307	293	10	0.340
Ash	119 a	114 b	12	0.047
Organic matter	880 b	886 a	2	0.047
Crude protein	88 b	96 a	2	0.009
Neutral detergent fiber	698	682	7	0.087
Acid detergent fiber	417 a	392 b	6	0.003
Hemicellulose	281	289	4	0.135
Lignin	44 a	37 b	1	0.001
Ether extract	14 b	16 a	1	0.001
Total digestible nutrients	422 b	435 a	3	0.010
Total carbohydrates	818	814	3	0.310
Non-fibrous carbohydrates	119	132	6	0.184

Means followed by distinct letters on the line differ from each other by the F test at 5% probability.
SEM: standard error of the mean; P: probability.
DM- Dry matter
[1]LI - Pre-grazing and post-grazing sward height of 40 cm and 24 cm, respectively (defoliation intensity of 50%). HI - Pre-grazing and post-grazing sward height of 40 cm and 10 cm, respectively (defoliation intensity of ±70%).

Fraction “a” was highest in HI pastures in the post-grazing period (P<0.05), although no significant differences (P>0.05) were observed for fraction “b”, fraction “c”, ED and uF, with means of 47.51; 1.53; 65.06; 28.36 and 34.92%, respectively (Table 6).

Relative to the ruminal degradability of NDF, no significant differences were observed for Bp, fraction “c”, ED and uF (P>0.05), with means of 56.02; 0.12; 10.54 and 43.97%, respectively. Forage intake was influenced by management strategies (P<0.05) (Table 7). Animals grazing pastures managed under the HI strategy had higher intakes of DM, CP, NDF and TDN than those in LI pastures.

Table 4
Chemical composition of post-grazing Marandu grass under two grazing management strategies

Item (g kg^{-1} DM)	Strategies[1]		SEM	P-value
	Low intensity (LI)	High intensity (HI)		
Dry matter	452 b	519 a	1	0.001
Ash	107	105	2	0.561
Organic matter	893	895	2	0.561
Crude protein	81 a	72 b	2	0.054
Neutral detergent fiber	709 a	678 b	5	0.001
Acid detergent fiber	419 a	392 b	5	0.001
Hemicellulose	291	286	4	0.389
Lignin	59	56	2	0.347
Ether extract	11 a	9 b	1	0.001
Total digestible nutrients	426 b	443 a	2	0.001
Total carbohydrates	842	849	3	0.073
Non-fibrous carbohydrates	132 b	172 a	5	0.001

Means followed by distinct letters on the line differ from each other by the F test at 5% probability.
SEM: standard error of the mean; P: probability.
DM- Dry matter
[1]LI - Pre-grazing and post-grazing sward height of 40 cm and 24 cm, respectively (defoliation intensity of 50%). HI - Pre-grazing and post-grazing sward height of 40 cm and 10 cm, respectively (defoliation intensity of ±70%).

Table 5

Ruminal degradability of dry matter and neutral detergent fiber of Marandu grass pre-grazing under two grazing management strategies

Item	Strategies¹		SEM	P-value
	Low intensity (LI)	High intensity (HI)		
Dry matter				
Fraction a (%)	19.65 b	22.84 a	0.69	0.003
Fraction b (%)	53.14	52.42	1.95	0.795
Degradation Rate c (% h^{-1})	2.19	1.69	2.50	0.163
Potential degradability (%)	72.79	75.27	2.13	0.419
Effective degradability (%)	34.07	35.07	0.65	0.291
Indigestible fraction (%)	27.20	24.73	2.13	0.419
Neutral detergent fiber				
Fraction Bp (%)	71.84	68.15	1.98	0.206
Degradation Rate c (% h^{-1})	1.44	1.37	0.16	0.779
Effective degradability (%)	15.16	15.02	0.62	0.873
Undegradable fraction (%)	31.84	28.16	1.98	0.206

Means followed by distinct letters on the line differ from each other by the F test at 5% probability.
SEM: standard error of the mean; P: probability;
Fraction "a": soluble fraction; Fraction "b": insoluble and potentially degradable fraction; effective degradability (k = 5% h-1); IF: indigestible fraction; Fraction Bp: standardized potential degradability.
¹LI - Pre-grazing and post-grazing sward height of 40 cm and 24 cm, respectively (defoliation intensity of 50%). HI - Pre-grazing and post-grazing sward height of 40 cm and 10 cm, respectively (defoliation intensity of ±70%).

