



Citrus pulp-based supplement reduces the detrimental effects of high grazing pressure on the performance of beef cattle under a rotational system of *Urochloa brizantha*

Suplemento energético a base de polpa cítrica diminui os efeitos deletérios da alta pressão de pastejo no desempenho de bovinos de corte em sistema rotacionado de Urochloa brizantha

Costa, Diogo Fleury Azevedo^{1,2,*}; Da Silva, Sila Carneiro¹; Bittar, Carla Maris¹; Takiya, Caio Seiti^{3,4}; Dórea, João Ricardo Rebouças^{1,5}; Del Valle, Tiago Antonio³; Malafaia, Pedro⁶; Santos, Flavio Augusto Portela¹

¹Department of Animal Sciences, College of Agriculture “Luiz de Queiroz”, University of Sao Paulo, Piracicaba, SP 13418900 Brazil

²Centre for Animal Science, Queensland Alliance for Agriculture and Food Innovation, Gatton, QLD, 4343 Australia

³Department of Nutrition and Animal Production, University of Sao Paulo, Pirassununga, SP 13635-900 Brazil

⁴Department of Animal Sciences and Industry, Kansas State University, Manhattan, KS 66506 USA

⁵College of Agriculture and Life Sciences, University of Wisconsin, Madison, WI 53715 USA

⁶Federal Rural University of Rio de Janeiro, Department of Animal Nutrition and Pastures, Seropedica, RJ, Brazil 23897000;

*Corresponding author: Diogo Costa, e-mail: d.costa@uq.edu.au, phone: +61409445454 Queensland Alliance for Agriculture and Food Innovation, Gatton, QLD, Australia 4343.

ORCID iD

<https://orcid.org/0000-0001-8118-8380>

SUMMARY

The objectives were to evaluate the performance of bull calves under two grazing strategies and the use of energy supplementation in a rotational system of marandu palisade grass (*Urochloa brizantha*) and to assess the morphological and chemical composition of the grass. Eighty eight-month-old bulls of 224 ± 2.4 kg body weight (BW) were used in a completely randomized block design in a 2×2 factorial arrangement of two post-grazing heights (*i.e.* 10 cm or 15 cm) and of a citrus pulp-based supplement (*i.e.* 72% total digestible nutrients) fed daily at 0 or 6 g/kg BW. Initial grazing height was set at 25 cm with variable grazing intervals and stocking rate adjustments used to control the grazing heights. Statistical analyses were performed using the SAS Mixed procedure. Significance was set at 0.05. Forage data from 12 pre-determined paddocks showed no differences in forage mass (FM) and

morphological composition at pre-grazing, but greater post-grazing FM and shorter grazing interval in pastures managed at 15 cm. Higher grazing pressure resulted in lowest BW gains for non-supplemented bulls in the 10 cm treatment. The use of an energy supplement and 15 cm post-grazing height resulted in the greatest BW gains; however, combination of 10 cm post-grazing height and energy supplementation allowed greater stocking rates. Under high grazing pressure, supplementary feed overcame the normal limitations, and high gains were achieved.

Keywords: Energy supplementation, grazing management, tropical pasture.

RESUMO

Os objetivos foram avaliar o desempenho de tourinhos em duas estratégias de pastejo e a suplementação energética em um sistema de



lotação rotacionada de capim marandu (*Urochloa brizantha*) e avaliar a composição morfológica e bromatológica da gramínea. Oitenta bezerras não castradas com 8 meses de idade [$224 \pm 2,4$ kg peso vivo (PV)] distribuídos em blocos casualizados com arranjo fatorial 2×2 entre altura de saída (*i.e.* 10 cm ou 15 cm) e suplemento (*i.e.* 72% nutrientes digestíveis totais) fornecido diariamente à 0 ou 6 g/kg PV. Análises estatísticas foram feitas com o procedimento Mixed do SAS, adotando-se nível de significância à 0,05. A altura de entrada nos pastos foi de 25 cm. O intervalo entre pastejos foi variável com taxa de lotação ajustada de acordo com as premissas de pastejo. A massa de forragem (MF) pré- e pós-pastejo, taxa de crescimento da MF e o acúmulo de MF foram mensuradas em 12 piquetes pré-determinados. A

MF no pré-pastejo foi semelhante, porém maior MF e menor intervalo entre pastejos foram observados nos pastos com altura de saída de 15 cm. A composição morfológica entre os dois manejos foi semelhante na entrada, porém a proporção de folhas foi maior no 15cm. A suplementação combinada a altura de saída de 15 cm gerou os maiores ganhos. Porém, a suplementação associada a altura de saída de 10 cm permitiu maior taxa de lotação, não afetando produtividade. Os efeitos deletérios da pressão de pastejo sobre o desempenho animal foram reduzidos quando a suplementação foi utilizada.

