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Milk production and ingestive behavior of cows grazing on Marandu and Mulato II pastures under rotational stocking

Joana Baptista Demski[1], Irineu Arcaro Junior[2], Flavia Maria de Andrade Gimenes[2*], Luciandra Macedo de Toledo[2], Mariana Santos de Miranda[2], Alessandra Aparecida Giacomini[2], Gianni Aguiar da Silva[1]

[1] Instituto de Zootecnia, Programa de Pós-Graduação em Produção Animal Sustentável, Nova Odessa, SP, Brasil.
[2] Instituto de Zootecnia, Nova Odessa, SP, Brasil.

***Corresponding author:**
flavia@iz.sp.gov.br

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ABSTRACT - The objective of this study was to evaluate milk production and ingestive behavior of Holstein cows and the structural characteristics of Mulato II, a hybrid *Brachiaria* grass CIAT 36087 (*B. ruziziensis* × *B. decumbens* × *B. brizantha*), and Marandu (*Brachiaria brizantha* cv. Marandu) pastures under rotational stocking. The experiment was conducted from December 2011 to April 2012 after 10 months of adaptation to the grazing management objectives (25 cm pre-grazing height and 15-20 cm post-grazing height). An area of 4 ha was divided into 28 paddocks: 14 with Mulato II pasture and 14 with Marandu pasture. The treatments consisted of the two grasses and a completely randomized design of the grazing variables with six repetitions each (paddock of evaluation) was used. For the animal variables, a randomized matched pairs design of 20 Holstein cows forming 10 blocks of two animals with similar production each was used. The forage mass or accumulation rate did not differ between grasses. Mulato II pastures had a higher tiller population density (822 tillers m^{-2}) and crude protein content (143.5 g kg^{-1}) than Marandu pastures (636 tillers m^{-2} and 130.3 g kg^{-1} crude protein). Cows kept on Mulato II exhibited shorter nighttime grazing activity (234 and 246 min in summer and autumn, respectively) than animals kept on Marandu (273 and 394 min, respectively). The average milk yield during the experimental period was higher for Mulato II (15.3 kg cow^{-1} day^{-1}) compared with Marandu (14.3 kg cow^{-1} day^{-1}). Both grasses have potential to be used in milk production systems for the grazing management objectives evaluated.

Keywords: *Brachiaria*, dairy cow, nutritional value, milk composition, pasture, tropical forage

Introduction

Milk production in Brazil is based on the use of pastures because it is a lower-cost option than processed forage (Pereira et al., 2016). Among the options of forage plants, Marandu grass (*Brachiaria brizantha* cv. Marandu) occupies 60% of the 178 million hectares of pasture area in Brazil. However, large areas of Marandu pasture can be considered monocultures, with the consequent risks deriving from the low genetic diversity of these systems (Euclides et al., 2010). An alternative would be Mulato II grass, also called Convert HD 364 (Dow AgroSciences, São Paulo, Brazil), a cultivar obtained by the International Center for Tropical Agriculture (CIAT) based in Colombia, which originated from crosses between *Brachiaria decumbens*, *Brachiaria ruziziensis*, and *Brachiaria brizantha* (Argel et al., 2007).

Mulato II grass has shown good results of forage production, with an accumulation rate ranging from 70 to 100 kg dry matter (DM) of forage/day (Pequeno et al., 2015; Silva et al., 2016ab; Holschuch, 2018; Almeida, 2018). Pequeno et al. (2015) highlighted the greater residual leaf mass of Mulato II compared with Marandu, even during the dry season, which increases its regrowth rate, demonstrating the potential use of this grass in rotational grazing systems. Mulato II grass also has a high nutritive value, whose crude protein (CP) content is higher than that of Marandu when cut at 28 days without irrigation (Pequeno et al., 2015), or cut every 30 days (Cabral et al., 2013).

Despite data on the agronomic and chemical characteristics of Mulato II, information obtained with the use of grazing animals for the evaluation of animal production is still lacking. The hypothesis of the present study is that Mulato II could be an alternative to Marandu in pastures for dairy cattle, whose structural and nutritional characteristics would allow to improve the ingestive behavior of animals and to achieve equivalent or higher milk yields when compared with Marandu. Therefore, the objective of this study was to evaluate milk production and ingestive behavior of Holstein cows and the structural characteristics of Mulato II and Marandu pastures under rotational stocking.

Material and Methods

The experiment was conducted from December 21, 2011 to April 22, 2012 after 10 months of adaptation to the experimental grazing conditions (sward height targets) in Nova Odessa, São Paulo, Brazil (approximate geographic coordinates: 22°42' S, 47°18' W, and 528 m altitude).