Pasture sward height remained stable and within the target ranges for each management strategy (LI x HI). Defoliation intensity in LI pastures was 42.96% (from 41.9 to 23.9 cm) and 70.34% in HI pastures (from 40.8 cm to 12.1 cm). Therefore, the number of grazing cycles in the LI grazing management strategy increased by 20% compared with the HI strategy.

Table 6

Ruminal kinetics of dry matter and neutral detergent fiber of Marandu grass after grazing submitted to two grazing management strategies

Item	Strategies¹		SEM	P-value
	Low intensity (LI)	High intensity (HI)		
	Dry matter			
Fraction a (%)	16.43 b	18.68 a	0.53	0.005
Fraction b (%)	46.76	48.26	1.29	0.422
Degradation Rate c (% h-1)	1.50	1.56	1.60	0.782
Potential degradability (%)	63.19	66.94	1.45	0.079
Effective degradability (%)	27.55	29.18	0.56	0.063
Indigestible fraction (%)	36.80	33.05	1.45	0.079
	Neutral detergent fiber			
Fraction Bp (%)	57.67	54.38	1.67	0.169
Degradation Rate c (% h^{-1})	0.14	0.11	0.12	0.140
Effective degradability (%)	11.45	9.63	0.71	0.080
Undegradable fraction (%)	42.33	45.62	1.67	0.169

Means followed by distinct letters on the line differ from each other by the F test at 5% probability.
SEM: standard error of the mean; P: probability;
Fraction “a”: soluble fraction; Fraction “b”: insoluble and potentially degradable fraction; effective degradability (k = 5% h-1); IF: indigestible fraction; Fraction Bp: standardized potential degradability.
¹LI - Pre-grazing and post-grazing sward height of 40 cm and 24 cm, respectively (defoliation intensity of 50%). HI - Pre-grazing and post-grazing sward height of 40 cm and 10 cm, respectively (defoliation intensity of ±70%).

Table 7

Nutrient intake by F1 Holstein/Zebu cows kept in Marandu grass pasture submitted to two grazing management strategies

Item	Strategies¹		SEM	P-value
	Low intensity (LI)	High intensity (HI)		
Dry matter	9.84 b	13.31 a	0.94	0.011
Crude protein	0.83 b	1.23 a	0.07	0.001
Neutral detergent fiber	6.90 b	9.09 a	0.66	0.023
Total Digestible Nutrients	4.15 b	5.80 a	0.41	0.006

Means followed by distinct letters on the line differ from each other by the F test at 5% probability. SEM: standard error of the mean; P: probability.
¹LI - Pre-grazing and post-grazing sward height of 40 cm and 24 cm, respectively (defoliation intensity of 50%). HI - Pre-grazing and post-grazing sward height of 40 cm and 10 cm, respectively (defoliation intensity of ±70%).

The moderate defoliation intensity in the LI strategy (42.96%) suggested that only the upper stratum of the pasture was removed (Oliveira et al., 2015; Cardoso et al., 2020). Consequently, the post-grazing heights in LI pastures were proportionally high, which allowed rapid pasture recovery, more grazing cycles and shorter resting periods for reaching the target pre-grazing height in the subsequent grazing cycle (Rodrigues et al., 2014). The pre-grazing FMP was 18.33% higher in LI than in HI strategy, with a total production of 11.62 t ha^{-1} of DM, which in turn increased the forage density by 13.21%. This higher productivity combined with low pasture intensity (42.96%) increased the post-grazing FMP by 49.06%, or an additional of 4.45 t ha^{-1} of DM compared with the HI strategy. This can be explained by the higher GFMP in LI management and also by the intense defoliation in HI strategy (70.34%) that reduced the residual forage mass, represented in this study by the low post-grazing GFMP. Consequently, the time required for forage recovery increased and the number of grazing cycles reduced. The pdFMP in pre- and post-grazing were 21.3% and 39.6% higher in LI than in HI strategy (8.70 and 6.85 vs. 5.41 and 3.27 t ha^{-1}, respectively). This may provide greater forage availability, allowing maximum dry matter intake during grazing. The GFMP, which corresponds to leaves and stems, was 15% and 45% higher in LI than in HI strategy in the pre- and post-grazing periods, respectively. These values are above the 1.11 t ha^{-1} suggested as a limiting factor for grazing production, which could influence forage selection and animal performance (Barbero et al., 2012, 2015).

Regarding the forage chemical composition, the DM contents of the whole plant, leaf and stem in the post-grazing period were 12.91, 25.60 and 14.46% higher in HI than in LI strategy, respectively. Intensively grazed pastures had higher leaf: stem ratio before and after grazing compared with LI pastures. The leaf: stem ratio is of great importance to animal production and forage plant management as it is directly related to forage intake. According to Van Soest (1994), the higher the leaf: stem ratio, the higher the nutritional value of the forage. Leaves are rich in crude protein but low in fiber; consequently, leaves are more digestive than other plant fractions.