Palavras-chave: Manejo do pastejo, pastagem tropical, suplementação energética.



INTRODUCTION

In a scenario where world population is increasing under uncertain climatic conditions, combined efforts should be sought to increase farming efficiency and food production per area. The main factors affecting nutrient intake by grazing ruminants, which would directly affect their performance, are forage allowance (Drescher et al., 2006) and sward structure (da Silva et al., 2013); both affected by grazing pressure, defined as the ratio of the animal bodyweight (BW) to forage mass per area. Hodgson (1990) indicated that swards managed at 95% light interception (LI) at the initial grazing point resulted in pastures with greater forage yield, with increased proportion of leaves and decreased proportion of stems. The adopted sward height of 25 cm in this work is correlated to 95% LI on pastures of marandu palisade grass (*Urochloa brizantha*), regardless of the post-grazing height (Trindade et al., 2007). In spite of this, the grazing pressure used to reduce the post-grazing height may affect animal performance, considering that forage mass (FM) ingestion rate of grams of dry matter (DM) per minutes depressed when cattle are forced to graze down more than 40% of the initial sward height (Fonseca et al., 2012). Energy supplementation for cattle grazing tropical pastures under a high stocking rate could potentially minimize these deleterious effects by increasing energy intake, thereby leading to improvements in performance. Santos et al. (2014) reported that feeding a corn-based energy supplement at 6 g DM/kg BW to grazing yearling bulls decreased forage intake by 18.4%, but increased total DM intake by 10.5%. Hence, the use of citrus pulp in the current experiment, a feedstuff high in pectin, used as the energy supplement at 6 g DM/kg BW, as recommended by Santos and colleagues (2014).

The primary objective of this study was to evaluate the performance of bull calves under two grazing intensities in a rotational grazing system of marandu palisade grass in combination with energy supplementation. Secondly, the morphological characteristics and chemical composition of the grass were evaluated. We hypothesized that feeding an energy supplement to weaner grazing cattle would reduce the detrimental effects of high grazing pressure on animal performance, thereby increasing beef yield in the system.

MATERIAL AND METHODS

All procedures were conducted in accordance with the guidelines of the Animal Care and Use Committee of the College of Agriculture “Luiz de Queiroz”, University of Sao Paulo (ESALQ-USP).

Experimental area and preliminary procedures

The experiment was conducted at the Animal Sciences Department of the ESALQ-USP, Piracicaba, SP, Brazil. The experimental area was 8.5 ha uniformly covered with marandu palisade grass (*Urochloa brizantha*, syn. *Brachiaria brizantha*), and divided into four sub-areas containing eight paddocks each. Thus, there were 32 paddocks, of 0.265 ha each. Cattle had access to management centers equipped with feed bunks and water troughs in each sub-area.

The experimental period lasted 180 days from November 2005 to May 2006. Pasture data was collected throughout the experiment, but only the first 105 days were considered in the analyses because climate conditions did not allow the pastures to fully recover and reach sward heights of 25 cm during the final experimental period. The maximum and minimum temperatures during the whole



experiment were 28.8 and 16.9 °C, respectively, with 607 mm of rain. For 114 days prior to the start of the trial, pastures were managed using Nellore cows from the department's breeding herd. Grazing intervals were variable and stocking rate adjustments with different occupation periods were used to control the grazing heights. About 75 kg K/ha, 36 kg P/ha and 30 kg micronutrients mixture/ha were applied on October 2005, and then, approximately 2.5 kg N/ha/day was applied in the form of urea, between grazing cycles.

Animals and treatments

Eighty crossbred ($\frac{1}{4}$ St. Gertrudis \times $\frac{1}{4}$ Nellore \times $\frac{1}{2}$ Brown Swiss) bull calves, 8 months of age and 224 ± 2.4 kg BW (mean \pm SEM), were used. A second cohort of 70 animals was used to adjust the stocking rate. Two groups consisting of supplemented and non-supplemented bull calves were rotated between the two sub-areas managed with 10 cm of post-grazing height, whilst the other two groups rotated between the sub-areas managed with 15 cm of post-grazing height. If not in the experimental area, the cohort animals were kept in an area with the same management regime. Cattle were vaccinated for foot and mouth disease, clostridiums, and rabies, with Bovifel (Valée, Montes Claros, Brazil), Fortress 7, and Rai-Vac K (Zoetis, Campinas, Brazil), respectively, and treated for internal and external parasites every 60 days with either Dectomax (1% w/v Doramectin, Zoetis) or Ivomec (1% w/v Ivermectin, Merial, Campinas, Brazil). Animals were blocked by initial BW and randomly allocated to one of four treatments: 1) no supplement and 10 cm post-grazing height, 2) no supplement and 15 cm post-grazing height, 3) 6 g of supplement kg BW/day (on DM-basis) and 10 cm of post-grazing height, and 4) 6 g of supplement kg BW/day (on DM-basis) and