According to the Köppen system, the climate of this region is humid subtropical climate (Cwa) characterized by dry winters, with average temperatures of less than 18 °C in the coldest month and higher than 22 °C in the warmest month. The data of average temperature was 22, 25, 24, and 22 °C and average precipitation was 172, 123, 36, and 90 mm in January, February, March, and April, respectively. Four hectares were divided into 28 paddocks of 1,425 m^2, 14 with Marandu grass [*Brachiaria brizantha* cv. Marandu (Hochst ex. A. Rich) Stapf.] and 14 with Mulato II grass (hybrid *Brachiaria* CIAT 36087). The pastures were established on 29 November 2010 on soil classified as Red-Yellow Latosol (Santos et al., 2006). Liming was performed with 1,500 kg ha^{-1} of dolomite lime and fertilization with 100 kg ha^{-1} of P_2O_5 in the form of single superphosphate and soil harrowing. In addition, 100 kg ha^{-1} of ammonium nitrate was distributed in two applications (30 and 60 kg N), both in January 2012.

In February 2011, grazing was standardized to a canopy height of 20 cm, followed by management under rotational stocking with heifers and dry cows to adapt the forage canopy to the management conditions of a pre-grazing height of 25 cm and post-grazing height of 15 to 20 cm according to the need of moving to the next paddock. These heights were chosen because they exhibited the best morphological composition and cattle performance for Marandu grass (Trindade et al., 2007; Gimenes et al., 2011). Since no management objectives have been established in the literature for Mulato II, the same canopy heights as those applied to Marandu were chosen for management.

A completely randomized design with repeated measures over time was used, in which two treatments (Mulato II and Marandu) and three periods (January: December 21, 2011 to January 31, 2012; February: February 1 to 28, 2012; and March/April: March 1 to April 21) were studied, with six repetitions corresponding to the paddocks of evaluation chosen among the 14 paddocks of each treatment based on their representativeness of the area. All pasture assessments were performed in these paddocks.

Pre- and post-grazing canopy height was measured at 50 sites per paddock along transect lines using a sward stick (Barthram, 1985). The mean canopy height of the measurements obtained was used for analysis.

Forage mass was collected pre- and post-grazing in three areas of each paddock of evaluation using a frame of 0.25×0.25 m (0.50 m^2) placed randomly in areas representative of the pasture condition. All forage was cut at ground level, collected, and taken to the laboratory where the fresh weight was determined. Two subsamples were then removed, one for the calculation of DM and the other for the evaluation of morphological composition, in which the plants were divided into leaves (leaf blades), stems (sheath + stem), and dead material. These samples were dried in a forced-circulation oven at 65 °C until a constant weight was obtained, and results were used to calculate forage mass (kg DM ha^{-1}) and botanical/morphological composition (g kg^{-1} of total forage mass).

Forage accumulation (FA) per paddock for each grazing period was calculated through the formula:

$$FA = \text{pre-grazing } FM - \text{post-grazing } FM,$$

in which pre-grazing FM = forage mass during pre-grazing (of the current grazing cycle) and post-grazing FM = forage mass during post-grazing (of the previous grazing cycle).

Forage accumulation rate (kg DM ha^{-1} day^{-1}) was calculated by dividing forage accumulation by the number of regrowth days per paddock for each grazing period. Monthly accumulation rate was calculated as the weighted mean of the rates obtained per period in the paddock in the month evaluated.

Samples used to estimate the nutritive value of forage consumed were collected by simulated grazing according to the method of Sollenberger and Cherney (1995) and prepared as described for the forage mass samples. After drying in the oven, the material was ground in a Wiley mill equipped with a 1-mm mesh sieve and sent for chemical analysis to the laboratory for determination of the following parameters: CP according to the AOAC (1995); insoluble neutral detergent fiber (NDF), insoluble acid detergent fiber (ADF), and lignin according to Van Soest et al. (1991); and mineral matter (ashes) and *in vitro* dry matter digestibility (IVDMD) according to Goering and Van Soest (1970).

Tiller population density (TPD) was determined by counting the total number of tillers present inside three metal frames of 0.25 m^2 per paddock, released at sites whose condition was similar to that of the average canopy in terms of pasture height and forage mass after visual evaluation. The data collected were used to calculate TPD, which corresponds to the number of tillers per unit area (tillers m^2).

The assessments of animal behavior consisted of the determination of the time spent grazing, ruminating, and performing other activities and bite rate. The period of evaluation was divided into two phases. The first in summer (called “summer”) and comprised six days: day 1 = 01/23/2012, day 2 = 01/25/2012, day 3 = 01/27/2012, day 4 = 01/29/2012, day 5 = 01/31/2012, and day 6 = 02/02/2012. The second phase occurred at the beginning of autumn (called “autumn”) and comprised three days: day 1 = 04/19/2012, day 2 = 04/20/2012, and day 3 = 04/21/2012. We decided to increase the number of evaluation days in summer because of the heavy rains during the observation periods.