The different grazing management strategies affected the protein content of the forage. In the pre-grazing period, the CP content was 8.33% higher in HI than in LI strategy, which may be associated with the higher leaf: stem ratio observed in the HI management. On the other hand, the CP content in the post-grazing period was 11.11% higher in LI than in HI management (81 and 72 g kg^{-1} DM, respectively), which probably occurred due to the higher amount of residual green dry matter in the forage sward in LI pastures.

The TDN content is approximately 55% in forages and is used to express the energy content of feeds (Van Soest, 1994). In this study, TDN values in the pre- and post-grazing periods were close to 45% regardless of the grazing management strategy. In the pre-grazing period, the TDN content increased by 2.99% in HI compared with the LI treatment, which can be explained by the decrease in ADF obtained in the HI strategy. Intensively grazed pastures had higher NFC content in the post-grazing period (23.26%) compared with LI pastures, which may be related to the reduction in NDF, CP, EE and ash contents.

The evaluation of fibrous constituents of forages is essential for the formulation of ruminant diets due to their correlation with dry matter intake and feed digestibility. There was no difference between strategies for NDF content in the pre-grazing period. Both NDF contents were above the minimum required of 55-60% in forage-based diets (Van Soest, 1994; Monção et al., 2019; 2020; Queiroz e al., 2021). The pre-grazing ADF and lignin contents, and post-grazing NDF and ADF contents were 5.99; 15.91; 4.37 and 6.44% higher in LI strategy than in HI, respectively.

Although the values of the fibrous fraction were above those recommended by Van Soest (1994), they did not affect forage degradability in both treatments, what is interesting for tropical grasses. Only the DM degradability of fraction "a" was influenced by the different management strategies, which was 13.97% and 12.05% higher in HI than in LI strategy in the pre- and post-grazing periods, respectively. Fraction "a" corresponds to the primary source of energy for rumen microorganisms, leading to a reduction in lag time. The proportion of fraction "a" in early-harvested forages is smaller due to the lower soluble carbohydrate content at reduced harvesting ages compared with more advanced growth ages.

No significant differences were observed for the ruminal degradability of NDF, showing behavior similar to that of DM degradability. Fiber digestibility in forages is not constant for all animals or all feeding conditions, but the primary source of variation stems from differences in structure, chemical composition and maturity stage (Van Soest, 1994; Monção et al., 2019). However, although the different sward heights in the present study affected some structural and chemical characteristics, they did not significantly affect the ruminal degradation of DM and NDF, which may favor animal performance.

The different grazing management strategies affected the forage intake of animals. Pasture structural characteristics can influence the forage intake. The lower DM intake of animals grazing pastures managed under the LI strategy may be related to the lower leaf: stem ratio observed in this management. The high proportion of dead material and/or stem may limit animal selectivity and forage intake even when DM production is high. The intakes of DM; CP; NDF and TDN were 26.07; 32.52; 24.09 and 28.45% higher in animals grazing pastures managed under the HI strategy compared with those in LI management, respectively. The higher DM intake observed in animals grazing pastures managed under the HI strategy is probably related to the higher CP and TDN content compared with LI strategy, which in turn increased the intake of these nutrients.

The NDF intake was 24.09% higher in HI strategy compared to the LI strategy, mean of 6.9 kg/day. Similar DM intake would be expected between strategies when repletion is the limiting factor, given that there was no difference in NDF content between strategies, and that the NDF content is negatively correlated with DM intake (Detmann, Valente, Batista, & Huhtanen, 2014). Thus, it can be inferred that forage intake may have been controlled by factors external to the animal, such as plant structural characteristics. Borges et al. (2019) evaluated different tropical forages on the productive performance of F1 Holstein x Zebu cows in feedlot. The authors concluded that the NDF intake varied from 6.17 to 9.94 kg/day without changing milk yield (mean of 12.57 kg/day). Rabelo et al. (2020) and Ramos et al. (2021) also evaluated different tropical grass silage (i.e., forage sorghum silage, biomass sorghum silage) with NDF content above 60% in the diet of F1 Holstein x Zebu cows and found no change in milk yield.

Conclusion

The intensive rotational grazing strategy in Marandu grass pastures increased forage productivity without compromising pasture renewal due to the higher dry matter production but similar nutritional quality to that of less intensive rotational grazing strategy.

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