15 cm of post-grazing height. The supplement (905 g/kg of DM, 110 g/kg CP, and 720 g/kg of total digestible nutrients) consisted of 803 g/kg citrus pulp, 154 g/kg cottonseed meal, 43 g/kg minerals, and 90 ppm of sodium monensin on a DM basis, which was offered each day, fed as a group. Adjustments on total amount of supplement offered were done after each weighing interval.

Pasture management and forage collection

The grazing height utilized as the starting point in the current work was chosen based on the high correlation found in marandu palisade grass by Trindade et al. (2007) with 95% LI, which is considered as the ideal point to maximize forage yield with increased the proportion of leaves and decreased proportion of stems (Hodgson, 1990). The pre-grazing sward grazing height of 25 cm was achieved by varying the stocking rate, occupation periods, and grazing intervals throughout the experiment. Allocation of animals within paddocks was based on the estimated amount of FM present in the paddock and the amount necessary to be removed to achieve the aimed post-grazing height, by estimating the period until the next paddock reached 25 cm. The sward height was measured (Fagundes et al., 1999) in all paddocks at every grazing cycle. Pre- and post-grazing FM, forage growth rate (FGR), and the accumulated FM were measured in 12 pre-determined paddocks (6 for each pasture management regime) using 4 samples per collection, cut at 1 cm above ground level with the use of a rectangular frame of 0.5 m². Forage accumulation (kg DM ha/day) was calculated from FM differences in pre- and post-grazing in every grazing cycle for 105 days. The FM accumulated in every grazing cycle was used to calculate FGR. Total FM accumulated was calculated from FGR and



extrapolated to 105 days because of different grazing intervals between treatments. Morphological composition was determined using DM proportions of leaf, stem, and dead material from a sub-sample of approximately 500g. The leaf component was considered as the leaves that had completely emerged from the sheath. Dead material was considered as any leaf or stem with 50% or more of the superficial area and a yellowish color. Grazing horizon FM samples were collected from all paddocks. Briefly, four different areas within the paddocks were delimited by square metal frames (0.25 m²) and forage was cut above the post-grazing heights of 10 or 15 cm. Samples from each paddock were analyzed for chemical composition. Approximately 500g from each of the latter samples was oven dried at 55 °C for 72h, and ground through a 1-mm screen. Moisture and organic matter content were determined according to AOAC (1990) methods. Nitrogen was determined using Leco FP-2000 (Leco Instruments, Inc. St. Joseph, MI) and a conversion factor of 6.25 for CP estimates. Ash-free neutral detergent fiber (NDF) and ash-free acid detergent fiber (ADF) were determined according to Van Soest et al. (1991) using ANKON bags (ANKON Technology Fairport, New York). Total ether extract was determined according to AOAC (1990) and *in vitro* degradability of organic matter (IVOMD) and DM (IVDMD) according to Goering and Van Soest (1970).

The experimental animals were used as markers and, if necessary, a non-fixed number of animals were used to control sward heights according to treatment. The FM of the grazing horizon collected from each paddock before grazing was initiated, was used to calculate FM allowance and allocate animals in paddocks. Based on observations obtained prior to the start of the experiment, FM allowance required for a lower grazing pressure was 0.4 g/kg BW,

whereas 0.25 g/kg BW was used for the higher grazing pressure, discounting the extra DM supplied as feed for the supplemented animals.

Animal performance

Animals were weighed at the start of the experiment and every 30 days after a 14 hour curfew of feed and water. Individual average daily gain (ADG) was calculated as the slope of the BW as a function of the time, and it was expressed in kg/d. Stocking rate and beef yield were calculated using the sum of the BW averages and the ADG data of the animals used as markers, respectively.