The observations of ingestive behavior were made at night because of the two daily milkings. In summer, the observations started at 18.00 h and ended at 7.00 h of the next day, totaling 13 h. In autumn, the observations started at 17.00 h and ended at 8.00 h of the next day, totaling 15 h. These are the real observation times, with more observation hours in autumn because of the larger number of hours of darkness during this season. The evaluations were performed by Master’s students and trainees of the Dairy Cattle Sector, who took turns in pairs during the observation period. The 10 animals of the batch entered the paddock for grazing. For the behavioral assessments, three focal animals of the batch per treatment with similar production were randomly selected following a paired scheme and were used as repetitions. These animals were identified with ribbons wrapped around their neck and by their natural marks.

Grazing time was defined as the time spent by animals in the selection and apprehension of forage and was determined from the frequency of grazing. The latter was recorded by instantaneous scan sampling, with visual observations every 10 min during the period that the animal remained on pasture (Jamieson and Hodgson, 1979). The following activities were recorded: ruminating, grazing, and other activities.

Rumination time was defined as the time the animal spent chewing the food bolus, and the variable “other activities” comprised everything the animal did, except grazing and ruminating. The measure for the determination of bite rate was obtained with videos in which the focus of the image was the muzzle of the animal during the first hour of grazing. The videos had a duration of 3 to 5 min, necessary to allow the accurate counting of the number of bites that the animal performed in that moment. Bites were defined as jaw movements for forage apprehension characterized by head movement of the animal and/or the characteristic sound when the animal is ripping the grass off. Bite rate was defined as the time necessary to perform 20 bites (Hodgson, 1990). The observation consisted of filming the animals during grazing for the subsequent counting of bites. This was only obtained during the summer period from January 23 to February 02, 2012, because there were problems with the film archives in autumn, which were unusable. For this evaluation, the three focal animals and days were considered the repetitions. The values were transformed mathematically into number of bites min^{-1} (Forbes and Hodgson, 1985).

A randomized matched pairs (block) design was used for the evaluation of milk production (animal performance) using 20 Holstein cows with a mean weight of 550 kg. The animals were divided into 10 blocks of two animals each, paired and randomly assigned to each treatment (grass) (Table 1).

Milking was performed twice a day, in the morning at 7.00 h and in the afternoon at 16.00 h, with a mechanical milking machine in a tandem milking parlor using an individual collection system with a volumetric balloon. Milk was stored in an expansion cooling tank. During the interval between milkings, the animals remained in a rest area where concentrate (whose ingredients and chemical composition are described in Table 2) divided into two meals was offered after the morning milking and before the afternoon milking. The animals received supplements to meet their nutritional requirements. For this purpose, 1 kg of concentrate was offered individually for each 3 kg of milk produced. The animals were subjected to ectoparasite control and weighing every two weeks in the interval between milkings.

Table 1 - Initial condition of the animals in 2012: number of animals, number of lactations, beginning of lactation, and initial production

Animal number	Mean production (kg animal^{-1} day^{-1})	Last calving	Lactation order
	Marandu		
1232	16.6	08/22/2010	3
1126	14.1	03/02/2011	7
1193	15.4	02/04/2011	4
4452	14.4	02/03/2011	2
1270	17.0	11/10/2010	2
1391	21.3	07/30/2011	1
1387	19.9	09/17/2011	1
4417	22.1	08/04/2011	2
1352	22.7	08/04/2011	1
4408	13.3	09/06/2011	3
	Mulato II		
1289	16.4	09/22/2010	1
1172	13.8	02/13/2011	6
1241	14.7	11/12/2011	3
1265	14.5	11/12/2010	1
1214	19.5	09/18/2010	4
1364	20.4	07/24/2011	1
1377	18.4	08/06/2011	1
1360	25.1	09/10/2011	2
1380	21.9	09/14/2011	1
4457	14.1	02/09/2011	2

Table 2 - Ingredients and chemical composition of the concentrate supplied to the animals during the experimental period

Ingredient	Proportion in concentrate (g kg^{-1})
Corn	690.0
Soybean meal	285.0
Sodium bicarbonate	15.0
Mineral mixture	10.0
Chemical composition	Proportion in concentrate (g kg^{-1})
Dry mass	880.4
Crude protein	234.9
Crude fiber	29.5
Ethereal extract	40.0
Non-nitrogenous extraction	665.2
Mineral matter	30.6
Total digestible nutrients	862.1

The milk yield of each animal was measured at the end of each milking (morning and afternoon) and summed to obtain the milk yield animal^{-1} day^{-1}. The data were collected from January 6 to April 30, 2012. For the determination of milk composition (total solids, fat, protein, and lactose), milk samples homogenized in a volumetric balloon were collected every two weeks during the two milkings of the day. The samples were refrigerated and sent to the laboratory for analysis.

The plant data were analyzed by analysis of variance using the PROC MIXED procedure of the SAS for Windows® package (Statistical Analysis System, version 8.2). Akaike's information criterion was used for selection of the variance and covariance matrix (Wolfinger, 1993). Treatment means were estimated with the LSMEANS procedure and compared with the PDIFF (probability of difference) option using the Tukey test at a level of significance of 5%.