Statistical analysis

Data of pasture productivity, morphological, and chemical composition were analyzed using the MIXED procedure of SAS (version 9.4, SAS Institute, Cary, NC), according to the model below:

$$Y_{ijkl} = \mu + PM_i + \omega_{j:i} + C_k + e_{ijk}$$

In which: $\omega_{i,j} \approx N(0, \sigma_{\omega}^2)$ and $e_{ijk} \approx MVN(0, R)$; where, Y_{ijkl} is the value of dependent variable; μ is the overall mean; PM_i is the fixed effect of pasture management ($i = 1$ and 2); $\omega_{j:i}$ is the random effect of paddock j within i^{th} level of pasture management ($j = 1$ to 12); C_k is the fixed effect of pasture cycle ($k = 1$ to 5); e_{ijk} is the residual error; N stands for the Gaussian distribution; σ_{ω}^2 is the variance associated with paddocks; MVN stands for the multivariate normal; and R is the variance-covariance matrix of residuals due to the repeated measurements. Autoregressive (AR) matrix was applied for all variables. Degrees of freedom were calculated according to Kenward and Rogers (1997). The least square means and SEM values for each pasture management are presented. Data of animal performance



were analyzed using the MIXED procedure of SAS, and the following model:

$$Y_{ijk} = \mu + PM_i + S_j + PM \times S_{ij} + b_k + e_{ijk}$$

In which: $b_k \approx N(0, \sigma_b^2)$ and $e_{ijk} \approx N(0, \sigma_e^2)$; where, Y_{ijk} is the value of dependent variable; μ is the overall mean; PM_i is the fixed effect of pasture management ($i = 1$ and 2); S_j is the fixed effect of animal supplementation ($j = 1$ and 2); $PM \times S_{ij}$ is an interaction term; b_k is the random effect of block ($k = 1$ to 20); e_{ijk} is experimental error; N stands for the Gaussian distribution; σ_b^2 and σ_e^2 are variances associated with blocks and residual, respectively. As we had a balanced trial, we showed a general residual SEM for each variable. Because animals were maintained in different paddocks in each interval between BW measurements for the 30 days of evaluation period, the experimental group (supplementation and pasture management combination) within each period was considered the experimental unit for stocking rate (AU/ha) and beef yield (kg/ha/day) evaluations. In this approach, the limitations are recognized, but it was decided to allow a discussion based on statistical significance. A similar model to the one used for animal performance evaluation was applied to evaluate

stocking rate and beef yield, replacing the random effect of blocks with the random effect of evaluation period ($k = 1$ to 5).

RESULTS

Productivity, morphology, and chemical composition of pastures

The initial grazing sward height maintained for both treatments did not vary ($P=0.224$), resulting in similar FM ($P=0.671$) between treatments. In contrast, post-grazing FM was lower ($P=0.004$) for the treatment of 10cm sward height at post-grazing. As planned, post-grazing sward height was lower ($P<0.001$) in pastures managed with 10 cm compared to those managed with 15 cm at post-grazing. Forage accumulation, forage growth rate, and bulk density were similar ($P>0.05$) between treatments. The average grazing interval for pastures managed at 10 cm was higher ($P=0.006$) than those managed with 15 cm of height at post-grazing (Table 1).



Table 1. Pre- and post-grazing sward heights, forage mass (FM), bulk density, total forage accumulation, growth rate, and grazing interval of marandu palisade grass (*Uruclioa brizantha*) subjected to different grazing intensities

Item	Post-grazing sward height		P-value
	10 cm	15 cm	
Pre-grazing sward height (cm)	24.5 ± 0.47	25.1 ± 0.42	0.224
Post-grazing sward height (cm)	11.5 ± 0.29	15.3 ± 0.24	<0.001
Pre-grazing FM (kg DM/ha)	4914 ± 234.4	5019 ± 209.6	0.671
Post-grazing FM (kg DM/ha)	2695 ± 163.2	3254 ± 131.9	0.004
Bulk density (kg DM/ha/cm)	144 ± 13.5	117 ± 12.4	0.051
Forage accumulation (kg DM/ha/cycle)	2230 ± 272.8	1704 ± 212.7	0.076
Total forage accumulation ¹ (kg DM/ha)	9996 ± 2395	9881 ± 1537	0.969
Forage growth rate (FGR) (kg DM ha/day)	95.2 ± 21.5	94.1 ± 17.0	0.962
Grazing interval (days)	23.9 ± 1.73	18.2 ± 1.35	0.006

¹Total FM accumulated was calculated from FGR of sampling paddocks and extrapolated to 105 days.

Pasture morphological composition at pre-grazing was similar ($P \geq 0.407$) between pastures. However, the 10cm post-grazing treatment had a lower

proportion of leaf ($P=0.001$) and a greater proportion of dead material ($P=0.001$) compared to those managed at 15 cm post-grazing (Table 2).

Table 2. Morphological composition of marandu palisade grass under two grazing intensities

Item	Post-grazing sward height		P-value
	10 cm	15 cm	
Pre-grazing (g/kg DM)			
Leaf	536 ± 41.0	514 ± 36.8	0.604
Stem	353 ± 24.5	348 ± 22.5	0.854
Dead material	111 ± 26.8	135 ± 23.9	0.407
Post-grazing (g/kg DM)			
Leaf	199 ± 25.7	295 ± 21.1	0.001
Stem	472 ± 25.9	456 ± 21.2	0.547
Dead material	326 ± 22.9	248 ± 19.2	0.001

As expected, pastures (*i.e.* grazing horizon samples) had a similar chemical composition, with the exception that lignin content was greater ($P=0.018$) in pastures managed at 10 cm (Table 3).

No differences were detected ($P \geq 0.299$) on *in vitro* DM and organic matter degradability between pasture management regimes (Table 3).



Table 3. Chemical composition of grazing horizon samples of marandupalisadegrass pastures under different grazing intensities

Item	Post-grazing sward height		P-value
	10 cm	15 cm	
Dry matter (g/kg as fed)	194 ± 10.0	207 ± 8.9	0.249
Forage composition(g/kg DM)			
Neutral detergent fiber	631 ± 14.5	616 ± 12.4	0.413
Acid detergent fiber	313 ± 6.2	309 ± 5.1	0.532
Hemicellulose	319 ± 11.9	309 ± 10.2	0.500
Cellulose	278 ± 6.8	284 ± 5.6	0.441
Lignin	34.2 ± 3.64	25.4 ± 3.02	0.018
Crude Protein	154 ± 5.9	157 ± 4.7	0.675
Ash	107 ± 0.89	101 ± 0.73	<0.001
Non-fiber carbohydrate	81.8 ± 18.8	99.0 ± 15.6	0.440
Ether extract	22.6 ± 0.30	22.5 ± 0.26	0.577
<i>In vitro</i> degradability (g/kg)			
Dry matter	611 ± 6.0	617 ± 5.4	0.553
Organic matter	631 ± 5.9	623 ± 5.2	0.299

Animal performance

Energy supplementation increased ($P \leq 0.018$) ADG, final BW, stocking rate, and beef yield (Table 4). Adopting a higher grazing pressure at 10 cm post-grazing reduced ($P < 0.001$) the ADG and final BW, but increased ($P < 0.001$) stocking rate and had no effect on beef yield. No interaction effects between energy supplementation and pasture management were observed ($P \geq 0.128$) in the animal performance variables (Table 4).



Table 4. Average daily gain (ADG), stocking rate (SR), beef yield (BY), and final body weight (BW) of bull calves supplemented or non-supplemented under different grazing intensities

Item	Treatment ¹				SEM	P-value ²		
	Post-grazing sward height of 10 cm		Post-grazing sward height of 15 cm			SUP ²	GP ³	SUP×GP
	Non-supplemented	Supplemented	Non-supplemented	Supplemented				
Initial BW (kg)	219	225	225	225	2.4	0.475	0.539	0.530
ADG (kg/d)	0.397	0.790	0.519	0.907	0.0213	<0.001	0.001	0.934
Final BW (kg)	291	369	319	390	5.6	<0.001	<0.001	0.573
SR (AU ³ /ha)	7.04	8.45	5.77	6.12	0.276	0.018	<0.001	0.128
BY (kg ha/d)	5.70	11.3	5.62	9.08	0.833	<0.001	0.121	0.146

¹Different post-grazing sward heights and the use of a citrus pulp-based energy supplement fed daily at 0 or 6 g/kg BW. ²Probabilities for effects of supplement (SUP), grazing pressure (GP), and their interaction. ³Animal unit = 450 kg BW.