The animal data were analyzed using the MIXED procedure of the SAS® program to determine the structure of the variance and covariance matrix. The level of significance adopted for analysis of variance was 5%. The mean effects of the treatments on milk production and composition were compared by the F test (95% confidence) in analysis of variance, considering a statistical model for a randomized paired design, with repeated measures over time for weekly samplings. The assumptions of normality and homogeneity of variances for analysis of variance were met.

In the statistical model for the matched pairs design (block design ANOVA), the pairs have random effects, and there are no interactions or repetitions within blocks, where the pairs were assembled from the cow data (described in Table 1). Since the treatments only had two levels, the F test is similar to the paired t test for testing the null hypothesis (H0:u1 = u2), with the alternative hypothesis being Ha:u1 ≠ u2. The model can be written in matrix form:

$$yij = u + Ti + Bj + eij,$$

in which yij is the total milk yield for treatment i and pair j, with i = 1 to 2 and j = 1 to 10; u (mean) is the constant associated with the model; Ti is the fixed effect of treatment i; Bj is the random effect of pair j; and eij is the normally and independently distributed (NID) experimental error (0, s^2), i.e., the deviations are normal and independently distributed, with mean 0 and variance s^2, according to Montgomery (2004). The statistical analyses were performed using the Minitab 13 software.

For lactose, Levene's test (at a probability level of 5%) revealed the lack of homogeneity of variance, and the Anderson-Darling test indicated the lack of normality. Thus, the nonparametric Wilcoxon test was applied to the paired data to compare the effects of treatments on this milk quality variable.

Results

In general, canopy heights were close to the targets established (Table 3). Forage accumulation rates did not differ between grasses (P = 0.8497), with mean rates of 82.0 (±29.81) kg DM ha^{-1} day^{-1} for Marandu and of 107.7 (±23.93) kg DM ha^{-1} day^{-1} for Mulato II. No significant difference in pre- or post-grazing forage mass was observed between the grasses evaluated (P>0.05) (Table 3). The proportion of the morphological components of forage mass did not differ between grasses or between months of evaluation (P>0.05). A difference was detected in the leaf:stem ratio between pastures in the pre-grazing (P = 0.0488) and post-grazing condition (P = 0.0082), with the observation of a higher ratio for Mulato II compared with Marandu in both periods (Table 3).

The chemical data were log transformed. The results showed a higher CP content over the average period for the Mulato II pasture (143.5 g kg^{-1}) compared with Marandu (130.3 g kg^{-1}) (P = 0.006). Among the months studied, a difference between grasses was only observed in February (161.4±0.61 g kg^{-1} for Mulato II and 137.4±0.29 g kg^{-1} for Marandu; P = 0.017). The following chemical components, reported as mean and standard error of the mean in parentheses, did not differ between pastures or between the months evaluated (P>0.05): NDF 615.6 g kg^{-1} (0.53), ADF 314.5 g kg^{-1} (0.32), and IVDMD 703.2 g kg^{-1} (0.76). Cellulose (264.8 g kg^{-1}) and hemicellulose (307.3 g kg^{-1}) levels were higher in Marandu grass than in Mulato II (P<0.05), while Mulato II (37.0±0.06 g kg^{-1}) had a higher lignin content (P = 0.0001) than Marandu (32.6±0.07 g kg^{-1}).

The grasses exerted an effect on TPD (P = 0.0001), with the observation of a higher density for Mulato II (mean = 822.00±22.11 tillers m^{-2}) compared with Marandu (mean = 635.96±22.11 tillers m^{-2}).

The total daily observation time during the summer assessments was 13 h. There was a significant difference between grasses in time spent grazing (P = 0.0427), but no difference was detected in

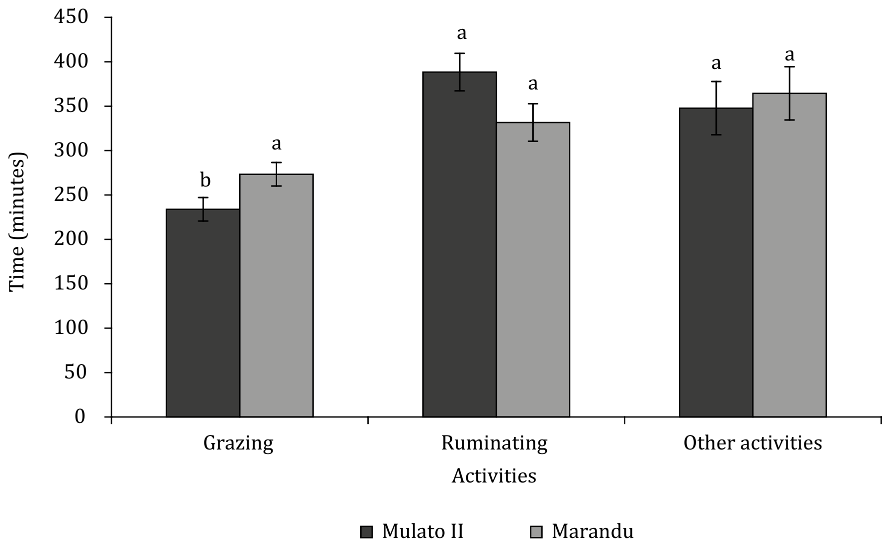
Table 3 - Canopy heights, forage mass, leaves, proportion of stems and dead material, and leaf:stem ratio of Marandu and Mulato II grasses in the pre- and post-grazing conditions from December 2011 to April 2012