DISCUSSION

The use of a citrus pulp-based supplement on a well-managed tropical pasture during the wet season increased the ADG of growing bulls. Energy intake was most likely the primary limiting factor for performance, considering that the CP content of grasses appeared adequate for growing cattle (NRC, 2000) in both grazing intensities. The quality of marandu palisade grass at the pre-grazing condition in combination with the supplement, provided not only the protein, but also supplied the metabolizable energy required for improvements in performance. The higher forage allowance in the 15cm post-grazing height resulted in an intermediate ADG for non-supplemented animals in that treatment, but the use of a supplement at 6 g/kg BW decreased the deleterious effect of lower ADG observed in non-supplemented animals in pastures managed at 10cm post-grazing height. The net intestinal absorption of protein from tropical grasses is relatively low due to their low energy content, leading to N losses when CP exceeds either 210 g of CP/kg of digestible organic matter or 151 g of CP/kg DM (Poppi & McLennan, 1995). In cases where the digestibility of grass is below 70%, such as was observed in the current experiment, values of CP of 132 g/kg of DM would be in excess and would lead to N losses. Thus, the energy supplementation may have increased the digestibility of the diet, considering that there were no differences between the *in vitro* digestibility of forage samples, allowing a more efficient utilization of the grazed forage. The 10 cm post-grazing height increased stocking

rate but decreased performance when supplementation was not in place.

The use of an adequate grazing height for pasture management (Hodgson, 1990; Congio et al., 2018) resulted in high FGR and FM accumulation and a high proportion of leaves in FM at pre-grazing, independent of the grazing intensity. The 25 cm pre-grazing and 15cm post-grazing heights were reached satisfactorily. However, the 10 cm post-grazing height was not reached consistently, averaging 11.3 cm. Similarly, in pastures of marandu palisade grass managed at 95% LI at pre-grazing, Trindade et al. (2007) could not reach lower post-grazing heights in more severe grazing, such as 10 cm, during the higher growth season, averaging 12.7 cm over summer.

More severe grazing had no negative effects on pre-grazing FM and morphological composition in the current experiment but resulted in fewer leaves and more dead material in post-grazing FM of marandu palisade grass, similar to results reported by Trindade et al. (2007). The chemical composition of the grazing horizon FM in the current experiment was also similar between treatments. The leaf is most likely the main component influencing forage intake because of its relatively high digestibility (Poppi et al., 1981). High grazing intensity may reduce intake since there is a decrease in the proportion of green leaves, as observed in the current study, but it can potentially increase harvest efficiency (Carnevali et al., 2006). Dairy cows grazing elephant grass (*Pennisetum purpureum*) managed at 95% LI were almost 10% more efficient on the harvesting process that resulted in an extra 2.0 kg of milk per day compared to cows grazing pastures managed at



maximum LI (Congio et al., 2018). The grazing efficiency in the work of Carnevalli et al. (2006) using Mombaça grass (*Panicum maximum*) reached maximum efficiency (87%) when a treatment of 95% LI was combined with more severe grazing (*i.e.* 30 cm vs 50 cm). Stems impose a physical barrier to the grazing process and more intense grazing forces animals to explore lower grazing horizons, whilst lower grazing intensities provide better selection opportunities for animals, resulting in greater intakes. Difante et al. (2009) observed decreased intake (20%) for 25 cm in comparison to 50 cm post-grazing heights in *Panicum maximum* managed at 95% LI. The CP content found in pastures in the current study was relatively high, reflecting the plant growth stage and the use of N fertilizer. Assuming a ruminal degradability of protein of 800 g/kgCP (Bowen et al., 2008), it would result in rumen degradable protein (RDP)/digestible organic matter (DOM) ratios of 195 and 197 g RDP/kg DOM for both grazing intensities, values that are in excess of the RDP requirements for microbial protein synthesis in the rumen (CSIRO, 2007). The lower ADG observed in the high grazing pressure is primarily a result of the lower FM allowance used for that pasture management, but could also be linked to harvesting constraints and/or lower availability of leaves in the lower strata, as suggested by the differences found in morphological composition between the post-grazing FM in both treatments. In spite of that, no significant differences were found between treatments in the chemical composition of the grazing horizon samples. However, as stated by Fonseca et al. (2012), the grazing-down process reaching sward heights inferior to 60% of the initial grazing point would

negatively affect the short-term forage intake, leading to lower performance, as observed in animals on more severe grazing treatment. The use of energy supplement at 6 g/kg BW very effectively minimized the deleterious effects on performance, resulting in the second highest ADG for the supplemented animals subjected to high grazing pressure, despite the lower FM allowance.