Grass	Grazing condition	
	Pre-grazing	Post-grazing
	Canopy height (cm)	
Mulato II	26.3a (3.11)	18.1a (2.04)
Marandu	25.8a (2.85)	19.9a (2.13)
	Forage mass (kg DM ha^{-1})	
Mulato II	9,012a (1,322)	6,770a (1,321)
Marandu	7,983a (2,128)	7,381a (2,128)
	Proportion of leaves (g kg^{-1})	
Mulato II	289.42a (12.430)	234.20a (14.803)
Marandu	281.04a (11.695)	215.21a (15.330)
	Proportion of stems (g kg^{-1})	
Mulato II	231.49a (10.303)	270.00a (13.912)
Marandu	249.68a (9.694)	253.33a (14.452)
	Proportion of dead material (g kg^{-1})	
Mulato II	479.09a (16.913)	512.16a (22.00)
Marandu	474.27a (15.913)	529.81a (22.00)
	Leaf:stem ratio	
Mulato II	1.38a (0.068)	0.99a (0.07)
Marandu	1.19b (0.066)	0.82b (0.07)

Means in the same column followed by different letters differ from each other by the Tukey test (P<0.05). Value in parentheses correspond to standard error of the mean (±SEM).

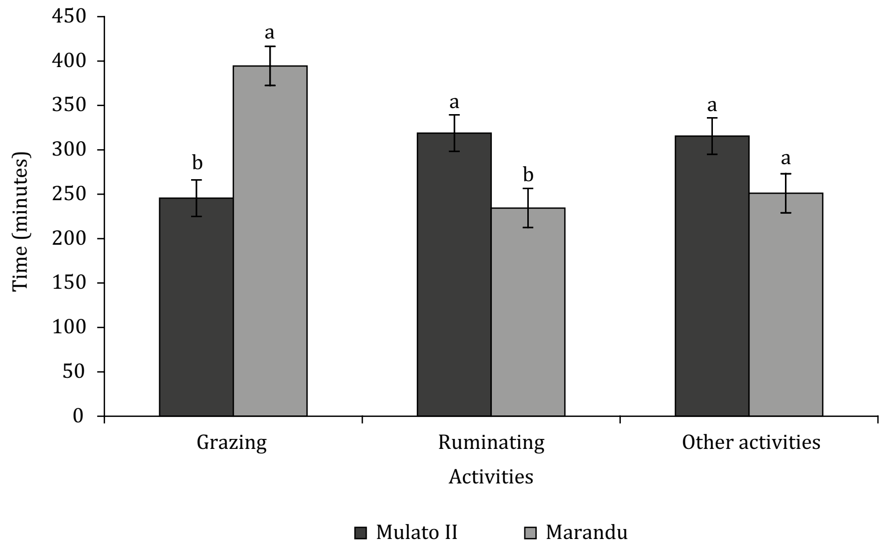
rumination (P = 0.0664) or idle time (P = 0.5098). During the period evaluated per day, animals kept on Marandu pasture spent a longer time grazing than animals kept on Mulato II (Figure 1). The mean rumination time was 360 min evaluation period^{-1} and the mean of other activities was 356.11 min evaluation period^{-1}.

With respect to the assessments performed in autumn, significant differences between grasses were observed for grazing (P<0.0001) and rumination (P = 0.0137) time, while idle time was similar (P = 0.1293). Grazing time was longer for cows on Marandu pasture than on Mulato II (Figure 2), while rumination time was longer for animals kept on Mulato II (Figure 2). The average idle time of cows grazing on the two pastures was 283.33 min evaluation period^{-1}.



Bars represent the standard deviation of the mean per grass.
Graph columns in the same activities followed by different letters differ from each other by Tukey's test (P<0.05).

Figure 1 - Time spent grazing, ruminating, and other activities by lactating cows grazing on Mulato II and Marandu pastures during summer 2012.



Bars represent the standard deviation of the mean per grass.
Graph columns in the same activities followed by different letters differ from each other by Tukey's test (P<0.05).

Figure 2 - Time spent grazing, ruminating, and other activities by lactating cows grazing on Mulato II and Marandu pastures during autumn 2012.

Bite rate evaluated during the summer period was higher (P = 0.0325) for cows grazing on Marandu (55.0±1.648 bites min^{-1}) compared with those grazing on Mulato II (50.0±1.514 bites min^{-1}).