The FM samples had a high proportion of leaves in all treatments, although they required different grazing intervals. The intervals varied from 10 to 24 days for 15 cm post-grazing height and from 15 to 31 days for pastures managed at 10 cm post-grazing height. No differences in forage accumulation can be explained by a compensation in the number of grazing cycles. Therefore, the high stocking rate achieved was due to either a lower intake and/or a more efficient grazing process. Using variable grazing intervals, Euclides et al. (2014) found more leaves in *Panicum maximum* compared with fixed grazing intervals (553 vs. 483 g/kg). Higher pasture utilization achieved with higher grazing pressure could negatively affect the production and persistency of the grass in the long term with a non-variable grazing interval if not enough time was allowed for the plants to recover. However, the adoption of a target pre-grazing height could overcome this problem by allowing time for plants to replenish their reserves, and, as previously stated, sward height of approximately 25 cm in marandu palisade grass has been positively correlated to 95% LI (Trindade et al., 2007). In spite of this, to maximize forage intake, it is necessary to remove animals when the sward reaches 60% of the pre-grazing height (Fonseca et al., 2012). Trindade et



al. (2007) found a lower proportion of leaves in extrusa samples harvested from esophageal-fistulated animals during the grazing-down process. The 10 cm post-grazing height treatment most likely did not result in enough allowance of FM to provide better selection opportunities, and therefore resulted in decreases in ADG, despite the minimal differences in FM chemical composition. The 17.4% decrease in ADG between the two grazing intensity treatments when non-supplemented, demonstrates the impact of forage allowance on animal performance. The use of a citrus pulp-based supplement decreased this deleterious effect.

The pasture stocking rate of non-supplemented animals was 31% higher [7.80 vs. 5.95 Animal Units (AU=450 kg BW)/ha] in pastures managed at 10 cm post-grazing height but beef yield (8.55 vs. 7.35 kg BW gain/ha/day) was not increased because of lower individual performances. Sarmiento (2007) observed a decrease in AD Gof cattle grazing marandu palisade grass with severe grazing, but a much higher stocking rate that resulted in increased beef yield. The supplementation in the present study increased in 82% the ADG (0.81 vs. 0.445 kg BW) resulting in animals 65 kg heavier than non-supplemented ones (360 vs. 295 kg), regardless of the pasture management strategy. As this supplementation strategy results in heavier cattle, it is

most likely that animals will require less days on feed during feedlot phase or will have heavier carcasses at slaughter for specific market demands.

CONCLUSION

The use of 6 g/kg BW supplement was more effective than grazing management to increase beef yield, most likely because of increments of metabolizable energy in the final diet. Growing bulls achieved highest BW gains when supplementation was combined with lower grazing pressure, resulting in positive synergistic effects on animal performance. Despite not reaching as high BW gains, the use of an energy supplement was effective to overcome the negative effects of more severe grazing, increasing individual ADG of growing bulls and resulting in high beef yields despite the grazing strategy adopted.

ACKNOWLEDGEMENTS

The authors are grateful to Professor Dennis Poppi and Dr. Simon Quigley (SAFS-UQ, Australia) for reviewing the manuscript and providing valuable suggestions, and the São Paulo Research Foundation (FAPESP) for partially funding this research.

REFERENCES

AOAC International - Association of Official Analytical Chemists. Official Methods of Analysis. 15th Ed. **AOAC Press**, Gaithersburg, USA.1990

BOWEN, M.K.; POPPI, D.P.; MCLENNAN, S.R. Ruminant protein

degradability of a range of tropical pastures. **Australian Journal of Experimental Agriculture**, v. 48, p. 806-810, 2008.

CSIRO - Commonwealth Scientific and Industrial Research Organization, Nutrient requirements of domesticated



ruminants. **CSIRO Publications:**
Collinwood, Victoria, Australia. 2007.

CARNEVALLI, R.A.;DA SILVA,
S.C.;BUENO, A.A.O.;UEBELE,
M.C.;BUENO, F.O.;HODGSON,
J.;SILVA, G.N.;MORAIS,
J.P.G.Herbage production and grazing
losses in *Panicum maximum* cv.
Mombaça under four grazing
managements. **Tropical Grasslands**, v.
40, p.165-176,2006.

CONGIO G.F.S.;BATALHA,
C.D.A.;CHIAVEGATO,
M.B.;BERNDT, A.;OLIVEIRA,
P.P.A.;FRIGHETTO,
R.T.S.;MAXWELL,
T.M.R.;GREGORINI, P.;DA SILVA,
S.C. Strategic grazing management
towards sustainable intensification at
tropical pasture-based dairy systems.
Science of The Total Environment, v.
636, p. 872-880, 2018.

DA SILVA, S.C.;GIMENES
F.M.A.;SARMENTO
D.O.L.;SBRISSIA A.F.;OLIVEIRA
D.E.;HERNANDEZ-GARAY A.;
PIRES A.V. Grazing behavior, forage
intake and animal performance of beef
cattle heifers on marandu palisade grass
subjected to intensities of continuous
stocking management. **Journal of
Agricultural Science**,v. 151, p. 727-
739,2013.