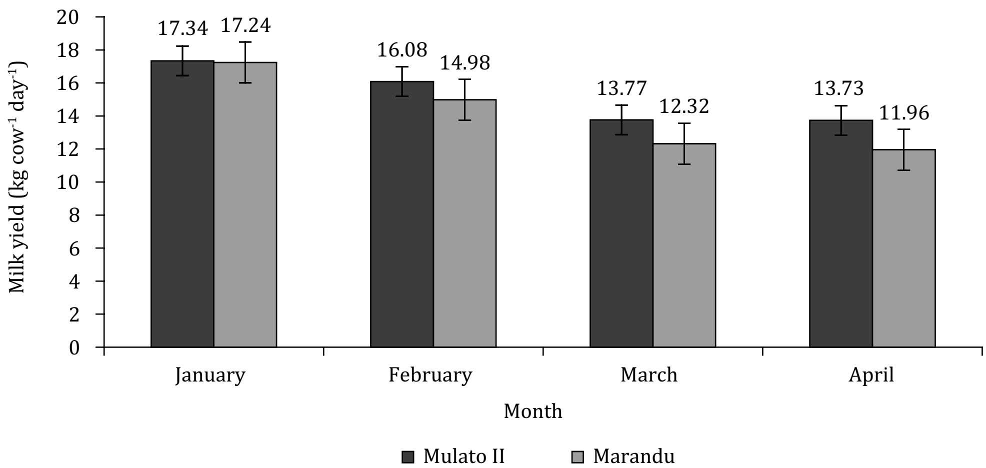
Mean milk yield evaluated over the period was higher for Mulato II (15.3 kg cow^{-1} day^{-1}) compared with Marandu (14.3 kg cow^{-1} day^{-1}) (P<0.0001) (Figure 3). The influence of the month of evaluation was not analyzed, and a statistically significant difference was, therefore, only detected between grasses.

There was no significant difference in milk composition variables (fat, protein, and total solids) between grasses (Table 4). Lactose content was higher in Marandu grass than in Mulato II (P<0.0001).

Discussion

Pasture height determines how the feed is offered to the animal (Hodgson, 1990), and the results obtained for Marandu pastures suggest that the most adequate grazing management is a pre-grazing height of 25 cm and a post-grazing height of 15 cm (Trindade et al., 2007; Giacomini et al., 2009) or oscillating above 15 cm (Gimenes et al., 2011). No canopy heights have been established for Mulato II pastures, but a mean pre-grazing height of 25.8 cm and post-grazing height of 18.15 cm have shown good results and can be recommended for the management of this grass. In a cut experiment Gobbi et al. (2018) indicated that at 23 cm, Mulato II sward height reaches 95% light interception and is recommended as pre-grazing height for this genotype. The results obtained are quite consistent since, although the experimental period was only five months (December 2011 to April 2012), a period of 10 months was allowed for the pasture to adapt to the canopy management targets before the beginning of the measurements, ensuring the dynamic equilibrium of the canopy structure.

The removal of approximately 30% of pre-grazing height by means of grazing animals is classified as lenient defoliation, i.e., the severity of defoliation is considered low. Holschuch (2018) and Almeida



Bars represent the standard deviation of the mean per grass and the numbers the milk yield.

Figure 3 - Milk yield of cows grazing on Mulato II and Marandu pastures from January to April 2012.

Table 4 - Proportion of fat, protein, total solids, and lactose in milk of cows grazing on Mulato II and Marandu pastures

Content (g kg^{-1})	Mulato II	Marandu
Fat	39.5a (0.73)	38.8a (0.49)
Protein	34.9a (0.65)	34.6a (0.29)
Total solids	125.7a (6.68)	127.2a (12.26)
Lactose	42.4b (2.10)	43.0a (3.00)

Means in the same row followed by different letters differ from each other by Wilcoxon test (P<0.05). Value in parentheses correspond to standard error of the mean (±SEM).

(2018) studied lenient (removal of 40% of pre-grazing height) and severe (removal of 57% of pre-grazing height) defoliation of Mulato II grass with mean canopy heights of 20 and 30 cm and demonstrated the phenotypic plasticity of this genotype, which adapted to the different management systems without differences in forage accumulation. Similar forage accumulation rates for Mulato II and Marandu pastures have also been described by Teodoro (2011) and Faria (2014) in cutting experiments. Cruz-Sánchez et al. (2018) suggested a defoliation frequency of 28 days (12.647 kg DM ha^{-1}) and a post-grazing height of 20 to 25 cm (11.504 kg DM ha^{-1}) to increase annual forage accumulation of Mulato II.

Forage accumulation or forage production is the result of the balance between growth and senescence of tissues and, as such, can be compensated among morphogenetic characteristics (Hodgson, 1990). In this respect, grasses with greater phenotypic plasticity better adapt to different structural objectives and their forage accumulation does not differ within the range of use, as observed for Marandu under continuous (Da Silva et al., 2013) and rotational (Gimenes et al., 2011) stocking and for Mulato under continuous (Silva et al., 2016ab) and rotational (Teodoro, 2011; Faria, 2014) stocking. However, Pequeno et al. (2015) found a 12% higher forage accumulation of Mulato II compared with Marandu when irrigated and harvested by cutting at 28 days, indicating the high forage production potential of this genotype.

The percentage of leaves in the post-grazing pasture mass can be considered high when compared with other similar grazing management experiments and is probably due to the proportion of canopy height removed by grazing of approximately 28.5% Gimenes et al. (2011) reported an annual mean leaf percentage of 155 g kg^{-1} during post-grazing of Marandu grass using the same management objectives as the present study, with an animal productivity of 690 kg of weight gain ha^{-1} year^{-1}. The proportion of leaves during the post-grazing period can be considered high and might be attributed to the post-grazing residue that remained high (above 18.0 cm), ensuring sufficient leaf area for regrowth. In the studies of Holschuch (2018) and Almeida (2018), the proportion of leaves and leaf area index (LAI) during post-grazing of Mulato II grass were higher for lenient defoliation (160 g kg^{-1} of leaves and LAI of 1.3) compared with pastures managed by severe defoliation (110 g kg^{-1} of leaves and LAI of 0.7), suggesting that this management (pre-grazing height of 25 cm and post-grazing height of 15 to 20 cm) is the most adequate for Mulato II pastures.

The higher leaf:stem ratio of Mulato II grass may have influenced the nutritive value of the selected forage and milk production (Figure 3), since a higher ratio facilitates forage apprehension and thus increases DM intake (Stobbs, 1973), resulting in a diet with a higher CP content and nutritive value (Van Soest, 1994). Faria (2014) and Pequeno et al. (2015) reported a higher proportion of leaves and greater leaf mass for Mulato II grass compared with Marandu. Pequeno et al. (2015) emphasized that Mulato II grass allocated a higher proportion of photoassimilates (210 g kg^{-1}) to the production of new leaf tissues compared with Marandu (110 g kg^{-1}), showing that leaf production is a priority of resource allocation in the former.

The higher CP content of Mulato II grass may be due to its higher leaf:stem ratio compared with Marandu. Pequeno et al. (2015) observed higher CP levels in Mulato II pastures at the higher cutting frequency (every 28 days), while there was no difference between grasses at the lower frequency (every 42 days). A higher frequency of defoliation resulted in higher CP levels for Mulato II (Cruz-Sánchez et al., 2018) and Marandu (Gimenes et al., 2011) pastures. In the present experiment, the grazing management used was characterized by a high frequency of defoliation, with rest periods shorter than 28 days, suggesting that these grazing objectives (pre-grazing height of 25 cm and post-grazing height of 15 to 20 cm) have permitted leaf area renewal and the allocation of photoassimilates to the production of new leaves in the Mulato II forage, resulting in higher CP levels. Cabral et al. (2013) also reported higher N concentration in the aerial part and higher N utilization efficiency of Mulato II forage compared with Marandu forage.

Faria (2014) also described a higher TPD for Mulato II grass (1,671 tillers m^{-2}) compared with Marandu (1,580 tillers m^{-2}), reported as the average of two cutting frequencies (28 and 42 days of regrowth). This fact may have compensated for the higher leaf elongation rate of Marandu observed in that experiment, resulting in a similar forage accumulation rate. However, the TPD found by Faria (2014) was higher than those obtained in the present experiment, which might be due to the different times of tiller counting. In the study of Faria (2014), tillers were counted in the pre-cutting condition (pre-grazing), while in this study, counts were performed post-grazing after the presence of animals. Another explanation is that the pastures of the present experiment were defoliated by grazing, which can increase tiller death by trampling, injuries, or defecation when compared with defoliation by cutting.

Grazing time is an indicator of the ease of forage intake by the animals (Hodgson, 1990; Carvalho et al., 1999). Da Silva et al. (2013) evaluated variables of ingestive behavior for four pasture heights of continuously grazed Marandu grass and reported that bite size was reduced with decreasing canopy height. The animals tried to compensate for this reduction by increasing the grazing time and bite rate, which were higher on shorter pastures (10 cm) compared with the other heights (20, 30, and 40 cm). Inversely, intake and animal performance were greater in taller pastures. Similarly, in the present experiment, longer grazing times (Figures 1 and 2) and higher bite rates were observed for Marandu pastures, results accompanied by a lower leaf:stem ratio and lower animal performance (milk production). These findings show that, even if maintained at the same pre- and post-grazing canopy heights, the Mulato II pastures probably offered a canopy structure to the animals that favored greater forage intake than the Marandu pastures.