DIFANTE, G.S.;EUCLIDES,
V.P.B.;NASCIMENTO, D.; Da SILVA
S.C.;TORRES,R.A.A.;SARMENTO,
D.O.L.Ingestive behavior, forage intake
and grazing efficiency of beef cattle
steers on Tanzania guinea grass
subjected to rotational stocking
managements. **Revista Brasileira de
Zootecnia**,v. 38, p. 1001-1008, 2009.

DRESCHER, M.;HEITKONIG,
I.M.A.;VAN DEN BRINK P.J.;
PRINSH.H.T. Effects of sward structure
on herbivore foraging behaviour in a
South African savanna: An
investigation of the forage maturation
hypothesis. **Australian Ecology**, v. 31,
p. 76-87,2006.

EUCLIDES, V.P.B.; MONTAGNER,
D.B.; DIFANTE G.D.S.; BARBOSA,
R.A.;FERNANDES, W.S.Sward
structure and livestock performance in
guinea grass cv Tanzania pastures
managed by rotational stocking
strategies. **Scientia Agricola**,v. 71, p.
451-457, 2014.

FAGUNDES, J.L.;DA SILVA,
S.C.;PEDREIRA,
C.G.S.;CARNEVALLI,
R.A.;CARVALHO, C.A.B.;SBRISSIA,
A.F.;PINTO, L.F.M.Índice de área
foliar, interceptação luminosa e
acúmulo de forragem em pastagens de
Cynodon spp. sob diferentes
intensidades de pastejo.**Scientia
Agricola**,v. 56, p. 1141-1150,1999.

FONSECA, L.;MEZZALIRA,J.C.;
BREM, C.;FILHO, R.S.A.; GONDA,
H.L.;CARVALHO, P.C.F. Management
targets for maximizing the short-term
forage intake rate of cattle grazing in
Sorghum bicolor. **Livestock Science**, v.
145, p. 205-211,2012.

GOERING, H.K.;VAN SOEST, P.J.
Forage fiber analyses (apparatus,
reagents, procedures and some
applications). In '**Handbook No. 379.**'
**Agricultural Research Service/United
States Department of Agriculture
(ARS/USDA)**. Washington DC,
USA,1970.



HODGSON, J. Grazing Management: Science into Practice, **Longman Scientific and Technical**, New York, NY, USA,1990.

KENWARD M.;ROGER, J. Small sample inference for fixed effects from restricted maximum likelihood. **Biometrics**, v. 53, p. 983-997,1997.

NRC - National Research Council Nutrients requirements of beef cattle. 7th Ed. **The National Academy of Sciences**, Washington DC, USA,2000.

POPPI, D.P.; MCLENNAN, S.R. Protein and energy utilization by ruminants at pasture. **Journal of Animal Science**, v. 73, p. 278-290,1995.

POPPI, D.P.;MINSON, D.J.;TERNOUTH J.H. Studies of cattle and sheep eating leaf and stem fractions of grasses. 3. The retention time in the rumen of large feed particles. **Australian Journal of Agricultural Research**, v. 32, p. 23-137,1981.

SANTOS, F.A.P.;DOREA, J.R.R.;DE SOUZA, J.;BATISTEL, F.; COSTA, D.F.A.Forage management and methods to improve nutrient intake in grazing cattle. In: **25th Annual Florida**

ruminant nutrition symposium, Gainesville, Florida, USA. p 144-165,2014.

SARMENTO, D.O.L.; Forage accumulation, morphological composition and nutritive value in *Brachiaria brizantha* (Hochst x A. Rich) Stapf. Cv Marandu subjected to rotational stocking strategies with beef cattle. **PhD dissertation**. University of Sao Paulo, Piracicaba, SP, Brazil.2007,

TRINDADE, J.K.;DA SILVA S.C.;DE SOUZA S.J.Morphological composition of the forage consumed by beef cattle during the grazing down process of marandu palisade grass subjected to rotational strategies. **Pesquisa Agropecuária Brasileira**,v. 42, p. 883-890,2007.

VAN SOEST, P.J.;ROBERTSON, J.B.;LEWIS, B.A.; Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. **Journal of Dairy Science**, v. 74, p. 3583-3597,1991.

WAINMAN, F.W.; DEWEY, J.S. Feedstuffs evaluation unit - fifth report, Bucksburn, Scotland, UK: Rowett Research Institute, p.123 1988.