Farinatti et al. (2009), studying lactating cows in a rotational system, found a mean grazing time of 538 min, with a mean bite rate of 42.66 bites min^{-1}, a grazing time slightly shorter than that found in this study. The difference might be due to the fact that the animals were milked only once a day and, therefore, spent more time in grazing. Zanine et al. (2007) reported a nighttime grazing time of 205 min in coast-cross pasture (*Cynodon dactylon* (L.) Pers), a value similar to that found for the two grasses in summer (Figure 1) and shorter than that observed for Marandu grass in autumn (Figure 2), indicating the difficulty of animals in ingesting this grass during autumn, as an increase in grazing time may indicate a lower intake rate and smaller bite size (Carvalho et al., 1999). In that study, the nighttime rumination time of lactating cows was 369 min, which was greater at night than during the day. These values are similar to those found for the Mulato II grass and higher than those obtained for Marandu (Figures 1 and 2). The nighttime evaluation was necessary, since the animals left the pasture twice a day for milking, followed by the supply of concentrate, and had time to rest, a fact that makes daytime grazing not representative. The higher milk production of 7% observed in the present experiment for Mulato II grass compared with Marandu is probably due to the higher leaf:stem ratio, which resulted in a shorter grazing time (Figures 1 and 2) and lower bite rate in summer. In addition, Mulato II grass had a higher CP and lower lignin content than Marandu grass and is, therefore, considered to have a better nutritive value. The milk yields obtained agree with the milk production of pasture systems using tropical grasses such as elephant grass (*Pennisetum purpureum*), ranging from 14.09 to 16.72 kg cow^{-1} day^{-1} (Voltolini et al., 2010) and from 18.5 to 15.5 kg cow^{-1} day^{-1} (Congio et al., 2018), and Mombasa grass (*Panicum maximum* Jacq. cv. Mombaça), ranging from 10.8 to 14.1 kg cow^{-1} day^{-1} (Hack et al., 2007). The values obtained in the present experiment are higher than those described by Fukumoto et al. (2010), who obtained mean milk yields of 8.7, 9.1, and 9.1 kg cow^{-1} day^{-1} for Marandu, Tanzania (*Panicum maximum* Jacq. cv. Tanzania-1), and African star grass (*Cynodon nlemfuensis* Vanderyst cv. Estrela Africana), respectively, indicating that the values obtained in the present experiment are consistent with animals grazing on pastures that are to be more productive and nutritious, such as elephant and Mombasa grass.

The levels of milk solids (Table 4) agree with those reported by Voltolini et al. (2010), who evaluated different grazing management systems of elephant grass and found similar results for fat (39.8 and 37.5 g kg^{-1}) and protein content (32.3 and 30.8 g kg^{-1}). The milk protein contents obtained for Marandu and Mulato II are equivalent to those achieved in elephant grass pastures, indicating the potential of the former to be used in pasture-based milk production systems. Porto et al. (2009) found similar levels of milk solids (121 g kg^{-1}) and fat (38 g kg^{-1}) in Marandu, Star Grass, and Tanzania grass, while protein content was higher in animals grazing on Tanzania grass (29.0 g kg^{-1}) compared with the other pastures (27 g kg^{-1}). Both values are lower than those obtained in the present study. The lactose content was higher in Marandu grass than in Mulato II. Although the numerical variation was small (43.0 vs 42.4 g kg^{-1}), the difference might be due to a higher concentration of this carbohydrate in milk, since milk production was lower for Marandu grass (Figure 3). The results are within the expected, since the grasses are of the same genus and were handled in the same way before and throughout the experimental period. The animals also received the same concentrate (Table 2).

Conclusions

The two grasses studied here have the potential to be used in milk production systems. When managed at a pre-grazing height of 25 cm and post-grazing height of 15 to 20 cm, Mulato II grass may provide higher leaf:stem ratios, protein content, and milk production than Marandu.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: J.B. Demski, I. Arcaro Junior, F.M.A. Gimenes, L.M. Toledo, M.S. Miranda, A.A. Giacomini and G.A. Silva. Data curation: J.B. Demski, I. Arcaro Junior and F.M.A. Gimenes. Formal analysis: J.B. Demski, F.M.A. Gimenes, L.M. Toledo, M.S. Miranda, A.A. Giacomini and G.A. Silva. Funding acquisition: I. Arcaro Junior and F.M.A. Gimenes. Investigation: J.B. Demski, I. Arcaro Junior, F.M.A. Gimenes, L.M. Toledo, M.S. Miranda, A.A. Giacomini and G.A. Silva. Methodology: J.B. Demski, F.M.A. Gimenes, L.M. Toledo, M.S. Miranda, A.A. Giacomini and G.A. Silva. Project administration: I. Arcaro Junior, F.M.A. Gimenes, L.M. Toledo, M.S. Miranda, A.A. Giacomini and G.A. Silva. Resources: I. Arcaro Junior. Supervision: I. Arcaro Junior and F.M.A. Gimenes. Validation: J.B. Demski, F.M.A. Gimenes, M.S. Miranda and G.A. Silva. Visualization: J.B. Demski, F.M.A. Gimenes and L.M. Toledo. Writing-original draft: J.B. Demski, I. Arcaro Junior, F.M.A. Gimenes and A.A. Giacomini. Writing-review & editing: J.B. Demski, F.M.A. Gimenes and L.M. Toledo.

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